# Suggestions to Authors of the Reports of the United States Geological Survey

## Seventh Edition

*REVISED AND EDITED BY*

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# Suggestions to Authors
## of the Reports of the United States Geological Survey
## *Seventh Edition*

Wallace R. Hansen, *Editor*

## PUBLICATIONS OF THE U.S. GEOLOGICAL SURVEY

SCIENTIFIC PUBLICATIONS are the chief products of the U.S. Geological Survey and the chief basis for the Survey's good reputation in the scientific community. When the Survey's organic act was signed into law in 1879 by President Rutherford B. Hayes, the new Survey was obliquely directed to publish the results of its investigations: "The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology." From these simple guidelines the Survey's present broad base of operations has evolved. In its first years, the Survey released its results as inclusions in annual reports to the Secretary of the Interior. These results, then as now, are of two general categories: (1) topographic, geologic, geophysical, and hydrologic maps and atlases, and (2) varied series and formats of textual reports, including books. The first separately published books appeared in 1883: U.S. Geological Survey Bulletin 1 and the first "Mineral Resources of the United States" (for the calendar year 1882). Since then, thousands of books and maps have been published to record the results of investigations of the physical features and resources of the Nation, the Earth, the Moon, and the planets.

Catalogs and supplementary lists of publications of the Geological Survey contain directions for ordering available items. Reports and maps currently published are listed in "New Publications of the Geological Survey" (free of charge) together with brief descriptions of their contents and prices. Out-of-print Survey publications may be found in Survey libraries and in public and institutional libraries throughout the country.

Besides reports published under the imprint of the U.S. Government Printing Office (GPO), the Survey releases much investigative information through other media. Thousands of Survey-generated reports have been published by cooperating Federal, State, and foreign governmental agencies and by scientific and technical societies. Survey authors should familiarize themselves with these in-house and outside media. Most publishing organizations have their own style manuals or technical standards for guidance of would-be contributors. "Suggestions to Authors" (STA) concerns mainly the preparation of the Survey's own book reports, atlases, and maps. Table 1 summarizes the Survey's currently (1988) active publication series.

**Table 1.** Current publications of the U.S. Geological Survey

| Publication | Scope | Format |
|---|---|---|
| | **Books and pamphlets** | |
| Professional Papers | Comprehensive reports of significant and lasting scientific interest. Include results of resource studies and of geologic, hydrologic, or topographic investigations. Also collections of related papers addressing a single topic. | 9⅛ x 11⅝ inches. Generally in two columns, rarely three. High-quality illustrations that may require special techniques of preparation, including plates and color photographs if appropriate. Set in type or camera ready. |
| Bulletins | Significant data and interpretations of lasting scientific interest but generally narrower in scope than professional papers. Results of resource studies, geologic or topographic studies, and collections of short papers on related topics. | 8½ x 11 inches. Generally in two columns. High-quality photographs and illustrations including color if appropriate. Set in type or in camera-ready type generated on word processors. |
| Water-Supply Papers | Reports on all aspects of hydrology, including quality, recoverability, and use of water resources; statistical reports on streamflow, floods, ground-water levels, and water quality; and collections of short papers on related topics. | 8½ x 11 inches. Similar to bulletins except for specialized content. Folded plates and color if appropriate. |
| Circulars | Technical or nontechnical information of popular interest including timely administrative or scientific information. Available to public free of charge. | 8½ x 11 inches. Generally two columns. Editorial, type, and graphics standards permit quick publication. No plates or color artwork. |
| Techniques of Water-Resources Investigations. | Manuals that describe approved procedures for planning and executing field and laboratory studies, including collecting, analyzing, and processing hydrologic data. | 8½ x 11 inches. Oversize illustrations permitted, but no color. |
| National Water Conditions. | Comprehensive monthly statistical summary of reservoir contents, streamflow, and ground-water conditions in United States and southern Canada. | 8½ x 11 inches. Type copy prepared in-house. Illustrations are page size or smaller. No color plates. |
| Annual State Water-Data Reports. | Surface and ground-water data for each State, Puerto Rico, and Trust Territories. | 8½ x 11 inches. Camera-ready copy from word processors, computers, or typescript. Illustrations are page size or smaller. No plates or color. |
| Earthquakes and Volcanoes. | Current general interest information on earthquake, seismic, and volcanic activity. Also addresses landslides, subsidence, and related geologic hazards. Published bimonthly. | 5⅞ x 9⅛ inches. Photographs and line copy at page size or less. Multicolors. |
| Preliminary Determination of Epicenters—monthly listing. | Basic data on earthquake epicenters derived from Worldwide and National Seismic Networks. Not an author publication outlet. | 8½ x 11 inches. Pamphlet without illustrations. |
| New Publications of the Geological Survey. | Monthly lists of all new products of the Geological Survey. Available to the public free of charge. Not an author publication outlet. | 8½ x 11 inches. Pamphlet includes newsworthy events. |
| Special Book Publications. | Books outside the formal series, such as "Suggestions to Authors," USGS Yearbook, and others. | Not prescribed. Highly varied. Not a medium for publishing results of research. |
| General-Interest Publications. | Brief nontechnical summaries of topics often asked about, such as earthquakes, energy resources, mineral resources, water resources, volcanoes, glaciers, and rivers. Leaflets free of charge. | Booklets, brochures, leaflets, folders, and essay reprints in varied colors and formats. |
| | **Maps and charts** | |
| Geologic Quadrangle (GQ) Maps. | Detailed geologic maps depicting areas of special importance to the solution of geologic problems. May portray bedrock or surficial units, or both. May include brief texts, structure sections, and columnar sections. | 7½- or 15-minute quadrangles printed in multicolor on topographic bases that meet National Map Accuracy standards. |
| Miscellaneous Investigations (I) Series. | High-quality maps and charts of varied subject matter such as bathymetry, geology, hydrogeology, landforms, land-use classification, vegetation, and others including maps of planets, the Moon, and other satellites. | Various scales. Topographic or planimetric bases; regular or irregular areas; black and white or multicolor. Single or multiple sheets; maximum sheet size 44 x 58 inches (image 42 x 56 inches). May include a text printed as an accompanying pamphlet. |
| Mineral Investigations Resource (MR) Maps. | Information on mineral occurrences, mineral resources, mines and prospects, commodities, and target areas of possible resources other than coal, petroleum, or natural gas. | Small scale (1:250,000 or smaller) on a sheet no larger than 44 x 58 inches (image 42 x 56 inches). |
| Oil and Gas Investigations (OM) Maps. | Apply particularly to areas of known or possible petroleum resources. Typically include cross sections, columnar sections, structure contours, correlation diagrams, and information on wells drilled for oil and gas. | Single or multiple sheets no larger than 44 x 58 inches (image 42 x 56 inches) in black and white or color. Text usually on map sheet but sometimes printed as an accompanying pamphlet. |
| Oil and Gas Investigations (OC) Charts. | Information about known or possible petroleum resources, presented as logs, correlation diagrams, graphs, and tables, but ordinarily not as maps. | Single or multiple sheets no larger than 44 x 58 inches (image 42 x 56 inches) in black and white or color. Camera-ready text, keyboarded on word processor, printed on same sheet or in an accompanying pamphlet. |

**Table 1.** Current publications of the U.S. Geological Survey—Continued

| Publication | Scope | Format |
|---|---|---|
| | **Maps and charts**—Continued | |
| Coal Investigations (C) Maps. | Origin, character, and resource potential of coal deposits shown by geologic maps, structure contours, cross sections, columnar sections, and measured coal sections, where appropriate. | Sheets no larger than 44 x 58 inches (image 42 x 56 inches) in black and white or color. Text on map sheet or in an accompanying pamphlet. |
| Geophysical Investigations (GP) Maps. | Chiefly the results of aeromagnetic and (or) gravity surveys shown by contours. Area depicted may range in size from a few square miles to an entire country. | One or more sheets no larger than 44 x 58 inches (image 42 x 56 inches), commonly printed in black and one other color with contours in red or green. Also multicolor. |
| Land Use and Land Cover (L) Maps. | Various categories of land use and cover, both artificial and natural, for use by geographers, land-use planners, and others. | Planimetric maps at scales of 1:250,000 or 1:100,000 on a single sheet no larger than 28 x 42 inches (image 26 x 40 inches), mostly in black and green, but occasionally multicolored. |
| Hydrologic Investigations Atlases (HA). | A wide range of hydrologic and hydrogeologic data of regional and national interest, such as streamflow, ground water, water quality, and extent of flooding. | Various scales. Multicolor or black and white on topographic or planimetric bases. Single or multiple sheets no larger than 44 x 58 inches (image 42 x 56 inches). Text on sheet or in an accompanying pamphlet. |
| Miscellaneous Field Studies (MF) Maps. | Rapidly prepared, low-budget maps in a broad range of presentations in terms of portrayal, completeness, interpretations, draftsmanship, scale, and area coverage. | Flexible layout. One or more sheets on planimetric or topographic bases not larger than 44 x 58 inches (image size 42 x 56 inches); generally in black and white. Author responsible for preparing camera-ready maps, cross sections, and other illustrations. Text should be keyboarded on word processors. |
| | **Informal report series** | |
| Open-File Reports (OF). | Unedited preliminary manuscripts, maps, and other material made available for public use but not considered part of the formal literature. Wide range of subject matter. | Varied scales, areas covered, shapes, and methods of presentation. Black and white paper copies and microfiche available for most reports. Some color. Computer programs and data on floppy disks. |
| Water-Resources Investigations Reports (WRIR). | Hydrologic information, mainly of local interest, intended for quick release. Book or map format. | Map size normally 44 x 58 inches. Book pages 8½ x 11 inches. Map sheet no larger than 44 x 58 inches (image 42 x 56 inches). Text, drafting, and layout by originating office. Color and oversize illustrations if appropriate. |
| Reports of the Office of Water-Data Coordination. | Products of interagency water-data coordination activities. | Various types based on need. |
| Index to Water Data. | Tabular information on water-data collection sites and hydrologic investigations published every 2-4 years. Data maintained in a central computer file. | Computer-generated camera-ready copy on 8½ x 11-inch paper, black and white; illustrated only with index maps. Standard covers. |
| National Handbook of Recommended Methods for Water-Data Acquisition. | Various methods of water-data acquisition, updated periodically. | Twelve chapters, typeset; 8½ x 11-inch paper, without color and with few illustrations. Special notebook covers. |
| Federal Plan for Water-Data Acquisition. | Present and future plans of 30 Federal agencies; directed to water-data collectors and users and to administrative and legislative branches of the Federal Government. | Camera-ready copy generated on word processors on 8½ x 11-inch paper, without color, with standard covers. Page-size computer-generated graphs. |
| Administrative Reports. | Prepared to meet specific internal needs or needs of other governmental agencies having proprietary interests. Unpublished and not to be quoted or cited except in followup administrative reports or unless released to the public by a cooperating agency. | No set standards; copy prepared to meet specific needs. |
| | **National Topographic Maps** | |
| Standard series maps:<br>1:24,000-scale, 7½-minute<br>1:62,500-scale, 15-minute<br>1:100,000-scale<br>1:250,000-scale<br>1:1,000,000-scale International Map of the World | | Special maps:<br>National Parks and Monuments<br>Orthophotomaps<br>Orthophotoquads<br>County maps<br>State maps<br>National Atlas of the United States<br>Maps of the United States |

# THE SURVEY PUBLICATION PROCESS

WHEN YOU AS AUTHOR submit a finished manuscript for review, only the first step has been taken in a long process that transforms raw field, laboratory, and other research data into finished scientific reports. Such reports are available to the public on the authority of the Director of the Survey, whose approval is required before any Survey publication can be released. All reports resulting from the official work of Survey employees, moreover, must be approved by the Director before release, whether published within the Survey or elsewhere. As a practical matter, the Director delegates responsibility for approval to the Office of Scientific Publications.

New ways are constantly being explored to reduce the time between submittal of manuscripts and release of printed reports. Automated word processing has greatly facilitated manuscript preparation, and promising new techniques of computer-generated cartography will drastically alter map-making procedures, but technological advances in processing are balanced against increasing publication loads. Many factors may alter scheduling—changed priorities, new programs and projects, mandates from high administrative levels, reorganizations, reassignments of responsible individuals, failures by individuals to set and enforce attainable deadlines, changed appropriations or allotments, and unforeseen geologic contingencies (a volcanic eruption, for example, or a catastrophic earthquake).

## REFERENCE BOOKS

All science writers, critics, and editors are likely to have specialized reference books close at hand for their special needs. Additional, more general reference books should be readily accessible also, some closer at hand than others. The books listed here without comment are only a few of the many widely available, excellent general references related to technical writing. This list was generated largely by Malde (1986) and Cochran and Marsh (1986). Most books listed rate at least three stars out of a possible four, but their listing does not constitute special endorsement by STA.

### ATLASES


The national atlas of the United States, 1970: Washington, D.C., U.S. Geological Survey, 417 p.

National Geographic atlas of the world (5th ed.), 1981: Washington, D.C., National Geographic Society, 383 p.

The Times atlas of the world, 1980: New York, Times Books, 227 p.

Webster's new geographical dictionary (revised ed.), 1984: Springfield, Mass., Merriam Webster, 1,376 p.


### DICTIONARIES


The American Heritage dictionary, second college edition, 1982: New York, Houghton Mifflin, 1,586 p.

Webster's third new international dictionary of the English language unabridged, 1981: Springfield, Mass., Merriam Webster, 2,262 p.

Webster's ninth new collegiate dictionary, 1983: Springfield, Mass., Merriam Webster, 1,563 p.


### EDITING AND REVIEWING


Bishop, C.T., 1984, How to edit a scientific journal: Philadelphia, ISI Press, 138 p.

DeBakey, Lois, 1976, The scientific journal; editorial policies and practices; guidelines for editors, reviewers, and authors: St. Louis, Mo., C.C. Mosby Company, 129 p.

Judd, Karen, 1982, Copyediting, a practical guide: Los Altos, Calif., William Kaufmann, Inc., 287 p.

Malde, H.E., 1986, Guidelines for reviewers of geological manuscripts: Alexandria, Va., American Geological Institute, 28 p.

O'Connor, Maeve, 1979, The scientist as editor; guidelines for editors of books and journals: New York, John Wiley & Sons, 218 p.

Plotnik, Arthur, 1982, The elements of editing; a modern guide for editors and journalists: New York, Macmillan, 156 p.


### ENGLISH USAGE AND GRAMMAR


Bernstein, T.M., 1965, The careful writer; a modern guide to English usage: New York, Atheneum, 487 p.

Follett, Wilson, 1974, Modern American usage; edited and completed by Jacques Barzun in collaboration with Carlos Baker and others: New York, Warner Paperback Library, 528 p.

Fowler, H.W., 1965, A dictionary of modern English usage (2d ed., revised by Sir Ernest Gowers): New York, Oxford, Oxford University Press, 725 p.

Freeman, M.S., 1983, A treasury for word lovers; *with a foreword* by Edwin Newman: Philadelphia, ISI Press, 333 p.

Gordon, K.E., 1984, The transitive vampire: New York, Times Books, 144 p.

Hill, Mary, and Cochran, Wendell, 1977, Into print; a practical guide to writing, illustrating, and publishing: Los Altos, Calif., William Kaufmann, 175 p.

Johnson, E.D., 1983, The Washington Square Press handbook of good English: New York, Washington Square Press, 309 p.
Strunk, William, Jr., 1979, The elements of style; *with revisions, an introduction, and a chapter on writing* by E.B. White (3d ed.): New York, Macmillan, 85 p.

## Glossaries

Bates, R.L., and Jackson, J.A., eds., 1987, The glossary of geology (3d ed.): Alexandria, Va., American Geological Institute, 788 p.
U.S. Bureau of Mines, 1968, Dictionary of mining, mineral, and related terms: Washington, D.C., U.S. Government Printing Office, 1,269 p.

## Report Writing

Bates, J.D., 1980, Writing with precision; how to write so that you cannot possibly be misunderstood (3d revised ed.): Washington, D.C., Acropolis Books, 226 p.
Bernstein, T.M., 1971, Miss Thistlebottom's hobgoblins; the careful writer's guide to the taboos, bugbears and outmoded rules of English usage: New York, Farrar, Straus, and Giroux, 260 p.
Cochran, Wendell; Fenner, Peter; and Hill, Mary, 1984, Geowriting; a guide to writing, editing, and printing in earth science (4th ed.): Alexandria, Va., American Geological Institute, 80 p.
Day, R.A., 1983, How to write and publish a scientific paper (2d ed.): Philadelphia, ISI Press, 181 p.
Kilpatrick, J.J., 1984, The writer's art: Kansas City, Mo., Andrews, McNeel & Parker, 254 p.
Kirkman, John, 1980, Good style for scientific and engineering writing: London, Pitman Publishing Limited, 131 p.
Williams, J.M., 1981, Style; ten lessons in clarity and grace: Glenview, Ill., Scott, Foresman and Company, 238 p.

## Style Manuals

The Chicago manual of style, 1982, (13th revised ed.): Chicago, University of Chicago Press, 738 p.
The New York Times manual of style and usage; a desk book of guidelines for writers and editors, 1976 (revised and edited by Lewis Jordan): New York, Quadrangle-Times Books, 231 p.
U.S. Government Printing Office, 1984, Style manual, 1984: Washington, D.C., 479 p.
VanLeunen, Mary-Claire, 1978, A handbook for scholars: New York, Knopf, 354 p.

## Other

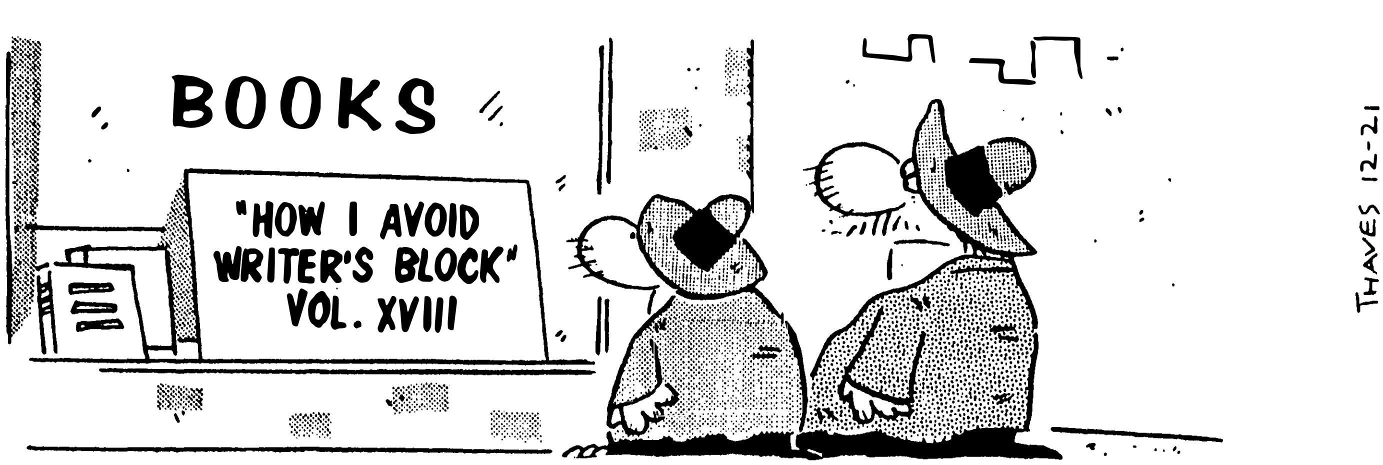
Roget, P.M., 1977, Roget's international thesaurus (4th ed., revised by R. L. Chapman): New York, Crowell, 1,317 p.
Bartlett's familiar quotations (15th ed., edited by E.M. Beck), 1980: Boston, Little, Brown & Co., 1,540 p.
Tufte, E.R., 1983, The visual display of quantitative information: Cheshire, Conn., Graphics Press, 197 p.

# Getting Started

If geologists could only be brought to realize that the addition of another paper to the swollen flood of our scientific literature involves a serious responsibility, that no man should publish what is not a real consequence, and that his statements when published should be as clear and condensed as he can make them, what a blessed change would come over the faces of their readers.

*Archibald Geikie, 1897*

Putting down the first word is hard for most authors, including many who have written best sellers. Scientific reports rarely are best sellers, but the pain of writer's block can be no less real to their authors. Just knowing that other writers suffer the same malaise can be reassuring and helpful. Self-discipline is the key. Writer's block and indolence are close relatives, but one is no excuse for the other. Steps outlined on the following pages should help obviate both, though even the most gifted writer must have the self-discipline to see an exercise through to completion, especially if the topic is long and complex. If you know your subject matter, are reasonably well organized, and have completed the few essential preparations described in the next few paragraphs—before you pick up your pencil or sit down at the keyboard—the block will melt away like butter in a hot skillet.



Steps outlined here apply to routine processing. If a report has special urgency, it may receive priority processing, and some steps may be telescoped or otherwise varied, but the end product generally will be of higher quality if the report has followed established publication channels. Your responsibility as author is to know the style of your publisher, to prepare your report accordingly, and to present your data clearly. Your manuscript "should be able to withstand scrutiny as a good piece of writing, exclusive of the science" (Sindermann, 1982, p. 29).

This section summarizes the steps that you will normally follow in planning and writing a Survey report, beginning when your investigation is authorized and ending with final review and proofing just before printing. Procedures and practices that may be useful at different stages are also suggested. This section is brief, generalized, and mainly chronologic; subsequent parts of STA contain the many details of form, content, arrangement, and expression that are required or suggested for reports of the Geological Survey.

## Before Beginning the Investigation

The course and results of investigative or research projects can be foreseen only within widely varying degrees of clarity and assurance. If a project is rather specific, its duration and results can be forecast reasonably well—for example, a geologic study of a particular area in which the objective is well defined and in which the stratigraphic, structural, and other features are fairly well known. On the other hand, such predictions may prove faulty if a project involves research in problems that are little known. To the extent feasible, you as investigator and your supervisor should estimate and tentatively plan the following:

1. The time you will need for the study itself and for the collateral and supplemental tasks, such as searching the literature, making and checking calculations, and making laboratory tests.
2. The number, kind, and size of the reports and maps that you intend to prepare and the length of time you will need to ready them for first transmittal to the supervisor. Maps or other illustrations that will be complex and costly to publish should be discussed with the supervisor and other responsible persons to determine the most efficient methods of preparation.

## After Completing the Investigation

After the investigation and its collateral tasks have been completed, you and your supervisor should—

1. Review and evaluate the results and decide what is worth reporting.
2. Consider your possible readership: Where to aim the report(s).
3. Discuss how to present the results most effectively.
4. Decide the general types, size, scope, and number of reports or maps that you should prepare.
5. Reevaluate the time needed to prepare and revise a first draft and the date of its transmittal to your supervisor for review. This estimate should be realistic. Adherence to the time schedule is an official obligation, and substantial delays are permissible only for officially prescribed reasons. Your performance in report writing is judged for promptness and care, just as any other assignment is.

### Choice of Publication Medium

To select a suitable publication medium you should first consider the size and type of the intended primary readership, the immediacy and permanency of the information, and the size and type of the illustrations. Except for reports aimed at outside scientific journals, the subject matter and size of the manuscript may have less to do with the choice of publication medium than some of the other factors have. The medium, moreover, may be decided by authorities higher than yourself. In any event, you should seek advice and suggestions as to a probable medium early in the manuscript-preparation process; only then can you efficiently plan and prepare the illustrations, text, and tables. Checking table 1 should help you decide where a report best fits. If a report has transient interest and is needed quickly by just a few users, it may be appropriate for the Survey's open files, or if needed quickly by many users it may be published as a Circular.

Maps in black and white are also sometimes open filed for early availability while more finished colored versions are being prepared for publication. If a standard quadrangle map, for example, meets rigid requirements as to base, scale, and size, it is printed in color as a Geologic Quadrangle (GQ) map. A map other than a standard quadrangle but of equal accuracy and permanence should be published in one of the other map series. So, too, should a map that focuses on special features such as geochemical anomalies or hydrologic characteristics or that is intended for printing without color. Guidelines for map preparation are on page 184.

Many of the factors listed apply also to non-Survey publications. Before submitting a paper to an outside journal, you should learn the journal's preference as to subject matter, length, and illustrations policy by scanning recent issues and by checking the journal's policy statements, specifications, and style. Most publishers have their own rules of style, either devised by themselves or by some other publisher whose style fits their needs. Some stylistic conventions are neither technically right nor wrong, and they may differ appreciably from one publisher to another. Publication style is just intended to provide guidance to authors and editors in preparing their reports and to provide internal editorial consistency.

### The Detailed Outline

Many details have been omitted which would have been given had the facts been presented as they were collected * * * but it was thought that such a method would result in encumbering geological literature with a mass of undigested facts of little value.

*J.W. Powell, 1876*

You are now ready to draw up a more detailed outline. Done carefully and thoughtfully, this task is one of the most constructive and profitable steps in all your preparations. Without careful planning, even the most experienced author will fritter away time in marshaling thoughts and will waste even more time later in recasting the manuscript to supply the missing logic and completeness. In the long run the hours or days spent drawing up a well-rounded outline are thoroughly justified.

As a background, familiarize yourself with the general order of topics in most Geological Survey reports by leafing through recently published ones and by studying this volume, where many details of form and arrangement are explained. Many reports follow a rather conventional pattern, particularly reports that summarize a survey of an area and present scientific and economic conclusions. Reports on more abstract research may be organized more diversely, especially where an order of treatment must be chosen to bring out clearly and convincingly the solutions to complex problems and the evidence for the resulting theories and conclusions.

From these examples and suggestions, and with due thought to the nature and purpose of the proposed report and the needs of the readers, you can then choose the most logical and appropriate order. At this stage it would be wise to discuss your plans with local editors and graphic specialists. Outline the organizational pattern as a tentative, more or less detailed table of contents, with headings and subheadings to indicate the topics to be discussed. For a rather brief and simple report, such a generalized outline may suffice for arranging the material and doing the actual writing. You must sort out all notes and observations, omit what is irrelevant, and arrange what will be included. Ideas may be set down on cards or sheets of paper, with one topic per card or sheet. Later, each topic may be developed in greater detail—perhaps on a word processor. The cards or sheets help exclude irrelevant material and help prevent the omission of important data. They also enable you to add, subtract, combine, or rearrange data as the report progresses, to ensure order and balance.

Try during this planning stage to reach tentative conclusions about illustrations and tables. Illustrations can show at a glance what could not possibly be described in the text, or what would require many words to explain. Carefully chosen photographs can illustrate significant features not otherwise easily depicted. Concise tables can summarize data that otherwise would be difficult for the reader to assimilate.

One other point should be borne in mind at this stage: If advice and decisions about the use of new geographic and geologic names will be required from the Board on Geographic Names or from the Survey's Geologic Names Committee, you should anticipate such needs as early as possible.

### The First Draft

Writing the first draft is the longest and most arduous part of authorship. To express information and ideas clearly, concisely, logically, and convincingly, and to prepare copy for illustrations, requires thought and perseverance. Authors and supervisors, moreover, should avoid the start of new duties until the first draft of a manuscript-in-progress is finished. When your manuscript is complete, you and your supervisor should carefully monitor its movement through review, editing, and the various other processing channels leading to publication. Conscientious and thorough execution of these tasks brings many rewards, including personal satisfaction, speedier handling of the manuscript by fellow workers, higher quality and quicker publication, and greater value to the reader.

Methods of drafting manuscripts vary widely, and no rule or guide fits the needs of all. Each author develops personal techniques and habits. Working from a topical outline, an author usually drafts out one topic before taking up another. This method provides continuity of thought and completeness of coverage. Not all sections, however, need be written in the order of their appearance in the finished report—for example, the abstract and the introductory material should be prepared after the rest of the text has been written.

The manuscript may be written in various ways, each of which has adherents. One author may focus attention solely on the subject matter, completing the first draft without interrupting the flow of thought to criticize and improve the writing. Adherents believe this method results in a clear, though roughly cast, exposition of the author's ideas.

Another author mentally assembles ideas and thoughts in their best perceived order, then ponders how best to express them clearly, logically, and forcefully. This author writes deliberately—weighing not only what to say but also how to say it. The resulting first draft will be superior to a more rapidly written draft and later will require less recasting to achieve polish. Most authors wisely read and work over their manuscripts many times, a step greatly facilitated by the use of word processors. You should doublecheck for logic, order of treatment, prominence given significant features, completeness, accuracy, irrelevant material, confusing statements and disagreements of facts, and repetition, and for compliance with the requirements and suggestions given in this volume.

At this stage you should also prepare near-final copy for all maps, charts, diagrams, tables (to be reproduced from office printers such as daisywheel and laser printers), and photographs. Reviewers and editors will need copies, which illustrators will later put into form for publication. Whether to complete this task before or during the writing of the manuscript depends on the complexity of the material, but the tables at least should be compiled and the illustrations and their titles should be firm enough to be cited and discussed at appropriate places in the text. Suggestions for preparing illustrations are given on subsequent pages.

While preparing the text and illustrations, you can profit greatly by consulting fellow workers on both general and specific topics. Also, you may ask knowledgeable associates to preview all or parts of the manuscript. Such informal previews require comparatively little effort on your part or your reviewer's, but they pay large dividends. You may wish to again consult text or map editors about stylistic matters.

## Preparing and Checking Report for Technical Review

The next step is to prepare the typescript for formal technical review. Authors using word processors may combine this step with the previous one. The first keyboarding should be done in accordance with the practices specified on pages 250–264. Several stages of review and revision will follow, and eventually some or many pages must be redone at least once before the manuscript is sent to the printer. If the report will go to several reviewers, you might make extra copies for simultaneous review; the advantages of so doing must be weighed against the additional effort of reconciling comments and transferring responses to a single copy.

When your typescript ("hard copy") is prepared, proofread it thoroughly to eliminate typographical errors and omissions. Word processors offer programs that will catch most spelling errors, but only you can detect omissions or words correctly spelled but wrongly used. At this time you should also check the accuracy of the whole report, including illustrations, quotations, mathematics, and citations of publications. The report should meet all requirements as to content, format, and supplemental information such as acknowledgments. Then you are ready to submit the completed document to your project supervisor, accompanied perhaps by a suitable memorandum of transmittal explaining any special circumstances and suggesting reviewers.

## Technical Review and Revision

The report is reviewed by professional colleagues within the originating office. It may also be sent to other offices if all or parts of it relate to their fields. The sequence of steps that follows next may vary in different Divisions of the Survey, but the objectives are the same: to assure the best possible science and presentation. If your report is being processed by the Water Resources Division, its routing procedure is outlined on page 30. The procedures immediately following apply to all Divisions. At least one reviewer should be specially qualified by knowledge and interest in the problems discussed. Another reviewer might read the report for general content. Both must strive to assure scientific validity and clarity. To that end they call attention to weak spots in text and illustrations through marginal notes and interlineations, or through attached memorandums if their questions and suggestions are complex. See also guidelines for reviewing technical reports and maps (p. 226).

Knowing the purpose of the review and the spirit in which the comments are made, you must try to profit from them. Every comment should be thoughtfully considered, all questions raised by the reviewers should be addressed, and appropriate changes or corrections should follow. Unaccepted differences with the reviewer must be explained, either in the margin of the manuscript or on an attached memorandum. If the differences are substantial, or if there seem to be misunderstandings, you should elaborate by written responses attached to the manuscript. The Survey encourages informal consultations and discussions between reviewers and authors to clarify viewpoints and reach agreement. Such interactions are not generally possible, however, for reports written for outside journals. There, the journal editor usually acts as intermediary.

Stratigraphic names and correlations are checked at this point by the Geologic Names Unit (GNU) to assure consistency and compliance with the established usage. Instructions from GNU must be strictly followed, unless GNU modifies them after further discussion. Your designated approval officer signs off approval when satisfied that your paper is ready to go forward for further processing, and sends it to the appropriate publications office. Manuscript copy from this point forward is referred to as "mill copy," a term used repeatedly in STA.

After the report leaves your office it receives further processing if it is intended for formal Survey publication. (Outside papers originating in the Geologic Division are checked further only on request.) Maps, diagrams, and other illustrations involving geology are examined by a geologic map editor, who looks for errors and inaccuracies and also indicates changes in format necessary to assure clarity, conformity with Survey practices and standards, and economical printing. Reviewers' comments and other papers must stay with the manuscript; review markings on text and illustrations must not be erased.

### Editing

Editing follows technical review. The editorial staff prepares for the printer all manuscripts that are to be published by the Survey. The editors examine (1) the content and rank of headings, (2) the form of the footnotes and the citations of publications, (3) the use of geographic names, (4) the form of tables and sections, and (5) the various features of typographic style—such as capitalization, punctuation, spelling, and sizes and styles of type—as well as many other details. Much of this work follows prescribed rules, including those of the U.S. Government Printing Office Style Manual.

### The Author and the Editor

Editing serves another purpose: The editors approach the manuscript as detached but sympathetic readers who look at it from the viewpoint of the intended readership. Most editors are gentle people whose overriding concern is to maintain the quality of their publications. Most of them suffer silently the brickbats of short-tempered authors and seldom seek or receive the plaudits they deserve. They try to understand your ideas, and in trying to help express those ideas as clearly and concisely as possible, they make suggestions about organization, paragraphing, grammar or rhetoric, how to recast obscure passages, how to eliminate repetitious or irrelevant matter, and many other topics. These suggestions are made solely to improve the report. You as author might be reassured to remember that editors have helped polish the manuscripts of F. Scott Fitzgerald, Ernest Hemingway, James Michener, and many other talented writers, and with their blessings and gratitude (Garfield, 1985).

Editors, like authors, are not infallible, and they occasionally prick points of authorial tenderness. Oddly enough, some scientists are more sensitive to assaults on their grammar and rhetoric than on their technical prowess. Recognizing your own frailties as an author is one step toward harmony with all your supporting staff.

Editorial changes usually are made to rectify perceived shortcomings. Editors may inadvertently alter an author's meanings, especially obscure meanings, but if an editor or a critic feels compelled to make a change or raise a question, something in the manuscript probably needs attention. And before you protest that your "colleagues will understand what is meant," realize that the Survey, too, wants them to understand but also wants its products grammatically correct, syntactically clear, and logically put together. With a bit of introspection, you can avoid such tiresome marginal cliches as, "Stet! You changed my meaning," or "A geologist [or hydrologist, or astrogeophysicist] would understand," or "Nitpicking!" Take heart, and save your energy for more productive ends.

Perceptive authors and editors alike recognize that science editing is an art in shades of gray, not in black and white. Tactful editorial comment, therefore, must be tentative, discreet, and needed. After all, the names of authors, not editors, grace title pages, book spines, and file cards. Authors receive lasting praise for all their pearls of wisdom, but they also take the knocks for any blunders. Editors just go to unmarked graves. You as author should remember that your editors and critics stand briefly in the stead of your readers—readers who will ultimately judge the merits of your writings. As the last filter between you and your readers, your editors should be seen as collaborators, not adversaries. For their part, and to minimize the chances of misreadings, editors can help by making their comments neatly and legibly with a well-sharpened pencil. Few things bother authors more than blatant, illegible markings all over their reports.

When your edited manuscript is returned, you must carefully examine all suggestions and corrections. Make sure that the intended meaning has not really been altered, and if any change seems out of line, try to reconcile it with the editor without delay. Changes must be avoided that would conflict with the official approval of the report. When all such conflicts are resolved, your report is forwarded for Director's approval, though the exact sequence of events may vary from Division to Division.

### Director's Approval

The high quality and scientific integrity of Geological Survey publications have earned wide respect for the Survey for more than 100 years. Survey investigations best serve the public at large, rather than serving special interest groups or individuals. Approval by the Director is the final step in the processing of a report before its release for production and publication.

All interpretive writings in which the Survey has a proprietary interest, including abstracts, letters to the editor, and all writings that show the author's title and Survey affiliation must be approved by the Director before release or publication. The Survey has a proprietary interest in all data and manuscripts derived from research or investigations funded by the Survey. The objectives of the Director's review are to final-check the technical quality of the report and to make certain that the report meets Survey publication standards and is consistent with policies of the Survey and Department of the Interior. Director's approval ensures that (1) each publication is impartial and objective, (2) its conclusions do not compromise the Survey's official position, (3) the report does not take an unwarranted advocacy position, and (4) the report does not criticize or compete with other governmental agencies or the private sector.

The Director has delegated approval authority to the Associate Chief, Office of Scientific Publications, Geologic Division. Reports may acknowledge official authorization by using the wording "Manuscript approved for publication (month/day, year)".

After the Director has approved your report, an important milestone has been reached, and toasts are in order all around. Beyond that point no further change may be made in the text or illustrations, except of an editorial nature, unless the proposed change is submitted through official channels, is suitably endorsed, and is formally approved.

### Checking Drafted Illustrations

Maps and other illustrations prepared by the illustrators (graphics specialists and cartographic technicians) are reexamined by several designated persons, including map and text editors and you as author. Long experience has shown that errors, especially omissions, may appear in the drafting itself and in the wording on the illustrations, despite the skill and care of the illustrators. As the person most familiar with the details, you must thoroughly scrutinize the illustrations at this stage before approving and returning them. To minimize the need for corrections and revisions, please submit the best and clearest possible drafts of your illustrations to the graphics staff before final preparation begins. Corrections or other changes made on illustrations may require changes in the text. Important revisions must be submitted through official channels for approval.

### Galley and Page Proofs

Your last step before the manuscript is published is to examine proofs of the text and proofs of maps and other illustrations. This step should be thorough, and there is a special need for promptness to avoid delaying publication. How to read proof is outlined on page 265. The chief purpose of proofreading is to detect errors introduced during typesetting and reproduction. Because the manuscript was fully prepared and polished before its transmittal for reproduction, you must not attempt further factual revision at the proof stage. Some minor changes from copy may be permitted in galleys to correct errors of fact that have escaped notice during earlier reviews, but changes in proofs are costly and are permitted only to correct definite errors. Any other changes require exceptional justification. When the report has been published, several copies are furnished to you as author for personal disposition.

## Word Processors: Changing the Way Scientists Write

Rapid technological advances in computer word processing are changing how scientists write. Rather than laboriously composing in longhand or on a typewriter, many authors now keyboard their thoughts directly into the storage disk of a computer. Word-processing systems thus increase the efficiency and accuracy of preparing text and of editing and revising typed reports.

A word processor is a computer geared to generate, edit, process, and print text material. It is a software-based, microprocessor-controlled typing system. Large (mainframe) and small (personal) computers have many capabilities, including word processing. Until recently, word-processing functions were fairly difficult to learn and operate, but new systems are increasingly simple and versatile. STA provides no operator instructions; it merely outlines the advantages of the new technology.

A word-processing system consists of an electronic keyboard, a video display, a means of storing data in readable form on a magnetic disk or tape, and a printer. The system should feature easy entry of text



and equations, elementary formatting, simple revision, and effortless printing. After typescript ("hard copy") is printed, the report follows conventional Survey review and editing procedures, but all changes and corrections are made on the word-processing disk. Then, after revision and approval of the manuscript, the disk version can be formatted for automatic typesetting and transmittal to the typesetter via telecommunication techniques. The goal of word processing is to keyboard data only once and to deal with machine-readable copy thereafter.

The ease of entering information and, most importantly, the ease of making corrections affect the quality of reports prepared on the word processor. Scientists are quick to recognize that as they type they may develop ideas and lines of reasoning completely separate from the part of the report they are working on. Once keyboarded into the word processor, these thoughts can be tagged or coded and quickly moved as a unit to more proper places in the report, or even stored for later use. The scientist can then continue with the original report until the next idea strikes.

Many scientists are slow and inaccurate typists, but once they are used to the ease of keyboarding corrections on word processors, their typing speed commonly improves, because typographical errors are so easily rectified. Most scientists simply proofread and correct their material on the video screen before printing hard copy (although hard copy has to be proofed also). Many word-processing programs now include spell-correction packages that catch many typographic mistakes.

Before the advent of word processors, the turn-around time from manuscript submittal to typist and return could be as long as several weeks or even months. The scientist's concentration on the subject and train of thought were broken during such a period, and valuable time was lost refreshing memories, checking references and notes, and getting back on track with the research paper. In addition, revisions were reluctantly made on the typescript because of the long turn-around time and extra work involved in retyping, but nowadays, as authors are encouraged to keyboard and correct their own reports, they can expend their full energies on the manuscript from conception to completion without distractive waiting periods and delays in the typing pool.

Accessibility is important. A word processor or computer terminal should be on the scientist's desk or nearby where the manuscript can be brought up conveniently onto a viewing screen. Translating an idea to text easily and conveniently and being able to devote periods as short as several minutes to a manuscript can only improve efficiency and productivity.

# DUTIES, ETHICS, AND PROFESSIONAL WRITING PRACTICES

PERSONAL CONTACTS take place between authors and many other contributors throughout the Survey publication process. Ideally, these contacts are harmonious and mutually beneficial. Interpersonal frictions sometimes arise, but even strong personal differences can yield positive results when everyone observes courtesy, good will, and professional respect. Some authors tend to regard reviewers and editors as punctilious adversaries. Punctiliousness, in fact, is a vital part of the review process that helps transform rough-hewn manuscripts—some replete with minor mistakes and inconsistencies—into paragons of accuracy, style, and proper usage. Conversely, some reviewers wrongly see their participation as an onerous task standing in the way of their own creative research.

The responsive author is receptive to suggestions and recognizes that other members of the group reviewing publications share responsibility to the Survey and to the users of Survey reports. Similarly, good reviewers, like good editors, are tactful and constructive. Their function is to assist authors, not censor them. Authors should also remember that their reports, though bearing their names, are not their personal property. The Survey provides salaries, office space, laboratories, libraries, and other facilities, and the results of all its research are in the public domain.

## MANY CONTRIBUTORS

You as author are only the first of many people who contribute to the finished report. Only your name appears on the title page, but each report in final form is the product of a largely anonymous and unsung staff of typists, manuscript coordinators, reviewers, editors, illustrators, cartographers, printers, and distributors. As the chief contributor, you assemble the facts and theories and have a personal interest in committing them clearly to print. The Survey encourages that interest and recognizes it as essential to the high morale and personal esteem of the organization. Authors should understand, however, that the Survey has a statutory interest in all its manuscript reports and may use them as it sees fit or may require that they be modified. The Survey rarely exercises this prerogative except to ensure that a report is scientifically sound, reaches the proper readership, and reflects credit on the Survey and the author. To these ends, your colleagues, supervisors, and staff associates all bring their specialized knowledge, skills, and judgments to bear on your report.

## PLAGIARISM ESCHEWED

In using the works of other writers, you as author must scrupulously avoid any hint of plagiarism. You must take great care to duly cite the ideas and publications of other workers in the subject area, and you must clearly attribute any direct or indirect quote from another author in a way that leaves no doubt as to its source. The name of the author and year of publication should unmistakably precede or follow the quote. For citations from longer papers, or of specific data, inclusion of page numbers is a courtesy to both the author and the reader. (See p. 234 for citation style.) In quoting from others, you should use only original source material or should cite exactly where the quote came from.

## ACKNOWLEDGMENTS

Acknowledgments in reports by Survey authors can generally be divided into three groups: (1) acknowledgments to outside agencies or persons, (2) acknowledgments to previous investigators for borrowed data used by the author, and (3) acknowledgments of assistance by colleagues. These groups are discussed at length in the current Survey Manual.

**Outside agencies.** Cooperative relationships are explicitly acknowledged by the Survey, generally in the introductory part of the Survey report. Any formal cooperative agreement must be concisely cited on the cover and title page of a book report and on appropriate margins of separately published maps, charts, and atlases. In reporting on areas outside the United States, take care to avoid offending the sensitivities of coworkers of the host country: Double-check such matters as correct spelling of names and use of personal titles. Carefully avoid criticizing local customs and facilities. Remember that mapping standards differ from one country to another, both as to accuracy and as to appearance. Any non-Survey financial support should be acknowledged.

**Borrowed data.** Authors must have permission, preferably written, to use borrowed data or conclusions and should properly credit data or conclusions of collaborators. Permission from private companies to publish confidential information, such as mine maps, well logs, and production data, should be indicated in the manuscript or in attached documents. Company names and trade names of equipment or material are avoided in Survey reports unless special reasons require their inclusion. Photographs should not show company names or trade names.

Discussions of subject matter outside the Geological Survey's field of competence require citation of authorities. For example, statements giving the limits of chemical constituents acceptable for public water supply should cite appropriate State or Federal standards; statements concerning matters of waste disposal, or limits of such constituents in irrigation water, should also cite authoritative sources such as boards of health, the U.S. Public Health Service, or the Environmental Protection Agency.

**Colleague contributions.** Every Survey investigation and report has benefitted from suggestions of the author's colleagues as a routine part of their work, and such assistance ordinarily need not be recounted unless it is noteworthy. If acknowledgment is made, an unadorned statement of specific aid will help fix responsibility and will probably be more appreciated by the recipient than an effusive expression of gratitude. "John Smith gave me access to his unpublished data" is more informative then "I am extremely grateful to John Smith for his unstinting help and generosity during the compilation of this report." Analyses, computations, and identifications of minerals and fossils, by either Survey or non-Survey personnel, must be credited. Such credits should appear in the tables, lists, or statements in which the work is reported, not in the formal "Acknowledgments" paragraph. This credit is courteous, honest, and mandatory. It also helps place responsibility.

Photographs other than your own should be acknowledged. Credit the photographer, by name, in the caption of each such illustration.

**Permission to use copyrighted material.** Authors are responsible for getting permission from the owner to use or quote from any copyrighted material. Some publishers require specific forms of acknowledgment. Copyright permissions must accompany your manuscript when it is submitted to the Director for approval.

**Other assistance.** Family members, typists, editors, illustrators, librarians, and others contribute in many ways to the production of nearly all reports. Extraordinary assistance by such persons warrants a credit line, but letters of appreciation addressed to the employees' supervisors are generally more suitable and more immediately profitable to the individuals than mention in a technical paper. Thanks for help from family members can be expressed in personal ways.

For acknowledgments and other occasions of personal reference, the preferred form is "Joseph P. Smith" or "Mary M. Smith" the first time the person is referred to; thereafter, "Smith" or "Mr., Mrs., Miss, or Ms. Smith" are preferable. Usage should be consistent; don't use "Smith" in one paragraph and "Mr. Smith" in the next. Military and political titles ("Colonel," "Senator") are used in Survey papers, but academic and professional titles ("Doctor," "Professor") are ordinarily omitted.

## Dedication of U.S. Geological Survey Publications

According to the U.S. Geological Survey Manual, Section 503.2.6,

> It is not the policy of the USGS or of the Federal Government to dedicate its publications. Only two USGS publications have been dedicated to an individual. These exceptions, Professional Papers 1249 and 1250 describing the 1980 erruptions of Mount St. Helens, were dedicated to David A. Johnston who lost his life during the main eruption. This exception was made following a commitment by the President of the United States, and may remain a unique occurrence.
>
> Other appropriate ways to honor individuals are available, including permanent awards to USGS employees for their accomplishments, and memorial volumes published by leading professional societies. Outside publications are especially fitting because they encourage non-Geological Survey scientists to participate in the memorials.

## Credits and Copyrights

Besides any general acknowledgment of a book or article in the text, credit for each borrowed illustration should be shown on the illustration or in its caption. The preferred credit line is "From Smith (1948)" if the illustration is reproduced essentially as originally published, even if the format or style is slightly changed or the illustration is redrafted. Use "modified from" if the substantive content is changed in any way. "After" carries a more nebulous connotation that implies use of an idea but not a direct copy. "Adapted from" is equivalent to "Modified from" but is not preferred usage. Photographs taken by you as author are not credited; uncredited photographs are assumed to be your work. Individual credit may be given, however, if the report has multiple authorship. Borrowed photographs or other illustrations should be acknowledged in the figure caption, even if modified by the borrower.

Proprietary information, such as mine maps, drill-hole production, or sampling records, requires both an acknowledgment and written permission from the owner, even if published only in open file.

If copyrighted material is to be reprinted, written permission must be had from the owner of the copyright, and a statement of such permission must appear in the caption, either in the specific words requested by the owner or as "Reprinted from * * * and published with permission." You as author retain the written permission. Though Government-published maps and texts are not subject to copyright, proper credit must be given for cited or republished Government work; it is also courteous to notify the original author of work being used.

## COPYRIGHT TRANSFER

Because the subject of copyright transfer to outside journals sometimes causes confusion, the following form clearly states the position of Government (Survey) authors with respect to copyright. An author may sign and attach this form to any forms received from outside journals. The work of Survey authors cannot be copyrighted and, therefore, copyright cannot be transferred.

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**COPYRIGHT TRANSFER FOR U.S. GOVERNMENT AUTHORS**

Date:

Title of article:

I (we) certify that the article named above was prepared as part of my (our) official duties. The article is thus in the public domain and cannot be copyrighted.

Signature(s) of U.S. Government author(s):

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## WRITING SKILLS

Scientific research of itself seldom involves much writing practice, but practice is essential for acquiring writing skills, and the only way to learn is to write. Good writers are made, not born. Survey scientists who strive to write well soon learn that what is good for the Survey is good for themselves. Few scientists achieve professional stature through the spoken word; a surer way is through high-quality publications. Right or wrong, the research and academic worlds tend to equate your fitness for advancement with the size of your bibliography, chiefly because published reports are easy yardsticks of growth and productivity. Even the rare scientist who lacks the normal need or desire for financial advancement finds that professional recognition, election to fellowship, and attainment of high office in scientific societies are based more often on published writings than on other accomplishments.

Mere practice alone, however, will not assure writing proficiency. Broad reading of good literature helps, although good literature and scientific reporting are not necessarily synonymous. The many published grammar primers, technical manuals, style guides, glossaries, word-usage guides, dictionaries, and writers' handbooks also will help sharpen writing skills. Most bookstores have several to choose from. Writing classes are profitable and can be enjoyable, particularly those that offer one-to-one criticism.

Thoroughly understanding your subject matter is essential to committing it clearly to writing. So is clear thinking: The Survey geologist who reported "limestone blocks the size of a large woman's purse" evidently was unaware that a small woman might carry a purse of the same size.

See the section on "Suggestions as to expression" (p. 124) for hints to enhance writing skills; many examples are taken from actual Survey manuscripts. Every Survey author can profit from studying those examples.

## ACCURACY

Vague writing has no place in the scientific literature. Accurate reporting is a self-evident obligation, ethic, and good professional practice—accurate reporting not only of all scientific data, but also of such basic things as arithmetic and geographic locations. Simple typographical errors in numbers and directions are easily overlooked in proofing. If the text says a site is just northeast of Pine Mountain, the location on the map should be nowhere else. Section numbers, townships, and ranges should be carefully checked. The total thickness of a stratigraphic column should equal the total of individual beds, and if the total is a rounded one, that fact should be stated. Mineral analyses and their totals should agree. All these things seem obvious, but they are common sources of error, and if incorrect, they reflect on the credibility of the entire report. A point is reached in the proofing of a manuscript where every word and every figure must be individually checked by the author. No other procedure assures accuracy.

## QUOTATIONS

Famous remarks are very seldom quoted correctly.

*Simeon Strunsky*

Authors are responsible for the accuracy of quotations. Because errors are sometimes made in copying printed matter, the typed copy of every quotation should be carefully compared with the original. Quotations ordinarily are not verified in editorial review.

Short quotes may merely be set within quotation marks; longer ones may be indented or set in different type sizes as determined by the editor. In quoted material, the exact words of the original should be preserved. It is not necessary to reproduce details of printer's style, such as indentions, type size, and spacing, or typographical errors or incorrect spelling. Capitalization, punctuation, or grammatical errors need not be preserved either, except where the preservation of quaintness or exactness of form is desired. Titles of references should be quoted without change except to correct typographical errors. Any other word considered to be in error should be reproduced exactly, followed by "[sic]," which indicates that the erroneous word or passage is precisely reproduced.

Italic in the original should be retained. If you italicize a word or phrase that is not italicized in the original, this change should be indicated immediately after the italic by a bracketed phrase such as "[italic mine]." Omissions within quoted matter should be indicated by three asterisks (* * *); comma and final period are placed inside the quotation marks. Other punctuation marks are placed inside the quotation marks only if they are part of the material quoted. To indicate quotations within quotations, use double quotation marks for the original quotation and single quotation marks for the quotation within the original.

Ordinarily, quotations from foreign languages are translated into English; if a quotation in the original language is desirable, both the original and a translation should be given. Set the translation in brackets.

## PROMPTNESS

Author and supervisor together share the responsibility for promptness in completing reports on time. A researcher is obligated to complete a report of an investigation as soon as possible after the close of the research. The obligation is not fulfilled until the results are published. Supervisors share the obligation. Employees taking on new assignments, moreover, will gain professional stature if they reserve sufficient time in their new schedules to complete any unfinished reports on time.

An employee who plans to resign is obligated to complete and submit all such reports before leaving the Survey. Furthermore, even though an author completes the report before leaving, and thus satisfies that obligation, reputations may be endangered and the Survey may be embarrassed if unpublished information gained during Government employment is used in private employment. To assure the highest personal and ethical conduct at all professional levels, the Survey relies on the honor and scientific integrity of its employees.

## PROFESSIONAL DISAGREEMENTS

Factual comparisons in reports should be so worded as not to offend or cause wrong impressions. Authors who must relate their findings to those of other workers will do well to concentrate on clear, logical presentations of their own subjects; references to other writers and quotations from other writings should contribute to the presentation without distracting the reader. Expressed opinions, especially about writers who have erred or who hold contrary views, should be tactful and dignified. If you find a mistake in a predecessor's work, you may tingle with self-satisfaction, particularly if your predecessor is an eminent scientist, but before gloating in print, consider the state of knowledge and the working conditions when the mistake was made. Consider also the reminder of Lucan, still valid after 2,000 years: "Pigmies placed on the shoulders of giants see more than the giants themselves."

## CLARITY

Scientific thought is exact and direct, and scientific writing must therefore be accurate and to the point. * * * [Any] writer's first duty is to be intelligible. * * * [Plain] writing is not something beneath the plane of endeavor of the scientific investigator * * *. It is our ambition that the reports of the Geological Survey shall be written in the language of the people.

*George Otis Smith*

In 1973, Survey Director V.E. McKelvey added to the plea of George Otis Smith:

> [Policies, plans, and decisions concerning] resource adequacy, strip-mining, land use * * *, powerplant siting, preservation of coastal wetlands, wilderness area withdrawals, offshore drilling, * * * surface and subsurface waste disposal, air pollution and [other problems] that are central issues in the United States today are * * * made by legislators, social scientists, lawyers, and others who understand and represent people, but who do not understand

[scientific] language. [The information required to solve these problems needs] to be in plain terms and in forms in which it can be used effectively * * *.

In our efforts to increase the use of resource and land information in planning and decision-making, we have found that one of the most difficult problems is how to bridge the information gap between scientists and nonscientists * * *. The earth scientists, on the one hand, and the planning and urban decision-making community on the other, despite the best efforts of both, have been unable to totally bridge the gap between them.

Suggestions to Authors stresses the need for clarity. To ensure effectiveness, reports must not only be accurate but must be so clearly and simply written that they are easily read and understood by their intended readership. To write clearly one must also think clearly; what could the author have been thinking who wrote that "most of the data on recent sediments in intracratonic basins are surrounded by Archean rocks"? The more esoteric aspects of earth sciences published nowadays cannot be written in layman's language, but no matter how abstruse the message, the purpose of writing remains the same: to tell somebody something, to report data accurately, and to present information clearly for contemporary and future readers.

The more concise a scientific report, the better. Henry David Thoreau once wisely said that life is frittered away by detail. A lean, crisp report is processed faster and more cheaply than a rambling one and when published is read and understood by more readers. An adequate but brief manuscript demands more of an author's energy and skill than a fat-filled production. Concise writing demands practice.

After a manuscript is completed it should be set aside to cool. Resist the urge to rush it along. Then go over it afresh to delete needless words, phrases, sentences, and paragraphs. Even then, a space-conscious journal editor may demand significant shortening ("condensation"), but if you condense your manuscript before submitting it, processing will be more rapid and less painful.

Technical aspects of earth science cannot be easily described in lay terms, despite the admonition of George Otis Smith, but there is no place in Survey writing for showy and stilted writing. If communication is to be effective, it must be understood, and chances of being understood are enhanced if ideas are expressed as simply as possible in the fewest possible words.

## Name Continuity

Authors should decide early in their careers how they want their names to appear on reports and maps, and hence in bibliographic citations. Confusion will be avoided if the name form is not changed later. Name continuity not only eases the work of librarians and bibliographers but also enables fellow scientists and other researchers to find all the works by an author in one place in reference lists, bibliographies, card catalogs, and computer files.

Women scientists should consider the desirability of retaining one name for professional purposes throughout their careers, even if they change their surnames by marriage. A hyphenated combination of wife's maiden surname and husband's surname ("Jane R. Jones-Smith") is not recommended because it causes bibliographic problems in reference lists and catalogs.

Use of the first name and middle initial is preferred. In the event of name similarities, a distinctive combination of names or initials is advisable. The author's choice in this matter will be respected. Regardless of the form of the name on the title page of a report, Survey bibliographic citations traditionally give only the initials unless there are (1) name similarities or (2) only one given name (see "Preparing References" section, p. 234).

## The Scientist as Volume Editor

WANTED: Scientist doing Nobel-prize-level research to edit proceedings volume for major conference. Must be charming, creative, determined, diplomatic, enthusiastic, firm, organized, patient, persuasive, resourceful, tactful, witty. Needed for about one year. No stipend. May have to suspend own work.

Despite these requirements for sainthood, many scientists take on the task of assembling and editing a group of papers for publication in a single volume. If you find that you have agreed to be scientific editor of such a volume, the following guidelines may help you through the trying times ahead.

The most immediate discussions will be with your employer, whose support is vital to your undertaking. If you are between projects when you accept the editorship, you probably can find time to dovetail your own work with editorial tasks, but if your workload is steady, you and your employer must agree on an equitable allocation of your time.

Next, determine beyond all doubt that the sponsoring organization has a firm commitment—both financial and professional—to publish the volume. Be sure that the sponsor places complete confidence in you as editor and will honor your actions for meeting all objectives, which is to say that the sponsor will provide the money to publish and will back up your decisions.

If your employer is also the sponsoring organization (such as the Survey), you may need to iron out a few more wrinkles before you begin. Be sure everyone involved shares the same expectations and perceptions of the project and agrees on priorities and scheduling.

To set up a schedule for the volume, you must decide fairly early (1) the intended readership, (2) the intended publication date, and (3) the publisher. You may have to decide the tone of the volume—informal, as might suit a workshop, or formal, as might fit an international congress. You must assess what funding, resources, and people will be available, and you must set up a system for keeping track of everything. Some elaboration on these topics may be instructive.

From the anticipated publication date, you can work backward to the present with the publisher/printer to get an idea of what deadlines the completion date requires. List everything you can think of that has to be done, and estimate how much time will be needed to complete each step. Then enter the deadline date for each step.

For example, if the papers presented at a meeting in October are to be published in time for the next year's meeting and you start planning in early September before the meeting, you'll have about 12 months from beginning to end. The following hypothetical publication schedule lists many of the tasks to to be done in that time (although the order can vary), working from the target date backward.

Keep in mind that even the best of schedules is subject to human and postal frailties. In large measure, your editorial efforts will be devoted to anticipating problems and devising ways to avoid them.

## Hypothetical Publication Schedule

In the following schedule, read up from "Project Begins." Estimated time is how long a task might take from the beginning of one step to the beginning of the next. Be realistic. Allow time at each step just to handle and record the arrival or departure of material, which in aggregate can be surprisingly long. Note also who will be responsible for each task. The order of steps may vary, and many steps may need to be added.

Myriad questions will spring up as you think about the schedule. The following questions are samples of what you might consider:

How will papers be solicited and selected?

How many papers might be anticipated? (The projected cost of the volume will affect its length and content.)

How long should each paper be?

| | Date | Estimated time |
|---|---|---|
| PROJECT ENDS | | |
| Thank-you notes written to all | 9/30 | |
| Copies of volume are delivered | 9/30 | |
| | | 2 weeks |
| Volumes are packaged and shipped | 9/15 | |
| | | 2 weeks |
| Volume is printed | 9/1 | |
| | | 2 weeks |
| Volume is delivered to printer | 8/15 | |
| | | 1 week |
| Volume is prepared for printing (final corrections and layout) | 8/8 | |
| | | 1 week |
| Copy for printer is complete to your satisfaction | 8/1 | |
| | | 4 weeks |
| You approve all papers | 7/1 | |
| | | 4 weeks |
| Authors return final version to you | 6/1 | |
| | | 8 weeks |
| You review papers and send to authors | 4/1 | |
| | | 8 weeks |
| You receive papers | 2/1 | |
| | | 14 weeks |
| Initial tasks: | | |
| Instructions are sent to authors who write papers | 10/14 | |
| Publisher is selected and consulted | | |
| Deadlines are set | | |
| Kind of author copy is decided upon | | 6 weeks |
| Volume design and format are settled | | |
| You accept the editorship | 9/1 | |
| PROJECT BEGINS | | |

What about the number and size of tables and figures in each paper?

Should authors follow one style guide (such as STA) or will consistency within each paper suffice?

Will author-prepared art be accepted (or required), or will artwork be redrafted? Redrafted by whom?

How about peer review for each paper? Who will do it and how long will it take?

How do you visualize yourself as scientific editor—as a technical advisor or as absolute authority?

What influence might electronic media have on the project? For example, will a paper on a word-processing disk be acceptable or useful?

Will the papers be camera ready or typeset?

What guidelines will authors require and when?

Will you adhere to your deadlines? Will you reject papers that fail to meet them, or will you slip your schedule for the slowest author? How much flexibility is possible without disrupting the entire schedule (and irritating the prompt authors)?

Will you be concerned with how the volume is marketed and (or) distributed?

A few answers crucial to the success of the project may require agonized soul-searching on your part. Take the matter of deadlines: If you set reasonably firm deadlines (give or take a week, say), how will you respond to the creative excuses of an anguished colleague whose paper you know will be late despite your exhortations?

Once the schedule is set and major decisions are made, the time has come to compile names, addresses, and phone numbers of everyone on the project, particularly authors. Any format is fine that can withstand heavy use and can be easily modified. Authors will constantly crave news about the project (their own papers in particular) and will demand much attention, despite your more pressing duties. As Survey geologist Tom Fouch suggests, try to calm their anxieties about every 3 weeks with brief progress reports, news, or instructions. Your final communication will be the thank-you notes you write to everyone involved in the project. Be sure to send one to yourself—you will have earned it!

# FORM AND CONTENT OF THE REPORT

## TITLE PAGE

Besides the report title itself, the title page of a Survey book report carries the name(s) of author or authors, series and number, volume title if applicable, a statement of cooperation if applicable, and a brief descriptive statement characterizing the report. The title and authorship also appear on the first page of text above the abstract, about 2 inches from the top of the manuscript page to allow space for directions to the printer and for volume title if needed. Check several recently published papers for examples of format.

### TITLE

Use great care in choosing an informative title. It may be the only reference a reader will have to the report. Most literature and subject searches start there, and nothing will better catch the reader's eye. The title should be as brief and clear as possible; it should give the reader a clear idea of your paper's content, but it should not serve as a summary of the report. Long titles do not necessarily indicate scholarship, and they are seldom quoted in their entirety anyway, but do not attempt to shorten the title through the use of multiple compound modifiers, or through a pyramid of prefixes.

Avoid beginning the title with insignificant words or needless words such as "The," "A," "Notes on," "Report on," and "On." These words can be effective in text headings, but in a book title a more meaningful word is better. The first word should be an important one.

For some Survey reports there are no guidelines, and the author must devise an informative title, but many Survey reports have fairly standardized titles:

> Mineral Resources of the North Absaroka Wilderness Study Area, Park and Sweet Grass Counties, Montana
>
> Environmental Geology of the Front Range Urban Corridor and Vicinity, Colorado
>
> Stratigraphy and Structure of the Western Kentucky Fluorspar District
>
> Geologic Map of Dinosaur National Monument and Vicinity, Utah and Colorado
>
> Geologic Map of the Ripley Quadrangle, Jackson County, West Virginia
>
> Ground Water in North Monterey County, California

Titles of standard quadrangle reports customarily include the county name or names involved; county names may be appropriate for other reports also.

## AUTHORSHIP

Authorship is an extension of the responsibility of seeing a research project through to completion. When more than one investigator has participated, the project chief or supervisor ordinarily decides how authorship is to be divided, after having evaluated the relative contributions of the collaborators and their abilities to deliver segments of the joint manuscript. For any research project that involves more than one scientist, all workers should clearly understand at the outset what parts of the research are their responsibility, what parts of the final report they are to prepare, and where their names will fall, if at all, in the order of authorship. The person in charge of the investigation, or the one who prepares the report or map, will naturally be author or coauthor. Other coauthorship is restricted normally to participants who contribute substantially to the results of the investigation. Administrators and supervisors are not normally included, nor are individuals who contribute only routine technical assistance.

Seniority, grade, and like distinctions are not criteria for deciding authorship or coauthorship, nor should such distinctions influence the choice of names on the title page, in the section on acknowledgments, or in a table of laboratory results. Credit should be based on responsibility for the finished product and for the work and thought that went into it. Laboratory assistants and other support personnel are more commonly credited in text or tables, but a participant who has shared greatly in the outcome of a research investigation might be listed as coauthor or, more rarely, as senior author.

Survey reports seldom warrant more than four principal authors. The form "*by* A.B. Brown, C.D. Smith, E.F. Jones, and others" is sometimes used, but if so, contributors not named as authors should be given due credit in the text or in a preface. A supplemental contribution on a related phase may be credited by adding, to the main title and authorship, the words "*With a section on* (subject), *by* (author)."

The author of each separately titled report will be named regardless of whether the report is published as an individually numbered publication or as a separate chapter under a more inclusive general title.

Multiple authorship of a single report can cause problems for supervisors, editors, librarians, bibliographers, and even promotion boards, as well as the authors themselves. In today's times of increased specialization and multidisciplinary research, many reports are prepared jointly by several persons whose shared responsibility should be credited; acknowledgment in the text will generally suffice. A listing of more than four authors for a short article or a journal abstract suggests a lapse of judgment on the part of the principal investigator.

The general title page of a collection of several chapters by named authors omits any authorship if the chapters have only a general topical or geographic relationship. Such chapters are commonly issued separately, but if the chapters are closely related, authorship is shown on the general title page in accordance with currently existing policies. For example:

Data of Geochemistry
*Sixth Edition*

Michael Fleischer, *Technical Editor*

*Chapter T.* Nondetrital Siliceous Sediments
*By* Earle R. Cressman

### Affiliations

Authors of Survey reports are assumed to be Survey employees, and no affiliation is shown unless some coauthors are not. In that event, affiliations of all authors are shown on the title page or on the first page of text. For most Survey reports, the senior author must be a Survey employee. For reports prepared in the Survey for outside publication, affiliations are shown for all authors, and if the Survey is to pay page charges, the senior author must be a Survey employee.

## Statement of Cooperation

Some Survey products are sponsored jointly with cooperating Federal, State, or other governmental agencies. If so, statements of cooperation must appear on the title pages and covers of book reports and on the margins of separately published maps. You as author are responsible for ascertaining the exact title of the cooperating agency for such statements. Some examples:

Report prepared jointly by the U.S. Geological Survey and the National Oceanic and Atmospheric Administration
Cooperating organization: Colorado Geological Survey

Prepared in cooperation with the U.S. Army Corps of Engineers, Mobile District

Jointly supported by the U.S. Geological Survey and the Department of Housing and Urban Development, Office of Policy Development and Research

Prepared in cooperation with the States of Illinois, Indiana, Kentucky, and Tennessee, and with other agencies

The work on which this report is based was performed in accordance with a cooperative agreement between the U.S. Geological Survey and the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia

You as author should follow the wishes of a sponsor or cooperator who desires a particular form of acknowledgment.

## Descriptive Statement

A brief statement characterizing the report should appear on the title page of the manuscript. The editor will know if it should be italicized. Examples from recent Survey reports:

The Figuera Lava and the overlying Fajardo Formation are redescribed and assigned to the Lower Cretaceous Series

A stratigraphic-paleontologic study of rugose corals as aids in age determination of Great Basin Devonian rocks

A descriptive summary of geologic conditions in a region of varied physiography and rapid urbanization

A study of the problems associated with fission-track dating of glass

Modal and chemical data on plutonic rocks of the Mariposa quadrangle

## Front Matter

### Foreword and Preface

A foreword is written and signed by, or carries the name of, someone other than the author; a preface is by the author. Both precede the table of contents—the preface after the foreword if a report has both—but most Survey publications have little need for either. Carefully prepared introductory material generally eliminates the need for a preface, and few reports need any comment other than the author's text. Prefatory statements may be appropriate, however, if (1) publication is unusually important, (2) a report has an overall title but consists of a collection of related papers, each having its own author and title, or (3) a report is a result of a cooperative investigation with another governmental agency. Such publications may benefit by a foreword that is written and signed by an appropriate official who cites the importance and circumstances of the investigation.

A preface can be a prominent place for bibliographic information, such as the relationship of a report to earlier editions or to other reports on the same subject, or for certain credits and acknowledgments not included on the title page. In reports authored by an organization, such as those on surface-water supplies of the United States, the preface can credit suppliers of data who would be recognized as authors in other types of reports. A preface may be unsigned or it may carry the name or initials of the author.

### Contents, Illustrations, and Tables

The manuscript should include lists of "Contents," "Illustrations," and "Tables." Suggestions for formatting are given in the section on "Formatting Survey Manuscripts for Review and Editing," page 250. To get an impression as to how your headings should be organized, scan recently published examples of similar reports. The "Contents" consists of the headings in the manuscript, except that repeated minor headings are omitted. The rank of headings is indicated by appropriate indention, and few manuscripts require more than three or four; excessive ranking confuses the reader. The "Page" column shows final manuscript page numbers. Illustrations should be listed as figures in the manuscript; they will eventually be separated into plates and figures, if necessary, by the illustrators and editors, who will then make the needed changes in the manuscript. An exception is the paleontologist's preparation of plates on which groups of figures show photographs or drawings of individual fossils. "Contents" is a de facto outline of the report.

## Abstract for the Written Report

An abstract for a written report may differ significantly in purpose and content from one for an oral presentation, so the two are discussed separately here. Except for certain statistical reports, such as streamflow records, and composite group efforts that may be unsuitable for abstracting, any but the briefest scientific paper is preceded by an informative abstract. A proposal to present a paper orally must have one also.

Early rough-draft summaries should not be made over into abstracts; they might be helpful in planning a report, but the final abstract should be a concise summary of the completed manuscript. Preparation of a good abstract—one that summarizes the important content of the report and nothing more—deserves as much thought, rewriting, and polishing as any other part of the report. Your abstract is a digest of your report, and its adequacy determines much of the report's impact and usefulness. Used by abstract journals and indexing services, moreover, an informative abstract will increase potential readership and the reference value of the report in the literature. Busy readers may even ignore the report unless the abstract provokes their interest. For an oral presentation, the adequacy of the written abstract probably will determine whether a paper is accepted or rejected and, if accepted, whether it will draw an audience. To assist reader comprehension, avoid abbreviations and acronyms.

The abstract should be informative rather than descriptive. Some water-resources reports, by their nature, require a descriptive abstract, but abstracts for most Survey reports should spell out the results of the research and state briefly the conclusions. Inappropriate phrases, commonly in the passive voice, include "are discussed," "is described," "were investigated," or "conclusions are given." The abstract should relate what the report tells, not what the report is about. For example:

Write "A gravity high of 25 milligals suggests that * * *," not "The gravity anomalies in the area are discussed."

Write "The Cretaceous rocks yield 50–150 gallons per minute of moderately mineralized water to wells 800–1,200 feet deep," not "Ground water in the Cretaceous rocks is described and its depth is given."

An author's conclusions are the most valuable part of a report or abstract, but within space limitations the abstract should also indicate the method of attack and the type of data used and should clearly orient the paper in place and function. It should supplement the title, not duplicate it, and it should not be a mere expansion of the table of contents. It should contain no information that is not discussed in the report. The abstract should stand by itself, independent of the text; references to text tables and illustrations should be avoided. Reference to a published work is rarely needed and should also be avoided.

The Survey sets no specific limits on lengths of abstracts in its publications, but short abstracts are more likely to be read than long ones and are more apt to be included in their entirety in abstract journals.

Few abstracts are long enough or complex enough to need center headings, except for monographic treatises, and few need to be amplified by examples. Abstracts offered to scientific meetings generally must meet rigid limits on words or space; exceeding those limits risks rejection of the proffered paper. For still-timely advice on abstract preparation, the classic counsel of Landes (1966) is reprinted in full as follows:

## A SCRUTINY OF THE ABSTRACT, II

KENNETH K. LANDES
Ann Arbor, Michigan

ABSTRACT

A partial biography of the writer is given. The inadequate abstract is discussed. What should be covered by an abstract is considered. The importance of the abstract is described. Dictionary definitions of "abstract" are quoted. At the conclusion a revised abstract is presented.

For many years I have been annoyed by the inadequate abstract. This became acute while I was serving a term as editor of the *Bulletin* of The American Association of Petroleum Geologists. In addition to returning manuscripts to authors for rewriting of abstracts, I also took 30 minutes in which to lower my ire by writing, "A Scrutiny of the Abstract."[1] This little squib has had a fantastic distribution. If only one of my scientific outpourings would do as well! Now the editorial board of the Association has requested a revision. This is it.

The inadequate abstract is illustrated at the top of the page. The passive voice is positively screaming at the reader! It is an outline, with each item in the outline expanded into a sentence. The reader is told what the paper is about, but not what it contributes. Such abstracts are merely overgrown titles. They are produced by writers who are either (1) beginners, (2) lazy, or (3) have not written the paper yet.

To many writers the preparation of an abstract is an unwanted chore required at the last minute by an editor or insisted upon even before the paper has been written by a deadline-bedeviled program chairman. However, in terms of market reached, the abstract is *the most important part of the paper*. For every individual who reads or listens to your entire paper, from 10 to 500 will read the abstract.

If you are presenting a paper before a learned society, the abstract alone may appear in a preconvention issue of the society journal as well as in the convention program; it may also be run by trade journals. The abstract which accompanies a published paper will most certainly reappear in abstract journals in various languages, and perhaps in company internal circulars as well. It is much better to please than to antagonize this great audience. Papers written for oral presentation should be *completed prior to the deadline for the abstract*, so that the abstract can be prepared from the written paper and not from raw ideas gestating in the writer's mind.

My dictionary describes an abstract as "a summary of a statement, document, speech, etc. . . ." and that which *concentrates in itself the essential information* of a paper or article. The definition I prefer has been set in italics. May all writers learn the art (it is not easy) of preparing an abstract containing the *essential information* in their compositions. With this goal in mind, I append an abstract that should be an improvement over the one appearing at the beginning of this discussion.

ABSTRACT

The abstract is of utmost importance, for it is read by 10 to 500 times more people than hear or read the entire article. It should not be a mere recital of the subjects covered. Expressions such as "is discussed" and "is described" should *never* be included! The abstract should be a condensation and concentration of the *essential information* in the paper.

# Abstracts for Talks at Scientific Meetings

Abstracts for talks at scientific meetings differ from abstracts of written reports because those for talks may be supported by fewer data, are generally more temporal and less archival, and may be based on tentative hypotheses. Such abstracts are useful, however, because they commonly are the first published results of an investigation and, historically, are sometimes the last.

Most abstracts are printed in a prescribed format that allows space for about 250 words. Commonly they are printed as received with little or no further review or editing. The Survey, however, requires technical review, editing, Division approval, and Director's approval.

You might consider this kind of abstract writing as a 250-word contest to win listeners for your talk, professional acclaim, and subsequent endorsement for your project—maybe even funding. With such scientific prizes at stake, such abstracts must be precise, scientifically sound, and skillfully written. The abstract should be informative, even though its results and conclusions may be preliminary when submitted months before the meeting. Abstracting a talk that won't be delivered for several months is a challenge, and you as author must distill a wealth of ideas into one or two exciting concepts, despite incomplete data. Try to write the abstract as if there were no talk, as if the abstract were the only vehicle to convey the findings of your research.

A few guidelines may help you use the available space most effectively:

**The title.** The title must balance length against content. A short title may be vague and a long one cumbersome. At the very least, it should state the topic and any geologic/geographic fix. Ideally, the title expresses the essence of the talk, and perhaps outlines the talk as well. Such a title calls for strong, precise words (a dictionary and a thesaurus may help); avoid prepositions and strings of unit modifiers. Strong punctuation—such as a dash—can supplant connecting words.

Note the varied titles possible from the following simple abstract, depending on what finding is most significant:

> Recent geologic mapping of the Great Silver Gulch Formation in Montana provided evidence that ore deposits in the formation were structurally controlled and that the formation is older than reported previously by Q.R. Smith. The structures are such that new deposits may be found, although exploration will be costly because the geology is complex.

Here are three examples of an informative title:

> The Great Silver Gulch Formation, Montana—Evidence indicates Cretaceous age
>
> The Cretaceous Great Silver Gulch Formation, Montana—New ore deposits possible
>
> Structure controls ore deposits—Great Silver Gulch Formation, Montana

By contrast, here is a short, vague title:

> The Great Silver Gulch Formation

**The beginning.** Begin the abstract by putting the "news" up front. In the first sentence or two say what you did, why you did it, and what you learned or expect to conclude. Stress what you did now, rather than what others did earlier, and distinguish your results from your conclusions. Then use the remaining text space to expand on these subjects—perhaps in the same order as they appear in the title.

A conventional scheme is to state the problem, list results, and draw conclusions. Try to adapt this scheme to your material.

**Voice.** Strive for the active voice. It is stronger and takes fewer words than the passive voice.

**Style.** Write an informative abstract—one that presents ideas rather than one that merely says what you're going to talk about. The two styles are contrasted in the following examples.

Informative abstract:

> Recent geologic mapping in the Great Silver Gulch Formation, Montana, indicates that the ore deposits are structurally controlled.

Uninformative abstract:

> The Great Silver Gulch Formation will be discussed and the genesis of the ore deposits will be reported. [Note passive voice.]

**References.** Avoid citing references (most societies prohibit them). They are generally unnecessary in an abstract, they use up words, and they may frustrate your reader, who won't know what you're referring to if you say, for example, "* * * Cretaceous, an age older than that reported by Smith (1975)." If acknowledgment of previous work is essential, however, choose one of the following models:

1. Incorporate the full name(s) and time(s) into the text.

   > * * * Cretaceous, an age older than that reported by Quentin R. Smith and colleagues in 1975.

2. Abbreviate the reference in parentheses without the title.

   * * * reported by Q.R. Smith and others (1975, GSA Bull., v. xx, p. yy–zz).

3. Give a conventional reference at the end of the abstract.

   Smith, Q.R., Prinze, Olga, and North, L.M., 1975, Age of the Great Silver Gulch Formation, Montana: Geological Society of America Bulletin, v. xx, p. yy–zz.

The trick is to use the available block of space on the abstract form as effectively as possible.

**Abbreviations and Acronyms.** Avoid abbreviations and acronyms (p. 104), particularly those contrived to save space. They are unnecessary and just interrupt the reader, who must try to remember what they mean. Some shortcuts are available, however, and formation names are an example. If, for example, you are going to discuss only the Great Silver Gulch Formation in the abstract, write it out in the title and first sentence, then refer to it subsequently as the "Silver Gulch" or "the formation."

If a series of items, such as various rock units in a formation, might be too lengthy to state repeatedly, try numbering each item in the sentence rather than abbreviating each one. This device tells the reader precisely what you are talking about.

> The Great Silver Gulch Formation contains (1) massive biotite and two-mica granite, (2) hornblende-biotite tonalite and biotite granodiorite, (3) the Gold Creek unit (an informal name for the massive, rusty granite), and (4) massive pink granite. The contact between 1 and 2 is obscure.

**Figures or Tables.** Extraordinarily complex data may require a wordier explanation than space permits. A small sketch or table may be an appropriate substitute if the society allows one in the abstract. Many societies print abstracts from camera-ready copy submitted on their required form, and a sketch or table that fits within the boundaries of the form and that can stand the required reduction to publication size may be an ideal alternative to words.

**General Advice.** Carefully follow the instructions in the society's announcement of the meeting and call for papers—instructions as to length, format, style, and acceptability of artwork. Start your abstract through Survey processing as early as possible so as to easily meet the deadline and avoid the last-minute crush that usually develops for typists, reviewers, and editors when many authors submit abstracts for the same meeting. Meticulous planning and attention to detail will impress a society's program chairman who despairs of abstracts that are late, carelessly written, or poorly typed on the wrong form (Lucchitta, 1986). Lucchitta further suggests a few simple rules for keeping program committees and abstract coordinators happy and effective, to the benefit of everyone involved:

- ► Submit abstract on time.
- ► Submit abstract on correct abstract form.
- ► Scrupulously follow instructions attached to the form and fill in all blanks.
- ► Be sure abstract is well written, well typed, and complete.
- ► Make no revisions and changes after abstract is submitted either before or after the deadline.
- ► Aim abstract at the proper meeting and at a wide audience.
- ► Limit contribution to one volunteered abstract unless multiple abstracts are explicitly welcome.
- ► Do not request confirmations unless you provide stamped, self-addressed return envelopes.
- ► Check the appropriate publication frequently for information and registration forms for the meeting of interest.
- ► Do not bother the program chairman for information and forms that are routinely printed in the society's publications.

# THE TEXT

## THE INTRODUCTION

Introductions in Survey books and articles vary greatly in size and content, depending mostly on the length and subject matter of the report. In lengthy reports, several subheadings are appropriate; for shorter reports, a single heading may suffice. Like abstracts, introductions are generally best written after the body of the report. Nearly all introductions should mention the purpose of the study and the approach taken. Most should cite acknowledgments of assistance and cooperation. You should consider the advisability of discussing other topics such as location and access, geographic setting, previous work, and your fieldwork. Some of these topics may be unneeded, but some may be important enough to warrant separate headings outside the introduction.

- ► If an area is well known, you need say little about the location, access, topography, climate, or vegetation, all of which may be relevant only insofar as they bear on geologic or hydrologic problems or on fieldwork. Detailed information on these subjects is rarely necessary.

- The introduction may mention your conclusions on local or regional issues, on further development of current theories, or on differences between your conclusions and those of earlier workers.
- One introduction and one summary generally suffice for a single report, but if a summary of one of the report's subdivisions is desirable, its heading should indicate the subject discussed, such as "Summary of Conditions Affecting Streamflow."

All technical and professional help from non-Survey personnel should be acknowledged, usually in the introduction. General help given by members of the Survey usually need not appear. Further suggestions regarding acknowledgments are on page 12.

## Body of the Report

Most reports, in their presentations and discussions, have headings, footnotes, illustrations, tables, geologic and geographic names, significant figures, and so on. All these aspects of the report warrant detailed attention as to style and expression. All are discussed further on the pages that follow and are listed in the index. Beginning writers should take these pages to heart. Experienced writers might profit from occasional reviews.

### Headings

Headings indicate the topics described in the text. They offer cues for the reader's train of thought and convenient landing places for rapid skimming. Long discussions need occasional headings if only as rest-and-recovery places for the reader. They provide starting and stopping places, and they enhance reader comprehension of the text.

The text, however, should be self-contained and independent of the headings. In general, headings should be noun phrases, though short sentences may be effective in nontechnical publications. Phrases such as "Discussion of," "Statement of," and "Table Showing" are superfluous. "General Features" is more appropriate than "General Statement." Avoid inserting a perfunctory secondary heading where a brief general statement precedes a detailed discussion that requires its own heading.

Excessive refinement in subdividing the text confuses the reader; three or four ranks of headings, plus paragraph sideheads where applicable, should suffice. The sidehead has no specific rank; it is a subordinate heading used for terms or phrases that may be repeated under higher ranking headings, as "Age," "Composition," and "Chemical Analysis."

Headings should preferably be typed on separate lines set off from text with space above and below. The rank of headings is indicated by indention in the "Contents." As a further convenience to the editor, you might also indicate the rank of headings by penciling circled numbers in the manuscript. The copy editor may decide that ranks of certain headings should be changed. This decision is better made by the editor than the author.

### Footnotes

Footnotes break the reader's train of thought. They are seldom needed in scientific writing except, perhaps, in tables or in short papers that have few references and no bibliographic list. Disclaimers and addresses generally are footnoted. A well-constructed paragraph needs no explanatory footnote, nor should you as author make a footnote of a thought that came late and that should have been woven into the text. A rare footnote may be justified when relevant contradictory or supplementary information becomes available after a manuscript is finished or in proof stage. Otherwise, footnotes are generally more appropriate to literary than to scientific writing. The Survey style of footnoting is given on pages 252 and 255.

### Concluding Section

The concluding section should be a concise statement of the main points covered by the report. In a short report the section may need no separate heading; it may be just the last paragraph of the text. In a longer report it may be a "Conclusion(s)," a "Summary," an "Application to Field Problems," a "Need for Further Study," a "Summation of Petroleum Potential," or some other appropriate heading. In some expository reports a concluding section is unneeded, though the reader may feel left in limbo unless some suitable phrasing clearly marks the ending.

### Reference List

Nearly all Survey book reports have a list of references or a bibliography that follows the conclusion of the text and precedes the appendix, the list of tables or basic data, if any, and the index. Survey bibliographic style is discussed in the section on preparing references (p. 234).

## The Appendix

Few Survey publications need an appendix. If long tables of basic data, analyses, well logs, measured stratigraphic sections, or other such information would interrupt the reader's train of thought by intruding into the body of the text, these data may instead be placed after the references. If used at all in a Survey report, however, an appendix should be limited to specialized data needed only by a few potential readers. If a report contains more than one appendix, each should be numbered for ease of reference. Nowadays, material that might once have been appended is often placed in open files.

## INDEX

Indexing is a technical and tedious editorial function, but no part of a report is more useful than a full, well-prepared index, or is more time saving to a busy reader. The index is not part of the manuscript but is prepared from the page proof. Few authors are trained in index preparation, but the basic principles are easily mastered. Software for indexing, moreover, is available in many computer packages. If an index is planned for your report, adequate time should be budgeted in the printing schedule. While you are still writing, you can compile a list of terms that should not be missed. Consider the feasibility of hiring the services of a professional indexer who is used to working more efficiently and rapidly than you yourself as author-indexer, and under a specific deadline (Mulvany, 1986, p. 66).

Survey indexes are alphabetized word by word, then letter by letter. Thus the order of precedence in Survey indexes is:

East End
East Indies
Eastern time
Easternmost exposures

Authors of papers that are to be listed in a computer data bank may be asked to furnish a list of "descriptors" as selected from the index thesaurus of the agency operating the bank. Most data-bank agencies welcome additional "identifiers" or "key terms" that an author believes are needed for adequate indexing. See, for example, any issue of the semimonthly "Selected Water Resources Abstracts" and the "Water Resources Thesaurus," both published by the USGS.

# PLANNING AND MANAGEMENT FOR WATER-RESOURCES REPORTS

THE WATER RESOURCES DIVISION of the Survey provides accurate and timely information on all aspects of water resources to the Nation's water resources planners and managers. To that end, the Division has research centers in Reston, Virginia; Denver, Colorado; Menlo Park, California; and Bay St. Louis, Mississippi; and offices in every State, Puerto Rico, and Guam. In 1985, Water Resources Division personnel at more than 200 locations collected, analyzed, and researched hydrologic data for about 1,500 reports for publication in a wide variety of formats.

This chapter provides the background information authors need to prepare water-resources reports of high quality and timeliness. Processing procedures in the Water Resources Division differ somewhat from those in the Geologic Division or in the various outside publishing organizations, but the author of any technical report planned or in progress can profit from a scan of the steps and requirements outlined below. Quality control and scheduling are rigorous.

The following introductory paragraphs briefly describe the principal organizational units of the Water Resources Division, list the kinds of reports prepared, and emphasize the importance of quality and timeliness. A section on "Planning and Managing Reports" outlines (1) the elements of planning a quality report, (2) the characteristics of a quality report, and (3) the quality-control system used by the Water Resources Division. A concluding section discusses an author's responsibility after a report has received Director's approval for publication.

## PRINCIPAL ORGANIZATIONAL UNITS

Figure 1 shows the principal organizational units of the Geological Survey. In the Water Resources Division most technical reports are prepared in the District offices and Regional Research Centers. Studies in District offices are funded jointly with State and local cooperators, who pay half the cost, and with other Federal agencies or with Federal monies appropriated to the Water Resources Division. Studies and research at the Regional Research Centers or at Headquarters are funded almost entirely by Federal monies.

Funding source can profoundly affect the kind and scope of a study, the readership addressed in the report, the publication outlet, and also importantly, the pressures to publish a report by a particular date. Cooperators in jointly funded studies expect usable results (a published report) by the termination of the period funded for the study.

## REPORTS PREPARED BY THE WATER RESOURCES DIVISION

The wide range of books and maps, leaflets, pamphlets, journal articles, and audio-visual products of the Water Resources Division include Water-Supply Papers, Professional Papers, Techniques of Water-Resources Investigations, Circulars, Water-Resources Investigations Reports, Open-File Reports, Water-Data Reports, Hydrologic Investigations Atlases, Miscellaneous Investigations Series Maps, cooperator-published books and maps, and general-interest leaflets and booklets, water fact sheets, and slide-cassette, video-cassette, and moving-picture-film presentations. Further descriptions of these varied reports are elsewhere in this volume, and in Alt and Iseri (1986).

Most reports prepared by District-office personnel are published or released as Water-Resources Investigations Reports, Open-File Reports, Water-Data Reports, Water-Supply Papers, or cooperator series reports. The bulk of the reports prepared by research personnel are published as journal articles, Professional Papers, or Water-Supply Papers. Thus, if you work in a district you are likely to prepare multidiscipline reports on area water resources, published as Water-Resources Investigations Reports; if employed in the research program, you are likely to author single-discipline articles for technical journals.

The Water Resources Division requires authors to produce technically correct, timely reports, regardless of the series, subject matter, or origin.

## IMPORTANCE OF QUALITY AND TIMELINESS

For more than 100 years, the U.S. Geological Survey has been known worldwide as a source of reliable information on the mineral and water

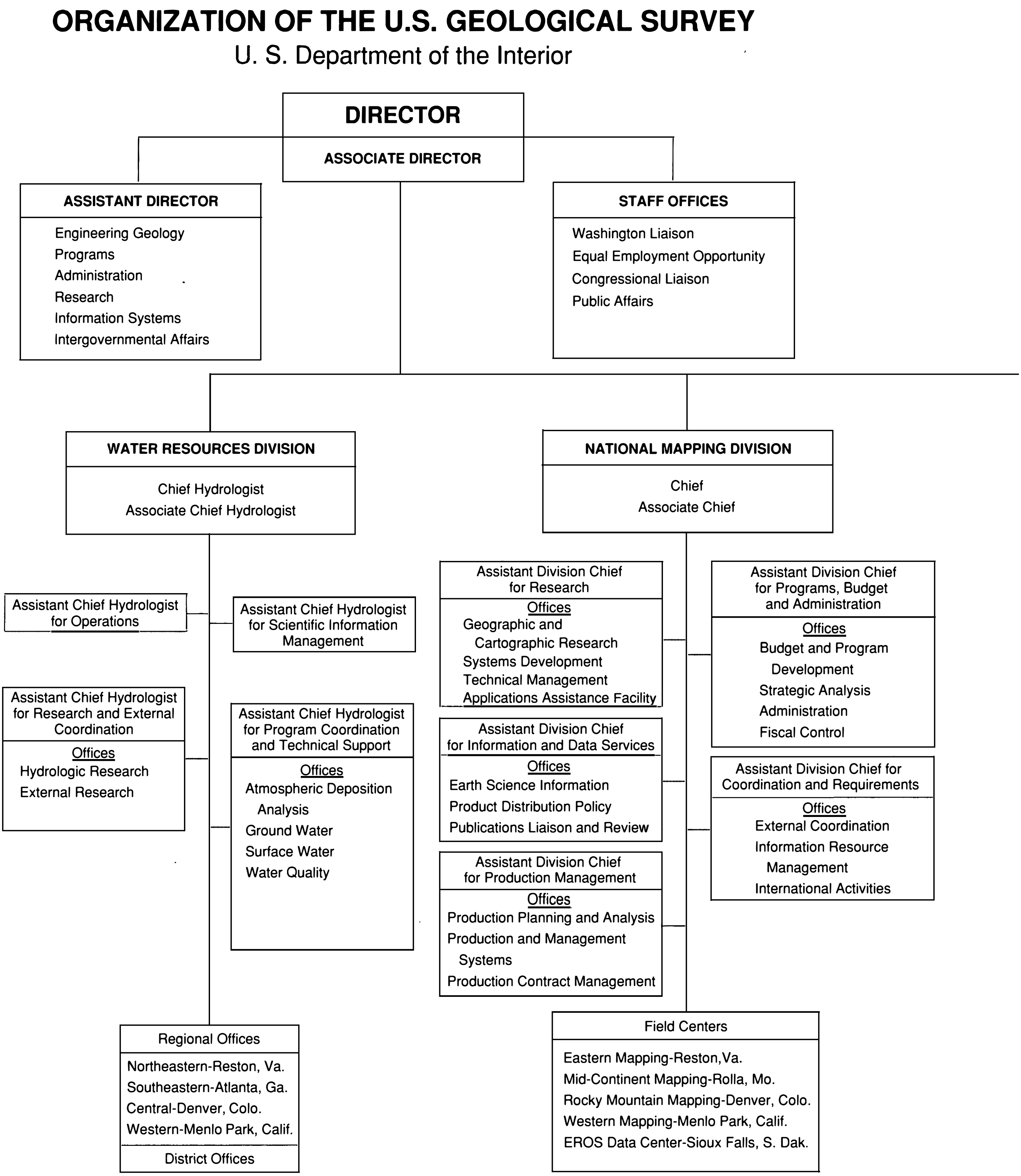


**Figure 1.** Organization chart of the U.S. Geological Survey.

**GEOLOGIC DIVISION**

Chief Geologist
Associate Chief Geologist
Assistant Chief Geologist for Program

**Office of Scientific Publications**

Geologic Names Committee

Branches

- Eastern Technical Reports
- Central Technical Reports
- Western Technical Reports
- Library and Information Services
- Visual Services

**Office of Mineral Resources**

Branches

- Alaskan Geology
- Western Mineral Resources
- Central Mineral Resources
- Eastern Mineral Resources
- Geophysics
- Geochemistry
- Resource Analysis

**Office of Energy and Marine Geology**

Branches

- Coal Resources
- Petroleum Geology
- Sedimentary Processes
- Pacific Marine Geology
- Atlantic Marine Geology

**Office of International Geology**

**Office of Regional Geology**

Branches

- Western Regional Geology
- Central Regional Geology
- Eastern Regional Geology
- Isotope Geology
- Paleontology and Stratigraphy
- Astrogeology

**Office of Earthquakes, Volcanoes and Engineering**

Branches

- Tectonophysics
- Engineering Seismology and Geology
- Seismology
- Geologic Risk Assessment
- Global Seismology and Geomagnetism
- Igneous and Geothermal Processes

**Assistant Chief Geologists**

- Eastern Region
- Central Region
- Western Region

**INFORMATION SYSTEMS DIVISION**

Chief
Associate Chief

**Policy, Planning and Coordination Staff**

Offices

- Management Services
- Customer Services
- Computer and Communication Services

**Office of Field Services**

Centers

- Denver, Colo.
- Menlo Park, Calif.
- Flagstaff, Ariz.

**ADMINISTRATIVE DIVISION**

Chief

Offices

- Financial Management
- Facilities and Managment Services
- Systems Management
- Personnel
- Procurement and Contracts

**Administrative Service Center**

**Management Offices**

- Central-Denver, Colo.
- Western-Menlo Park, Calif.

resources of the United States. Survey publications are basic references for academicians, other scientists, industrialists, resource planners and managers, students, litigants in court actions, and many other people.

Many cooperative studies and research investigations result from (1) needs for resource information in support of management decisions by cooperators, (2) needs for insight into hydrogeologic processes, or (3) needs to help abate environmental degradation. In any event, if a need exists when a study begins, planners and managers will make decisions within their own deadlines, regardless of the availability of potentially valuable information from the Survey. Even if a Survey report contains the only substantive information on a subject, its greatest value is lost if it is not available in time for planning and management decisions. Quality reports therefore must be produced within agreed time limits.

## PLANNING AND MANAGING REPORTS

Adequate planning and management of report preparation are the only proven means of producing consistently high-quality reports on time, especially in the work environment of authors who also are involved in program development, projects management (more than one project at a time), research, data-collection-technique development, and personnel management. Most of the work in producing a quality report is done in the originating office. Regional and Headquarters evaluators can make minor repairs but cannot make a quality report from a mediocre or poor one.

Report planning in the Water Resources Division begins with a well-prepared project proposal that contains report plans. Report plans include numbers and kinds of proposed reports, their readership, report outlines, and work schedules. An example of a project-and-report review sheet is shown in figure 2.

As soon as a project is approved, a report schedule (fig. 3) should be prepared for each report listed in the project-and-report review form. Note that the last item under planning and prewriting in the report schedule is a final annotated outline or preliminary report. A properly prepared annotated outline or preliminary report is a key planning document for any project or study. It includes a comprehensive or an annotated list of illustrations and tables. Either an annotated outline or annotated list of illustrations and tables will indicate what kinds of data must be collected and will help the investigator estimate the time needed for data collection. If a study is funded for 3 years, the investigator should not plan to collect 3 years of data, because the report is scheduled for delivery at the end of the funding. A careful analysis of the funding, time, and desired elements for a report will help tailor a study and its report(s) to meet the overall scheduling and resources available. Generally, several months are required for colleague review, plus Region and Headquarters approval. Accordingly, reports should be submitted for approval several months before a project end date.

The data needs and other work elements identified by the annotated outline or preliminary report are key factors in project work plans. If followed, they will yield quality reports at the end of the funding period. Examples of annotated outlines and project work plans are shown by Moore and Chase (1985). These examples provide general guidance: Authors should understand that each project has different problems to solve, different hydrologic settings, different times for study, and different readership for the resulting report(s). Consequently, each project, and its report(s) must be custom designed to achieve the most appropriate and useful results.

## CHARACTERISTICS OF A QUALITY REPORT

The U.S. Geological Survey enjoys a reputation for professional excellence because its workers and managers at all levels strive to assure the technical veracity and quality of their data and analyses. Word use and clarity of expression also receive careful attention. To incorporate the above basic ingredients into effective communication packages, the Water Resources Division has found that the best reports have the following characteristics:

- ► Logical organization—the more important elements stand out.
- ► Writing style fits the intended readership.
- ► Minimal jargon.
- ► Effective illustrations, designed for the publication format.
- ► Clear, simple tables, adequately labeled.
- ► Pleasing design (cover and color).
- ► Pleasing and appropriate layout.

The author of every report is committed to—

- ► Prepare the best product possible for the originating office before colleague review.
- ► Get in-house technical and editorial reviews by district or project personnel (such as a district report specialist) before submitting report for colleague review.
- ► Supply a clean copy of text, illustrations, tables, abstract for Water Resources Scientific Informa-

## PROJECT AND REPORT REVIEW SHEET

PROJECT NUMBER: ____________________ DATE: ____________________

PROJECT TITLE: ________________________________________

PROJECT CHIEF: ________________________________________

| WORK ITEMS | DEADLINE | COMPLETE | INITIALS |
|---|---|---|---|
| 1. Proposal | ______ | ______ | ______ |
| 2. Work plans | ______ | ______ | ______ |
| 3. Report outline review | ______ | ______ | ______ |
| 4. Equipment and instruments | ______ | ______ | ______ |
| 5. Construction | ______ | ______ | ______ |
| 6. Base map | ______ | ______ | ______ |
| 7. Annotated outline review | ______ | ______ | ______ |
| 8. Data collection | ______ | ______ | ______ |
| 9. Data analysis | ______ | ______ | ______ |
| 10. Illustrations review | ______ | ______ | ______ |
| 11. Tables review | ______ | ______ | ______ |
| 12. Report completed | ______ | ______ | ______ |
| 13. Section chief review | ______ | ______ | ______ |
| 14. Report specialist review | ______ | ______ | ______ |
| 15. Cooperator review | ______ | ______ | ______ |
| 16. District chief review | ______ | ______ | ______ |
| 17. Colleague review | ______ | ______ | ______ |
| 18. District transmittal | ______ | ______ | ______ |

Comments: ________________________________________

________________________________________

New Project Review Date: ____________

**Figure 2.** A project and report review sheet used in the Water Resources Division.

tion Center (WRSIC), press release, and note for monthly list of new publications, as applicable, along with an up-to-date routing sheet to all colleague reviewers.
- Assure that all illustrations and tables are neat, legible, and complete.
- Acknowledge and incorporate all comments by colleague reviewers or give reasons for not accepting.
- Personally acknowledge, by memorandum, efforts by colleague reviewers.
- Forward all marked-up review copies with the manuscript to the next review/evaluation step.

# Quality Assurance in the Water Resources Division

Reviews of project-and-report planning and project elements at prescribed intervals will help authors prepare timely reports of high quality. The steps listed in the project report schedule (fig. 3) before colleague review are preliminary parts of a quality assurance system that has evolved over the years. Colleague review is the key element in the system.

## Colleague Review—the Cornerstone of Quality Assurance

A report is reviewed by colleagues after an author, supervisor, and District or Project Chief agree that it is ready (usually after several drafts have been prepared). The Water Resources Division requires that at least two colleagues review all manuscripts, including at least one review from outside of the author's organizational unit. A report authored by someone in the Colorado District, for example, must be reviewed by someone outside the Colorado District's organization, perhaps in another State. Similarly, a report authored by someone in a regional research project office must be reviewed by someone outside that project, and preferably in another region. Long experience has shown that a fresh, unfamiliar viewpoint has real value in detecting flaws of logic and errors of omission and commission in manuscripts.

Colleague review is arranged by supervisors, who informally contact a District or Research Project Chief to ascertain the availability of someone to review the report in the time desired. Sometimes a person with special knowledge is requested.

Commonly, however, the contacted District or Project Chief will agree to provide a colleague review by someone on the staff. The responsibility for the colleague-review process (Olcott, 1985) is shared as follows among District Chiefs, Research Project Managers, and the designated reviewers:

### District Chiefs and Research Project Managers

- Become personally involved in the review process. Read the report—especially for technical and editorial adequacy and Survey policy.
- Accept reports from other organizational units and allow time for their review by technical people in your charge.
- Train personnel in techniques of colleague review.
- Insist on at least one out-of-office colleague review of all technical reports produced under your supervision. A subdistrict report reviewed by colleagues in another subdistrict in the same State would not count for the out-of-office review.
- Insist on full consideration of all review comments by authors, and help monitor author responses.
- Include colleague review as part of the duties and performance standards of all professionals.

### Reviewers

- Ensure technical soundness and clarity of the report.
- Suggest alternative methods of analysis or interpretation, if appropriate.
- Devote adequate time to check mathematics, methods of approach, organization, soundness of conclusions, adequacy of data to support conclusions, accuracy and adequacy of illustrations, tables, and presented data.
- Clearly indicate problems through well-thought-out, legible marginal comments, and a summary memorandum.
- Avoid humorous, sarcastic, or derogatory comments.
- Maintain a positive attitude toward colleague review duties.

Following colleague review and after the author's response and rewrite, the District or Research Project Chief reevaluates the manuscript. If it is found to be satisfactory, it is transmitted to the appropriate Regional Hydrologist with a request that it be approved for publication. The manuscript package includes the complete review copies of the report (reviewed by colleagues), the colleagues' summary evaluations, and other materials as shown by Finch and Aronson (1985).

## Regional Evaluation

All reports generated in a particular region (district and research program) are evaluated in the office of a Regional Hydrologist. After receipt of a report, the

## PROJECT REPORT SCHEDULE

Project ________________________________________
Report title ________________________________________
Author(s) ________________________________________
Intended audience ____________________________________
Report type and publication medium __________________________

| *Report schedule* | *Target date* | *Completion date* |
|---|---|---|
| Planning and prewriting | | |
| Preliminary report outline | ______ | ______ |
| Base map request | ______ | ______ |
| Initial annotated outline or preliminary report | ______ | ______ |
| Table plan | ______ | ______ |
| Illustration plan | ______ | ______ |
| Final annotated outline or preliminary report | ______ | ______ |
| Writing, self-editing, and rewriting | | |
| First draft | ______ | ______ |
| Author's review and revision | ______ | ______ |
| First typing | ______ | ______ |
| Editing and review | | |
| Editorial review | ______ | ______ |
| Author's revision | ______ | ______ |
| Section chief or discipline specialist review | ______ | ______ |
| Author's revision | ______ | ______ |
| Assistant district chief or district chief's review | ______ | ______ |
| Author's revision | ______ | ______ |
| First colleague review | ______ | ______ |
| Author's revision | ______ | ______ |
| Second colleague review | ______ | ______ |
| Author's revision | ______ | ______ |
| Final typing and editing | ______ | ______ |
| District chief's review | ______ | ______ |
| Approval and publication | | |
| Transmittal to region | ______ | ______ |
| Report approval | ______ | ______ |
| Report publication | ______ | ______ |

*Support needed*

Maps ________________________________________
Typing ________________________________________
Drafting ________________________________________
Consultations ____________________________________
Special illustrations ________________________________
Report review
Technical ______________________________________
Editorial ______________________________________
Suggested reviewers ________________________________
______________________________________________
Other __________________________________________
______________________________________________

**Figure 3.** A project report schedule used in Districts of the Water Resources Division.

Regional Reports Advisor determines the following:

1. The title is appropriate and complete (dates and places included if necessary).
2. The contents reflect topics in the title.
3. The abstract and summary or conclusions are consistent with the title, contents, and each other.
4. Illustrations and tables are appropriate and complete.
5. Numbers in text, tables, and illustrations have been verified.
6. Annotations for references cited are complete and in Survey style.
7. The manuscript has received adequate colleague review.
8. Authors have responded appropriately to all reviewers' comments.
9. Manuscript complies with Geological Survey policy.
10. Manuscript is organized in a way that readily conveys its information to a reader.
11. Manuscript is technically accurate and methods used are appropriate and properly explained.

If any technical aspect of the manuscript is questioned, the Regional Reports Advisor will request additional evaluation by a Regional discipline specialist or a recognized expert in the appropriate subject on the staff of the Regional Research Hydrologists.

If serious technical, organizational, or policy problems remain, the manuscript will be returned via the author's supervisor for additional work, accompanied by specific suggestions on ways to overcome the deficiencies. If there are no serious problems or deficiencies, the manuscript is sent to Headquarters with a recommendation that it be approved by the Director and that suggestions made in the Regional office be considered and responded to by the author after Director's approval.

The Director delegates authority to the Regional Hydrologists to approve basic data reports, interpretive reports intended for refereed journals, and abstracts for presentations at professional society meetings and conferences; some Regional Hydrologists redelegate authority to District Chiefs to approve basic data reports. All other interpretive reports require Director's approval, including administrative reports and all other writings such as textbooks, book reviews, field-trip guidebooks, newsletters, and comments and replies for technical journals.

## Headquarters Evaluation

When a manuscript is received at Headquarters, it is logged into the Water Resources Division's Report Tracking System in the Publications Management Unit (PMU). Abstracts (including copies of the abstract for the Water Resources Scientific Information Center) are circulated to 14 offices, including the Assistant Chief Hydrologists; Chief, Office of Ground Water; Chief, Office of Surface Water; Chief, Office of Water Quality; and Chief, Branch of Scientific Publications. These abstracts are reviewed for information content, and if of special interest, their related manuscripts are requested for review. The Office of Surface Water, for example, reviews almost all reports on surface-water hydraulics.

All manuscripts that contain geologic names are routed to the Geologic Names Committee for verification of stratigraphic nomenclature. Illustrations for all manuscripts designated for publication in formal U.S. Geological Survey book or map series—Water-Supply Papers, Professional Papers, Bulletins, Circulars,

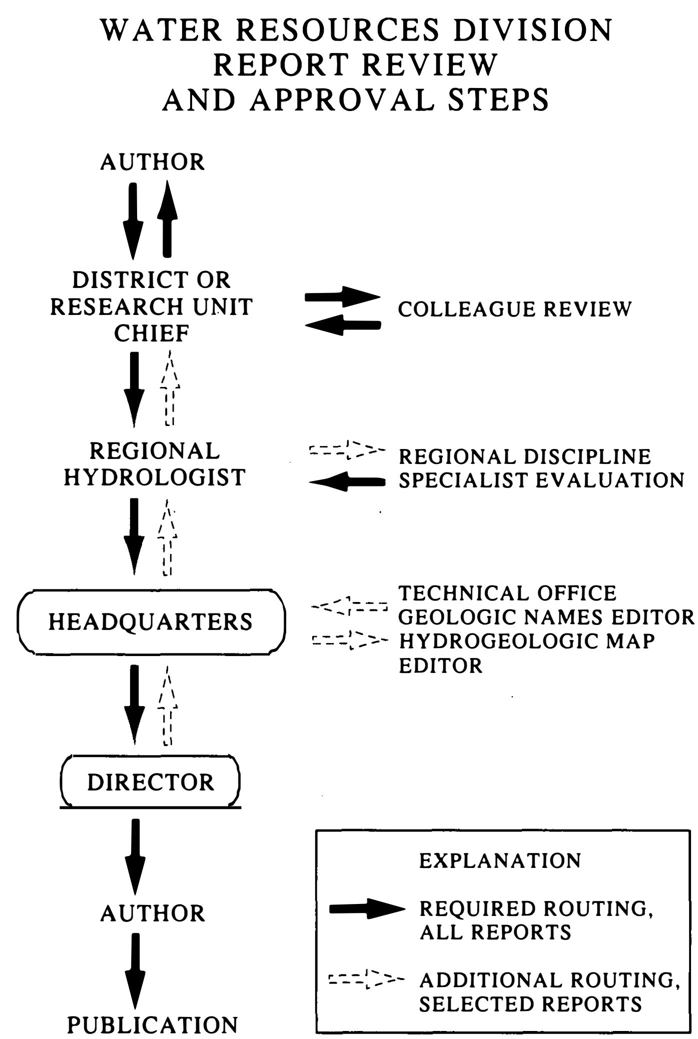


**Figure 4.** Generalized diagram of the manuscript approval process in the Water Resources Division.

Hydrologic Investigations Atlases, or Miscellaneous Investigations Maps—are reviewed by the Hydrogeologic Map Editor. After these steps are completed, manuscripts are transmitted to the Staff Hydrologist for Reports, who reevaluates the same 11 aspects of the report evaluated by the Regional Reports Advisor. If the Staff Hydrologist for Reports is unfamiliar with the technical content of a manuscript, or has reservations about it, a discipline expert will be contacted for additional evaluation. Most discipline experts who are consulted work at Headquarters in the Offices of Ground Water, Surface Water, or Water Quality. Occasionally, experts are consulted from the Office of Hydrologic Research, Branch of Systems Analysis, Geologic or National Mapping Divisions, or academia.

If a manuscript is judged to be technically adequate, and if it meets quality standards, it is sent to the Director for approval. The Director has designated the Associate Chief, Office of Scientific Publications (Geologic Division) to approve or reject all reports after skimming them for content and policy. All manuscripts are then returned to the Publications Management Unit for transmittal to the author, if approved, or to the Regional Hydrologist if rejected. Figure 4 shows generalized steps in the manuscript approval process.

## AUTHOR'S RESPONSIBILITIES AFTER DIRECTOR'S APPROVAL

Although Director's approval is a critical milestone in the Survey publications process, an author's responsibilities do not end there. Authors have important and necessary further responsibilities through the actual printing and distribution of the report.

### PREPARING MANUSCRIPTS FOR PRINTING

An author's euphoria on receiving manuscript approval is soon tempered by the reality of responding to the reviewers' comments, suggestions, and directions accumulated by the manuscript during the approval process. Authors are expected to respond fully to all such comments, and to seek clarification directly from the reviewers, if necessary. For reports published or released by the author's offices (Water-Resources Investigations Reports and Open-File Reports) this step is generally the last quality-control check for technical content prior to printing.

In the formal report series (Water-Supply Papers, Professional Papers, Circulars, Hydrologic Investigations Atlas, for example) book reports are carefully edited for completeness and consistency by the Branch of Technical Reports (Geologic Division); map reports are similarly edited by the Publications Management Unit (Water Resources Division). Edited text and drafts of illustrations are sent to authors for proofing before final drafting and typesetting. It is imperative that authors schedule time to adequately review the edited text and drafts of illustrations. Similarly, authors must review galley or page proof of typeset text and proofs of final-drafted illustrations. This review is the author's last chance to assure the technical accuracy of the report before printing, and it must be done within the time allotted to assure no delay in printing. Authors will sometimes be asked to examine printer's page proofs. For special jobs, perhaps involving color, authors may participate in press inspections at a printing plant.

In many offices, authors of locally published informal reports must read proof in the various stages of the printing process. Detailed instructions for processing water-resources manuscripts after Director's approval are given in Alt and Iseri (1986, beginning on page 286).

### RELEASING AND DISTRIBUTING PUBLISHED REPORTS

To assure timely and equal availability to the public, most reports of the Water Resources Division are announced in releases to local news media. The remainder are announced only in "New Publications of the U.S. Geological Survey," issued each month. Authors outside Water Resources Division, as well as inside, could profit from the following procedures.

About 2 weeks before the scheduled delivery of printed reports that are to be announced by news release, authors should ascertain that the persons responsible for releasing reports have approved copies of the news release, a distribution list, and appropriate transmittal memorandums. When the printed copies are received, public-inspection copies are to be mailed to depositories. The issue date for the news release should be set to allow time for copies to reach depositories. Comprehensive instructions for the disposition of printed copies of reports are given in Alt and Iseri (1986, p. 329).

# THE SURVEY'S PUBLICATION PROCESS SUMMARIZED

## REVIEW AND APPROVAL

All reports written by Survey scientists in connection with their official duties must be approved by the originating Division and the Director.

- All reports require at least one technical review, and most have two or more; Water Resources Division requires at least two.
- Reports that contain geologic names or ages require review by the Survey Geologic Names Unit.
- Book reports and maps published by the Survey require editing within their originating Division.
- Abstracts of papers to be presented at scientific meetings require editing and approval according to individual Division policy.
- Reports for publication outside the Survey are edited according to individual Division policy.
- Open-File reports are not edited but are reviewed for policy and reproducibility.
- You have some latitude as to whether or not your paper for outside publication has a Survey edit. Given a choice, however, consider the advantages of such an edit, because a well-edited report generally is more acceptable to a publisher and reader than one that is not.

## TYPICAL MANUSCRIPT SEQUENCE

Here is a sequence typical of a Survey manuscript through the Geologic Division from inception to publication, complete with hints and admonitions. The left column shows who does what; the right column details the action. Because procedures vary among

| | |
|---|---|
| 1. Author assesses resources for preparing manuscripts. | Begin by determining what resources (such as typists and machines) are available in your Branch or Office preparing manuscripts and what procedures are followed there. |
| 2. Author options for producing draft. | You presently have several options for preparing a draft of your report, depending upon your resources and inclination. You can keyboard the report yourself on a word processor or computer; or you can write the report in longhand or dictate it or rough-type it for later keyboarding on a word processor or computer by a manuscript typist. |

| | |
|---|---|
| 2. Author options for producing draft—Con. | |
| Hint/admonition | If the report is to be published by the Survey, be sure the output from your word processor can be transmitted to the phototypesetter. Check with a local editor about machine readability. |
| Hint/admonition | If a typist keyboards your report, stay ready to decipher your own possibly illegible handwriting and to answer questions. |
| Hint/admonition | Neatly handwritten, long, complex tables are acceptable for reviewers and editors, but at some time the tables will have to be keyboarded for typeset copy or for camera-ready copy (copy from which a printing plate is made). The same thing is true for equations. Keep this in mind as you plan your report; your local editor can apprise you of current procedures. If you lack the skills to keyboard complicated tables and equations, plan to have an expert do the job for you. |
| 3. Author proofreads draft. | Proofread the draft of your manuscript carefully. (See section on "Proofreading" for why, when, and how.) Double-check numerical values and computations on a printing calculator. Keep the calculator tape for verification should questions arise from reviewers or editors. Make any changes to the report so that it is ready for technical review. |
| 4. Author assembles copies to send to Branch or Office for technical review. | Assemble as many complete copies of the report as are necessary for technical review. A complete copy generally includes the following: Front matter (such as title page and contents), text, tables, figure captions, illustrations, and routing sheet. All textual matter (including tables) is double spaced and paginated for review and editing. You keep a copy for yourself. |
| 5. Author sends copies to Branch or Office. | Send copies to your Branch or Office, according to transmittal procedures and routing instructions of |

| | |
|---|---|
| 5. Author sends copies to Branch or Office—Con. | your Division. Always send material flat, except for oversize maps and tables, which have to be rolled. If the material is in more than one package (say, three), label each piece as 1 of 3, 2 of 3, and 3 of 3. |
| 6. Branch or Office attaches a routing sheet to report. | Someone in the Branch or Office will fill out and attach a routing sheet. (Ask your supervisor who does this.) The routing sheet (fig. 5) is a record of who looks at the report and when. It accompanies the report from now until the report receives Division and Director's approval. |
| Hint ------------------ | A signature on the routing sheet indicates that the signer is finished; initials indicate that the person wants to see the report again. Hence the derivation of the phrase "sign off on the report." |
| 7. Author revises after technical review. | Revise according to reviewers' comments, and add publisher's format, if not done already. See that corrections are made in the machine-readable media by a skilled typist. Have a fresh copy printed out. Proof this copy carefully. |
| 8. Author sends revised copies and technical review copies to Branch or Office chief. | Send report and technical review copies to your Branch or Office chief for approval. Use the lists at the end of this section to check that the manuscript and its parts are complete before you send it to your Branch or Office chief. You will want to keep a copy should questions arise. Gather and label the originals of all illustrations and file them together. |
| 9. Branch approves and sends report to Division for edit. | When your Branch or Office chief has approved the report, the Branch will transmit it and the technical review copies to the next place according to Division procedure. This copy becomes the "mill copy"—the primary copy of the report used by editors, graphics specialists, cartographic technicians, and drafters. |
| 10. Division edits; author responds. | If your manuscript is to be published as a formal USGS series book report or map, a Division editor will review the mill copy for expression, clarity, mechanical condition, and conformity with USGS and GPO style, usage, and format. You are responsible for having corrections made and for providing fresh printouts. |
| 11. Author proofreads | Proofread the final mill copy of the entire manuscript again; the destination of the report will dictate just when. Commonly what you see on the final mill copy is what will appear in print.<br>Proofread reports for publication by the USGS just before Director's approval and after all corrections have been made on the disk, or whenever your Division editor suggests.<br>Proofread reports for publication outside the USGS after Director's approval and before you submit your report or abstract to the journal or outside publisher. |
| 12. Report sent for Director's approval. | Your Division will submit your report for Division and Director's approval. Mill copy of reports to be published by the USGS is sent for typesetting and drafting. Mill copy of reports to be published outside the USGS is returned to you. |
| 13. Author proofs galleys and check prints. | You will receive galley proofs (or page proofs) and check prints of illustrations of USGS books and maps. Scrutinize them meticulously, as this is your last chance to eliminate any lingering errors. You may be asked to proof the text word for word with another person. Now, however, is not the time for sweeping changes. |
| 14. Division editor approves layout, printer's proof, and inspection copy. | After any changes are made in galleys and check prints, the reproducible type (the galley) is laid out and sent with the final art to the printer. When the printer's proof is returned to Division, your editor reviews it, requests any changes, and approves it for publication. The editor also approves the advance inspection copy from the printer. Normally, you will not see layout, printer's proof, or inspection copies. |
| 15. Author's book is published. | Your book or map is in print, you have received your author copies, and you see no glaring errors. Congratulations are in order, and your thanks to those colleagues, typists, editors, graphics specialists, cartographic technicians, and typesetters whose efforts enhanced the presentation of your scientific information. |

Form 9-1325
(Rev. Dec. 1986)
U.S.G.S.--GEOLOGIC DIVISION

**MANUSCRIPT REVIEW AND APPROVAL SHEET**

BRANCH PROJECT NO.

FOR BTR USE ONLY
BTR #
MIS #

AUTHOR(S) (Last name first; show first name and/or initials as shown in manuscript)[1]

OFFICE & BRANCH:[2]

CONTACT (Name, address, phone)[3]

TITLE

______ TOTAL PAGES (Include title page and all page-size figures and tables)

______ TABLES COVERING _____ PAGES

NUMBER OF ILLUSTRATIONS

| Color | B & W | |
|---|---|---|
| _____ * | _____ | Line Drawings |
| _____ * | _____ | Photographs |
| _____ * | _____ | Fossil plates |
| _____ | _____ | Oversize plates |

* Written justification needed

FORM OF PUBLICATION

SERIES, JOURNAL, VOLUME, OR MEETING:[5]

☐ USGS Book†
☐ USGS Map
☐ Open-file report
☐ Abstract

Outside report or book review:
☐ Edit requested
☐ No edit requested[4]
☐ Other ______

If part of multichapter USGS book:

Total chapters ☐ To be published ☐ Together ☐ Separately

DEADLINE:[6]

ARE GEOLOGIC NAMES OR AGES USED? YES ☐ NO ☐

SUPERSEDES OPEN-FILE REPORT? NO ☐ Yes, number[7] ______

BRAND OF WORD PROCESSOR USED[8]

REMARKS

PLEASE REVIEW CHECKLIST ON BACK BEFORE SENDING REPORT TO BTR

| NAME Printed or typed | DATE IN | DATE OUT | CHECK PROCESSING STEP WITH "X" Branch Chief | Author | Technical Reviewer | GNU | BTR Log-in | GME | GTE | Other (Specify) | BTR Chief | Chief Geologist | Director | SIGNATURE (or initials[9]) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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SEE NUMBERED FOOTNOTES ON BACK OF THIS SHEET • CONTINUE ON ADDITIONAL FORMS IF NECESSARY

*Front*

**Figure 5.** Manuscript review and approval sheet (routing sheet), front and back, used in the Geologic Division.

Authors—HELP! Just before sending your report to Branch of Technical Reports, please check the following items:

**For ALL Reports:**

____ "Mill" copies of text, tables, and all illustrations are up to date and plainly identified.

____ All type is double spaced (Open-File Reports excepted).

____ Authors' complete mailing addresses are shown (except for USGS authors in USGS reports).

____ Cooperative note and acknowledgments are included if appropriate.

____ All references cited in text are shown in the reference list.

____ All parts of the report are attached, including any oversize plates and tables.

____ Highly complex maps and cross sections include one up-to-date black-and-white "mill" copy and one colored copy.

____ Technical reviewers' copies are included.

____ Title and authorship on front of this form are correct and current.

____ Complete project number (all nine digits) is shown.

____ Geographic area of study, if any, is named in title. (If report concerns an area that is not named in title, please attach explanatory note.)

____ Branch chief and all technical reviewers have signed and dated this form.

**For All USGS Books and Maps:**

____ "Author's Check List for Plates, Figures, and Photographs" (form 9-1517) has been filled out and attached to each illustration.

**For USGS Books and Maps With Text:**

____ Report is described succinctly in
- A 50- to 75-word note for "New Publications of the Geological Survey" AND
- A 15- to 25-word note for Superintendent of Documents.

**For All USGS Books:**

____ Title page includes a 5- to 25-word descriptive note (Circulars excepted), which is not just a restatement of the title.

____ All section headings, illustrations, and tables are listed in the Contents section.

____ Abstract is included.

____ Complete caption for each illustration is on a separate page attached to the illustration.

EXPLANATORY FOOTNOTES FOR MANUSCRIPT REVIEW AND APPROVAL SHEET

[1] Reports listing more than four authors should be accompanied by an explanatory note. (See "Authorship" section in Suggestions to Authors.)

[2] Use abbreviations shown in USGS telephone directories.

[3] A mail stop and extension number will suffice for authors at the same center with the servicing BTR. Out-of-town authors please note whether phone number is FTS or commercial.

[4] Branch chief must initial. NOTE: Abstracts are not included under "Outside reports"; all abstracts will be edited.

[5] For USGS publications, show SERIES (Professional Paper, Geologic Quadrangle Map, etc.) and, if applicable, show SUBSERIES (Studies Related to Wilderness, Contributions to Geochemistry, etc.). Show SCALE for maps.
For journal reports, show name of journal.
For chapters in books not published by USGS, show book title, publisher, and volume editor.
For abstracts and other reports prepared for meetings, show sponsoring organization and name, date, and place of meeting.
For other types of reports, explain the form of publication as well as possible.

[6] The BTR's give priority treatment to reports with reasonable, legitimate deadlines. Except for abstracts and "no edit" outside reports, manuscripts that have deadlines should be accompanied by a memo from the author's branch chief requesting priority. "Deadline" shown here should be date by which author must have report back to meet publisher's deadline.

[7] If report was unnumbered, show year of release in parentheses.

[8] Information required only for in-house USGS publications. May include computers not specifically designated as "word processors"; please show both the type of computer and the wp program used in such cases. If no word processor was used, enter "None."

[9] Generally, a full signature denotes approval. Initials mean only that the report has bee seen.

GPO 852-478

*Reverse*

Divisions, Offices, and Branches, the sequence is a general one. Water Resources Division reports travel a similar path, although the timing differs. Editing, for example, comes after Director's approval. (See figs. 3 and 4 in section on "Planning and Management for Water Resources Reports" for details). Not

FORM 9-1531
(JULY 1984)

U.S. DEPARTMENT OF THE INTERIOR – GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
MANUSCRIPT ROUTING SHEET

WRD NO. (ASSIGNED BY HDQRS.)

AUTHOR(S) (LAST NAME FIRST)

PROJECT NO. (Example VA099)

TITLE

NO. PAGES (INCL. TABLES)

NO. ILLUSTRATIONS

(CHECK ONE)
☐ INTERPRETIVE REPORT ☐ DATA REPORT ☐ ABSTRACT ☐ OTHER

TABLES
NO. ____ NO. PAGES ____

TYPE OF PUBLICATION (WSP, HA, OPEN FILE, JOURNAL, STATE PUBLICATION, ETC.)

COOPERATING AGENCY

DOES REPORT CONTAIN GEOLOGIC NAMES? ☐ YES ☐ NO

| | NAME (Print or type) | DATE IN | DATE OUT | TOPICS REVIEWED | NO. HRS SPENT | CHECK STEP COMPLETED: AUTHOR | EDITORIAL REVIEWER | *TECHNICAL REVIEWER | DIST/PROJ CHIEF | REGIONAL HYDROL | GEOLOGIC NAMES | ADDITIONAL EVALUATION | SCI PUB PROG SP&DM | DIRECTOR | ENTER NEXT ROUTING HERE (Print or type) |
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CONTINUE ON ADDITIONAL FORMS, IF NECESSARY.
* See instructions for technical reviewers on back of page.

*Front*

**Figure 6.** Manuscript review and approval sheet (routing sheet), front and back, used in the Water Resources Division.

**INSTRUCTIONS FOR TECHNICAL REVIEWERS**

A thorough and competent review is essential to maintain the technical quality of Water Resources Division reports. The purpose of the review is to give a technical evaluation that will improve the report and eliminate errors that may lead to the embarrassment of the author and the Division. The following guidelines summarize critical policies and procedures in the report-review process.

*Number of reviewers* – At least two technical reviews are mandatory for all interpretive reports. Whenever possible, the reviewers should be selected on the basis of special knowledge or interest in the subject material of the report. At least one technical reviewer should be outside the District or Research Project office.

*Role of reviewers* – The role of the technical reviewer is to ensure the technical adequacy of the report. However, significant editorial discrepancies, particularly in organization, should be identified.

*Specific items to consider during review* –

- *Technical correctness* – Is the report technically valid? Are conclusions properly supported by correctly interpreted data? Are all computations correct? Are assumptions reasonable and clearly stated?
- *Readability* – Is it written for the intended audience, and with correct grammar, syntax, and a minimum of scientific jargon? Are illustrations and tables legible and readily understandable?
- *Title* – Is it explicit and does it reflect the objectives of the report? Generally the title should not exceed 12 words and, if appropriate, should give the project location and study period.
- *Abstract* – Does it state the purpose of the report? Is it informative? Does it describe the study and summarize pertinent results and conclusions? See pages 267–270, WRD Publications Guide (1982), Volume 1.
- *Introduction* – Does it clearly describe the problem(s) addressed by the report, state the objectives and scope of the report, present pertinent background information, and acknowledge significant help? See pages 265–266, WRD Publications Guide (1982), Volume 1.
- *Methods* – Were appropriate techniques used in the study? New methods should be described.
- *Body of manuscript* – Is it organized and presented in a logical sequence that contains the basic information, interpretation of that information, and the results or conclusions of the interpretations?
- *Illustrations and tables* – Are all necessary; do they clearly present basic information and emphasize relationships? Illustrations and tables should be interpreted and referred to in the text, but should be understandable without the text.
- *Conclusions or results* – Do they summarize the principal findings of the study and answer each of the objectives described in the introduction? Are they sound and properly documented? No information should be given that was not discussed in the body of the report. See pages 271–272, WRD Publications Guide (1982), Volume 1.
- *References* – Are all references cited in text included in this section? Are they cited correctly? Were pertinent references omitted in preparing the report?
- *Policy considerations* – See pages 23–24, WRD Publications Guide (1982), Volume 1.

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*Reverse*

surprisingly, your responsibilities as author entail more than just writing the report. Manuscript review and approval sheets are shown by figures 5 and 6. The exact form and wording of these sheets have changed slightly through the years, but the contents have remained basically the same.

# STRATIGRAPHIC NOMENCLATURE AND DESCRIPTION

THE ROCKS OF THE UNITED STATES are classified for mapping purposes by a complex scheme of named material and temporal or geologic time terms. Most of the time terms (for example, Cretaceous) were defined and first used by European geologists and have since been accepted by geologists in most other parts of the world. As parts of the United States were mapped geologically, local divisions of rocks were recognized and named in individual study areas. Lithology, rather than faunal assemblages, is the basis of this local classification, principally to aid in recognizing and mapping the units so as to summarize the geologic history of each area and evaluate the geologic resources.

The stratigraphic units discussed in this chapter are classified into categories and ranks. The first category includes "material units" that are called lithostratigraphic, lithodemic, allostratigraphic, magnetopolarity, or pedostratigraphic units in the North American Stratigraphic Code (NASC) by the North American Commission on Stratigraphic Nomenclature (1983, p. 852). Lithostratigraphic unit is a term much used outside the United States (International Subcommission on Stratigraphic Classification). Some lithostratigraphic units may have faunal boundaries that coincide with lithologic ones. Uncertainties in interpreting original definitions of lithologic units, or in correlating them with units near or far, have led to many local geologic names and to increasing numbers of units each year. The second category is the "temporal units" which are chronostratigraphic, geochronologic, geochronometric, polarity-chronostratigraphic, polarity-chronologic, and diachronic units.

The term "geologic name" has evolved in its application by the Survey since the late 19th century. At that time the Geologic Names Committee (or GNC) not only considered names for lithologic units and the geologic age terms applied to them but also adjudicated (1) the correct use of petrologic terms and structural terms and their symbols, and (2) the aptness of colors, patterns, and all other symbols used on geologic maps and reports published by the Survey. The term "geologic name" as used in STA is the name of a defined rock body, or the local name applied to a mapped rock unit. The map unit is recognized by its lithologic content (homogeneous or heterogeneous) and its boundaries. It (1) is assigned a place within the geologic age sequence, (2) has a stratigraphic rank, and (3) is mappable. The unit may be formal: that is, it may be defined by standards of the presently (1983) accepted code, or may have been defined under a previously accepted (1933, 1961, 1970) code, or it may have been named and found useful before the writing of any code and has gained acceptance through common usage.

Formal geologic names are those that have been defined according to the standards of the time in which they were introduced. Units named and found useful before 1983, the publication date of the most recent code, are not discarded just because they were not defined according to current standards. Map units may also be informal and not defined by any standard. Any author using informal names should clearly distinguish them from formal names.

## GEOLOGIC NAMES UNITS AND THE GEOLOGIC NAMES COMMITTEE

Because the Geological Survey examines various aspects of geology throughout the United States, all its publications adhere to broadly uniform procedures in dealing with the nomenclature and classification of rock masses. The responsibility for this conformity is delegated to a group of Survey geologists assigned to one of the Geologic Names Unit (GNU) staffs in Reston, Va., Denver, Colo., and Menlo Park, Calif., under the technical guidance of the Geologic Names Committee (GNC).

The Geologic Names Committee was organized in 1899 to consider all names of geologic formations and other divisions of rock classifications, to determine whether the names comply with nomenclature used in previously published Survey reports, and to recommend policy on stratigraphic nomenclature. Members of the committee are appointed by the Chief Geologist and are responsible to him through authority delegated by the Director. The members of the GNC are chosen for their experience and knowledge in the science. In addition to the chairman, the committee currently consists of geologists chosen from the three centers (Reston, Va., Denver, Colo., and Menlo Park, Calif.).

The Geologic Names Committee defines and recommends policy and rules governing stratigraphic nomenclature and classification in all manuscripts and maps originating in the U.S. Geological Survey and concerning the geology of the United States. The actions of GNC apply whether these reports and maps are to be published by the Survey or by an outside organization, and whether they result wholly or partly from the work of Geological Survey employees. Except for papers intended as abstracts for talks or for some papers in the Open-File Report series, every manuscript that is written by a Survey author and that contains stratigraphic names is read and approved by a member of a GNU staff before its publication is authorized by the Director. Technical problems, such as differences of opinion among Survey authors or nonconformance to Survey policy or to the North American Stratigraphic Code, are referred to the committee for recommended solution.

The basis of the committee's action is the North American Stratigraphic Code (the code) and its predecessors. The North American Commission on Stratigraphic Nomenclature currently has more than 20 members chosen from 8 geological societies and State and Federal surveys in North America: American Association of Petroleum Geologists, Geological Society of America, Geological Survey of Canada, Geological Association of Canada, Canadian Society of Petroleum Geologists, U.S. Geological Survey, Association of American State Geologists, Asociación Méxicana de Geólogos Petroleros, Sociedad Geólogica Méxicana, and Instituto de Geología de la Universidad Nacionál Autónoma de México. Several editions of the code have been printed since the first one was prepared in 1933; the most recent edition, published in 1983, is for sale by the American Association of Petroleum Geologists, Box 979, Tulsa, OK 74101. Survey authors can get copies from one of the GNU offices. Amendments and additions to the code are proposed from time to time. They are published as Notes or Reports, usually in the American Association of Petroleum Geologists Bulletin. Before proposed changes are adopted by the commission for inclusion in the code, comments and discussions are invited from the geologic profession.

The classification and nomenclature of rock units in manuscripts resulting from cooperative investigations with State geological surveys, or other outside organizations or individuals, may follow the scheme of the cooperating organization, with an appropriate statement of explanation. Any classification scheme used must have been described in a published report or the description must be included in the proposed report.

Although the Geologic Names Units do not judge the validity or use of any name outside the publications of the U.S. Geological Survey, GNU records of stratigraphic names do include all formal geologic names of the United States as they are used in publications. These records are available for reference at all times to all geologists inside and outside the Survey. A geologist who plans to name a formal stratigraphic unit may reserve the geographic name with one of the GNU staffs in Denver, Menlo Park, or Reston so that other geologists who may inquire about the name can be informed of the first author's intention. If that geographic name is already reserved, an author then has an opportunity to select another suitable name. Proposals for new nomenclature and revisions of existing nomenclature are made in reports that are published in recognized scientific mediums as defined by the 1983 code. Proposals will be more quickly accepted if they are discussed with peers who work for State surveys, academia, and industry as well as with those who work for the Survey during the preparation of a report.

In reviewing manuscripts, GNU staff members depend on a file of annotated records, on the framework of policy and objectives as set forth by the GNC and its chairman, and on the North American Stratigraphic Code. Each staff member is expected to bring significant departures from these guides to the attention of the local committee members or to the chairman of the committee so that problems may be resolved expeditiously at a local level. The full committee formulates general policy and advises on specific nomenclatural problems.

## CONFORMANCE TO THE CODE AND MODIFICATION TO STRATIGRAPHIC UNITS

Four codes (Ashley and others, 1933; American Commission on Stratigraphic Nomenclature, 1961, 1970; North American Commission on Stratigraphic Nomenclature, 1983) have been written to provide guidance to scientists using stratigraphic terminology and to provide the profession with standards for naming, defining, and classifying "rock units and their spatial and temporal relations" (North American Commission on Stratigraphic Nomenclature, 1983, p. 847). Each code reflects advances in scientific knowledge and technology at the time of its preparation. Some recommendations in the 1983 code are similar to those drawn up in 1903 and published in the 24th Annual Report of the Director. Parts of the 1983 code serve researchers who work with discontinuity-bounded sequences (allostratigraphic units), with intrusive, deformed, and highly metamorphosed rocks (lithodemic units), and with rocks distinguished by remanent-magnetic properties (magnetostratigraphic units). Pedostratigraphic units replace the classification termed "soil-stratigraphic units" in the 1961 and 1970 codes. The term "lithostratigraphic unit" replaces the term "rock-stratigraphic unit" of the 1961 and 1970 codes.

Accuracy and clarity are the two main objectives in all written and graphic presentations of stratigraphic data. A common procedure of the GNU staff and one recommended to authors and technical reviewers of stratigraphic reports is to place the geologic-map explanation and the stratigraphic chart alongside the geology section of the text. As the geology section is read, it can easily be compared with the other two parts. An assessment may be made at that time concerning stratigraphic changes and conformance with the code. Questions that arise may be addressed to the GNU reviewer and resolved before turning the report in for review.

The stratigraphic nomenclature record file is updated whenever a report that adequately explains the reasons for a stratigraphic change is submitted for publication. Obviously, many of the changes added to the file as accepted by the Survey are those recommended by Survey authors on the basis of their work. Because the Survey prefers to have a uniform nomenclature for any one area, a person proposing a change should discuss it with a review staff member and with peers working near the report area before the report is completed. However, preference for uniform nomenclature does not preclude differences of interpretations as long as the differences of opinion are recognized and clearly documented.

The primary responsibility of the GNU staff is to ensure conformance to the code and proper use of formal stratigraphic nomenclature. When necessary, biostratigraphic nomenclature is checked by specialists in the Survey's Branch of Paleontology and Stratigraphy, and isotopic dates are reviewed by specialists in the Branch of Isotope Geology. GNU staff members carefully read the comments by technical reviewers of all major stratigraphic reports. In proposing or modifying nomenclature, authors should give careful attention to previous and current work of others, both within and outside the Survey. Proposals will be more quickly accepted if they are discussed with peers.

The published lexicon volumes should not be quoted as the authority in stratigraphic discussions; reference should be made to the original article upon which the lexicon data are based.

## TEMPORAL AND RELATED UNITS

Temporal units are used "to establish a time framework for the discussion of geologic history" (NACSN, 1983, p. 849). The terminology applied to temporal units is used beyond the local area; in fact, the boundaries of most temporal units have been accepted by international agreement. The terms "time-stratigraphic" and "geologic time" units of the 1960 code are designated only as chronostratigraphic and geochronologic units respectively in the 1983 code.

Units of time may be expressed in years (y or yr) as my, m.y., m.yr. for millions of years and as by, b.y., b.yr. for billions of years for an interval of time; or in annum as ka for kilo-annum, Ma for mega-annum, Ga for giga-annum for ages. For example, boundaries of the Late Cretaceous Epoch currently are calibrated at 66 Ma and 96 Ma, but the interval of time represented by this epoch is 30 m.y. (art. 13c of the code).

**Chronostratigraphic units.** These units designate the *position* of the material unit in geologic time. Examples of chronostratigraphic terms (listed in order of decreasing stratigraphic rank) are Phanerozoic Eonothem, Mesozoic Erathem, Cretaceous System, Upper Cretaceous Series, Maastrichtian Stage.

**Geochronologic units.** Geochronologic units (listed in order of decreasing stratigraphic rank) are used to designate the *age* of the material units within geologic time, such as Phanerozoic Eon, Mesozoic Era, Cretaceous Period, Late Cretaceous Epoch, and Maastrichtian Age. Boundaries used for geochronologic terms correspond to the time span of a chronostratigraphic unit.

**Geochronometric units.** Rocks older than 570 Ma are divided into geochronometric units (fig. 15). Their boundaries are usually internationally agreed-upon ages. No type localities have been designated. Examples are Archean Eon, Late Archean Era.

**Polarity-chronostratigraphic units.** The recognized polarity-chronostratigraphic units (listed in order of increasing age) are Brunhes, Matuyama, Gauss, and Gilbert.

*Polarity chronologic* and *diachronic units* are additions to the 1983 code; no named units have yet been designated.

## MATERIAL UNITS

Lithostratigraphic, lithodemic, allostratigraphic, magnetopolarity, and pedostratigraphic units are encompassed in the general term "stratigraphic unit" in this text section. References to all articles are those of the 1983 code.

### FORMAL NAMES

The 1983 code carefully lists the requirements for a formal geologic unit name (article 3) and states that the first letter in all words used in the formal geologic unit name is capitalized (arts. 3–16, 22–47, 55–60 of the code).

### New Names

Authors planning to define new formal lithostratigraphic, lithodemic, allostratigraphic, magnetostratigraphic, or pedostratigraphic units should read the appropriate articles of the code that list the requirements for new names. All formal geologic names are compound; they consist of a geographic name and a rank term or descriptive term. The geographic name—a river, town, or other permanent geographic feature—is at or near the place where the geologic unit is typically developed. The geographic name for a new unit should be referable to an established geographic name printed on a topographic map or on a State map, county map, Forest Service map, or other map that shows names approved by a national board for geographic names (art. 7a of the code). In the United States, the appropriate board is the Board on Geographic Names (p. 83). The author should determine that the geographic name has not been used for another previously named stratigraphic unit.

If stratigraphic units are to be named in areas without named geographic features, a new geographic name can be proposed through the Board on Geographic Names. Instructions and application forms for proposing new geographic names are available, and these forms should be completed by the author at an early stage in the preparation of a report.

The report in which the new stratigraphic name is defined should contain 11 basic elements:

1. Intent to designate or modify a formal unit
2. Designation of category and rank of unit
3. Selection and derivation of geographic name
4. Specification of type locality, section, or area (preferably on a geologic map with a topographic base showing location and mappability of units)
5. Description of unit
6. Definition of boundaries
7. Historical background
8. Dimensions, shape, and other regional aspects
9. Geologic age
10. Correlations
11. Genesis (where applicable)

"These requirements apply to subsurface and offshore, as well as exposed units" (North American Commission on Stratigraphic Nomenclature, 1983, art. 3, p. 851). None of these elements can be used as a single valid criterion for establishing a new name.

### Previously Defined Names

When using stratigraphic names that have not been adopted by the Survey or that have a complex history of controversial or varied use, authors should include citations that clarify their use of the name. The name could be referred to, for example, as the Deer Valley Limestone of Flint (1962) or Deer Valley Limestone (Flint, 1962), or an alternative statement could read, "Flint in 1962 named the Deer Valley Limestone."

To adopt a stratigraphic name that has been defined previously but has not been evaluated by the Survey for compliance with the code, an author should (a) confirm that the 11 elements listed above are attributed to the unit; if they are not, the author should complete them and include a statement of intent, such as, "This unit, named by Smith in 1970, is here adopted," or "here accepted," or "here used" and (b) briefly summarize Smith's description of the stratigraphic unit.

### Modification of Existing Names

Existing formal names may be modified if evidence for a change is presented in a published report. A name is said to be *revised* if the boundary of the unit is changed slightly, if stratigraphic rank is changed, if the unit is reassigned to another unit, if a unit is placed in a unit of higher rank, or if a unit is divided into units of lesser rank. The rank or descriptive term may be changed locally or regionally, for example, from "sandstone" to "formation." An *abandoned* term should be replaced by another stratigraphic name that may or may not be formal; an abandoned term may be *reinstated.* A *change in age designation* could result from new data, such as fossil identifications, isotopic ages, or a physical correlation with a dated unit or with a unit between two dated units. The *areal limits* of a unit may be extended by surface or subsurface mapping. The following modifications are listed in alphabetical order.

#### Abandoned names (art. 20 of the code)

If an author proposes to abandon the name of a stratigraphic unit, the author should state why (improperly defined or obsolete) and should give the name of the unit or units replacing the abandoned name. The old name is then referred to in subsequent reports as being obsolete, abandoned, or of former usage, or it is preceded by a dagger. An author may be more prudent to *not use* a term rather than abandon it, for other workers mapping at different scales may find the term useful. By stating the reasons for not using a term, the author will allow time to determine if subsequent workers agree that the name is invalid (art. 5a). The word "abandoned" should not be applied to the name of a unit that is being areally restricted. An abandoned name is understood to be abandoned everywhere, including its type section, locality, or area.

**Areal limits (art. 12 of the code)**

Some stratigraphic units can be recognized and mapped over wide areas, such as several States; others are limited to very small areas. The name for a defined unit may be extended to separately exposed rock bodies if they are demonstrably continuous, if they merge in the subsurface, or if they were formerly connected. Stratigraphic units should be extended away from the type locality (area or section) only as far as the significant lithologic features of the unit can be recognized.

**Assignment to another stratigraphic unit (art. 19c, d of the code)**

Regionally, a named member may extend from one formation into another, especially in areas of intertonguing. The component formations of a group may also change regionally. An author's discussion of the reassignment of a stratigraphic unit should include the geographic limits and the reasons for the new assignment.

**Change in age assignment**

A report that changes the age of a stratigraphic unit must include the evidence for the change. The author is reminded that the definition of a stratigraphic unit is "independent of time concepts" (art. 22d, e). Thus, a stratigraphic unit can be assigned to two or more systems, or to two or more series. The author should explain the evidence for age assignments that differ from ages reported by previous workers.

**Change in stratigraphic rank (art. 19b, c, d of the code)**

Laterally, a formation may become a member of another formation, and a formation may become a group or vice versa. If a change in stratigraphic rank is required, the author should clearly give the areal limits of the rank change as well as the reasons for the change. Units of group rank may be divisible into named units of formation rank or they may be divisible into named and unnamed units. A formation need not be divisible into formally named parts. When a unit is divided, the original name should not be applied to any of the divisions.

**Redescription or change in lithologic designation (arts. 17 and 18 of the code)**

Changes in lithologic designation may be necessary where the rocks between the upper and lower contacts of a formally defined stratigraphic unit vary areally in lithologic composition. Lithologic changes over great distances are due to either depositional or postdepositional causes. In a sedimentary rock that has been metamorphosed, for example, a sandstone (Dakota Sandstone) may become a quartzite (Dakota Quartzite) or a limestone (Leadville Limestone) may become a dolomite (Leadville Dolomite); a unit that is predominately sandstone may pass laterally into an interbedded sandstone and shale sequence (Dakota Formation). The lithologic description in the text is the place to delineate these changes. A lithologic designation is more meaningful than the word "formation"; if, for example, a lithostratigraphic unit is predominately sandstone, it should be called a sandstone and not a formation. However, if a unit is a heterogeneous mixture of lithologies (for example, sandstone and shale beds), the term "formation" can be used. Formally named lithodemic units whose mineralogic content changes over a large area may be changed in designation from place to place (Boulder Creek Granodiorite to Boulder Creek Quartz Monzonite).

**Reinstatement of an abandoned name (art. 20e of the code)**

An abandoned name rarely needs to be reinstated, but the procedure is acceptable if (1) the reinstatement will not cause confusion, (2) the original definition of the name is still valid, and (3) the geographic name has not been applied to another stratigraphic unit. These points should be discussed with other geologists knowledgeable about the area. A check of the name by GNU staff is also essential.

**Revisions of boundaries or contacts (arts. 19a and 23 of the code)**

Revision of the boundaries or contacts of a stratigraphic unit is a complex and difficult change for an author to make and for others to accept. Many units have been revised several times during their histories (fig. 10). Authors must then become acquainted with each revision and must state in their reports whose revision is followed. If revisions become extremely complex, abandonment of the name may be better than another revision or, if a unit is valid elsewhere, authors may restrict it from their areas of study or may simply not use it in their reports rather than abandon it.

## INFORMAL NAMES

The intended purpose of the 1983 code was to describe how to name formal geologic units. Only one section in the code (p. 850–851) compares formal and informal geologic unit nomenclature. For all informal stratigraphic units, custom dictates that the first letter of the first word may be capitalized, but the first letter of the second word is always lowercase.

Informally designated geologic units are widely used in the geologic literature. Many informal names have very important local and, in some instances, regional use. A clear distinction, therefore, must be retained between these two types of nomenclature if we are to communicate ideas to other scientists. If a first author clearly states that a term is informal, all subsequent users of that nomenclature have a responsibility to follow the first author's designation unless another author modifies the term in a published report. To convert an informal unit to formal status requires all the information about the unit outlined in article 3.

Informal names are those names applied to stratigraphic units that were not defined according to standards in use at the time of their first publication. In the past, some stratigraphic names that should have remained informal because they were not adequately defined and described in a publication have become formal through common usage. Failure to clearly categorize a name as formal or informal, to define and describe a new name, or to fully explain the revision of a previously introduced name results in difficulty in communication of stratigraphic ideas.

Informal units may have local extent or economic value, such as aquifers or coal beds, or they may be useful for correlation. Some are designated unranked terms within a formally named unit. An informal unit may be named for (1) color (Mahogany bed, orange marker, red marker); (2) position (lower member, upper unit); (3) lithology (shale member, sandstone unit); (4) type of deposit (terrace gravel, alluvium, Anderson coal); (5) letter (J sandstone, member A); (6) number (unit 2); or (7) locality (Dupuyer Creek unit, Sauk sequence).

Authors occasionally wish to link informal units with geographic localities. If so, the informal units must be clearly distinguished from formal units, which are always named for geographic localities. If a place name is combined with a stratigraphic rank or a descriptive term, the word order should be inverted to read, for example, sandstone at Pine Creek, member of Pine Creek, or bed near Pine Creek; the need for a clear distinction between formal and informal nomenclature prohibits the use of an uncapitalized rank or descriptive term following the place name. However, the place name can be used without inverted word sequence if the second word of the informal unit is not in the formal nomenclatural hierarchy. For example, combine a place name such as Pine Creek with an informal term such as assemblage, unit, sequence, interval, layer, rocks, strata, or deposits.

An unnamed part of a formally named stratigraphic unit such as the Pierre Shale may be designated informally by using a lithologic term with the geographic name (Pierre sandstone) after the formal name of the unit has been given.

Names of intrusive masses of igneous rocks, such as dike, sill, stock, pluton, batholith, and laccolith, are considered to be form terms and not part of the formal stratigraphic classification used by the U.S. Geological Survey, though many such features have been assigned names. In the descriptive material of map explanations and texts, lithology should be emphasized, rather than structural form. The 1983 code (art. 40) recognizes such masses as formal lithodemes if the requirements of a formally named stratigraphic unit are met.

The terms "facies" and "sequence" are not parts of the formal stratigraphic classification scheme and are not capitalized, even though some geologists use them for names of rocks in local and regional areas. Terms such as Catskill facies and Sauk sequence are informal.

The glacial-climate unit classification defined in the 1960 code is informal. The initial letters of terms such as interglaciation and glaciation are lowercase (for example, Wisconsin glaciation, Olympia interglaciation).

### Summary of Formal Versus Informal Usage

The distinction between formal and informal stratigraphic nomenclature must be kept clear throughout reports and maps. Follow guidelines in the North American Stratigraphic Code (1983) for formal nomenclature. Describe informal nomenclature and the style of its use early in a report. For informal nomenclature, do not use a geographic name as a subject nominative until the informal status is made clear in a report. Stratigraphic rank terms—such as supergroup, group, formation, member, bed, supersuite, suite, and complex—should never be used after a place or geographic name in informal nomenclature. In reports describing informal stratigraphic units, rock names must be connected indirectly with geographic names in the abstract, introduction, stratigraphic description, and conclusion of the text and in tables, illustrations, and plates.

### Examples of Informal Nomenclature

| | |
|---|---|
| Correct use (indirect connection): | tuff of Stony Point<br>limestone of Doe (1956)<br>granite of Baldy Peak |
| Correct after informal status is defined and described: | Stony Point tuff<br>Baldy Peak granite |

| | |
|---|---|
| Technically acceptable, but use not encouraged (indirect connection): | formation of or at Perry Canyon |
| Incorrect use (direct connection): | Stony Point member Baldy Peak formation |

# Stratigraphic Unit Descriptions

## Text Matter

In a geologic report the stratigraphy of an area is usually discussed chronologically, the oldest formation first and the youngest last, like the geologic history. This usage does not necessarily apply to the order of discussing strata penetrated in wells. For all nomenclature changes in all reports, the steps outlined in the 1983 code must be followed. In an accompanying abstract, a summary of the proposed stratigraphic changes may benefit the readers, and persons who read the abstract first may be enticed to read the full report.

Terms should be used consistently throughout the report. In paragraph headings, on maps, on illustrations, in tables, and in the first use of the name in a paragraph, the full formal name should be used.

## Explanations for Geologic Maps

The Survey format for a typical geologic-map explanation includes a correlation diagram or sequence of map units and a description or a list of map units. Design is dictated by modern preparation procedures, especially by the use of word processors.

### Correlation or Sequence of Map Units

The "Correlation of Map Units" (figs. 7, 8) or "Sequence of Map Units" is a chart that shows the general interrelations of all the mapped units. Lithostratigraphic, lithodemic, allostratigraphic, and pedostratigraphic units in correlation diagrams are arranged in vertical columns and in chronologic sequence, the youngest unit at the top and the oldest at the base. This arrangement contrasts with the recommended arrangement of texts of geologic reports, wherein the oldest rocks are discussed first.

In the vertical columns, boxes for individual map units are usually joined top to bottom, but if the individual map units are unconformable, the word "unconformity" is inserted between boxes. If two or more rock units have the same age, they are placed in separate boxes in separate columns but in the same horizontal position. The size of an individual box is determined by its relation to other units and not by its stratigraphic rank or thickness. Where several vertical columns are necessary, the author may wish to separate and title the columns by geography (West of Pine Creek) or geologic association (Pine Creek batholith) or another scheme. Boxes should be drawn as simply as possible, so users can readily distinguish map units by symbol and color and can recognize relationships of units to one another. Complex intertonguing of stratigraphic units can be shown in a separate diagram below the explanation.

Braces to the right of the map-unit boxes delimit the group or supergroup, complex, suite or supersuite, series or epoch, system or period, and occasionally, erathem or era (in that order, from left to right). The series or epoch and system or period braces are essential. For consistency, one of these classification schemes should be selected—either the position terms (series, system) or the time terms (epoch, period)—for an individual map explanation. If a relationship is unknown or uncertain, a map unit may be enclosed by a brace and the uncertainty indicated by a query in parentheses at the right side of the brace—for example, Pleistocene(?). For a few units, the designation "age uncertain," "age unknown," or "lithologic sequence and age uncertain (or unknown)" may best describe the placement of such units in the correlation diagram. These phrases are placed to the right of the boxes, next to the brace.

The lettering associated with all the braces is placed horizontally. Group, supergroup, complex, suite, supersuite, and series or epoch terms are in capital and lowercase letters (fig. 7). The system (and era, if used) is in capital letters (fig. 7). The words "system" and "series" or "period" and "epoch" are not shown on map explanations (Jurassic, not Jurassic System; Upper Jurassic, not Upper Jurassic Series), but the words "Group" and "Suite" are given (Glen Canyon Group; Routt Plutonic Suite).

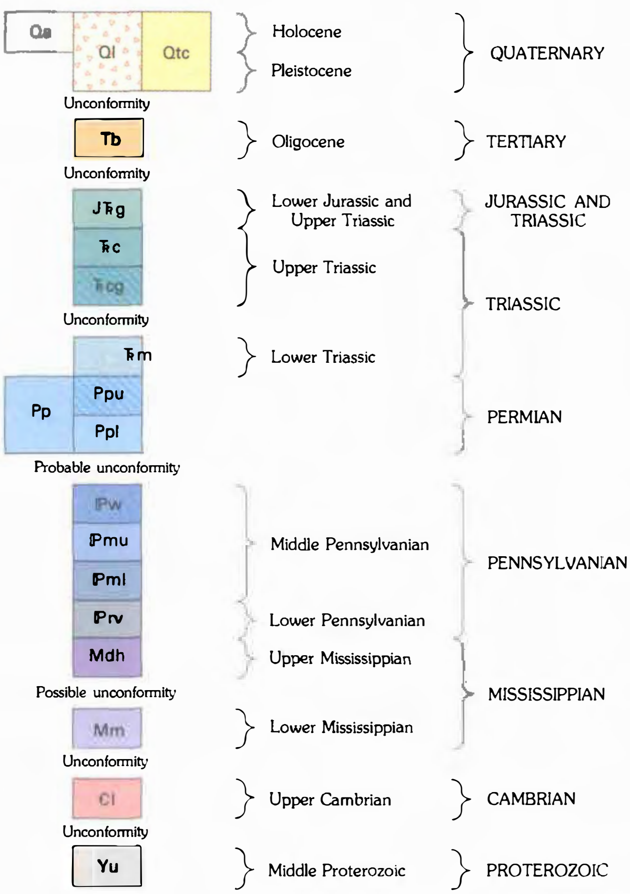
### Description of Map Units

The "Description of Map Units" is an abbreviated account of the lithology, color, and thickness of the rocks in each unit. Each unit is described in order of increasing age and from left to right. The upper member of a formation is thus described before the middle or lower members. Boxes showing the map-unit symbols are in the left column. The name of the stratigraphic unit is followed by its position (usually the series term) or age in parentheses to the right; for example:

$\boxed{\text{Kr}}$ **Raritan Formation (Upper Cretaceous)**

Epoch terms rather than series terms are suitable on map explanations especially on those showing non-

## CORRELATION OF MAP UNITS




## DESCRIPTION OF MAP UNITS

Qa **Alluvium (Holocene)**—Possibly includes some Pleistocene deposits. Poorly sorted silty sand and gravel, locally cob-bly and bouldery. In some places contains appreciable organic matter. Maximum thickness a few meters

Ql **Landslide Deposits (Holocene and Pleistocene)**—Very heterogeneous mixtures of rock fragments and soil. Maximum thickness several tens of meters

Qtc **Talus and other colluvium (Holocene and Pleistocene)**—Talus includes angular fragments of rock below cliffs and steep slopes. Colluvium includes slope wash. Heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders; intergrades with talus. Maximum thickness a few tens of meters

Tb **Bishop Conglomerate (Oligocene)**—Light-gray to pinkish-gray very poorly sorted loosely cemented pebbly, cobbly to bouldery conglomerate and sandstone. Some boulders exceed 2 m in diameter. Boulders and roundstones de-rived from nearby Paleozoic and Precambrian terranes. Tuffaceous interbeds. Thickness highly varied; may lo-cally exceed 60 m

J₹g **Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)**—Pink, highly crossbedded fine-grained eolian sandstone. About 230–240 m thick, but exposed only in a partial section at south boundary of quadrangle

₹c **Chinle Formation (Upper Triassic)**

Main body—At top, dark-red shale and siltstone about 15 m thick, pale-pink medium-grained sandstone about 5 m thick in middle, and varicolored red, yellow, and lav-ender shale and sandy shale about 52 m thick at base

₹cg Gartra Member—Gray to tan to red medium- to coarse-grained pebbly conglomeratic crossbedded sandstone. Pebbles mostly gray quartzite and chert. Forms cliffs and dipslopes. Thickness about 10–18 m

₹m **Moenkopi Formation (Lower Triassic)**—Varicolored red (predominant), brown, green, and gray (subordinate) shale, mudstone, and siltstone. Near base contains light-gray gypsiferous siltstone and shale. As much as 230 m thick, but on the poorly exposed flank of the Mud Springs monocline may be thinned tectonically or faulted to only about 110 m

Pp **Park City Formation (Permian)**—Undifferentiated on cross sections only

Ppu Upper unit—Mostly soft light-gray, light-greenish-gray, and light-yellow thin-bedded shale, siltstone, fine-grained sandstone, dolomite, and limestone; poorly exposed. Boundary with overlying Moenkopi Formation (₹m) is placed at the color change from overall tawny gray below to light red above. As mapped, upper unit is as thick as 40 m but may include some beds that could be assigned to the Moenkopi

Ppl Lower unit—Light-gray to brownish-gray unevenly bedded fine-grained sandstone, sandy cherty limestone, and claystone. Forms caprock on cliffs and dipslopes. Thick-ness about 15–18 m

₱w **Weber Sandstone (Middle Pennsylvanian)**—Light-gray to yellowish-gray very thick bedded crossbedded fine-grained sandstone. Forms massive cliffs and steep bare slopes. Thickness about 300 m

**Morgan Formation (Middle Pennsylvanian)**

₱mu Upper member—Red fine-grained crossbedded to planar-bedded sandstone and interbedded gray to pale-lavender cherty fossiliferous limestone. Individual beds less than 1 m to several meters thick. Pink to red chert nodules and lenses. Forms cliffs and ledgy slopes. Total thickness about 210–230 m, but not fully exposed

₱ml Lower member—Shown in cross section only

₱rv **Round Valley Limestone (Lower Pennsylvanian)**—Shown in cross section only

Mdh **Doughnut and Humbug Formations (Upper Mississippian)**—Shown in cross section only

Mm **Madison Limestone (Lower Mississippian)**—Shown in cross section only

Cl **Lodore Formation (Upper Cambrian)**—Shown in cross sec-tion only

Yu **Uinta Mountain Group (Middle Proterozoic)**—Shown in cross section only

**Contact**—Dashed where approximately located

**Fault**—Approximately located. Arrows indicate relative move-ment. Shown in cross sections only

**Fold**—Showing trace of axial surface. Dashed where approxi-mately located; dotted where concealed

Anticline, showing crestline

Asymmetrical anticline—Shorter arrow indicates steeper limb

Syncline, showing troughline and direction of plunge

Asymmetrical syncline—Shorter arrow indicates steeper limb

S Synclinal bend of monocline

A Anticlinal bend of monocline

6 **Strike and dip of beds**

90 **Strike of vertical beds**

**Trace of master joints**

**Figure 7.** A simple explanation for a Geologic Quadrangle Map.

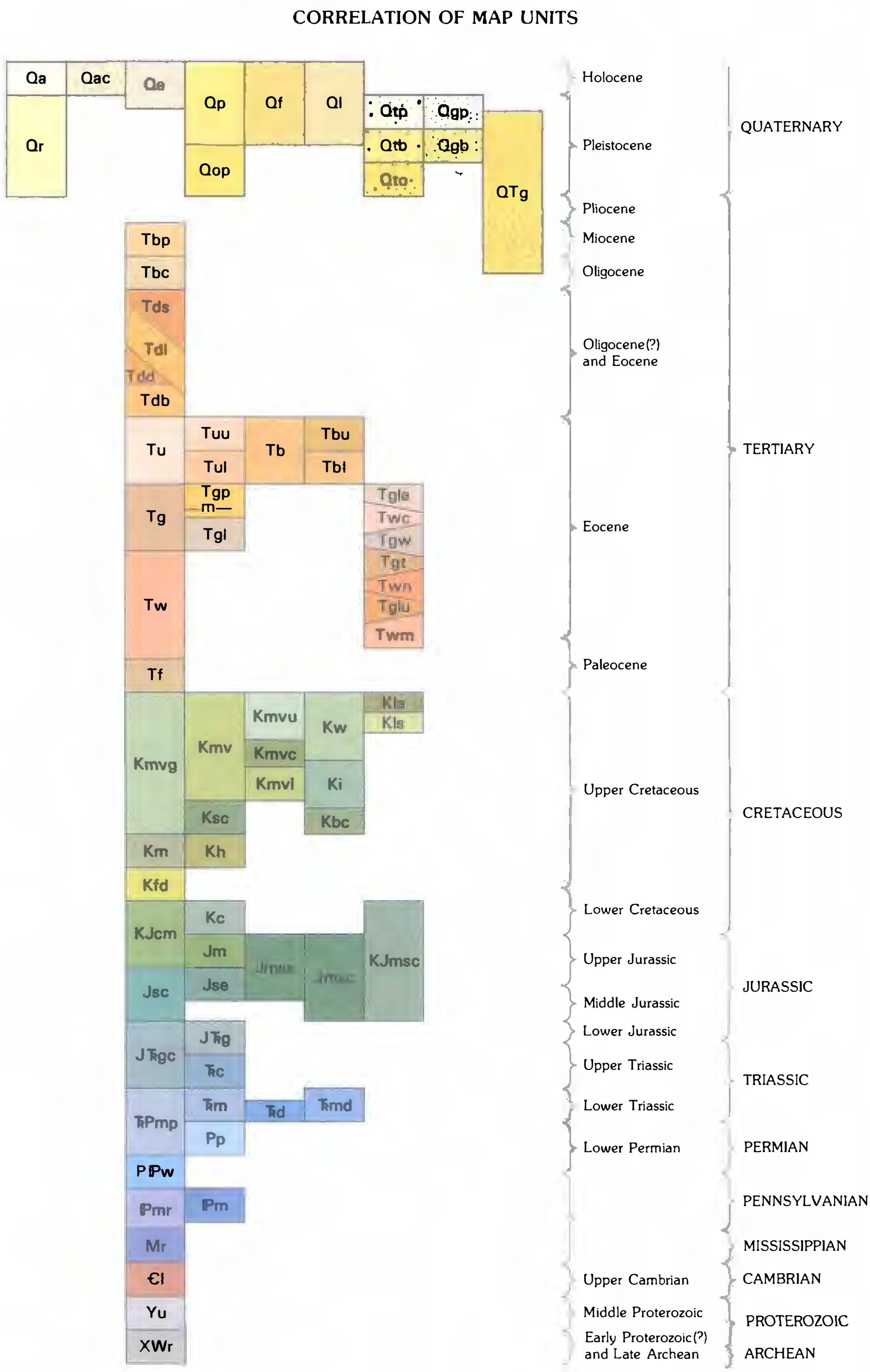



**Figure 8.** A moderately complex correlation diagram from the explanation of a 1-degree × 2-degree geologic map.

layered rocks, such as lithodemic units (art. 13d), some volcanic rocks, and glacial deposits.

Repetition of the position or age term with generally designated map units—for example "Cretaceous sedimentary rocks" or "Upper Cretaceous sedimentary rocks"—should be avoided if the age designation is shown to the right-side brace(s) of the correlation diagram.

### Symbols for Map Units

Letter symbols for map units are considered to be unique to each geologic map in that adjacent maps do not necessarily use the same symbols for the same map unit. Some parts of the symbols, however, are standardized for all maps. Symbols consist of capital and lowercase letters that convey two kinds of information. The capitalized first letter of the symbol stands for one or several of the chronostratigraphic, geochronologic, and geochronometric units, as shown in parentheses on figure 7.

The lowercase second part of the map-unit symbol stands for the rock-unit name. The letter or letters are usually chosen from the initial letters of the map-unit name, formal or informal, applied in the "Description of Map Units." If the map unit has a formal name, the geographic or place name is a key for part of the symbol. For example, the map symbol for the Sevier River Formation where it is of Pliocene and Miocene age could be Tsr or Nsr (T for Tertiary or N for Neogene). If the map unit has an informal name, such as "sandstone at Pine Creek," of Tertiary age, the map symbol would be Tpc. The lithologic term is usually keyed into the map symbol only when a place name is not associated with the map-unit name. Quaternary alluvium would be labeled Qa or Qal. Jurassic limestone would be labeled Jl. Series or epoch terms are not indicated in the symbol. Group names are seldom indicated either. The total number of letters applied to one map symbol should not be less than two nor more than four.

**Two or more systems.** If rocks in a single map unit belong to two systems, the symbol for the younger system is listed first. For example, a Quaternary and Tertiary assignment would be shown as QT. If one map unit is assigned to more than two systems, the symbols for the youngest and oldest systems, in that order, can be selected. For example, a Quaternary, Tertiary, and Cretaceous unit could be QK.

**Informal units.** Suitable lithologic terms should be applied to a map unit that has no formal name and is not associated with a specific geographic locality. The first letter of the first word of that lithologic term should be selected as part of the map symbol; for example, the map symbol for Cretaceous sedimentary rocks should be shown as Ks or Kr.

**Map symbols in text.** Map symbols should not be used in the text of a report as an abbreviated method of designating a unit. For example, Je should not be used in a text as a substitute for the "Jurassic Entrada Sandstone." Inclusion of map symbols in the text, in parentheses after the unit name, is useful to aid the reader in referring from text to map, and is justifiable when several similarly designated mapped units are being compared—for example, metasedimentary rocks (units Xd, Xsc, Xcg, and Xsi).

**Units spanning rocks of several ages.** If a map unit includes rocks of diverse kinds that span a large amount of time, the map symbol can be constructed by selecting the symbol for the youngest and oldest system, and a single lowercase letter for the rock. For example, DЄr could be used as a symbol for Devonian, Silurian, Ordovician, and Cambrian rocks. The letter "s" can replace "r" if "sedimentary" is part of the map-unit designation. Some circumstances may require use of a letter for an era or for several eras and a lowercase letter for the rock. Examples include CzPzr for Cenozoic, Mesozoic, and Paleozoic rocks, and Ꝑr for Proterozoic rocks.

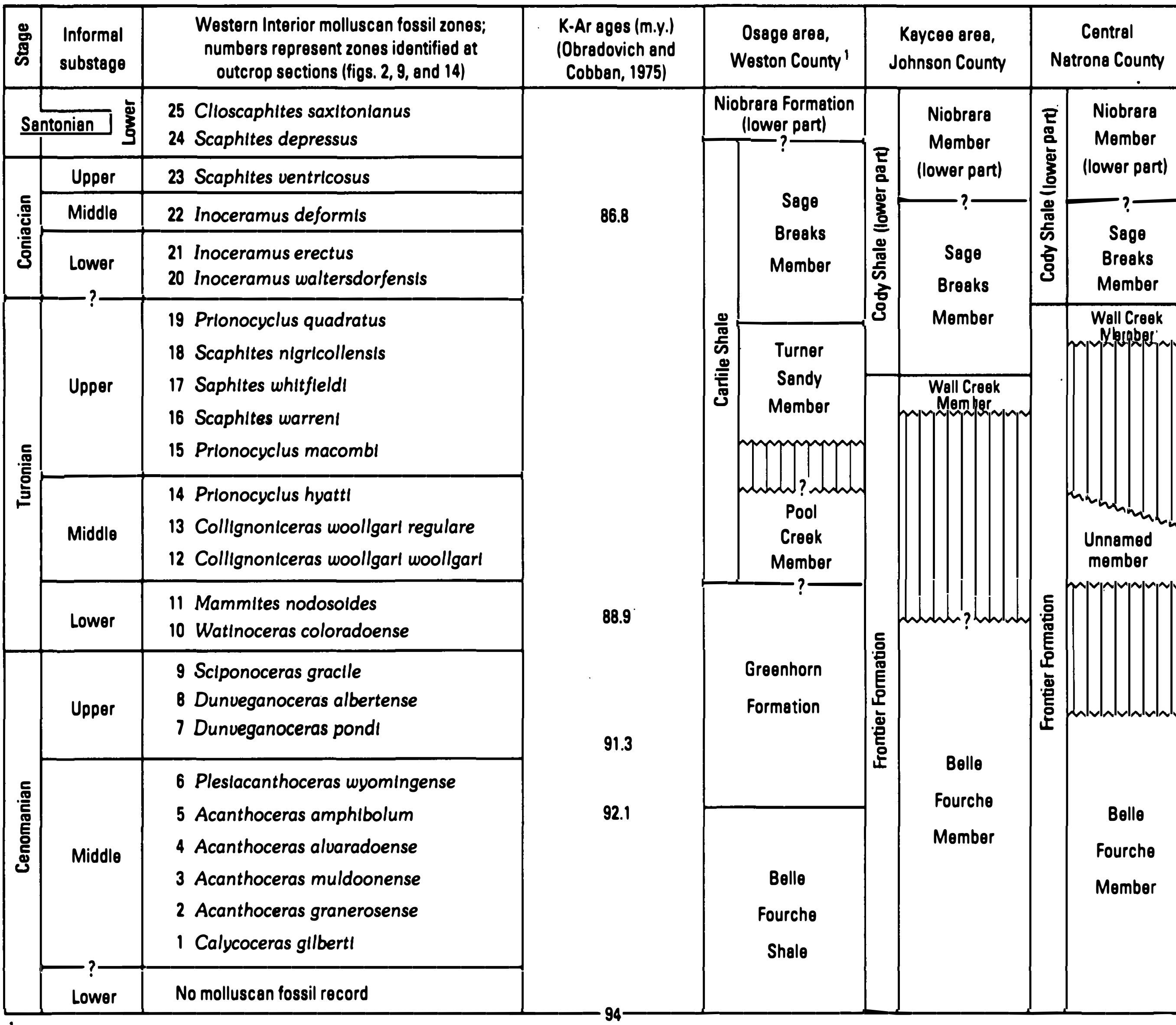
**Superscripts.** Superscript letters and numbers are used in some map symbols, especially for Tertiary and Quaternary terrace deposits. The youngest and lowest terrace deposit is assigned number 1. Older and higher terrace deposits are assigned numbers 2, 3, and so forth in order of increasing age.

**Dropped letters.** If a mapped area consists entirely of rocks belonging to one system, such as Quaternary or Precambrian, the letter (Q or pЄ) for the system may be dropped as part of the map symbol; for example, fg may be used for a Quaternary fan gravel or mb for a Precambrian migmatitic biotite gneiss.

## CORRELATION CHARTS AND STRATIGRAPHIC TABLES

The designs of correlation charts (fig. 9) and stratigraphic tables (fig. 10) are complicated because columns are read in both horizontal and vertical directions. Hierarchy or stratigraphic rank is shown by placing the largest or highest rank at the left side of each column. The units are listed in order of increasing age, the youngest at the top and the oldest at the bottom. If the diagram is to be spread across two pages, the author should indicate the top alignment of the diagram and should select the position of the gutter between the pages.

Correlation charts differ from stratigraphic tables, as the terms are used here, in that a chart usually shows an author's interpretation of rock units and




[1]Age of basal contact of Niobrara Formation from Evetts (1976, p. 121).

**Figure 9.** A correlation chart, showing stages, ages, molluscan zones, and formations at selected localities. Ruled lines indicate a hiatus in the sequence of beds.

| European stages (Imlay, 1980) | | Spieker's (1946) original definition | | | Hardy's (1952) proposed revision | | This article |
|---|---|---|---|---|---|---|---|
| Middle Jurassic | Callovian | Arapien Shale | Twist Gulch Member | Type 5 | Twist Gulch Formation | | Twist Gulch Formation |
| | Bathonian | | Twelvemile Canyon Member | Type 4 | Arapien Shale | Unit E | Arapien Shale |
| | | | | Type 3 | | Unit D | |
| | | | | | | Unit C | |
| | | | | Type 2 | | Unit B | |
| | | | | Type 1 | | Unit A | |

**Figure 10.** A stratigraphic table showing varied terminologies used for the same rocks.

their ages as related to units that other workers have recognized elsewhere. A table usually lists the rocks in the report area in increasing age from top to bottom or gives the historic development of nomenclature use by author and year. The sequence of vertical columns in tables may give the age or position, name, thickness, lithology, and other pertinent information on each unit in columns to the right of the rock-unit name.

Time terms are usually placed in the left columns of the chart or table (fig. 9). For readability, they may have to be repeated on the right side of a large chart or table. Diagonal or vertical rules or shading usually connote missing rock; wavy lines connote unconformities. All boxes for rock units should be identified by name, whether the names are formal (Frontier Formation) or informal (unnamed member). The names are usually shown by capital and lowercase letters, but the first letter of the first word in each entry, whether formal or informal, is capitalized. Abbreviations should be avoided, but if space is a problem, a standard abbreviation may be used, or the box size may be enlarged to accommodate the lettering, or a footnote may be used to identify the rock unit. Rarely, in the columns of large stratigraphic tables, rock units are identified by map symbols. Such symbols are best explained by headnotes in which the stratigraphic units are listed in proper stratigraphic sequence, the youngest first.

If a chart or table is a compilation of age and rock-unit assignments from several sources (fig. 10), the author may use individual headings at the top of each column. If the stratigraphy to be shown is extremely complex or poorly understood, the author may generalize by titling the chart or table as "A list of * * * (correlation of units shown in each column not implied)."

## MEASURED SECTIONS

The stratigraphic order of published measured sections, like tables and map explanations, is opposite that of the sequence as measured in the field. The youngest unit is listed first, and any divisions of it are indented under it or are set in a different type, descending in order of increasing age. The beds are numbered if needed for reference elsewhere in the text or on illustrations (fig. 11). The rock term is given first, followed by the descriptive terms (figs. 11, 12), to emphasize the rock type of each unit rather than other attributes, but the device is effective only if the emphasized term comes first in the line. Directions for formatting measured sections on a word processor are given on page 259.

BURKE FORMATION (LOWER PART) AND
PRICHARD FORMATION (UPPER PART)

**Section of lowermost Burke and uppermost Prichard Formations measured by pace and compass from outcrops along Mont. Highway 28 in T. 21 N., R. 24 W., and T. 21 N., R. 25 W. Sanders County, Mont. Base of section is in SW¼NE¼ sec. 31, T. 21 N., R. 24 W., 565 in northeast of Welcome Spring; top of section is opposite entrance to campground at east end of Rainbow Lake. Measured by E.R. Cressman in August, 1980.**

| | *Thickness (meters)* | *Cumulative thickness (meters)* |
|---|---|---|
| **Burke Formation (lower part only)** | | |
| **37. Siltite and argillite, interlaminated and very thinly interbedded; medium gray to olive gray (weathers mostly greenish gray, moderate brown along some joints); siltite and argillite in even layers 0.5-5 cm thick; silt layers exhibit load-casts at base and grade into overlying argillite layers** | **Not measured** | |
| **36. Poorly exposed; the few small exposures are similar to unit 33** | **19** | **19** |
| **35. Quartzite, medium-gray to olive-gray (weathers mostly light olive gray, moderate brown along some joints) in even beds mostly 0.2-0.4 m, thick; contains some faint wavy to planar larminae** | **9** | **28** |
| **34. Similar to unit 33; ripple marks common in lower half, mud cracks in upper half. Interval about 50 percent covered** | **320** | **348** |
| **33. Siltite and argillite, interlaminated; siltite is dark gray (weathers pale olive), argillite is greenish gray (weathers moderate brown along joints); laminae from less than 1 mm to 1 cm thick; siltite laminae commonly lenticular and channel into underlying argillite; mud cracks common. Outcrop appears massive; splits along planar bedding surfaces about 0.6 m apart** | **22** | **370** |
| **32. Quartzite, medium-gray (weathers light brown) in even beds 0.1-0.3 m thick; faint planar and trough lamination** | **10** | **380** |
| **31. Covered** | **35** | **415** |
| **30. Siltite, medium-gray (weathers greenish gray); in beds mostly 5-20 cm thick; contains some inconspicuous wavy laminae. Weathers to blocky fragments. Interval about 50 percent covered** | **16** | **431** |
| **29. Covered; hillside exposures suggest interval is mostly argillite similar to upper part of unit 28** | **44** | **475** |
| **28. Argillite and siltite; upper one-third is medium-gray well-cleaved argillite containing a few planar siltite laminae 1-2 mm thick and a few cross-laminated siltite lenses as much as 1 cm thick; middle one-third is interlaminated siltite and argillite containing some planar to broadly lensing siltite beds several cm thick; lower one-third is similar to upper one-third. Partly covered** | **36** | **511** |
| **27. Mostly covered; hillside float and a few exposures near road suggest that upper one-fourth is interlaminated siltite and argillite with irregular laminae and small-scale scour-and-fill features and that lower three-fourths is well-cleaved argillite similar to that of unit 23** | **103** | **614** |

◄ **Figure 11.** A part of a measured section showing bed numbers, bed thicknesses, and cumulative thicknesses.

Color terms used to describe rocks should be as specific as possible, and if colors are given in both wet and dry states, other workers will more easily recognize the rocks in the field. Exact color images are effectively conveyed from author to reader by reference of the "Rock-Color Chart" of the National Research Council (Goddard and others, 1948). This chart permits most rock colors to be accurately identified as to hue, value, and chroma by comparing the outcrop or hand specimen with the color chips on the chart. If the chart is used, it should be used consistently. If it is not used, color terms must be carefully chosen to clearly and consistently convey the author's meaning to the reader. Dark red and brick red, for example, are inexact terms; most rocks described in the literature as dark red are in fact light red, and red bricks come in many hues, values, and chromas.

## Cross Sections and Stratigraphic Columnar Sections

Stratigraphic limits of complexly intertongued units can be shown by pattern or by solid lines and arrows (fig. 13). Locations of nomenclature changes, sometimes arbitrarily limited, can be identified by vertical dashed lines. Note Chandler-Corwin limit on figure 13.

Columnar sections can be compiled for large areas to show the stratigraphic unit name, its position by geologic system, its rock type, and its thickness (fig. 14). Standard patterns indicate rock types. Standard outcrop form is used for cliff, ledge, and slope.

## Stratigraphic Style and Expression

### Abbreviations

Stratigraphic terms should rarely be abbreviated, but on charts, tables, graphs, and maps, the abbreviations listed below are acceptable if space is tight. Periods are used after the abbreviated term on charts, tables, and graphs, but generally not on maps.

| *Term or lithology* | *Abbreviation* | *Term or lithology* | *Abbreviation* |
|---|---|---|---|
| Group | Gp. | Quartzite | Qzt. |
| Formation | Fm. | Volcanics | Volc. |
| Member | Mbr. | Claystone | Clyst. |
| Sandstone | Ss. | Mudstone | Mdst. |
| Siltstone | Slts. | Granite | Gr. |
| Shale | Sh. | Gneiss | Gn. |
| Limestone | Ls. | Rhyolite | Rhy. |
| Dolomite | Dol. | System, period, or era. | Use map symbols (fig. 15). |
| Conglomerate | Cgl. | | |

SECTIONS OF THE STURGIS FORMATION

**Upper part of the section**

**[This part of the composite section includes 61 m of strata described from the core taken at the core hole Gil-30 locality and at the stratigraphic test hole, drill hole CS-1801, locality. It corresponds to the 21.3- to 82.3-m portion of the upper part of the section of the Sturgis Formation (Kehn, 1973, p. B11–B12). The systemic boundary between the Permian and the Pennsylvanian Systems may be within this unit]**

| *Unit* | *Depth (meters)* |
|---|---|
| Pennsylvanian System | |
| Upper Pennsylvanian Series | |
| Sturgis Formation (in part): | |
| Shale, green to gray, calcareous; clayey and brown to reddish near middle and silty at base | 118.9–120.7 |
| Sandstone, medium-gray, very fine grained; argillaceous | 120.7–122.7 |
| Shale, dark-gray | 122.7–124.9 |
| Shale, very dark gray to black; argillaceous; scattered limestone bands and nodules; carbonaceous in upper part | 124.9–134.3 |
| Coal, bright- and dull-banded; fine pyrite and calcite-filled veins at top | 134.3–134.8 |
| Shale, medium-gray, clayey, nonbedded | 134.8–135.1 |
| Coal, dull to bright, fusain partings; bony with carbonaceous shale partings at top and base; calcite laminations in bony coal at base | 135.1–138.5 |
| Shale, medium-gray, clayey, nonbedded; plant impressions at top; limestone nodules in lower part | 138.5–142.9 |
| Shale, medium-gray, and limestone, tan, dense; silty toward base | 142.9–146.3 |
| Shale, dark-gray; with laminations of light-gray siltstone and light-gray, fine-grained sandstone at base | 146.3–149.3 |
| Sandstone, light- to medium-gray, fine-grained | 149.3–150.3 |
| Shale, greenish-gray to black; carbonaceous at base; pyrite nodules and laminations | 150.3–152.6 |
| Coal, dull to bright, much fusain; pyrite bands on pyrite or on cleat; much bony coal and carbonaceous shale bands | 152.6–154.2 |
| Shale, medium-gray, nonbedded; calcareous, with white limestone nodules | 154.2–158.6 |
| Limestone, light-gray to gray, finely crystalline to dense | 158.6–160.3 |

**Figure 12.** A part of a measured section derived from a drill core.

### Capitalization of Stratigraphic Unit Names

The initial letters of formal geologic names have been capitalized by the Survey since 1961. Geologic names in material quoted directly from sources written before that time should follow the usage of the original author, but names in paraphrased material should be capitalized in manuscripts, tables, charts, and map explanations, even though the names were not capitalized by the original author. When three or more stratigraphic units are included as a sequence in one sentence, an author may prefer listing them with the general correct rank term, rather than the specific term. For example, Twin Creek Limestone, Morrison Formation, Dakota Sandstone, and Mancos

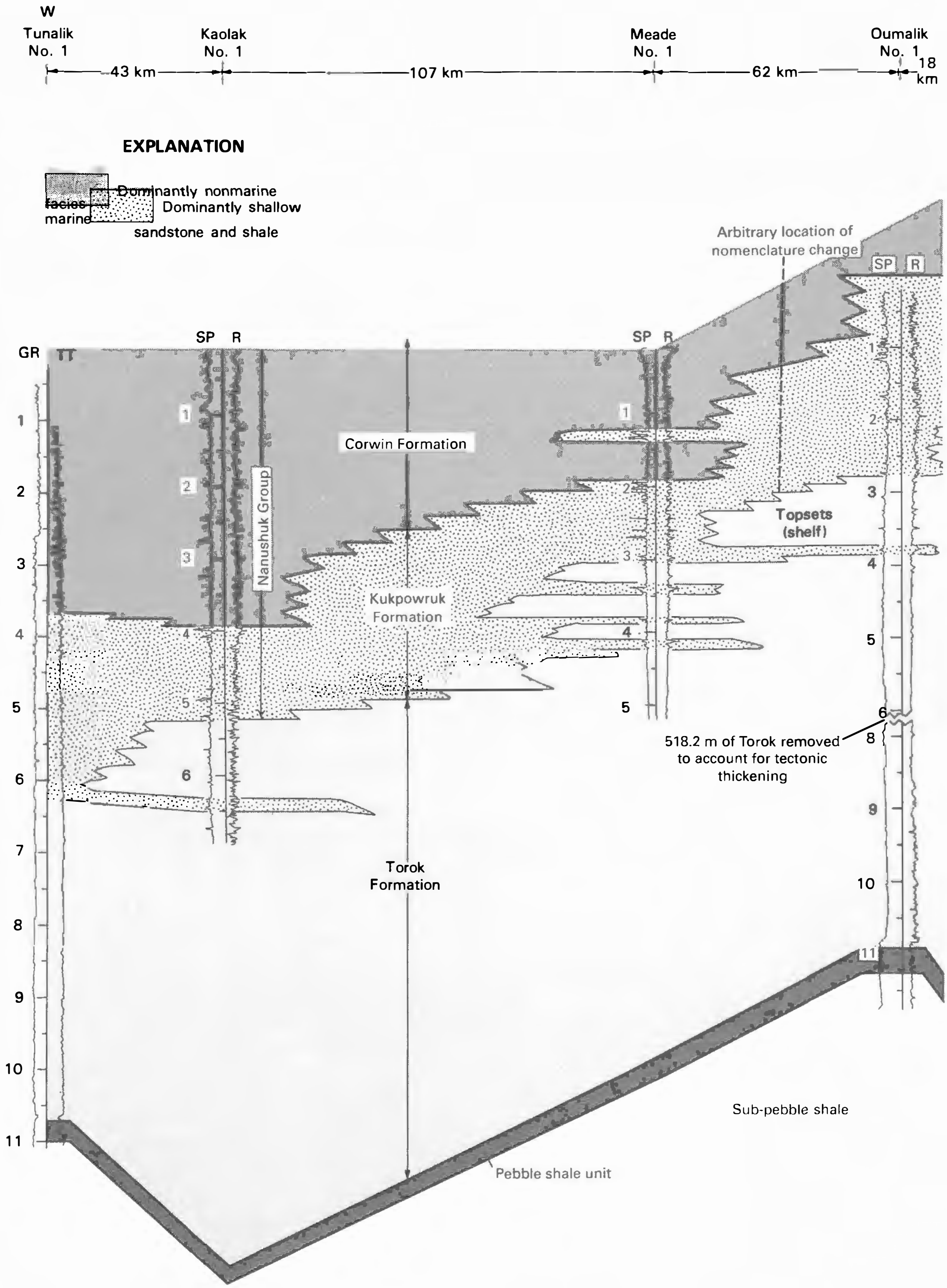
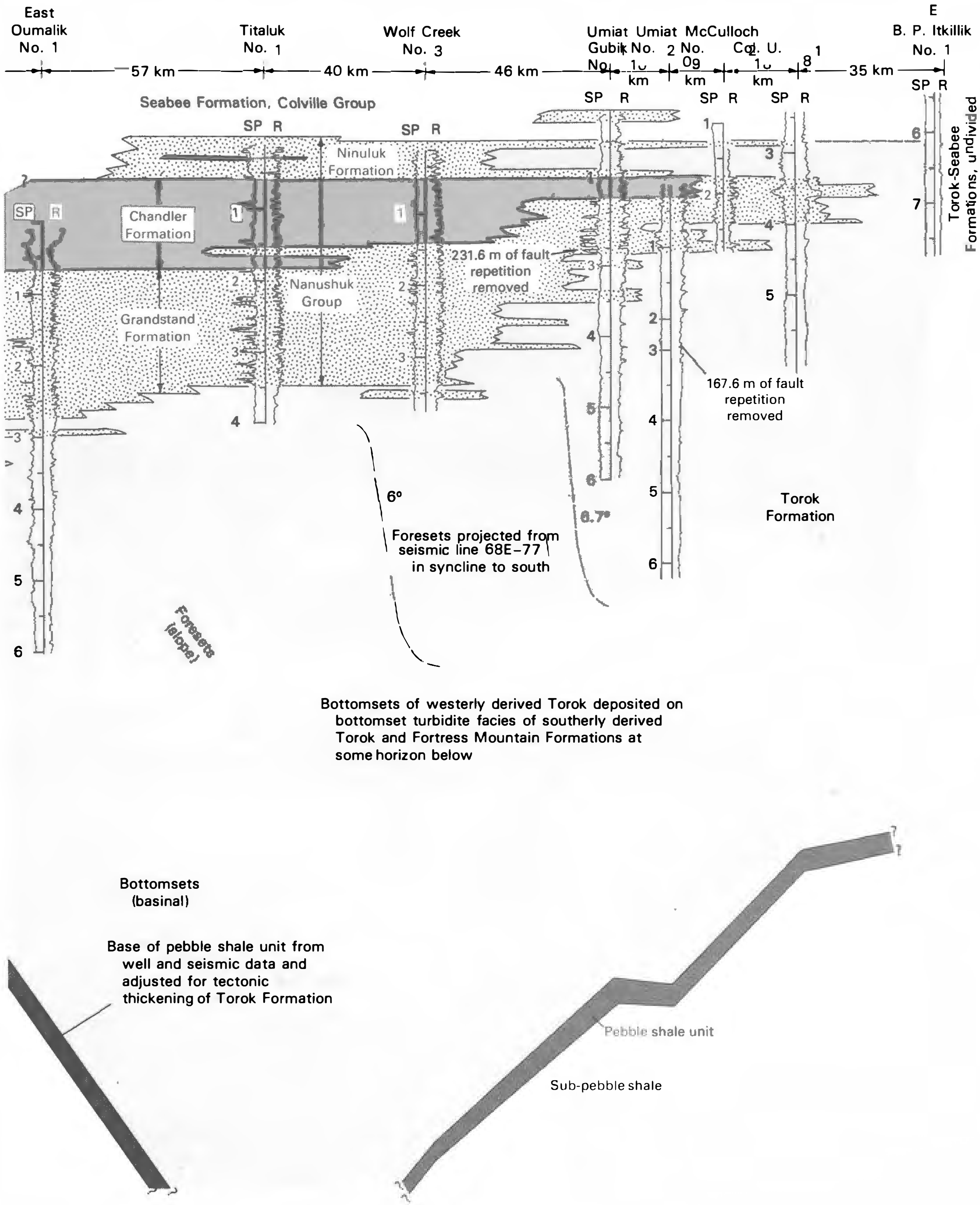



**Figure 13.** A stratigraphic cross section showing complex intertonguing.



East Oumalik No. 1
Titaluk No. 1
Wolf Creek No. 3
Umiat Gubik No.
Umiat No. 2
McCulloch No. 1
Umiat No. 9
Col. U. 8
E
B. P. Itkillik No. 1
57 km
40 km
46 km
35 km
10 km
SP R
Seabee Formation, Colville Group
Ninuluk Formation
Chandler Formation
Nanushuk Group
Grandstand Formation
231.6 m of fault repetition removed
167.6 m of fault repetition removed
Torok-Seabee Formations, undivided
Torok Formation
6°
6.7°
Foresets projected from seismic line 68E-77 in syncline to south
Foresets (slope)
Bottomsets of westerly derived Torok deposited on bottomset turbidite facies of southerly derived Torok and Fortress Mountain Formations at some horizon below
Bottomsets (basinal)
Base of pebble shale unit from well and seismic data and adjusted for tectonic thickening of Torok Formation
Pebble shale unit
Sub-pebble shale

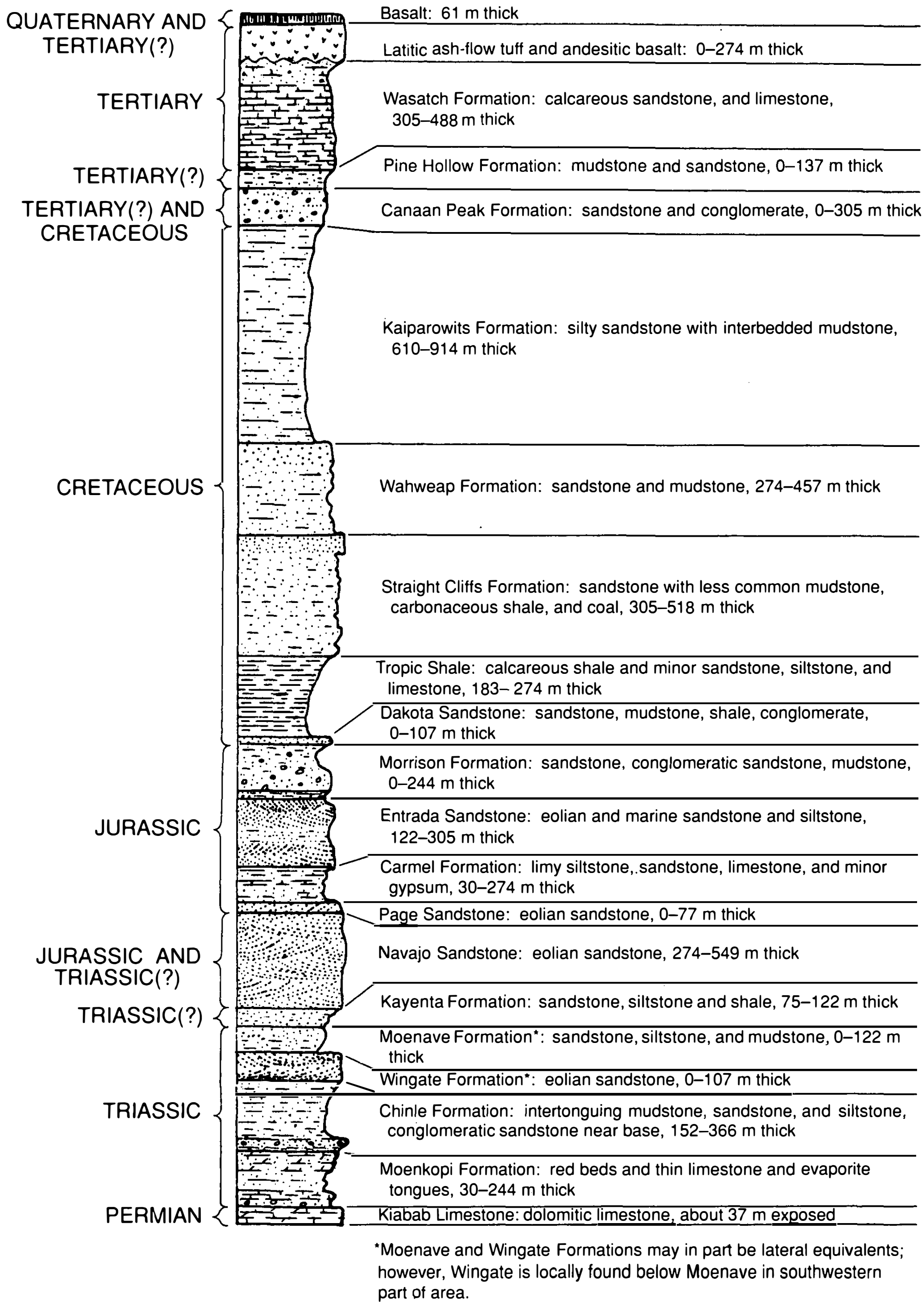



**Figure 14.** A stratigraphic columnar section.

Shale, though correct, could be listed simply as Twin Creek, Morrison, Dakota, and Mancos Formations. Such a listing enhances readability. Note that "Formations" is capitalized.

## Divisions of Geologic Time

The major divisions of geologic time, the symbols used on geologic maps, and the age estimates of their boundaries are shown in figure 15. The age estimates assigned to the boundaries resulted from a meeting of the Geologic Names Committee in 1980. Other published schemes may be followed instead (for example, Harland and others, 1982; Palmer, 1983; Snelling, 1985); in any event, specify what scheme is being followed.

### Precambrian

Divisions of Precambrian time (fig. 15) are based on isotopic or radiometric ages expressed in millions of

| Subdivisions (and their symbols) | | | | | | Age estimates of boundaries in mega-annum (Ma)[1] |
|---|---|---|---|---|---|---|
| Eon or Eonothem | Era or Erathem | Period, System, Subperiod, Subsystem | | Epoch or Series | | |
| Phanerozoic[2] | Cenozoic[2] (Cz) | Quaternary[2] (Q) | | Holocene | | 0.010 |
| | | | | Pleistocene | | 1.6 (1.6–1.9) |
| | | Tertiary (T) | Neogene[2] Subperiod or Subsystem (N) | Pliocene | | 5 (4.9–5.3) |
| | | | | Miocene | | 24 (23–26) |
| | | | Paleogene[2] Subperiod or Subsystem (Pɛ) | Oligocene | | 38 (34–38) |
| | | | | Eocene | | 55 (54–56) |
| | | | | Paleocene | | 66 (63–66) |
| | Mesozoic[2] (Mz) | Cretaceous (K) | | Late | Upper | 96 (95–97) |
| | | | | Early | Lower | 138 (135–141) |
| | | Jurassic (J) | | Late | Upper | |
| | | | | Middle | Middle | |
| | | | | Early | Lower | 205 (200–215) |
| | | Triassic (TR) | | Late | Upper | |
| | | | | Middle | Middle | |
| | | | | Early | Lower | ~240 |
| | Paleozoic[2] (Pz) | Permian (P) | | Late | Upper | |
| | | | | Early | Lower | 290 (290–305) |
| | | Carboniferous Systems (C) | Pennsylvanian (ℙ) | Late | Upper | |
| | | | | Middle | Middle | |
| | | | | Early | Lower | ~330 |
| | | | Mississippian (M) | Late | Upper | |
| | | | | Early | Lower | 360 (360–365) |
| | | Devonian (D) | | Late | Upper | |
| | | | | Middle | Middle | |
| | | | | Early | Lower | 410 (405–415) |
| | | Silurian (S) | | Late | Upper | |
| | | | | Middle | Middle | |
| | | | | Early | Lower | 435 (435–440) |
| | | Ordovician (O) | | Late | Upper | |
| | | | | Middle | Middle | |
| | | | | Early | Lower | 500 (495–510) |
| | | Cambrian (Ꞓ) | | Late | Upper | |
| | | | | Middle | Middle | |
| | | | | Early | Lower | ~570[3] |
| Proterozoic (Ᵽ) | Late Proterozoic (Z) | None defined | | | | 900 |
| | Middle Proterozoic (Y) | None defined | | | | 1600 |
| | Early Proterozoic (X) | None defined | | | | 2500 |
| Archean (A) | Late Archean (W) | None defined | | | | 3000 |
| | Middle Archean (V) | None defined | | | | 3400 |
| | Early Archean (U) | None defined | | | | 3800 ? |
| pre-Archean (pA)[4] | | | | | | |

[1] Ranges reflect uncertainties of isotopic and biostratigraphic age assignments. Age boundaries not closely bracketed by existing data shown by ~. Decay constants and isotopic ratios employed are cited in Steiger and Jäger (1977). Designation m.y. used for an interval of time.

[2] Modifiers (lower, middle, upper or early, middle, late) when used with these items are informal divisions of the larger unit; the first letter of the modifier is lowercase.

[3] Rocks older than 570 Ma also called Precambrian (pꞒ), a time term without specific rank.

[4] Informal time term without specific rank.

**Figure 15.** Divisions of geologic time—major geochronologic, chronostratigraphic, and geochronometric units.

years (m.y.) or billions of years (b.y.) for an interval of time, or mega-annum (Ma) or giga-annum (Ga) for a date. In Survey reports, divisions such as Azoic, Archeozoic, and Algonkian have been replaced by Archean and Proterozoic. The name Precambrian is considered to be informal and without specific stratigraphic rank.

Some geologists use the informal position terms "lower," "middle," and "upper" (or "early," "middle," and "late") Precambrian. These terms, however, have only local application, and lower (or early) Precambrian rocks in one area may not be equivalent to other rocks assigned to the same position (or age) in another area.

## Archean and Proterozoic

The Archean Eon is divided into the Early Archean, Middle Archean, and Late Archean Eras. The Proterozoic Eon is divided into the Early Proterozoic, Middle Proterozoic, and Late Proterozoic Eras. Position terms such as upper, middle, and lower are used with these divisions only informally; for example, upper part of the Proterozoic. The scheme of these geochronometric divisions has been devised simply to aid in the understanding of the Archean and Proterozoic history of the United States. The time boundaries have been chosen to split as few as possible known episodes of sedimentation, orogeny, and plutonism. Intentionally, the boundaries do not correspond to geologic events. The scheme is intended as an interim measure, pending development of an internationally accepted chronostratigraphic standard.

## Phanerozoic

The Phanerozoic Eon (or Eonothem) consists of the Paleozoic, Mesozoic, and Cenozoic Eras (or Erathems). No map symbol has been reserved for the Phanerozoic. Alternatives to the term include use of all three terms listed above or the informal term "post-Proterozoic."

## Carboniferous

The term "Carboniferous Systems" is used when the Mississippian and Pennsylvanian Systems are not differentiated, but the term is seldom used in the United States. Reports concerned with European nomenclature divide the Carboniferous into Upper and Lower Carboniferous, or Early and Late Carboniferous. The boundary between the two parts does not equate with the Mississippian and Pennsylvanian boundary in the United States, but the interval between the base of the Lower Mississippian and the top of the Upper Pennsylvanian composes the Carboniferous.

## Provincial Land-Mammal Ages of the Tertiary

Wood and others (1941, p. 8–13) devised a provincial time scale for the Tertiary of North America. Each name is based on a stratigraphic unit (Wasatchian from Wasatch Formation) or the name of a well-known local fauna (Blancan from Blanco local fauna). A suffix "an" or "ian" is added to distinguish land-mammal ages from the lithostratigraphic units. The 1983 edition of the code, however, specifically states that it is undesirable to convert a lithostratigraphic term to a time term by adding such endings (art. 7b). These provincial ages, though used in many reports, are not part of the formal stratigraphic hierarchy; specific reference should be made to the chart of Wood and others (1941) or to the designator of a more recently named land-mammal age when the terms are used.

## Provincial Series Terms

Provincial series terms are accepted as part of the formal nomenclature (fig. 16). The Cretaceous is divided into three provincial series—Coahuilan, Comanchean, and Gulfian—only in the U.S. Gulf Coast area. The Permian, Pennsylvanian, and Mississippian Systems have been divided into provincial series in most of the United States. The initial letters of each word are capitalized, as Gulfian Provincial Series.

## Neoglaciation

"Neoglaciation" is an informal term used to designate glacial expansions that are younger than the Holocene climatic optimum.

## Holocene and Recent

"Holocene" is the formal term for the epoch of the last 10,000 years. It replaces the former term "Recent." The term "recent" (lowercase r) informally connotes any very recent time of unspecified duration.

## Early, Middle, and Late Versus Lower, Middle, and Upper

The 1983 code and the Survey carefully distinguish between terms of time (geochronologic or geochronometric) and position (chronostratigraphic), especially in discussions of layered rocks. Many divisions of these two classification schemes are recognized internationally and have type or standard sections outside the United States. The initial letters of the formal or

| Classification used by USGS: Standard series terms | Classification used by USGS: Provincial series terms | Alternate usage and notes | | | |
|---|---|---|---|---|---|
| Upper Cretaceous | Gulfian | European stage terms are used for divisions of the Upper and Lower Cretaceous in most of the United States. Terms of the Gulf Coast Region: Gulfian includes rocks between top of Navarro Group and base of Woodbine Formation and equivalents | | | |
| Lower Cretaceous | Comanchean | Comanchean includes Washita (Upper and Lower Cretaceous), Fredericksburg, and Trinity (Lower Cretaceous) Groups | | | |
| | Coahuilan | Coahuilan is a term from Mexico applied to pre-Trinity rocks, or the Sligo (top) and Hosston (base) Formations | | | |
| Upper Jurassic | None | Imlay (1980) removed the Callovian Stage from the Upper Jurassic as its basal stage and assigned it to the Middle Jurassic as its upper stage, thus redefining the Upper-Middle boundary in North America to conform with international usage. | | | |
| Middle Jurassic | | | | | |
| Lower Jurassic | | | | | |
| Upper Triassic | None | | | | |
| Middle Triassic | | | | | |
| Lower Triassic | | | | | |
| Upper Permian | Ochoan | Wardlaw, Collinson, Maughan (1979) | Upper Permian | Dzhulfian | Ochoan recognized in southeast New Mexico and west Texas (Oriel, 1967). |
| | Guadalupian | | | Guadalupian | |
| Lower Permian | Leonardian | | Lower Permian | Artinskian | Base of Guadalupian placed at base of Word Formation in Texas (Oriel, 1967, table 1, col. 1). |
| | Wolfcampian | | | Sakmarian | |
| Upper Pennsylvanian | Virgilian | | | | |
| | Missourian | | | | |
| Middle Pennsylvanian | Desmoinesian | Desmoinesian: spelling recently changed from Des Moinesian. | | | |
| | Atokan | | | | |
| Lower Pennsylvanian | Morrowan | Morrowan includes lower Middle Pennsylvanian rocks in Arkansas and Oklahoma (Gordon, 1976). | | | |
| Upper Mississippian | Chesterian | | | | |
| | Meramecian | | | | |
| Lower Mississippian | Osagean | | | | |
| | Kinderhookian | | | | |
| Upper Devonian | None | | | | |
| Middle Devonian | | | | | |
| Lower Devonian | | | | | |
| Upper Silurian | Cayugan | Berry, Boucot, and others (1970) | Pridoli | | Four standard series of Berry, Boucot, and others (1970) have been used in some USGS reports in preference to terms of first column. |
| Middle Silurian | Niagaran | | Ludlow | | |
| | | | Wenlock | | These authors recommended that the Cayugan, Niagaran, and Alexandrian, although useful in some areas, not be accepted as a standard for the United States. |
| Lower Silurian | Alexandrian | | Llandovery | | |
| Upper Ordovician | Cincinnatian | Ross and others (1982) | Cincinnatian | | Cincinnatian is "widely and consistently used." |
| Middle Ordovician | Mohawkian | | Mohawkian (restricted) | | Stratotype for base of Mohawkian designated in Tennessee. |
| | | | Whiterockian | | Canadian is considered an outmoded term, replaced by Ibexian. |
| Lower Ordovician | Canadian | | Ibexian* | | Ibexian named. Terms Upper, Middle, and Lower Ordovician not used in Ross and others (1982). |
| Upper Cambrian | St. Croixan | Alternate spellings for St. Croixan are Croixan, Croixian, and St. Croixian. | | | |
| Middle Cambrian | | | | | |
| Lower Cambrian | Waucoban | Waucoban is used in southern Great Basin, California-Nevada. | | | |

* Rocks in Ibex area, Utah, represent a continuous sequence from Late Cambrian into Ordovician. A stratotype for the Cambrian-Ordovician boundary has not yet been agreed upon.

**Figure 16.** Major series and provincial series terms used in the United States.

defined terms are capitalized; those of informal terms are not. Figure 15 shows formal terms only. Mesozoic Era, Jurassic Period, Late Jurassic Epoch, for example, are formal time terms. The corresponding formal position terms are Mesozoic Erathem, Jurassic System, Upper Jurassic Series. Divisions of the following time and position terms are informal: Precambrian, Phanerozic, Paleozoic, Mesozoic, Cenozoic, Tertiary, Quaternary. For example, the early Mesozoic, late Paleocene (geochronologic) and upper Quaternary, lower Oligocene (chronostratigraphic) are considered to be informal because their boundaries have not been defined and adopted; the first letter of the modifying word is lowercase (fig. 15).

Fossil ages are usually expressed in geochronologic terms. For example, fossils of Early Devonian age are Early Devonian fossils, not Lower Devonian.

Age terms rather than position terms are always used for lithodemic units (art. 13d), and they may be better applied also to Tertiary volcanic rocks from a caldera, glacial deposits of the Pleistocene, and coastal or alluvial terrace deposits of the Quaternary. In some volcanic deposits, for example, the youngest layer may be preserved at the base of the volcano, or many miles from the volcano. The oldest Pleistocene deposit may be highest on the mountain. Therefore, the designations "early volcanic rocks" or "oldest till" may be preferred to "lower volcanic rocks" or "upper till."

### European Stage Terms

European epoch and age terms that are commonly used as divisions of the Ordovician to Holocene, as follows, are based on (1) Van Eysinga, 1987; (2) Geological Society of America, 1983; (3) Snelling, 1985; and (4) B.A. Skipp, oral commun., 1988. The "ian" endings are not used by all stratigraphers.

| Epoch | Age (Sources) | |
|---|---|---|
| Holocene | | |
| | Versilian (1) | |
| Pleistocene (1) | | |
| | Tyrrhenian | |
| | Milazzian | |
| | Sicilian | |
| | Emilian | |
| | Calabrian | |
| Pliocene (1, 2) | | |
| | Piacenzian | |
| | Zanclean | |
| Miocene (1, 2) | | |
| | Messinian | |
| | Tortonian | |
| | Serravallian | |
| | Langhian | |
| | Burdigalian | |
| | Aquitanian | |
| Oligocene (1, 2) | | |
| | Chattian | |
| | Rupelian | |
| Eocene (1, 2) | | |
| | Priabonian | |
| | Bartonian | |
| | Lutetian | |
| | Ypresian | |
| Paleocene (1, 3) | | |
| | Thanetian | |
| | Montian—also spelled Monian | |
| | Danian | |
| Cretaceous, Late (1, 2, 3) | | |
| | Maastrichtian | Senonian |
| | Campanian | Senonian |
| | Santonian | Senonian |
| | Coniacian | Senonian |
| Cretaceous, Late (1, 2, 3)—Con. | | |
| | Turonian | |
| | Cenomanian | |
| Cretaceous, Early (1, 2, 3) | | |
| | Albian | |
| | Aptian | |
| | Barremian | |
| | Hauterivian | Neocomian |
| | Valanginian | Neocomian |
| | Berriasian | Neocomian |
| Jurassic, Late (2, 3) | | |
| | Tithonian | |
| | Portlandian | |
| | Kimmeridgian | |
| | Oxfordian | |
| Jurassic, Middle (1, 2, 3) | | |
| | Callovian | |
| | Bathonian | |
| | Bajocian | |
| | Aalenian—not used by Imlay (1980) | |
| Jurassic, Early (1, 2, 3) | | |
| | Toarcian | |
| | Pliensbachian | |
| | Sinemurian | |
| | Hettangian | |
| Triassic, Late (1) | | |
| | Rhaetian (1,3)—included as upper part of Norian by Tozer (1984); abandonment as an age or retention as a subage of the Norian not decided (Ager, 1987). | |
| | Norian | |
| | Carnian—also spelled Karnian | |
| Triassic, Middle (1, 2) | | |
| | Ladinian | |
| | Anisian | |
| Triassic, Early (1, 2) | | |
| | Scythian | |
| Permian, Late (2, 3) | | |
| | Tatarian | |
| | Kazanian | |
| | Ufimian | |
| Permian, Early (2) | | |
| | Kungurian | |
| | Artinskian | |
| | Sakmarian—also spelled Samarian | |
| | Asselian | |
| Pennsylvanian, Late and Middle (4) | | |
| | Stephanian | |
| Pennsylvanian, Middle and Early (4) | | |
| | Westphalian | |
| Pennsylvanian, Early and Mississippian, Late (4) | | |
| | Namurian | |
| Mississippian, Late and Early (4) | | |
| | Visean | |
| Mississippian, Early (4) | | |
| | Tournaisian | |
| Devonian, Late (1, 2) | | |
| | Famennian | |
| | Frasnian | |
| Devonian, Middle (1, 2) | | |
| | Givetian | |
| | Couvinian—also called Eifelian | |
| Devonian, Early (1, 2) | | |
| | Emsian | |
| | Siegenian | |
| | Gedinnian | |
| Silurian (2) | | |
| | Pridolian | |
| | Ludlovian | |
| | Wenlockian | |
| | Llandoverian | |
| Ordovician (1, 2) | | |
| | Ashgillian | |
| | Caradocian | |
| | Llandeilian | |
| | Llanvirnian | |
| | Arenigian | |
| | Tremadocian | |

## Expressions for Degrees of Doubt

"Probably," "presumably," "may be," and "(?)" are used to express doubt about stratigraphic, geochronologic, or geochronometric unit assignments. Designation of a term in doubt must be easily understood. For example, a unit described vaguely as "probably of Late Mississippian age" could be either Late(?) Mississippian or Late Mississippian(?).

If the identification of a geologic unit is doubtful, the query follows in parentheses after the geographic part of the name, as Morrison(?) Formation.

## Quotation Marks

Authors sometimes use quotation marks around stratigraphic names to indicate abandonment or misapplication. Because of their varied uses and implications, quotation marks used in a stratigraphic context should be briefly explained.

## Undesirable Expressions

Certain shortened or abbreviated terms should be avoided in geologic manuscripts:

Permo-Penn, for Permian and Pennsylvanian
Cambro-Ordovician, for Cambrian and Ordovician
Map symbols in text as shorthand versions of formation names, such as "Je" for Entrada Sandstone
Mid-Cambrian for Middle Cambrian
Westwater Member, for Westwater Canyon Member

## Units of Economic, Local, Subsurface, or Regional Interest

The local or commercial names of stratigraphic units of economic interest, such as oil sands, coal beds, and construction or ornamental stone, are considered to be informal names (articles 22g, 26a, 30h of the code). Only the first letter of the first word is capitalized; for example, Felix coal bed. The text should state that the names have local or economic interest only, or are informal units, subsurface units, or local drillers terms.

If a term is equivalent to a formal name or has been replaced by a formal name, the formal name has preference. The economic term can be shown in parenthesis as follows:

Leadville Dolomite (Yule marble)
Greenbrier Limestone (Big lime)
Saltsburg Sandstone Member (Little Dunkard sand)

## Publication of Stratigraphic Data

When planning a report, the author should consider the publication medium best suited for a paper containing stratigraphic information. Content, length, complexity of figures, tables, or stratigraphic changes, report area, and subject matter should be assessed in relation to the intended readership. For example, large maps and correlation charts may not fit the size limits of a given medium; an International Geological Congress volume might not be the best publication for name changes for rocks in a small area of West Virginia or Connecticut; a report on Quaternary terminology might reach the largest number of interested people in a journal devoted to Quaternary research. Certain kinds of reports, because of their format or lack of availability (open-file reports or abstracts, for example), are not proper vehicles for nomenclature changes (art. 4 of the 1983 code).

### Publication Restrictions

New stratigraphic names or significant stratigraphic changes should not be introduced in an abstract that is to be published separately from a more complete report. The essential conciseness of an abstract excludes the full definition that is specified by article 4 of the 1983 code. An informal designation such as limestone of, at, or near Hudson should be used in the abstract for the stratigraphic unit that is to be named and described later in a more complete report.

New stratigraphic units should not be named in guidebooks that are limited in distribution to only the field-trip participants (code, art. 4b). Definition of new nomenclature and revision of previously used nomenclature must be widely available to the scientific community.

Use of a name in a thesis or in "Dissertation Abstracts" does not constitute publication. A thesis prepared in conjunction with Survey work may be placed in open file, but the use of new or revised nomenclature in a thesis does not constitute publication. In preparing the thesis, the author should check proposed stratigraphic changes with a GNU staff member, and after the thesis is accepted by the concerned college, the new nomenclature should be prepared for publication as soon as possible.

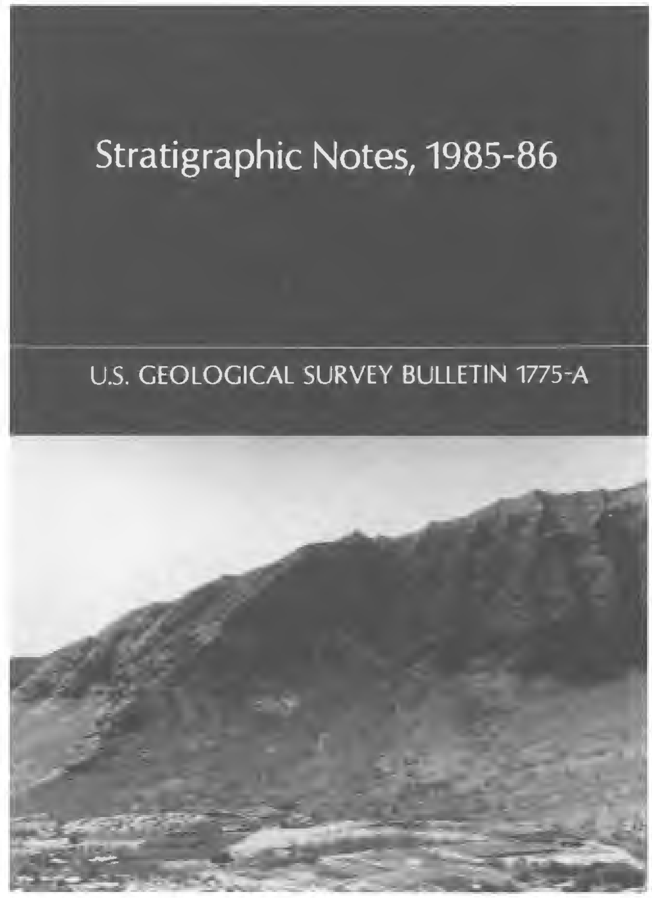
### U.S. Geological Survey Publications

An areal-geological report having important stratigraphic information can be published in a Survey Bulletin or a Professional Paper. The series rests largely on the subject matter and not on the size of the illustrations, charts, and tables.

A Bulletin series titled "Contributions to Stratigraphy" is designed especially for stratigraphic papers. One number is assigned each Bulletin each year. One chapter, "Stratigraphic Notes," includes all short papers regardless of area or subject matter. Longer papers are published as alphabetically designated chapters in the order received, carrying the assigned Bulletin number of the year.

All stratigraphic nomenclature changes shown on Geologic Quadrangle (GQ) Maps, Miscellaneous Investigations (I) Series Maps, and Miscellaneous Field

Studies (MF) Maps should be described either in the accompanying text or as a footnote to the explanation of the unit in the "Description of Map Units." If a new name is used on a map, it should be introduced either in the accompanying text or as a footnote to the "Description of Map Units." Take care to include all the required information, because the map may be the only published definition of the name. Just the "mention" of a name on a map explanation is not adequate explanation for a new name (code, article 4(a), p. 852).



# GUIDELINES FOR NAMING AQUIFERS

THE FOLLOWING GUIDELINES for naming aquifers are based on many discussions among Survey hydrologists (Laney and Davidson, 1986). An essential requirement for evaluating the hydrologic properties of in-place earth materials is to define and map hydrogeologic units—aquifers and confining units—on the basis of relative permeability. Hydrogeologic units are determined indirectly through studies of the geologic materials (geologic mapping, surface geophysical surveys, borehole geophysical logs, drill cuttings and core descriptions, and so forth) and through hydrologic testing (aquifer tests, laboratory permeability tests on core samples, and so forth). The physical properties of all rock units change laterally and vertically. Unconformities and faults may affect the flow of ground water. The process of designating and naming aquifers and confining units, therefore, is somewhat subjective and can lead to confusion if not thoroughly documented. Guidelines for naming aquifers can help you avoid confusion and problems associated with hydrogeologic studies if the guidelines are straightforward and flexible and apply to varied scales from site specific to regional. The guidelines that follow include (1) discussions of the aquifer nomenclature, (2) the definition of the hydrogeologic framework, (3) the recommended procedures for naming aquifers, and (4) examples of naming aquifers. In this section the terms "rock-stratigraphic" and "time-stratigraphic" are used (see p. 45).

## AQUIFER NOMENCLATURE

Because aquifers do not lend themselves to neat and simple definitions, a flexible hierarchy of terms is used for largest (regional) to smallest (local) water-yielding units, as follows:

- Aquifer system (Poland and others, 1972),
- Aquifer (Lohman and others, 1972), and
- Zone (R.H. Johnston, written commun, 1985; Miller, 1986).

Parallelism should be avoided in the hierarchy of terms for water-yielding rocks and rock-stratigraphic terms—aquifer system (group), aquifer (formation), and zone (member)—because water-yielding rocks can cross geologic boundaries or can constitute only part of a geologic unit. The scale of the study also may determine the best usage; for example, at the local scale, an aquifer system could be defined totally within a single formation, but at the regional scale an aquifer system could consist of several formations. The guidelines must be flexible to meet a variety of hydrogeologic scales and settings.

A brief discussion of the terms "aquifer," "aquifer system," "zone," and "confining unit" provides a common reference base. Agreement on definitions is not complete, but the terms are adequate to transfer knowledge to readers of reports. These guidelines are not intended to formally redefine the terms or to define new terms to take their place.

### AQUIFER

The term "aquifer" probably has more shades of meaning than any other term in hydrology (Freeze and Cherry, 1979, p. 47). It can mean different things to different people and different things to the same person at different times. Meinzer (1923, p. 52–53) defined an aquifer as follows:

> A rock formation or stratum that will yield water in sufficient quantity to be of consequence as a source of supply is called an "aquifer," or simply a "water-bearing formation," "water-bearing stratum," or "water-bearer." * * * It is water bearing not in the sense of holding water but in the sense of carrying or conveying water.

Lohman and others (1972) refined Meinzer's definition as:

> A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Both definitions imply that the aquifer is bounded by or is included within the formation(s) (or stratum), but the concept of the aquifer extending across formational boundaries is not indicated explicitly. In many local study areas covering a few tens to a few hundreds of square miles, the aquifer and the formation may be the same, and defining the aquifer in such areas may present few problems. Since the late 1970's, however, regional aquifers that cover hundreds of thousands of square miles have been studied under the Regional Aquifer System Analysis (RASA) Program, and results of the these studies have shown that (1) regional aquifers may include many formations and rock types and (2) the aquifers may cut across formational and lithologic boundaries so that no one formation is completely representative of the aquifer. In studies of regional scope, the shapes and the boundaries of the permeable rocks that form the aquifer have greater importance to understanding the flow system than do the individual formational boundaries. A definition that places less emphasis on the formal term "formation" (see North American Commission on Stratigraphic Nomenclature, 1983) and more on "permeable rocks" has merit. For example, aquifer is defined in the "Glossary of Geology" (Bates and Jackson, 1980) as follows:

> A body of rock that is sufficiently permeable to conduct ground water and to yield economically significant quantities of water to wells and springs.

Regardless of the fine points in any definition, delineating permeable rocks should be a major goal of hydrologists mapping and describing an aquifer. By the same token, detailed knowledge of the stratigraphic units and postdepositional processes (such as solution, cementation, folding, and faulting) are essential in determining the boundaries of the aquifer and in understanding the flow system. In addition, hydraulic properties (hydraulic conductivity and storage coefficient) are usually estimated indirectly by aquifer tests, analyses of drill cuttings and cores, borehole geophysical logging, and surface geophysical surveys. In many situations, hydrologic estimates and extrapolations can be based on rock type alone without any determination of hydrologic properties. For example, a widespread, thick clay separating two sand units could be designated tentatively as a confining unit on the basis of geologists' logs and borehole geophysical logs alone without any hydrologic data.

## Aquifer System

Poland and others (1972) defined "aquifer system" as follows:

> A heterogeneous body of intercalated permeable and poorly permeable material that functions regionally as a water-yielding hydraulic unit; it comprises two or more permeable beds [aquifers] separated at least locally by aquitards [confining units] that impede ground-water movement but do not greatly affect the regional hydraulic continuity of the system.

The definition of Poland and others would be more general if the term "aquifers" were used in place of "permeable beds." "Bed" implies a single stratigraphic unit, whereas the individual aquifer could include or cross many "beds." "Confining unit" should be used instead of "aquitard" because the definition of confining unit is broad enough to include varying degrees of "leakiness."

The hierarchy of aquifer and aquifer-system names may not always be consistent in practice. Because of differences in scales of investigations, different authors may combine individual aquifers into a single aquifer system, which may be only a part of yet another even larger aquifer system of a larger area. Authors are responsible for explaining these relationships clearly by means of comparison charts and text descriptions.

## Zone

The term "zone" may be used to subdivide an aquifer to delineate a hydrologic characteristic that is not typical of the entire aquifer. For example, the "Fernandina permeable zone" is a highly permeable subunit of the Lower Floridan aquifer (Miller, 1986, p. B70). The zone consists of vuggy, locally cavernous limestone that is traceable for as far as 100 miles in coastal Georgia and Florida. The permeability of the zone greatly exceeds that of most of the Lower Floridan aquifer.

## Confining Unit

Lohman and others (1972) defined the term "confining bed" as a body of "impermeable" material stratigraphically adjacent to one or more aquifers. In nature, however, its hydraulic conductivity may range from nearly zero to some value distinctly lower than that of the aquifer. Its conductivity relative to that of the aquifer it confines should be specified or indicated by a suitable modifier, such as "slightly permeable" or "moderately permeable."

Although the term "confining bed" (Lohman and others, 1972) is descriptive and could be used, the term "confining unit" is more appropriate, especially if more than a single bed makes up the confining unit. The term "bed" is incorrect usage for a thick sequence of stratigraphic units that could be of member or formation rank. Bed is particularly inappropriate when used for intrusive igneous rocks beneath an aquifer. The term "bed" has a formal definition (North American Commission on Stratigraphic Nomenclature, 1983, art. 26) and should not be used in definitions of aquifer nomenclature.

Many confining units are leaky under natural conditions and may contribute significant amounts of water to the aquifers they confine, or they may contribute even larger quantities of water if heads are lowered in the aquifer by pumping. Where withdrawals from aquifers have caused large declines in head, considerable water may be derived from storage in the confining unit. Poland and others (1972, p. 2) retained the terms "aquiclude" and "aquitard" in their definitions related to the mechanics of aquifer systems and land subsidence caused by fluid withdrawal. An aquiclude is defined as a body of saturated but relatively impermeable material that has very low values of "leakance" (the ratio of vertical hydraulic conductivity to thickness) and that allows negligible interaquifer flow. An aquitard is a saturated, poorly permeable bed whose values of leakance range from relatively low to relatively high. Where an aquitard is sufficiently thick, it may form an important ground-water storage unit.

For Survey reports, the general term "confining unit" is preferable to "aquitard," "aquiclude," and "aquifuge". The "leakiness" of the confining unit should be discussed if it can be estimated.

### Terms to Avoid

Terms intended to be synonymous with "aquifer" or "aquifer system" should be avoided. Terms such as "hydrofer" or "aquiformation" should not be used. "Aquigroup" should not be used in place of "aquifer system." The term "aquifer" may lack precision, but it has wide use and acceptance in the hydrologic literature. Coining new terms that are synonyms of aquifer and aquifer system or that propose slightly different meanings only creates confusion, especially among nonhydrologists. Use of the term "aquiformation," moreover, infers an equivalence between aquifer and formation that is not always correct.

## Definition of the Hydrogeologic Framework

In hydrogeologic studies, as in purely geologic investigations, the orderly, consistent designations of pertinent parts of the framework are essential to a clear reporting and understanding of the study results. In ground-water studies these designations involve defining and correlating water-yielding units and relating those units to established rock-stratigraphic units. Survey authors of reports on ground-water resources must follow the North American Stratigraphic Code for designating rock-stratigraphic units, just as authors of purely geologic reports do. The authors of ground-water reports also must identify significant water-yielding parts of the geologic framework. Commonly, the water-yielding parts do not correspond exactly to named geologic units and, therefore, do present additional nomenclatural problems. Exhaustive systematic guidelines for naming geologic units have been developed over several decades by the North American Commission on Stratigraphic Nomenclature, but comparable guidelines have not been developed for naming water-yielding units. The proper designation of hydrogeologic units involves the consistent use of ground-water terms as well as the actual naming of the units.

One of the first considerations in describing an aquifer in a report is mappability. The aquifer should be mappable at the map scale used in the report of the study area, but thin, highly transmissive aquifers that cannot be easily mapped at the principal map scale may still be important hydrologically. The report also should contain comparison charts; maps of the tops, thicknesses, and geographic extents of the aquifers; and hydrogeologic sections. Hydraulic characteristics should be discussed to show how the aquifers differ from the underlying and overlying confining units.

If additional information is needed to clarify the characteristics of an aquifer in the third dimension, a "type area" or "type locality" and (or) a "type well" can be described. Several surface exposures and wells may be required to characterize the aquifer if its characteristics change greatly vertically and laterally. If so, selected surface exposures and wells can be used to illustrate important aspects. For example, grain size, bedding thickness, faulting, folding, and effects of fracturing or solution may affect movement and storage of ground water. Borehole geophysical logs, drill cuttings and core descriptions, and drillers' and geologists' logs for wells can illustrate hydrologic properties in the subsurface.

A comparison chart is an essential part of a report that describes a ground-water flow system and aquifer names, and it should consist of three major components:

1. A correlation chart that shows rock- and time-stratigraphic (geologic) units for the water-bearing materials described in the report.
2. A comparison of hydrogeologic units to layers used in a digital flow model (if one is used).
3. A comparison of hydrogeologic units of the report with those in previous reports.

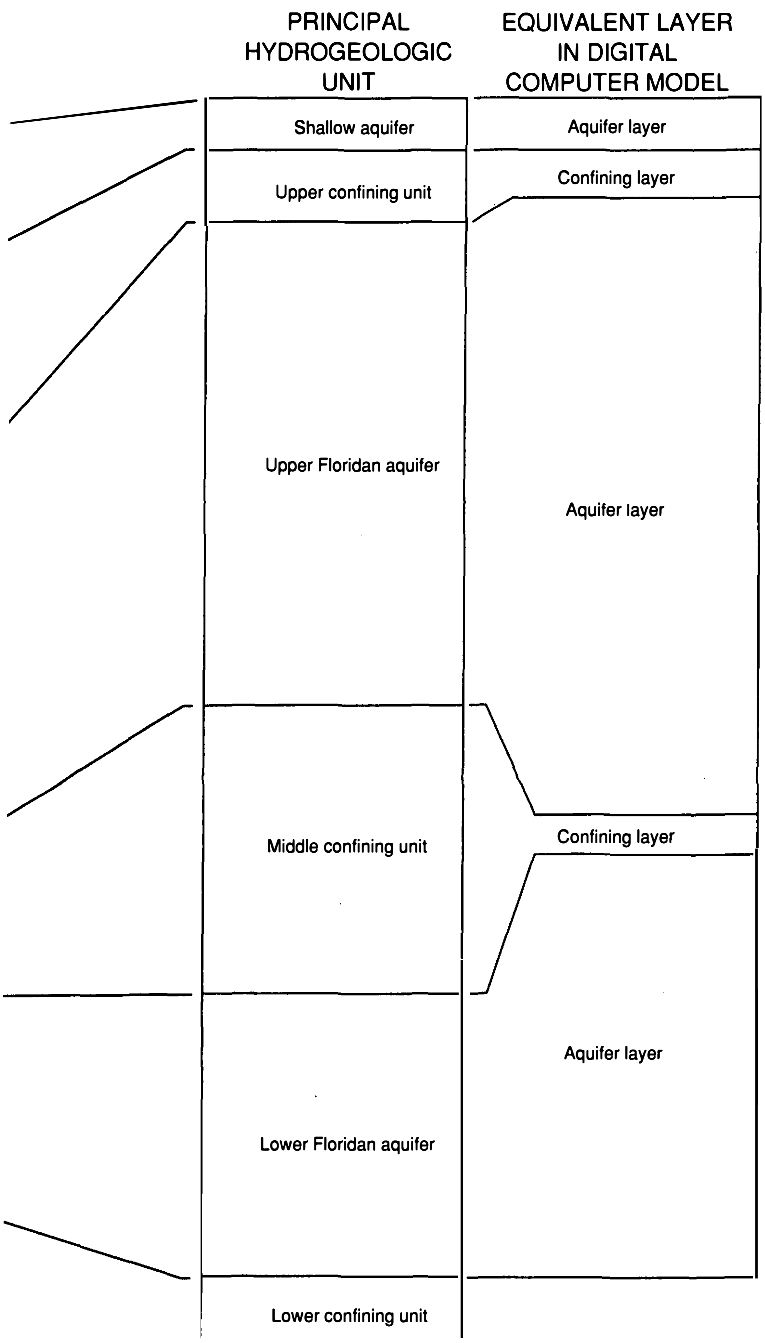
The amount of detail in the comparison chart depends on the scale and complexity of the investigation. If the report contains only a few geologic and hydrogeologic units, the comparisons may be shown in one illustration. The comparison chart should make clear to the reader the relationships of the hydrogeologic units to the geologic units (and to equivalent layers in the computer flow models if flow models are included in the report). For complicated investigations that involve many geologic and hydrogeologic units, two or three illustrations may be needed to show the comparisons.

## GEOLOGIC UNIT

| Erathem | System | Series | Stratigraphic unit | Thickness (meters) | Lithology | Aquifer |
|---|---|---|---|---|---|---|
| Cenozoic | Quaternary | Holocene | Unnamed alluvial lake and windblown deposits | 0–23 | Alluvium, freshwater marl, peats, and muds in stream and lake bottoms. Also, some dunes and other windblown sand | Shallow aquifer |
| | | | | | unconformity | |
| | | Pleistocene | Pamlico Formation and marine and estuarine terrace deposits | 0–23 | Mostly marine quartz sand, unconsolidated and generally well-graded. Also, some fluviatile and lacustrine sand, clay, marl, and peat deposits | |
| | | | | | unconformity | |
| | Tertiary, Upper | Pliocene | Jackson Bluff Formation | 0–23 | Marine sands, argillaceous, carbonaceous; and sandy shell marl. Some phosphatic limestone | |
| | | | Alachua Formation | 0–30 | Nonmarine interbedded clay, sand, and sandy clay; much of unit is phosphatic, base characterized by rubble of phosphate rock and silicified limestone residuum in a gray and green phosphatic clay matrix | |
| | | Miocene | Fort Preston Formation [1] | 0–30 | Nonmarine fluviatile sand, white to gray, variegated orange, purple, and red in upper part, fine- to coarse-grained to pebbly, clayey, crossbedded | |
| | | | Hawthorn Formation | 0–91 | Marine interbedded sand, cream, white, and gray, phosphatic, commonly clayey; clay, green to gray and white, phosphatic, often sandy; dolomite, cream to white and gray, phosphatic, sandy, clayey; and some limestone, hard, dense, in part sandy and phosphatic. Tends to be sandy in upper part and dolomitic and limey in lower part | |
| | | | | | unconformity | |
| | | Oligocene | Suwannee Limestone | 0–46 | Marine limestone, very pale orange, finely crystalline, small amounts of silt and clay | Floridan aquifer system |
| | | | | | unconformity | |
| | Tertiary, Lower | Eocene, Upper | Ocala Ls [2], Upper member [3] | 0–99 | Marine limestone, cream to white, soft granular, highly porous, coquinal; often consists almost entirely of tests of foraminifers; cherty in places | |
| | | | Ocala Ls [2], Lower member [4] | | Marine limestone, cream to tan and brown, granular, soft to firm, porous, highly fossiliferous; lower part at places is dolomite, gray and brown, crystalline, saccharoidal, porous | |
| | | | | | unconformity | |
| | | Eocene, Middle | Avon Park Formation | 183–488 | Marine limestone, light brown to brown, finely fragmental, poor to good porosity, highly fossiliferous (mostly foraminifers); and dolomite, brown to dark brown, slightly porous to good porosity, crystalline, saccharoidal, both limestone and dolomite are carbonaceous or peaty; gypsum is present in small amounts | |
| | | Eocene, Lower | Oldsmar Formation | 91–411 | Marine limestone, light brown to chalky, white, porous, fossiliferous, with interbedded brown, porous, crystalline dolomite; minor amounts of anhydrite and gypsum | |
| | | Paleocene | Cedar Keys Formation | 152–671 | Marine dolomite, light gray, hard, slightly porous to porous, crystalline, in part fossiliferous, with considerable anhydrite and gypsum, some limestone | |
| | | | | | unconformity | |
| Mesozoic | Cretaceous | | Upper and Lower Cretaceous rocks | 457–? | Mostly marine Upper Cretaceous carbonate and evaporate rocks, sands and shales; thin Lower Cretaceous clastic section in some of area | |
| | | | | | Coastal Plain bedrock | |
| Paleozoic and Precambrian | | | Devonian to Precambrian(?) rocks | Basement rocks | Marine Devonian, Silurian, and Ordovician quartzose sandstone and dark shale, lower Paleozoic(?) or Precambrian(?) rhyolite, tuff, and agglomerate | |

[1] Usage of Bureau of Geology, Florida Department of Natural Resources.
[2] Ocala Group of Bureau of Geology, Florida Department of Natural Resources.
[3] Crystal River Formation of Ocala Group.
[4] Inglis Formation and Williston Formation (older to younger) of Ocala Group.

**Figure 17.** A chart comparing geologic units, hydrogeologic units, and equivalent units in a digital ground-water flow model (from Tibbals, in press).




A comparison chart that interrelates geologic units, hydrogeologic units, and model layers is shown in figure 17. Figure 18 compares geologic and hydrogeologic units with those in previous reports. A chart such as figure 18 is especially important in reports that redefine and rename aquifers. Figure 19 summarizes hydrogeologic units made up of many rock-stratigraphic units. Unlike figure 17, figure 19 places the hydrogeologic units on the left side of the chart and combines the rock-stratigraphic units on the right side. This chart emphasizes hydrogeologic units primarily and rock-stratigraphic units secondarily, although considerable analysis of rock-stratigraphic data from throughout the study area was required to develop the chart. Such an analysis of time- and rock-stratigraphic units in a correlation chart should be shown as a separate illustration because of the great number of rock-stratigraphic units to be considered.

To prepare a comprehensive comparison chart, you must search the literature for all previous studies that contain rock-stratigraphic names and aquifer names in the project area. Your comparison chart should contain the following items:

- Headings entitled erathem, system, series, rock-stratigraphic unit, thickness, lithology, hydrogeologic unit, and hydrologic characteristics.
- The geologic units that are pertinent to the hydrology.
- The hydrogeologic units that you are using and how they relate to geologic units and previously named hydrogeologic units.
- A column that shows relations of hydrogeologic units to layers in the flow model, if one is included in the study.

Only the geology that pertains to the hydrology under study should be discussed and shown in detail. Your discussion should be limited mainly to what affects the movement and storage of ground water. An exception could be made if details of the stratigraphy were not well known before your hydrologic study, and hence by describing the hydrogeologic units you have clarified an understanding of the stratigraphy.

Differences of opinions as to what should constitute aquifer(s) and confining units(s) may still exist among hydrologists after your report is published. However, no uncertainty should exist as to what you include in your definition of the aquifer(s) and confining unit(s) and their relation to geologic and hydrogeologic units in previous investigations.

## DERIVING AQUIFER NAMES

Aquifer names used currently within the Survey, rightly or wrongly, are derived from the following sources:

- Rock-stratigraphic terms (Sparta aquifer).
- Geographic features (High Plains aquifer, Floridan aquifer).
- Time-stratigraphic terms (Cambrian-Ordovician aquifer).
- Lithology (limestone aquifer).

- Depth of occurrence ("500-ft" sand in the Memphis area).
- Depositional environment (shallow marine aquifer, glacial aquifer).
- Alphanumeric designations for model layers (A1 aquifer layer, C1 confining layer).
- Relative position (upper carbonate aquifer).
- Unusual locations (Clinton Street-Ballpark aquifer).
- Unusual geologic features of rock exposures (bird's-nest aquifer).

The many ways in which aquifers have been named and the varied scales of hydrologic investigations are among the causes of confusion regarding aquifer nomenclature. Until the advent of the RASA Program, few ground-water studies were areally large enough to face the problems of extending local aquifer and stratigraphic nomenclature to a regional scale. The gradational changes that are commonplace in geologic materials complicate the work of hydrologists who are trying to define aquifers and related confining units. At a study scale of a few tens to a few hundred square miles, gradations in the physical properties of the rocks are often not obvious, and because of the relative uniformity of the rocks within such an area, where a stratigraphic unit may make up an entire aquifer, rock-stratigraphic names can be applied to aquifers. At the scale of many of the RASA studies, however, differentiating regionally extensive units of relatively high or relatively low permeability becomes a problem within a sequence of rock units whose relations and variability are frequently complex, and whose names may change at political boundaries.

If your report involves hydrogeology, the Survey recommends that you first consider not naming aquifers. If aquifers are already named, or if the extent of an aquifer is reasonably well known, aquifer names should be derived from the following sources:

- Lithologic terms (sand and gravel aquifer).
- Rock-stratigraphic names (Sparta aquifer, after the Sparta Sand).
- Geographic names (High Plains aquifer, for the permeable parts of the Ogallala Formation and overlying and underlying hydrologically continuous deposits in parts of eight States; Floridan aquifer system, for permeable parts of several Tertiary carbonate formations in the Southeastern United States).

The Survey recommends that aquifer or aquifer-system names not be derived from the following sources (although some have been so-derived in the past):

- Time-stratigraphic names (Cretaceous aquifer).
- Relative position names (upper carbonate aquifer).
- Alphanumeric designations for model layers (A1 aquifer layer, C1 confining layer).
- Depositional environment (shallow marine aquifer, glacial aquifer).
- Depth of occurrence ("500-ft" sand).

| EPOCH | | Stringfield (1936) | | Parker and others (1955) | | Stringfield (1966) | | Miller (in Franks, 1982) | | Miller (1982 a, c) | | This report | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Formation | Aquifer | Formation | Aquifer | Formation | Aquifer | Formation | Aquifer | Formation | Aquifer | Formation | Aquifer |
| MIOCENE | Middle | Hawthorn Formation | | Hawthorn Formation | Where permeable | Hawthorn Formation | | Hawthorn Formation | Where permeable | Hawthorn Formation | | Hawthorn Formation | |
| | Early | Tampa Limestone | Principal artesian formation | Tampa Limestone | Floridan aquifer system | Tampa Limestone | Principal artesian aquifer | Tampa Limestone | | Tampa Limestone | Where permeable | Tampa Limestone | Where permeable |
| OLIGOCENE | | Oligocene Limestone | | Suwannee Limestone | | Suwannee Limestone | | Suwannee Limestone | Floridan aquifer system | Suwannee Limestone | Tertiary limestone aquifer system | Suwannee Limestone | Floridan aquifer system |
| EOCENE | Late | Ocala Limestone | | Ocala Limestone | | Ocala Limestone | | Ocala Limestone | | Ocala Limestone | | Ocala Limestone | |
| | Middle | | | Avon Park Limestone; Lake City Limestone | | Avon Park Limestone; Lake City Limestone | | Avon Park and Lake City Limestone | | Avon Park and Lake City Limestone | | Avon Park Formation | |
| | Early | | | | | Oldsmar Limestone | | Oldsmar Limestone | | Oldsmar Limestone | | Oldsmar Formation | |
| PALEOCENE | | | | | | | | Cedar Keys Limestone | | Cedar Keys Limestone | | Cedar Keys Formation | |

**Figure 18.** A chart comparing geologic and hydrogeologic units with those in previous reports (from Miller, 1986).

- Acronyms (the first letter of each formation in a multiaquifer system).
- Hydrologic condition ("principal artesian aquifer").

Each of these preceding sources of aquifer names is discussed in the following sections.

## Recommended Sources for Aquifer Names

Authors of reports on hydrogeology can handle aquifer nomenclature in the following ways: (1) Do not name the aquifers or (2) name the aquifers after lithologic terms, rock-stratigraphic names, or geographic names.

Water-bearing properties of rocks can be described without naming aquifers. Each rock unit and its water-bearing properties can be described in comparison charts and tables. Phraseology would be the principal difference between a report of this kind and one describing named aquifers. This approach could be used in studies involving both formal and informal rock-stratigraphic names, but it would apply particularly to areas where no formal rock-stratigraphic units had been designated or where the stratigraphy and the hydrology of the particular rocks are poorly known. Not cluttering the literature with aquifer names is advantageous if the hydrogeology of an area has not been studied in great detail, if a study describes an area in a cursory or reconnaissance fashion, or if a study area is so small that only a small part of an aquifer is investigated.

If aquifers must be named, use lithologic or rock-stratigraphic names to the extent permitted by permeability distribution and hydrologic continuity. Use geographic names for larger areas where lithologic or rock-stratigraphic names are inappropriate. For example, where an aquifer consists of a single rock-stratigraphic unit, the rock-stratigraphic name may be used for the aquifer. If a later study encompasses a larger area, judgment would be needed to determine if the rock-stratigraphic name remains appropriate. If the aquifer in the larger area consists of the same rock-stratigraphic unit as in the smaller area, the earlier name could be retained. However, a geographic name should be used if the aquifer consists of several units, none of which has an appropriate name, or if the aquifer extends across rock-unit boundaries. Such relations should be shown clearly in the comparison charts of the report.

If an aquifer is named for a rock-stratigraphic unit or a geographic feature, rules of priority should be followed, and a thorough literature search should be made to avoid name duplication. The name should be cleared through the Reston Geologic Names Unit and should not be preempted by a rock-stratigraphic name.

### Lithologic Names for Aquifers

Lithology-derived names of aquifers are useful in defining water-bearing materials where formal rock-stratigraphic names do not exist. The adjectives for lithologic names of aquifers may be based on lithologic terms—"sand and gravel aquifer," "granite aquifer," "limestone aquifer"—but if lithologic consistency throughout the extent of the aquifer is uncertain, a geographic name should be used. Lithologic names are especially useful for naming aquifers in glacial deposits. If several aquifers discussed in a report are in glacial deposits, however, lithologic terms for each might be similar, and local geographic names may be more appropriate.

### Rock-Stratigraphic Names for Aquifers

Rock-stratigraphic names may be used for aquifer names in studies that cover one State or parts of a State and an adjacent State. At the scale of such studies, the rock-stratigraphic unit and the aquifer commonly are equivalent. In addition to criteria for defining the hydrologic framework of a report, the following guidelines should be used, as appropriate, to assign names or to modify existing aquifer names based on rock-stratigraphic names:

1. Through the use of comparison charts, maps, and cross sections, show clearly how much of the rock-stratigraphic unit is included in the aquifer. In some areas, aquifers have been named for rock-stratigraphic units but consist of parts of the units only. In the Atlantic and Gulf Coastal Plains, sediments generally thicken oceanward and become progressively less permeable because of increasingly fine grain. Thus, an aquifer may thin as a formation thickens—the Tuscaloosa Formation or Group and the Tuscaloosa aquifer of Alabama, for example. A similar lack of agreement between an aquifer and a corresponding rock-stratigraphic unit of the same name can exist at any scale if the formation name is automatically used for an aquifer name without due consideration as to how much of the formation actually constitutes the aquifer.
2. Shorten the binomial name of the rock-stratigraphic unit for use as the aquifer name:

    A. Madison aquifer, after the Madison Group.
    B. Edwards aquifer, after the Edwards Limestone.
    C. Sparta aquifer, after the Sparta Sand.

<table>
<tr><th colspan="2">Hydrogeologic unit</th><th>Thickness (feet)</th><th>Lithology and hydrologic characteristics</th></tr>
<tr><td colspan="2">Western Interior Plains confining unit</td><td>0–6,000</td><td>Shale layer of very low permeability separated by permeable limestones and sandstones. Leakage through shale is slow.</td></tr>
<tr><td rowspan="6">Ozark Plateaus aquifer system</td><td>Springfield Plateau aquifer</td><td>0–1,500</td><td>Permeable limestone, fractured and solutioned locally. Well yields range from 1 to 300 gallons per minute, but typical yields are 5–10 gallons per minute.</td></tr>
<tr><td>Ozark confining unit</td><td>0–1,500</td><td>Shale of very low permeability; however, at most locations, thickness of shale is less than 20 feet. Thus, unit is moderately leaky.</td></tr>
<tr><td>Ozark aquifer</td><td>0–4,000</td><td>Mostly dolostone with limestone and sandstone layers. Dolostone highly fractured with very permeable zones of fractured and solutioned dolostone. Well yields range from 2 to 2,000 gallons per minute, but typical yields are 200–400 gallons per minute.</td></tr>
<tr><td>St. Francois confining unit</td><td>0–730</td><td>Shale, siltstone, dolostone, and limestone, all of low permeability. Unit is leaky to slightly leaky.</td></tr>
<tr><td>St. Francois aquifer</td><td>0–500</td><td>Fractured and permeable dolostone and sandstone. Well yields range from 1 to 500 gallons per minute, but typical yields are 50–200 gallons per minute.</td></tr>
<tr><td colspan="2">Basement confining unit</td><td></td><td>Mostly igneous and metamorphic rocks. Rocks are fractured and locally will yield small quantities of water to wells. No known aquifers beneath these rocks; thus, unit is the basal confining unit.</td></tr>
</table>

**Figure 19.** A chart showing comparison of hydrogeologic units, rock-stratigraphic units, and time-stratigraphic units (modified from Jorgensen, written commun., 1986, and Jorgensen and others, in press).

The argument has been made that including the full rock-stratigraphic name would provide additional information (Edwards Limestone aquifer), but if an aquifer is adequately described in the comparison table, the text, and the maps, a full name is redundant (and is incorrect if additional rock types are included in the aquifer). Including all the modifiers, moreover, makes for awkward names. For existing, entrenched names of aquifers, lithologic modifiers should not be capitalized (Burnam limestone aquifer, not Burnam Limestone aquifer).

3. Do not use the name of a rock-stratigraphic unit for an aquifer name if the unit is not part of the aquifer.
4. Aquifer names based on multiple stratigraphic units:
   A. If an aquifer includes all or part of two rock-stratigraphic units, one on the other, both unit names are used, separated by a hyphen, and the name of the younger unit name comes first. For example, the lower Hell Creek-Fox Hills aquifer consists of the lower part of the Upper Cretaceous Hell Creek

| Rock-stratigraphic unit | Time-stratigraphic unit |
|---|---|
| Marmaton Group, Cherokee Group, Atokan rocks, Bloyd Shale, Hale Formation, Morrowan rocks, Pitkin Limestone, Fayetteville Shale, and Batesville Sandstone | Middle Pennsylvanian through Upper Mississippian (Chesterian) |
| Moorefield Formation, St. Louis Limestone, Salem Limestone, Warsaw Limestone, Boone Formation, including St. Joe Limestone Member, Keokuk Limestone, Burlington Limestone, and Fern Glen Limestone | Upper Mississippian and Lower Mississippian |
| Chouteau Group (Limestone) and Chattanooga Shale | Lower Mississippian and Upper Devonian |
| Clifty Limestone, Penters Chert, Lafferty Limestone, St. Clair Limestone, Brassfield Limestone, Cason Shale, Fernvale Limestone, Kimmswick Limestone, Plattin Limestone, Joachim Dolomite, St. Peter Sandstone, Everton Formation, Powell Dolomite, Smithville Formation, Cotter Dolomite, Jefferson City Dolomite, Roubidoux Formation, Gasconade Dolomite, including the Gunter Sandstone Member, Eminence Dolomite, and Potosi Dolomite. | Middle Devonian through uppermost Cambrian |
| Elvins Group:<br>Doe Run Dolomite,<br>Derby Dolomite,<br>Davis Formation | Upper Cambrian |
| Bonneterre Dolomite and Lamotte Sandstone | |
| Mostly igneous and metamorphic rocks | Precambrian |

Note.—Although measurements in this example are given in inch/pound units, metric (SI) units are now preferred. (See "Metric System," p. 122, for USGS policy.)

Formation and the underlying Fox Hills Sandstone. This usage conforms to that of map explanations, tables, cross sections, and the computerized Water Data and Storage Retrieval System (WATSTORE).

However, an aquifer name designated from units in order of decreasing age is acceptable if it is entrenched in local usage or has been used in legal terminology. For example, the oldest- to youngest-named Potomac-Raritan-Magothy aquifer in the Cretaceous Potomac Group and the overlying Raritan and Magothy Formations has longtime usage in New Jersey.

B. If an aquifer includes three or more superimposed rock-stratrigraphic units, the aquifer name may include all units youngest to oldest (hyphenated) or only the youngest and oldest units. For example, the Galena-Platteville aquifer of local Wisconsin usage is in the Galena Dolomite (youngest), Decorah Formation, and Platteville Formation. An appropriate geographic name would be a desirable alternative of a cumbersome hyphenated rock-stratigraphic name.

C. If the middle rock-stratigraphic unit is the primary aquifer, its name may be used, provided the overlying and underlying stratigraphic units are clearly identified. For example, the Edwards aquifer in Texas is in the Georgetown Limestone (youngest), Edwards Limestone, and Comanche Peak Limestone.

D. An aquifer that includes many water-bearing rock-stratigraphic units that are hydraulically connected vertically and laterally should not be named for any of the individual rock-stratigraphic units. A geographic name would be appropriate. For example, the Floridan aquifer system includes the Tampa Limestone, Suwannee Limestone, Ocala Limestone, Avon Park Formation, Oldsmar Formation, and part of the Cedar Keys Formation.

5. An abandoned rock-stratigraphic name should not be used for an aquifer name; the newly assigned stratigraphic name should be used instead. If, however, the abandoned name is entrenched in local usage or is a legal term in State regulations, the name may be used, but the stratigraphic change should be described in the introduction of the report and should appear on a correlation chart.

**Using rock-stratigraphic names for aquifers.** The use of rock-stratigraphic names for aquifers carries some risk of confusion because you must distinguish the rock-stratigraphic unit from the aquifer throughout the text and in the illustrations of your report. After having first used a name in full, you can shorten both rock-stratigraphic and aquifer names in text by dropping the rank or descriptive part of the name if doing so improves readability and causes no doubt in the mind of the reader. For example, if the Baker aquifer makes up a large part of the Baker Formation, but not all of it, confusion might result if you say, "The Baker is 450 feet thick south of the Possum River." (The Baker Formation or the Baker aquifer?) If such doubt might arise, be sure to use the term "aquifer" when discussing the aquifer.

To avoid unnecessarily long names and to clarify the distinction between the aquifer and the rock-stratigraphic unit, do not use lithologic modifiers of rock-stratigraphic names for aquifers. Thus, an aquifer made up largely of the Jacob Sand Member of the Blackjack Formation should be called the Jacob aquifer, not the Jacob Sand Member aquifer. Lithologic modifiers have been used in aquifer names by authors who believed the modifiers added useful information to the aquifer names, but if the aquifer is clearly defined in the comparison charts, a reader should have no difficulty learning its composition. In addition, a single lithologic modifier of a name may be incorrect if more than one rock type makes up the aquifer.

Descriptions of aquifers and rock-stratigraphic units should be clearly separated or distinguished in the text and illustrations. For example:

1. Information on the potentiometric surface, storage coefficient, and specific yield describes the aquifer, not the rock-stratigraphic unit.
2. Information on dip, strike, plunge, and deposition of sediments describes the rock-stratigraphic unit, not the aquifer.

Terms such as porosity and permeability could refer to either the aquifer or the rock-stratigraphic unit.

### Geographic Names for Aquifers

Geographic names can be the basis for aquifer names where (1) no rock-stratigraphic names are available, (2) no single rock-stratigraphic name or combination of rock-stratigraphic names (or lithologic names) would be appropriate, or (3) the use of previously named aquifers in small-area studies would not be appropriate. Geographic names are appropriate for aquifers of subregional extent where the location of the aquifer might provide more meaningful information than its physical characteristics. Geographic names include the names of cities, towns, districts, hills, mountains, lakes, rivers, creeks, and physiographic regions or subregions. In addition to geographic names, a regional aquifer name could be derived from a geologic structural feature (a basin, for example) that has relevance in the area underlain by the aquifer. Physiographic names should be from well-known sources, such as Fenneman's map (1946), "Physical Divisions of the United States." Geographic names should be from standard topographic quadrangles of the Geological Survey. The "High Plains aquifer" and the "Floridan aquifer system" are examples of regional aquifer names derived from physiographic and geographic names.

## NONRECOMMENDED SOURCES FOR AQUIFER NAMES

### Time-Stratigraphic Names

Time-stratigraphic boundaries do not necessarily coincide with rock-stratigraphic boundaries or other physical changes in the hydrologic characteristics of rocks and should not be used as a basis for placing aquifer boundaries or for naming individual aquifers. Aquifers have been named for time-stratigraphic terms, but later studies and more detailed mapping have shown that some parts of an aquifer may be older or younger than the time-stratigraphic unit in the aquifer name. For example, several years after the "Tertiary limestone aquifer" in the Southeastern United States was named, it was found to contain Upper Cretaceous rocks. Another possible complication is that longstanding time-stratigraphic boundaries have been changed in this country to agree with boundaries established under international geologic agreements (for example, the change in the Miocene-Pliocene boundary from 10 million years ago to 5 million). Also, terms such as "Cretaceous aquifers" are not strictly correct. The aquifer is not of Cretaceous age; it consists of rocks of Cretaceous age whose hydrologic properties are not the same as they were when the rocks were formed. "Aquifers in rocks of Cretaceous age" is correct and should be used instead.

Some aquifer names based on time-stratigraphic names are in the literature and are commonly used—the "Cambrian-Ordovician aquifer" of the North Central United States, for example. Other aquifers in the country have similar time-stratigraphic names that are entrenched in local usage. These names should be phased out if possible. Time-stratigraphic nomenclature should not be used for newly named aquifers, and existing time-stratigraphically based aquifer names should not be extended from local use to aquifers of regional scale.

### Relative Position

If a layer of saturated permeable rock overlies another layer of saturated permeable rock—regardless of differences in lithology—the two layers form one aquifer and should not be designated "upper and lower" aquifers. If they are mostly separated by mappable, distinctly less permeable confining units, they are two separate aquifers.

The terms "upper" and "lower" may be used where parts of an aquifer are separated by confining units if the full extent of the aquifer or aquifer system is reasonably well known. For example, the Floridan aquifer system was described as the "Upper Floridan aquifer" and "Lower Floridan aquifer" in the part of the area where the two units are separated by a regional confining unit. Where the confining unit is nonexistent, the term "Floridan aquifer system" is used, but in fact, the term "Floridan aquifer system" is correct throughout the area, including places where the two parts are separated by the confining unit. If you are referring to parts of the same aquifer that have some distinctive difference, the term "zone" is preferred. For example, use "upper zone of the Chicot aquifer" (not "upper Chicot aquifer").

### Alphanumeric Designations

Alphanumeric designations, such as "A1 aquifer layer" and "C1 confining layer," are useful in discussing layers of a numerical ground-water flow model, but they should not be used as aquifer names. A clear distinction must always be made in a report between the real flow system and the simulated flow system. Illustrations such as figure 17 help differentiate these distinctions and relations.

### Depositional Environment

Names based on depositional environment can be misleading and should not be used for aquifer names. For example, "shallow marine aquifer" may be totally unclear as to what is meant and included. Even if the aquifer were described as consisting of "sand deposited in a shallow sea," problems and additional confusion may arise if the rocks of the aquifer grade into hydrologically continuous deposits from a different depositional environment or grade into different rocks in a similar depositional environment. Likewise, a "glacial aquifer" may contain or be hydrologically continuous with other deposits or rocks that are not of glacial origin. Lithologic or geographic terms would be more appropriate.

### Depth of Occurrence

Aquifers should not be named after depth of occurrence. The aquifer named after the "2,000-ft" sand may well be present at a depth of about 2,000 ft at a given location where it was named in a local study, but on a regional scale the sand may be present elsewhere at a greater or lesser depth and may have no relation to the name derived from the local study. Established local usage may require the continued use of a name, but the name should not be extended to regional use.

### Acronyms

Aquifers or aquifer systems should not have acronyms for names, such as an aquifer name derived from the first letter of each rock-stratigraphic unit that makes up the aquifer. If many rock-stratigraphic units make up an aquifer, a geographic name unrelated to any of the rock-stratigraphic names should be used.

### Hydrologic Condition

Terms such as "water-table aquifer" and "artesian aquifer" are not recommended, because they are based on hydrologic conditions that can change as outside stresses change (pumping, climate). Hydrologic conditions also can vary from place to place. For example, an artesian aquifer can be dewatered by pumping, and an aquifer that is under artesian conditions within one place may be under water-table conditions in another.

## Recommendations for Naming Confining Units

Confining units should not be named unless a clear-cut need exists for understanding a complex aquifer system. If several aquifers and confining units are discussed, the confining units could be given individual names, but a hierarchy of terms for confining units comparable to aquifer system, aquifer, and zone is not necessary. If names are applied to confining units, they, like aquifer names, should be derived from lithologic terms, rock-stratigraphic names, or geographic names. If a confining unit consists of one rock-stratigraphic unit, the confining unit may be named after the rock-stratigraphic unit. If a confining unit consists of several rock-stratigraphic units, it could have the hyphenated name of the youngest and oldest units, or preferably, a geographic name.

A confining unit could be named after the aquifer it confines, but two possible situations may cause confusion. First, what name would be given if the confining unit separates two aquifers? It confines both. It could be named, however, for aquifers it overlies. If crystalline basement or other rock having low hydraulic conductivity forms the lowest confining unit, a name unrelated to an aquifer name should be chosen, such as "basal confining unit."

Second, if an aquifer is named for a rock-stratigraphic unit that forms all or most of the aquifer, the same name should not be used for a confining unit. In other words, the confining unit should not be named for a rock-stratigraphic unit that is not part of the confining unit. For example, in western South Dakota, the upper part of the Minnelusa Formation is an aquifer named the Minnelusa aquifer. This aquifer is overlain by a confining unit that consists of six formal rock-stratigraphic units. The confining unit should not be called the "Minnelusa confining unit," because the Minnelusa Formation is not a part of the confining unit. The options are (1) do not name the confining unit, (2) name it after an appropriate combination of rock-stratigraphic units that are in the confining unit, or (3) name the confining unit after a geographic feature. However, if the lower part of the Minnelusa Formation is a confining unit, the name "Minnelusa confining unit" could be used.

## General Procedures, Style, and Expression

### Redefining and Renaming Previously Named Aquifers

A previously named aquifer can be redefined and renamed, and the approach is the same as that for naming an aquifer for the first time. Redefining and renaming an aquifer should not be done casually or just to change the name. The guidelines in the previous pages apply. Comparison charts are important, especially charts that show the relation of renamed aquifers to previously named ones. No hard, fast rules can be given for redefining and renaming an aquifer, but justification should result from a thorough analysis of the hydrogeology and should represent an improvement in the understanding of the hydrology. Technical review should be used to judge the merit of the nomenclature changes. The work of Miller (1986) is an example of a detailed hydrogeological analysis that resulted in redefining and renaming the water-bearing units of the Floridan aquifer system. In reality, *all* aquifer names are informal names (North American Stratigraphic Code, 1983, art. 26) that might be changed with additional study. To represent clearly the hydrology of a particular area is more important than to retain old names or introduce new ones.

### Format Conventions for Aquifer Names

The following format conventions are recommended for reports that name aquifers or contain discussions of aquifer names:

- The terms "aquifer," "aquifer system," "zone," and "confining unit" are not capitalized.
- Terms such as sand and gravel aquifer and limestone aquifer are not capitalized or hyphenated.
- Adjective modifiers, except parts of formal geographic names, are not capitalized: Mississippi River alluvial aquifer.
- Relative-position terms—upper, middle, and lower—are not capitalized. However, the terms may be capitalized if they represent parts of a regional aquifer system that are separated by a major confining unit. For example, Miller (1986) formally divided the Floridan aquifer system into an Upper Floridan aquifer and a Lower Floridan aquifer in all Florida and parts of adjacent States.
- Quotation marks are not used for aquifer names unless the term is a misnomer. The term "500-ft" sand is set in quotes only because the sand is not

at 500 ft below land surface everywhere. (As mentioned before, depth of occurrence should not be used to name aquifers.)

- Hydrologic and geologic terms should be clearly distinguished.

  A. Water from the Madison aquifer—not Madison water.

  B. Wells completed in Madison Limestone (or aquifer)—not Madison wells.

## EXAMPLES OF DESIGNATING AND NAMING AQUIFERS

Examples of designating and naming aquifers are shown in figure 20. The examples are hypothetical and generalized for convenience, but they illustrate characteristic hydrologic settings throughout the country. Even though most of the examples use rock-stratigraphic names, the options for naming aquifers in order of consideration are (1) do not name the aquifer, (2) use a lithologic name, and (3) use a rock-stratigraphic or geographic name, whichever is appropriate.

**Example 1: Aquifer and rock-stratigraphic unit coincide.** Example 1 shows an aquifer that coincides with a rock-stratigraphic unit and is confined above and below by much less permeable material. The aquifer probably would be named the Johnsville aquifer even though the full lateral extent of the aquifer may not be known.

**Example 2: Aquifer consists of one rock-stratigraphic unit and part of an adjacent rock-stratigraphic unit.** The aquifer shown in example 2 is made up of the lower two-thirds of the Whiskey Creek Formation (sandy silt and clayey sand) and the moderately cemented Devils Lake Sandstone. Hydrologically, the two units are continuous and form a single aquifer. The aquifer is confined above and below. The name of the aquifer could be taken from the rock-stratigraphic name "Whiskey Creek-Devils Lake aquifer." Likewise, a prominent geographic feature near the place where the aquifer was described (by wells or outcrops) could be the basis of the aquifer name. The description of the aquifer in the text, comparison chart, and illustrations should carefully state how the upper and lower boundaries of the aquifer were selected. In addition, the description should make clear that the upper formation and aquifer are not totally coincident.

**Example 3: Aquifer consists of a small part of two major rock-stratigraphic units.** The aquifer in example 3 consists mostly of the Murphy Member of the Ringer Formation and probably would be called the Murphy aquifer. If the Murphy Member had not been named, the aquifer might be called the Bell-Ringer aquifer. However, the aquifer makes up only a small part of each formation, especially the Bell Formation, so a local geographic name might be more appropriate.

**Example 4: Aquifer and aquifer system.** Example 4 represents an aquifer system consisting of three permeable carbonate formations and the sand facies of a clastic formation. The clay facies forms a confining unit over part of the area. If the study had included only the area east of the State line, two separate aquifers could have been defined—the Beckville-Jonesville aquifer and the Riley aquifer (or two aquifers named for geographic locations). If the study had included only the area west of the State line, the following options could be considered: (1) The aquifer might be called the Lewis aquifer if the sand were significantly more permeable than the limestone units, or (2) the aquifer might be called the Beckville-Riley aquifer if the permeability of the four units were not greatly different, or (3) the aquifer could be named after an appropriate geographic feature.

If the study area included all the units shown on the cross section, no individual rock-stratigraphic unit would be representative everywhere, and a geographic name should be used to name the aquifer system. If the sketch represented the full extent of the aquifer and the aquifer were given a name, say the Williamsburg aquifer, the parts above and below the confining unit could be named the Upper Williamsburg aquifer and the Lower Williamsburg aquifer in a manner similar to the naming of the Floridan aquifer system of Miller (1986). For local studies on either side of the State line, the local aquifer name could still be used if the names were entrenched in usage, but the authors of local reports should clearly show and explain the broader relation.

**Example 5: Aquifer system in a coastal area.** Example 5 illustrates an aquifer system (*A–B*) in a coastal area where the tendency has been to give separate aquifer names of hydrologically contiguous rock-stratigraphic units. For example, in a study area represented by section *A–B*, the aquifers from youngest to oldest are: surficial (the sand unit), Ford, Bass, Wilks, and Dade. In reality, all these named units form a single aquifer system that should be named after a physiographic or geographic feature. In a local-scale study represented by section *C–D*, the surficial deposits and the Bass Sand form one aquifer that should have a single name. It could be called the Bass aquifer as long as the designation clearly included the surficial deposits. The second aquifer under *C–D* would be the Wilks-Dade aquifer.

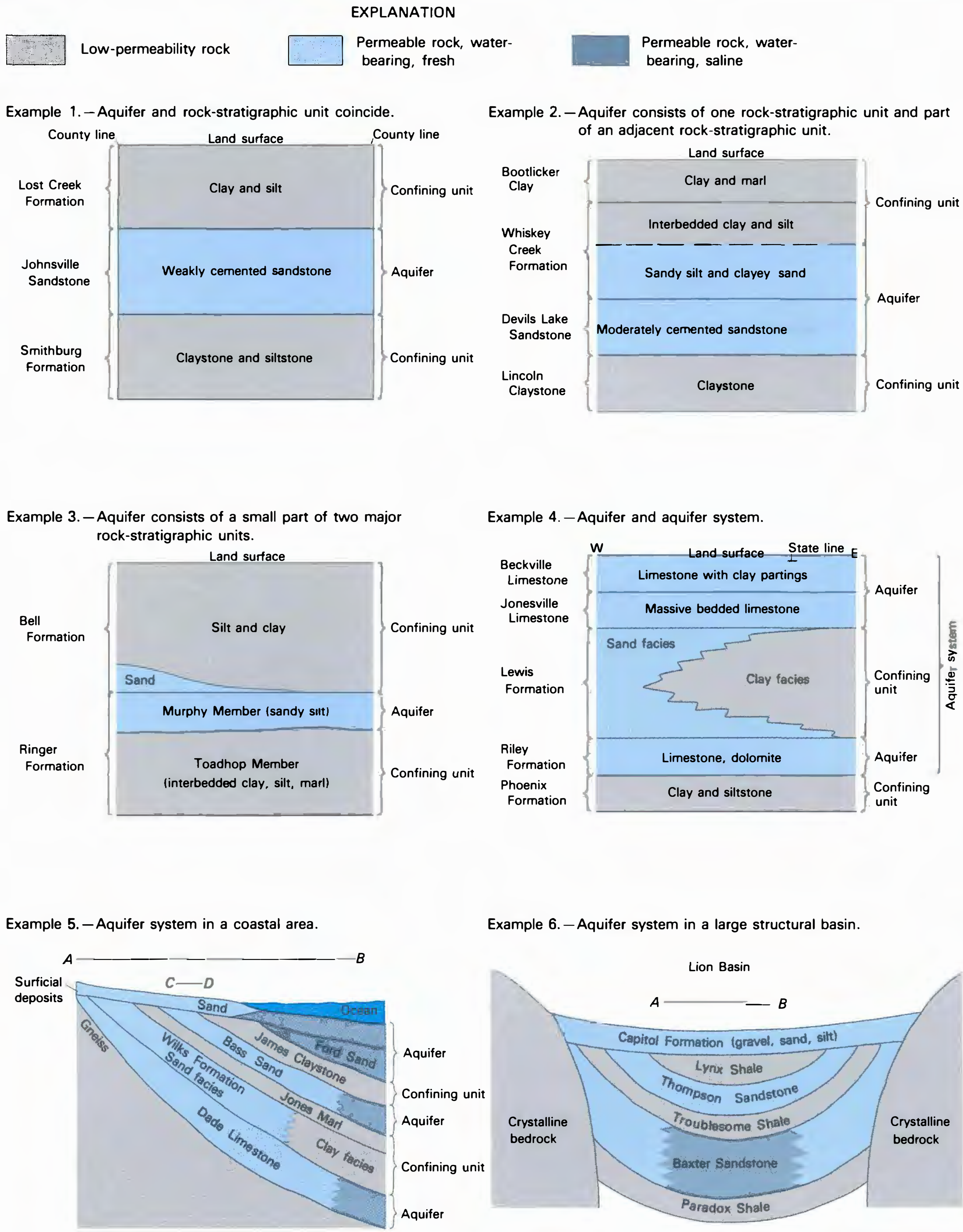
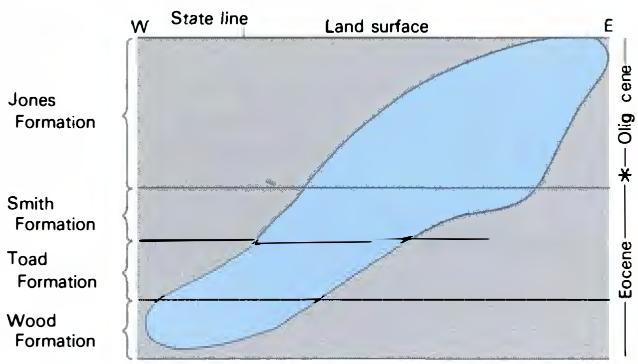
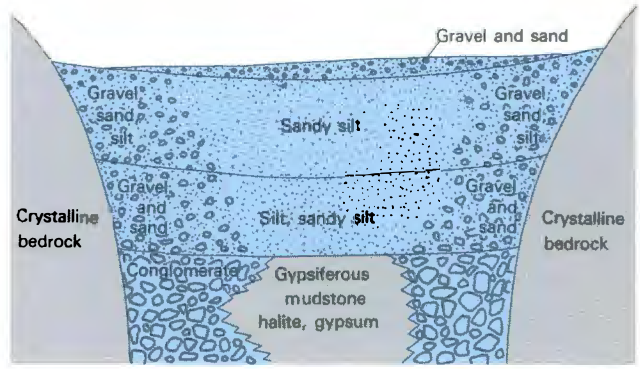



**Figure 20.** Examples of designating and naming aquifers.

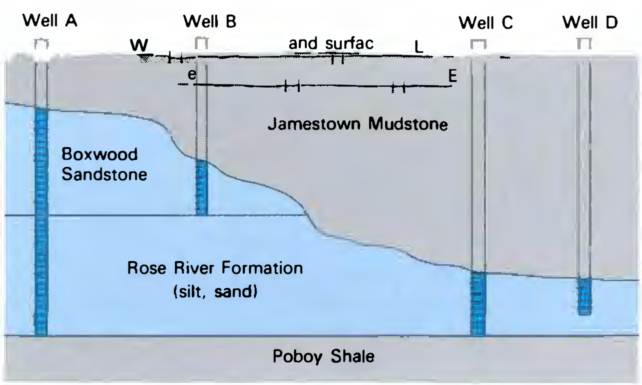
Example 7.—Aquifer crosses boundaries of rock-stratigraphic units and time-stratigraphic units.



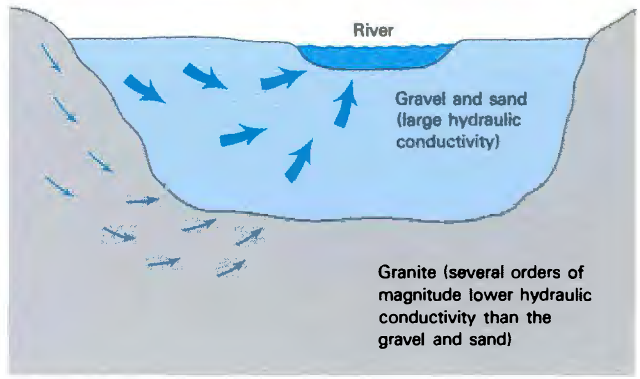

Example 8.—Aquifers in an alluvial basin in the West or Southwest.



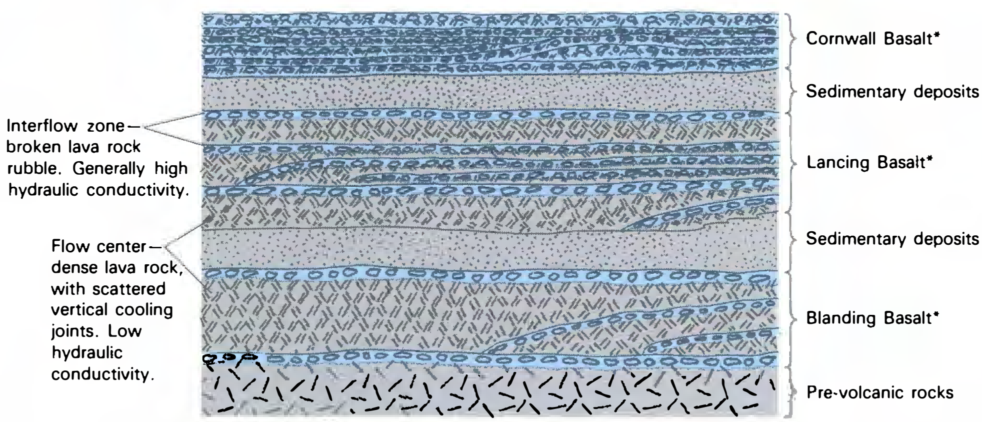

Example 9.—Use of aquifer terminology where rock-stratigraphic units are discontinuous.




Example 10.—Designation of aquifers and confining units for different purposes and scales of investigations.




Example 11.—Designation of aquifers in thick lava-flow sequences.




*Represents only a few of the flows in each basalt unit.

Aquifer materials that contain saline water are part of the same aquifer that contains fresh water. Interfaces between saltwater and freshwater are subject to movement, depending on the hydrologic conditions of the area, and should not be used as aquifer boundaries. However, the boundary between the salt water and fresh water and its apparent stability (or instability) should be defined as clearly as possible in the report.

**Example 6: Aquifer system in a large structural basin.** Example 6 depicts an aquifer system in a large structural basin. The aquifer system should be named after a physiographic or geographic feature, or as here, after a structural basin—the Lion aquifer system. If the tops and bottoms of the Capitol Formation, Thompson Sandstone, and Baxter Sandstone are all well defined, and if the boundaries of these units correspond largely to the boundaries of the aquifers in the system, rock-stratigraphic names could be used for individual aquifers. If the subsurface extent and boundaries of the rock-stratigraphic units are not well known, however, or if the individual aquifers consist of several rock-stratigraphic units, names unrelated to rock-stratigraphic terms should be assigned to the individual aquifers. If considerable uncertainty exists in defining the boundaries of the aquifers, the uncertainty should be indicated in the comparison charts and text. If the aquifer is well defined, it could be subdivided into the Upper, Middle, and Lower Lion aquifers, as was done for the Floridan aquifer system of Miller (1986). For local studies preceding the regional evaluation, as in the area represented by section *A–B*, individual aquifers might have been designated the Capitol aquifer, the Thompson aquifer, and the Baxter aquifer.

For subsequent local studies, the Lion aquifer system names could be used for individual aquifers unless the rock-stratigraphic names were entrenched or otherwise advantageous. If the rock-stratigraphic names are used as the basis for aquifer names, their corresponding equivalents in the regional aquifer system should be discussed and shown in the comparison table of the report.

**Example 7: Aquifer crosses boundaries of rock-stratigraphic units and time-stratigraphic units.** Example 7 shows an aquifer that crosses the boundaries of four rock-stratigraphic units and consists of parts of them. East of the State line the aquifer could be named the Jones-Smith aquifer; west of the State line it could be called the Toad-Wood aquifer. The aquifer boundaries bear no relation to the time-stratigraphic boundaries. In studies of the entire aquifer, a single rock-stratigraphic name is not appropriate; a geographic name should be used. Of course, a geographic name rather than a rock-stratigraphic name could be selected for the aquifer name at the local scale also.

**Example 8: Aquifers in an alluvial basin of the West or Southwest.** The sedimentary units shown in example 8 are representative of closed-basin deposits. In such a setting, the grain size generally decreases basinward from the source areas, and cementation increases at depth. Hydraulic conductivity likewise decreases downward and basinward. Even though the hydraulic conductivity generally is lower in the deeper units, many deposits in the upper part of the basin are hydraulically connected and consist of one aquifer. Most of the deposits do not have formal rock-stratigraphic names but may have informal names, such as basin fill, valley fill, cemented gravel, playa deposits, or lake deposits. Other rock units, such as volcanic flows interbedded with the basin deposits, may complicate the relationships. Well-defined confining clays in some basins subdivide the materials into two or more aquifers. In other basins, however, well-defined clay layers may be absent, or clay deposits may form "plugs" at depth in the centers of the basins. Your first option is to name no aquifers but to describe the water-bearing characteristics of the deposits. Informal rock names could be used (for example, valley-fill aquifer), or the aquifer could be named for a geographic feature, such as a basin or valley. Zones could be designated for hydraulic features that require emphasis or separation.

**Example 9: Use of aquifer terminology where rock-stratigraphic units are discontinuous.** The aquifer depicted in example 9 could be called the Boxwood-Rose River aquifer. Its upper boundary coincides with an erosional discontinuity, and although the Boxwood Sandstone is not present in the eastern part of the area, the name "Boxwood-Rose River aquifer" would be appropriate. Use of the aquifer name is illustrated by the wells in the sketch: Well A completely penetrates the Boxwood-Rose River aquifer, well B partly penetrates it, well C completely penetrates it, and well D partly penetrates it.

If a report were prepared on the area between wells C and D, the aquifer could be called the Rose River aquifer because the Boxwood Sandstone is not present in that area. However, if the entire sketch area were studied and if the Boxwood-Rose River aquifer were already named, the study report must contain text statements and comparison charts to show that the Rose River aquifer thickens west to include the overlying Boxwood Sandstone and there becomes the Boxwood-Rose River aquifer.

**Example 10: Designating aquifers and confining units for different purposes and different scales of investigations.** Example 10 depicts a highly permeable deposit of gravel and sand in a valley occupied by a major perennial stream. The bedrock is granite and is several orders of magnitude less permeable than the gravel and sand.

Because of the large permeability contrast, the deposit of gravel and sand is the aquifer, and the granite is the confining unit. If you were evaluating the potential for developing ground-water supplies from the gravel and sand, or were evaluating the interaction between ground water and surface water, you might consider the granite to be effectively "impermeable," and you could ignore the flow in the granite. If, however, you were evaluating the potential for storing high-level radioactive wastes in the granite, the designations of the aquifer and confining unit would not necessarily change, but you would have to consider the flow system through both units. The rate of flow through the granite into the gravel and sand would be slow, but you could not ignore it in evaluating minimum travel times of radionuclides that the ground water might transport through the granite. The depicted situation is similar to that of an aquifer overlain by a confining unit (such as clay over sand) that contributes water to the aquifer by leakage. A small to large part of the water withdrawn from the aquifer could come from the confining unit, but the designations of the aquifer and confining unit would not change. Therefore, the purpose of an investigation in a given area should not alter the designations of aquifers and confining units.

Aquifers and confining units may be designated differently in two or more investigations because of differences in scale or extent of the study areas. In an investigation of just the granitic terrane in the sketch (such as an evaluation of ground-water avail-ability for domestic use), the granite would be the aquifer because it is the only water-bearing unit in the study area. A report on a larger area that included the gravel should mention the previous report and should describe how the various hydro-geologic units were selected. Similarly, a unit of low hydraulic conductivity might be utilized locally as an aquifer, whereas a regional evaluation might show it as a regional confining unit. You as author should explain the apparent anomaly by means of the comparison charts and text.

**Example 11: Aquifers and confining units in thick lava-flow sequences.** Thick lava-flow sequences, as on the Columbia Plateau (Heath, 1984), require special consideration in the designation of aquifers and confining units. These sequences may be hundreds to thousands of feet thick and may contain individual flows a few feet thick to a few hundred feet thick. The most permeable parts are interflow zones of lava-rock rubble a few feet thick at the tops of flows and thinner rubbly zones at the bases of overlying flows. The interflow zones are interrupted laterally, or they terminate; continuous aquifers, therefore, are identifiable for only a few miles (Newcomb, 1969). The part of a flow between interflow zones—the flow center—consists of dense, vertically jointed lava rock that cooled slowly. The interflow zones may account for only 1–30 percent of the volume of the rock, but their lateral hydraulic conductivity may be several orders of magnitude greater than the vertical hydraulic conductivity of the dense, vertically jointed rock, unless the top of the flow had been subjected to long subaerial weathering before burial. If the top of a flow were extensively weathered before being covered by another lava flow, clay minerals in the altered lava rock might reduce the permeability of the interflow zone. The interflow zones may contain discontinuous deposits of fine-grained sediment that have little hydrologic effect on the flow sequence or that may grade into wider spread sedimentary deposits. The hydraulic conductivity of widespread sedimentary deposits varies but usually is much less than that of a rubbly interflow zone.

Designating aquifers may be governed by the scale of the study and the thickness of the individual lava flows. Where individual flows are several hundred feet thick (the middle and lower part of the sketch), the interflow zones are easily recognized as individual aquifers, and the dense lavas between interflow zones are obvious confining units. The part of the flow sequence consisting of several permeable interflow zones separated by dense, much thicker lava would be an aquifer system. At the other extreme, the designation of aquifer versus aquifer system may not be as clear cut in a sequence where the individual flows are only a few feet thick (the upper part of the sketch). At some point the ratio of interflow zone to dense zone may become large enough that the multiple thin-flow sequence could be considered a single aquifer. A comparison can be made with a sequence of inter-bedded sandstone and shale: Taken as a whole, the sequence might behave hydrologically as a single aquifer and not an aquifer system, even though thin continuous "confining units" are part of the aquifer. Other information, such as head measurements versus depth in areas where the aquifer is under stress, might be used to determine whether the sequence under study behaves as a single aquifer or as several aquifers separated by confining units.

If you assume that the thin-bedded flows in the upper part of example 11 behave as a single aquifer, the hypothetical lava-flow sequence consists of an aquifer and two aquifer systems, all of which constitute an even larger aquifer system. A higher category than aquifer system might appear to be needed in the hierarchy of nomenclature to classify the water-bearing rocks in this example, but the term "aquifer system" adequately encompasses the example shown. An appropriate geographic name should be used for the entire hydrologic system represented by the sketch, such as the "Rome River aquifer system," after a major river in the area. The individual parts of the system could be called "the Upper," "Middle," and "Lower Rome River aquifer," as in the Floridan aquifer system (Miller, 1986). An alternate method of naming would give the upper, middle, and lower parts individual names based on rock-stratigraphic units (or appropriate geographic names) that make up the aquifers, as follows:

| | |
|---|---|
| Rome River aquifer system | Cornwall aquifer (after Cornwall Basalt) |
| | Lancing aquifer (after Lancing Basalt) |
| | Blanding aquifer (after Blanding Basalt) |

As in any other aquifer description, the characteristics of the dense, less permeable parts of the aquifer versus the very permeable interflow zones must be carefully described in the comparison tables and text.

# GEOGRAPHIC NAMES

GEOGRAPHIC NAMES are the proper names of particular Earth features, places, and landmarks. They identify areas of cultural and administrative responsibility, define political boundaries, and provide legal evidence of property, mineral, and water rights. The Geological Survey, therefore, is obliged professionally and legally to use official names in all its publications and on all its maps. The choice, form, spelling, and application of official place names for Federal usage are determined by the U.S. Board on Geographic Names.

## THE U.S. BOARD ON GEOGRAPHIC NAMES

Established in 1890, the U.S. Board on Geographic Names was organized in its present form by public law in 1947. Its mission is to serve the Federal Government and the general public as a central authority for solving problems, making decisions, and answering inquiries about geographic names. Any person or organization, public or private, may request the Board to decide formally on new names, name changes, or conflicting names.

The Board is composed of representatives from several Federal agencies, and it shares its responsibilities with the Secretary of the Interior. It is authorized to establish and maintain uniform geographic-name usage throughout the Federal Government. It formulates principles and policies governing the use of foreign and domestic names and names of undersea and extraterrestrial features.

## NATURE OF GEOGRAPHIC NAMES

Geographic names normally originate in and are influenced by spoken language. This fact is important because the Board is concerned mostly with written forms of names, including matters of spelling, capitalization, word form, and writing marks that have little to do with spoken language.

Most geographic names are binomial in that they have two parts, denoting species and genus: Middleton (Middletown), Coal Hollow, or Sierra Nevada. The generic part tells the kind of place, feature, or area the name refers to, and the specific part modifies or uniquely identifies the particular place, feature, or area. The generic part of the name is usually a single topographic term such as brook, hill, bay, peak, mesa, or lake; the specific part may consist of one or more words such as Grosse Roche, Jenny Lind Run, and Casale Campo di Carne. The binomial form is strong and in written usage may lead to combining specific parts of the name, such as Threemile Run and Redhill Gulch. The names of some features can be long, especially if the specific part is a prepositional phrase: Cliffs of the Seven Double Pillars, Foot of the Mountains Run, and Cañon del Rajadero de los Negros.

Some names have unique generic forms; consider, for example, colorful American names like Bald Alley (ridge), Butlers Toothpick (pinnacle rock), Titans Piazza (hill), and Devils Racepath (ridge). Variations of the binomial form are one-word names that require a capitalized article: The Bend, La Pica, The Cape, The Nose, and The Maze.

Single-word specific names such as Boston, Oalite, and Pinhook are common for populated places and civil divisions; the kind of feature meant is implied by sentence context.

Several names with the same generic word may be treated as a group in text with the generic word capitalized and in plural form: Calumet, Manitowoc, and Sheboygan Counties; Wisconsin and Illinois Rivers.

## THE GEOGRAPHIC NAMES INFORMATION SYSTEM

The National Geographic Names Data Base is managed by the Geographic Names Information System (GNIS). The system currently has more than 2 million name records in the data base. These records include the names of natural features, populated places, civil divisions, areas and regions, and culture features such as mines, churches, schools, cemeteries, hospitals, dams, airports, and shopping centers. Official names are appropriately identified in the data base, which also includes records of named features not under the purview of the Board on Geographic Names. Each record includes the following information:

- Written form of the official or primary name.
- Term identifying the kind of named feature.
- Location and, if applicable, extent of feature by geographical coordinates.
- Map on which feature can be located.

- Elevation of feature, when appropriate.
- Official or nonofficial status of name and application (not all names in the data base are official).
- Variant names and spellings for the same feature.

Information from the data base can be retrieved, analyzed, and organized. Geological Survey personnel may access GNIS through the Earth Sciences Information Network (ESIN) or may request special searches and printouts from:

- Manager, GNIS, National Center, Reston, Virginia.
- Earth Science Information Center offices.

## Principles of National Standardization

The Board on Geographic Names is guided by the following principles in determining official names of places, features, and areas in the United States and its territories:

1. **Use of the Roman alphabet.** Official domestic geographic names are written in the Roman alphabet as normally used in the English language. Exceptions are occasionally made for Spanish and French names that have diacritical marks (see "Diacritical Marks in Domestic Names"). Names written in other forms of the Roman alphabet and in other alphabetical scripts may be used in parentheses after the official name.
2. **Names in local usage.** The underlying philosophy of the Board for establishing official geographic names and their applications recognizes present-day local usage or preferences, except when local spoken or written usage conflicts with specific Board policy or when the preferences of State or local governmental authorities disagree with local usage. Where local usage is weak or conflicting, well-established, documented names and names with historical significance receive strong consideration.
3. **Names established by act of Congress.** Geographic names and their applications specifically established by an act of Congress are official by law. Geographic names used incidentally in the language of an act of Congress enacted for other purposes are not necessarily official, unless the language clearly indicates that naming is part of the intent of the act.
4. **Names established by other authorities.** The Board on Geographic Names normally accepts as official the names of political subdivisions, bounded administrative areas, structures, and establishments in the United States and its territories, as determined by the appropriate responsible public or private authorities.
5. **One name for one geographic entity.** The Board will identify one name, spelling, and application as official for a geographic entity in the United States, its territories, and outlying areas. For certain entities, a shortened version of the official name also may be authorized for use in Federal publications; for example, State of Wisconsin and Wisconsin; New York City and New York.

## Spelling Geographic Names

Geographic names, like other proper names, are not subject to the spelling rules that apply to other words in the English language. The Board establishes standard spellings of geographic names in the United States for use by the Federal Government. Although these spellings generally conform to rules of English, they reflect historical spellings or forms commonly used or preferred by local citizens and may, therefore, include what appear to be grammatically incorrect, misspelled, improperly combined, or clipped words.

## Determining Official Names

Only official domestic geographic names will be used on Federal maps and in other publications. An official name is one in which the written form of that name and its application to the appropriate place, feature, or area are approved by the Board on Geographic Names. The primary reference for official names and their applications is GNIS. Names not in GNIS or not identified as official in GNIS must be submitted to the Board for approval before they can be used for Federal publication.

This procedure does not apply to the names of offices or establishments of governmental agencies or to the names of certain manmade features such as streets, roads, shopping centers, churches, schools, hospitals, and airports (see principle 4) or to those names used for historical reference or other similar situations in which the geographic names are not intended to represent current official usage.

## Domestic Names Decisions

Name problems and proposals submitted to the Board are researched individually by the Geological Survey support staff and are put on a monthly docket list for consideration by the Domestic Names Committee. Each list is sent to cooperating Federal and State agencies and to interested organizations and individuals about a month before the meeting at which the list is to be considered. Reviewing the merits of each case, the Committee decides between conflicting names and approves or disapproves proposed new names and name changes. Some actions are deferred temporarily to allow more time for State and local response or to get more information needed for a decision. A record of the decisions at each monthly meeting is submitted to the Secretary of the Interior for review. Decisions of the Domestic Names Committee automatically become decisions of the Board on Geographic Names and are published in a quarterly decision list.

## Geographic Names Policies

For uniformity in the decision-making process and to assist in national standardization, the Board on Geographic Names has policies and procedures that deal with particular naming problems or issues. The selected policies that follow are particularly relevant to the activities of the Survey. (A complete, up-to-date set of domestic name policies, with guidelines, may be obtained from the executive secretary for Domestic Geographic Names, care of 523 National Mapping Division, U.S. Geological Survey, Reston, VA 22092).

### Proposing New Names

When a name is proposed for an unnamed domestic feature, a report on the new name must be submitted to the Board for approval before publication of the document that uses the name. Proposed new names should be unique and euphonious, if possible, and not unduly long or clumsy. They should be acceptable to local citizens and should not be controversial. Indian or other ethnic names, if appropriate, and names suggested by local history or by a peculiarity of the topographic feature, such as form, vegetation, or associated animal life, are generally acceptable. Commonly duplicated words like elk, bald, mud, duck, round, or cottonwood should be avoided. The generic part of the name should conform with names common to the area, and the relational naming of forks, prongs, and branches of streams or canyons, such as East Fork or Middle Prong, should be avoided if possible, though such names sometimes need to be given to conform to existing relational names.

New-name proposals for features in national parks and wilderness areas should be coordinated with park or wilderness supervisors before being submitted to the Board. The number and kind of new names approved for such features is restricted.

The following information should accompany new names submitted to the Board:

- Full name being proposed.
- Location and clear identification of feature.
- Reason for needing a name.
- Origin or meaning of proposed name.

The Board on Geographic Names will consider proposals to assign the names of deceased persons to geographic features in the United States and its territories. The Board will not consider names that commemorate or may be construed to commemorate living persons. In addition, a person must have been deceased for at least 1 year before a commemorative proposal will be formally considered. The person should have had some direct association with the feature or should have made a significant contribution to the area or State in which it is located. A proposal commemorating an individual with an outstanding national or international reputation will be considered even if the person was not directly associated with the geographic feature.

A person's death, as in a mountaineering accident or a plane crash on or at a feature, or the mere ownership of land or the feature, does not normally meet the "direct association" criterion.

A proposal to commemorate an individual should contain evidence of local support for the proposed name and its application. Such evidence may be in the form of letters from local residents and administrative agencies or petitions containing original signatures of local citizens.

If the name being proposed commemorates a person, the following additional information is needed:

- Full name of the person.
- Birth and death dates (years).
- Person's title and profession or occupation.
- Person's association with the feature or area.

A short biography of the person is useful, and an annotated map showing the location and extent of the feature is helpful. Because the Board works closely with interested Federal and State agencies, State geographic boards, and local citizens before deciding on a name, final action on a proposal may take from 3 to 6 months.

## Proposing Name Changes

The Board will consider proposals for changing names, but it does not encourage changes in domestic names except where official Federal usage disagrees with well-established local usage or where existing names are derogatory or are duplicated. The reason for change should always be stated when a proposal is submitted to the Board. Information should include the identity of the feature, the origin or meaning of the new name, and the possible response of local citizens to the name change.

## Long and Short Forms of Names

According to principle 5, the Board identifies one name, form, spelling, and application when adopting an official domestic geographic name. All other forms or spellings of the same name, or other names for the same entity, are considered variant names and are not official for Federal use. Two exceptions relate to name forms: The Board allows optional use of long or short forms for incorporated places and political divisions (New York or New York City, Virginia or the Commonwealth of Virginia). The second exception permits the omission in text of the generic parts of names of a few classes of natural features such as rivers, oceans, and deserts. These names in sentence context are normally preceded by the uncapitalized definite article; for instance, the full specific-generic forms of such names are shown on maps (Potomac River, Mojave Desert, and Atlantic Ocean), but the author may drop the generic part in sentence context and refer to "the Potomac," "the Mojave," and "the Atlantic." When first used in text, or when its name could be misunderstood, the full name of the feature should be used.

## Parenthetical Use of Variant Names

The Board does not allow the use of an official name in parentheses, but a variant name in parentheses may be used with an official name if needed for clarity or reference. For example: Echo Park (Pats Hole). The independent use of any name other than the official name is not approved.

Use of a variant name in parentheses following an official name on a Federal map or in a report is at the discretion of the author and the issuing agency. On a map, a parenthetical name may appear either following the official name or below it. It should always be clear which name is the official one.

Names using special symbols to indicate glottal stops and stress, such as those derived from the Hawaiian language, are considered to be variant names, and each may be used in parentheses after the official name on maps or in text. The Board does not object to the listing of such variant names alone in a tabular or dictionary format to convey such special information as pronunciation, name origin, or word meaning. A statement can be made explaining the purpose of the table or dictionary and why the listed names vary from official names.

## Unacceptable Derogatory Names

For domestic geographic names, the Board will not adopt a name for Federal usage that is derogatory to a particular ethnic group, religion, or class of people, even if the name is used locally. Other unseemly names are unacceptable also.

## Diacritical Marks in Domestic Names

Diacritical marks are rarely used in English, but they are common in many other languages, including Spanish and French, from which many place names in the United States are derived. Most geographic names adopted from these languages have been assimilated into English usage and therefore lack the diacritical marks that were included in the original spelling. In some places in the United States, however, especially where Spanish or French is still spoken, local custom may indicate that diacritical marks should be used. Diacriticals are important if their omission would cause a significant change in the meaning of the name in the parent language. Diacritical marks, however, are officially excluded in a few names such as Canon City in Colorado (not Cañon City).

The presence of diacritical marks will not necessarily bar approval of a geographic name; each such name is considered individually. A spelling that includes diacritical marks will be approved if, in the judgment of the Board, substantial evidence such as official records, maps, and signs indicates active local use in the area where the feature exists.

The Board does not approve for Federal publications the use of writing marks in the written forms of geographic names derived from the Hawaiian and native American languages. Names using special marks not normally found in the English language are considered variant names (see principle 1).

## Name Duplication

Name duplication means that two or more nearby places or features of the same kind have the same name in local or published usage. Name duplication does not exist when places or features of different kinds have the same name, such as a stream called Long Creek and a village called Longcreek or Long Creek.

Names proposed for unnamed geographic features that duplicate another name in the State, or nearby in an adjoining State, will not normally be approved.

The Board on Geographic Names encourages State and local governments and local citizens to change or modify duplicate names wherever ambiguity is likely. Such name changes should be coordinated with the Board.

The Board normally does not initiate name changes to eliminate duplication. If duplication in Federal publications might cause confusion, the Board may add a modifier such as "East," "North," "South," "West," "Big," "Little," "Upper," "Lower," or "Middle" to one or more of the duplicate names. This option would be coordinated with State geographic names authorities. In States that lack an authority, the Board tries to work with appropriate local governments and citizens to promote an interest in eliminating the duplication. A name submitted as an alternative to a duplicate name should conform to the policy for naming an unnamed feature.

## Punctuation Marks

Punctuation marks such as hyphens and apostrophes are used occasionally in domestic geographic names. Usage varies, and care should be taken to use the standard form for a particular feature. Hyphens are sometimes used in names consisting of a phrase (Hole-in-the-Wall, Go-to-it Creek, Be-Cha-Tu-Da Draw) and in names having a dual-form specific (Clark-Mallard Ditch, Alma-Cassville Trail).

Apostrophes suggesting possession or association are not used within the body of a proper name (Pikes Peak, Henrys Fork). The word or words that form a geographic name change their function and together become a single denotative unit. The need to imply possession or association does not exist. Thus, we write "Jamestown" instead of "James' town" or even "Richardsons Creek" instead of "Richard's son's creek." "Martha's Vineyard" is a longstanding exception. The whole name can be made possessive or associative with an apostrophe at the end as in "Rogers Point's rocky shore." Apostrophes also are often used within the body of a geographic name to denote a missing letter (Lake O' the Woods) or when they normally exist in a surname used as part of a geographic name (O'Malley Hollow).

## Abbreviations and Number Names

Names of States can be abbreviated according to standards of STA 7 (p. 104). Other geographic names are not abbreviated in sentence context except that "Mount" and "Saint(e)" may be abbreviated as "Mt." and "St(e)." On maps and other illustrations, the generic part of a name and also a few modifiers may be abbreviated ("Middle," "North," "South," "Left," "Right," "Saint(e),"), but if space is available, they are better spelled out. The specific part of a geographic name may not be abbreviated even in illustrations.

Except as rarely approved, numbers in names should be spelled out (Arabic numerals are number symbols, not words):

Fortynine and One Half Creek
Fourmile Run

## Capitalization of Geographic Names

With few exceptions, all words considered part of a proper geographic name are capitalized, including all adjectives, common nouns, and the definite article:

| | |
|---|---|
| Adams Apple | Little Captain Island |
| Alva B. Adams Tunnel | Los Caños |
| Big Hill | Old Fundamental Church |
| Big Hole Basin | Pee Dee Ditch |
| Cuchilla Buena Vista | The Crooked Esses |
| Dark Hollow Brook | The Hogback |
| Farm River Gut | Upper Sulphur Creek |
| Lac Arnois | West Side Pond |

Exceptions to the rule of capitalization include articles and prepositions within multiple-word names:

| | |
|---|---|
| Alto de la Cruz | Posta de Roque |
| Cañada de Ojo del Agua | Red River of the North |
| Fond du Lac | Rock of Ages |
| Gap in Knob | Scarce of Fat Ridge |
| Lake of the Ozarks | Spread Eagle Chain of Lakes |

As noted earlier, when the generic part of a name is purposely omitted, as in "the Potomac," "the Mojave," and "the Atlantic," the definite article preceding the specific name is not capitalized. Proper names of geographical entities, such as regions, political divisions, populated places, localities, and physical features, including marine, are capitalized in both the singular and the plural:

Allegheny Front
Andromeda Cone
Atlantic Coastal Plain

Bach Seamount
Bighorn Basin
Blue Ridge
Brady Soil

Canal Zone
Central States
Catahoula Parish
Colorado Plateau
Colville Guide Meridian
Continental Divide
Continental Rise
Continental Shelf

Dennison Township
Driftless Area

Eastern Shore

Fall Line
Fall Zone
Far East (Asia)
Front Range

Grand Banks
Great Lakes
Gulf States

Half Dome
High Plains

Isle of Pines

Lower Town Landing

Mariana Trench
Middle Atlantic States
Monarch Geyser
Mount Rainier

Niagara Falls
North Atlantic States
North Slope

Outer Continental Shelf

Pacific Coast States
Pine Ridge Reservation
Potomac and James Rivers

St. Stephens Base Line
San Joaquin Valley
Second Principal Meridian
Skyline Drive

The Chute
Tidal Basin

Upper Peninsula
U.S. Gulf Coast

White Pass Recreation Area
West Coast (of the United States)
Western States

A descriptive term used consistently to denote a definite region, locality, or geographic feature is a proper name and is therefore capitalized (Eastern United States, Continental Divide); also for temporary distinction, a coined name of a region is capitalized; for example, Far Western States. (See U.S. GPO Style Manual, 1984, rule 3.21.)

Qualifying words used in a general sense for parts of named areas are not capitalized. Care should be taken to prevent misunderstanding; for example, "western Virginia" or "the western part of Virginia" is preferable to "west Virginia." However, local residents and news media may consistently use a qualifying word to modify the meaning of an existing geographic name in reference to a part of a State or other area. The modifying word then may become part of the proper name, to be uniformly capitalized with the rest of the name:

East Tennessee
Greater New York (City)
North Atlantic (Ocean)
South Mississippi
South Pacific (Ocean)
Upstate New York

## Names of Regions, Localities, and Geographic Features

To repeat for emphasis, a descriptive term used to denote a definite region, locality, or geographic feature is a proper name and is therefore capitalized; also, for temporary distinction, a coined name of a region is capitalized.

the North Atlantic States; the Gulf States; the Central States; the Pacific Coast States; the Lake States; East North-Central States; Eastern North-Central States; Far Western States; Eastern United States
the West; the Midwest; the Middle West; Far West; the East (United States)
the Eastern Shore (Chesapeake Bay)
the Badlands (South Dakota and North Dakota)
the Continental Divide (Rocky Mountains)
Deep South; Midsouth
Cape Hatteras Recreational Area; *but* Silvertip Mine area
the Occident; the Orient
the Far East; Far Eastern; the East
Middle East, Middle Eastern, Mideast, Mideastern (Asia)
Near East (Balkans)
the Promised Land
the Continent (continental Europe)
the Western Hemisphere
the North Pole; the North and South Poles
the Temperate Zone; the Torrid Zone
the East Side, Lower East Side
*but* lower 48 (States); the Northeast Corridor; Hollidaysburg quadrangle

A descriptive term used to denote mere direction or position is not a proper name and therefore is not capitalized:

north; south; east; west
northerly; northern; northward
eastern; oriental; occidental
east Pennsylvania; southern California
northern Virginia
west Florida; *but* West Florida (1763–1819)
eastern region; western region
north-central region
east coast; eastern seaboard
central Europe; south Germany; southern France

## Physical Divisions of the United States

The terms "province" and "section" are regarded as common nouns by the Government Printing Office and are not capitalized in the GPO Style Manual, but as listed below, they are used consistently to refer to specific physiographic entities and, therefore, are proper names and should be capitalized. (See p. 271.)

| *Major division* | *Province* | *Section* |
|---|---|---|
| Laurentian Upland | Superior Upland | |
| Atlantic Plain | Continental Shelf | |
| | Coastal Plain | Embayed Section |
| | | Sea Island Section |
| | | Floridian Section |
| | | East Gulf Coastal Plain |
| | | Mississippi Alluvial Plain |
| | | West Gulf Coastal Plain |
| Appalachian Highlands | Piedmont Province | Piedmont Upland |
| | | Piedmont Lowland |
| | Blue Ridge Province | Northern; Southern Section |
| | Valley and Ridge Province | Tennessee Section |
| | | Middle Section |
| | | Hudson Valley |
| | St. Lawrence Valley | Champlain Section |
| | | Northern Section |
| | Appalachian Plateaus | Mohawk Section |
| | | Catskill Section |
| | | Southern New York Section |
| | | Allegheny Mountain Section |
| | | Kanawha Section |
| | | Cumberland Plateau |
| | | Cumberland Mountain Section |
| | New England Province | Seaboard Lowland |
| | | New England Upland |
| | | White Mountain Section |
| | | Green Mountain Section |
| | | Taconic Section |
| | Adirondack Province | |
| Interior Plains | Interior Low Plateaus | Highland Rim |
| | | Lexington Plain |
| | | Nashville Basin |
| | Central Lowland | Eastern Lake Section |
| | | Western Lake Section |
| | | Wisconsin Driftless Section |
| | | Till Plains |
| | | Dissected Till Plains |
| | | Osage Plains |
| | Great Plains | Missouri Plateau, glaciated |
| | | Missouri Plateau, unglaciated |
| | | Black Hills |
| | | High Plains |
| | | Plains Border |
| | | Colorado Piedmont |
| | | Raton Section |
| | | Pecos Valley |
| | | Edwards Plateau |
| | | Central Texas Section |
| Interior Highlands | Ozark Plateaus | Springfield-Salem Plateaus |
| | | Boston "Mountains" |
| | Ouachita Province | Arkansas Valley |
| | | Ouachita Mountains |
| Rocky Mountain System | Southern Rocky Mountains | |
| | Wyoming Basin | |
| | Middle Rocky Mountains | |
| | Northern Rocky Mountains | |
| Intermontane Plateaus | Columbia Plateaus | Walla Walla Plateau |
| | | Blue Mountain Section |
| | | Payette Section |
| | | Snake River Plain |
| | | Harney Section |
| | Colorado Plateaus | High Plateaus of Utah |
| | | Uinta Basin |
| | | Canyon Lands |
| | | Navajo Section |
| | | Grand Canyon Section |
| | | Datil Section |
| | Basin and Range Province | Great Basin |
| | | Sonoran Desert |
| | | Salton Trough |
| | | Mexican Highland |
| | | Sacramento Section |
| Pacific Mountain System | Sierra-Cascade Mountains | Northern Cascade Mountains |
| | | Middle Cascade Mountains |
| | | Southern Cascade Mountains |
| | | Sierra Nevada |
| | Pacific Border Province | Puget Trough |
| | | Olympic Mountains |
| | | Oregon Coast Range |
| | | Klamath Mountains |
| | | California Trough |
| | | California Coast Ranges |
| | | Los Angeles Ranges |
| | Lower Californian Province | |

## Geographic-Geologic Names

Formal geologic-time and stratigraphic units are considered to have proper names, and the usual rules of capitalization apply. (For rules governing usage of these units see "Stratigraphic Nomenclature and Description.") Between strictly geographic and strictly geologic terminologies lie many named features that have both geographic and geologic significance. Names of such features, if used consistently to refer to specific entities, may be regarded as proper names and should be capitalized:

| | |
|---|---|
| Book Cliffs Coal Field | Lillie Belle Prospect |
| Killarney Claim | Matchless Mine |

Many geologic, nonstratigraphic terms that have geographic significance are widely viewed as proper names and are capitalized routinely in technical journals, in professional society guidebooks, and in the popular media.

If a geographic name is linked consistently to a specific nonstratigraphic feature, the combined name should be regarded as a proper name and both parts should be capitalized. Not to do so may confuse the intended meaning (Blackadar and others, 1980, p. 35). STA 7 continues to support such usage, following the lead of STA 6. A few examples:

| | |
|---|---|
| Cincinnati Arch | Teapot Dome |
| Sunset Crater | Rangely Anticline |
| Mother Lode | Golden Fault |
| Nacimiento Uplift | Wyoming-Utah Thrust Belt |
| Uinta Basin | Mount Taylor Volcanic Field |

Terms for areas of indefinite extent or context, and ordinary generic terms, are generally not capitalized:

| | |
|---|---|
| ABC mining district | Taconic region |
| Lexington area of Kentucky | Uravan mineral belt |
| Livengood gold placer deposit | |

## Foreign Geographic Names

Foreign names are handled by the Foreign Names Committee of the Board on Geographic Names, which is supported by an executive secretary and staff furnished by the U.S. Department of Defense, Defense Mapping Agency. The basic policy for determining standard names in foreign countries that use the Roman alphabet is to accept as official the written forms of names recognized locally. Names in countries that do not use the Roman alphabet are converted according to standard guides. The Board cooperates with agencies of foreign governments and with the United Nations to standardize foreign names for U.S. Government use.

Some diacritical marks (p. 105) may be essential to the spelling and form of official foreign names. These marks should be used as specified by the Board. The official standard forms of foreign names have been published by the Board in more than 100 gazetteers. Copies are in the U.S. Geological Survey libraries in Reston, Va., Denver, Colo., and Menlo Park, Calif., and also in more than 600 Federal, State, university, and local libraries. Readers are encouraged to report errors in the gazetteers to the Executive Secretary, Foreign Geographic Names (address below). The source of the correction should be identified.

For names of foreign countries, for features such as large bodies of water outside national boundaries, and for a few populated areas and natural features in foreign countries, the Board also has approved optional use of names that are conventional with English-speaking nations: "Jordan River (Mahr al Urdunn)," "Rome (Roma)."

The Board has published both a "Romanization Guide" and a "Conventional Names Gazetteer." Requests for these books, and inquiries concerning foreign gazetteers and foreign place names, including those of undersea and extraterrestrial features and Antarctica, should be addressed to Executive Secretary, Foreign Geographic Names, U.S. Board on Geographic Names, Defense Mapping Agency, Washington, DC 20305.

# CHEMICAL TERMINOLOGY

CHEMICAL TERMINOLOGY AND USAGE are governed by the International Union of Pure and Applied Chemistry (IUPAC). Various commissions within the IUPAC periodically update, revise, or clarify terminology in many areas of specialty. These revisions appear as recommendation articles in "Pure and Applied Chemistry," the official journal of the IUPAC. Recommendations published through 1979 are available in a handbook (International Union of Pure and Applied Chemistry, 1979), which is commonly referred to as the "green book" of the IUPAC. Recent editions of the Chemical Rubber Company's (CRC) "Handbook of Chemistry and Physics" (Weast, 1984) also contain much of this information.

Chemical names, rather than symbols, are generally used in text except for the following:

1. In a list, if the name list exceeds five elements, atomic symbols should be used for the sake of brevity: Analysis shows the presence of Mg, Sb, Rb, Pt, Ag, and Au.
2. In a complex term: $Ca\text{-}Mg\text{-}SO_3\text{-}NO_3$ solution.
3. In proximity: $Ca^+$ and $Mg^+$ ions combine with $CO_3^-$ and $SO_4^-$, respectively.

Symbols should also be used in tables and equations and within text where failure to do so would result in complex or ambiguous terms. A table of atomic names, symbols, and weights (International Union of Pure and Applied Chemistry, 1984) is reproduced in table 2, in the section on "Abbreviations, Signs, and Symbols."

Correct usage of chemical symbols as dictated by the International Union of Pure and Applied Chemistry is illustrated as follows:

$${}^{1}_{2}Ca^{3}_{4}$$

| *Field* | *Contents* |
| --- | --- |
| 1 -------------------- | mass number |
| 2 -------------------- | atomic number (usually omitted) |
| 3 -------------------- | charge |
| 4 -------------------- | number of atoms |

Isotopes are commonly designated by the atomic number (the number of protons in the nucleus) and the mass number (the sum of the protons and neutrons in the nucleus). The custom of writing the mass number as a left superscript, as ${}^{14}C$, is gradually becoming universal. Ratios, however, are generally more readable if the superscript follows the symbol, as $Rb^{85}/Rb^{87}$. Thus, an admixture of the two practices, even in the same paper, seems permissible. If the author chooses to use the form $Rb^{85}/Rb^{87}$, it should be used consistently for all ratios. Where the full name of an element is used in text matter, the mass number is presented with a hyphen, as carbon-14. The atomic number is commonly omitted but, if used, is written as a left subscript: ${}^{14}_{6}C$. Ionic charge is always indicated as a superscript numeral followed by a plus or minus sign.

IUPAC rules call for use of Greek terms for adjectives and prefixes pertaining to valences and other stoichiometric properties. Thus "monovalent," "divalent," "trivalent," "tetravalent," "pentavalent," and "hexavalent" are preferred.

The results of chemical analyses of rocks and minerals are generally reported in terms of weight percent of the oxides present. This practice naturally leads geologists to describe chemical changes in terms of the oxides, as "The introduction of silica and alumina during metasomatism * * *." This usage is generally proper, but inconsistencies may arise because there is no convenient term for total iron oxides. Consider, for example the sentence "Silica, magnesia, and iron were introduced," in which two oxides and one element are mentioned. Such difficulties can be avoided by describing chemical changes in terms of elements or perhaps by using the chemical symbols for the several oxides.

Any table reporting chemical analyses should clearly distinguish between reporting oxides and ions. Most researchers follow the reporting scheme used in Deer and others (1966) in which analyses are reported from highest to lowest oxidation-state cations (as oxides) followed by anions. The rare earth elements should never be referred to as rare earths. A rare earth is an oxide of a rare earth element; hence, the two terms are not interchangeable. Rare earths are generally reported together as a group.

The words "analyze" and "analysis" are often misused for "determine" or "determination." A report of "15 copper analyses" properly refers to 15 samples of copper ore that were analyzed for copper or for other elements; a report on the copper content of 15 rocks should refer to "15 copper determinations."

The spellings "sulfur," "sulfide," and "sulfate" have replaced the older spellings "sulphur," "sulphide," and "sulphate." "Beryllium (Be)" and "niobium (Nb)" have replaced the names "glucinium (Gl)" and "columbium (Cb)," but "columbium" is still correct in some technical references such as to ferrocolumbium alloys (and the mineral columbite, which contains niobium as an essential element, is still called columbite). "Mercury" is the correct term for the chemical element, but "quicksilver" is correct in technical or industrial usage.

The term "lime" (CaO) is commonly misused for calcium (Ca). "Soda," meaning sodium carbonate ($Na_2CO_3$), and "potash," meaning potassium carbonate ($K_2CO_3$), are also commonly misused, both when the elements are meant, as in "potash feldspar," and when the oxide is meant, as in "The analysis shows 4.35 percent potash," meaning potassium oxide ($K_2O$). Be explicit, therefore, and write "potassium oxide" and "potassium carbonate" when referring to these compounds. In technical usage, the term "potash," as in "potash deposits of the United States," is deeply entrenched and should be retained.

# MINERALOGIC TERMINOLOGY AND DESCRIPTIONS

AUTHORS WHO PLAN TO REPORT on the optical, physical, crystallographic, or chemical properties of either existing minerals or proposed new minerals should review the guidelines below.

## MINERAL NAMES

A complete compilation of mineral names, periodically updated and corrected, is given by Fleischer (1983), including errata. Fleischer's glossary provides correct spelling and chemical formulas for more than 2,900 mineral species in a convenient alphabetical format.

Authors should avoid colloquial names (sunstone), outdated names (plumbago instead of graphite), nonspecific mineral terms (sericite, psilomelane, asbestos), and varietal names without reference to the parent mineral species (kunzite without reference to spodumene).

## MINERALOGIC TERMINOLOGY

Correct standard terminology for morphological, physical, and optical properties of minerals may be verified in standard references such as Klein and Hurlbut (1985). Widely accepted abbreviations for physical quantities are given on the inside back cover of each issue of the journal "American Mineralogist." Some of these abbreviations are not included in the STA listing of abbreviations in table 4, page 109; some also differ slightly from those listed.

## REPORTING X-RAY DATA

Acceptable abbreviations for reporting X-ray diffraction data are also given by the "American Mineralogist." The use of nanometers (nm) rather than angstroms (Å) is now preferable (see "The Metric System," p. 122, for USGS policy).

Guidelines for the publication of X-ray powder data are given by Bayliss (1976). The use of single-crystal, powder diffraction, or Guinier film techniques is recommended over Debye-Scherrer or Gandolfi methods in the interest of unique indexing, more reliable intensity data, or better resolution, respectively. Correction of lines to an internal standard is desirable, and refinement of cell parameters by a suitable least-squares algorithm is standard practice. Questions regarding choice of crystallographic axes, standard settings, and other recognized conventions of crystallography are addressed by the "International Tables for X-Ray Crystallography" (International Union of Crystallography, 1952, 1959, 1962, 1974, 1983).

Conditions under which X-ray diffractometer data are collected should be described. For manual systems this description should include the data-collection speed in degrees $2\theta$ per minute, $2\theta$ range, slit configuration, time constant, and generator power settings. For automated systems or manual systems utilizing stepping motors, the slew speed is replaced by values for step size and step time. The use of a theta compensating slit should always be reported if no intensity corrections are made for its presence. Any algorithms used to locate or fit diffraction peaks should also be reported.

## CHEMICAL NOMENCLATURE AS IT RELATES TO MINERALOGY

General aspects of chemical nomenclature are described in the preceding section entitled "Chemical Terminology." Some special consideration is needed, however, when reporting minerals whose substitutional chemistry leads an author to propose a prefix, suffix, or adjectival modifier to indicate the nature of the substitution. Authors should be aware that the use of any prefix or suffix with an existing mineral name is considered to be a new name by the International Mineralogical Association (IMA) and that only adjectival modifiers can be used without creating a new mineral name. The distinctions between these three types of modifiers, and when their use is appropriate, are outlined in Hey and Gottardi (1980). The salient points of these usages are summarized below.

### USE OF MINERAL NAMES

To indicate a family name ("mica")
To indicate a dominant end-member species ("siderite")
To indicate a variety of a mineral species ("kunzite")

### Use of Prefixes

To indicate crystallographic information ("clinoenstatite")
No unique implication ("parachrysotile")
To indicate chemistry ("ferroglaucophane")

Prefixes may be joined with the mineral name or separated by a hyphen. Chemical prefixes should be used only when the element named is dominant in an isomorphous series and the author wishes to introduce a new name. (This usage constitutes a new mineral name and is subject to approval by the IMA.)

### Use of Suffixes

A mineral name also may be suffixed. A suffix, as used here, is a symbol, a chemical or crystallographic one, that follows a mineral name and is attached to it with a hyphen. The suffix gives some particular additional information; for example "monazite-(La)," which means a monazite in which La is dominant among the rare earth elements; another example is "graphite-2H," which names a special polytype of graphite (Hey and Gottardi, 1980).

The use of a suffix also creates a new mineral name and is subject to approval by the IMA. Use of a chemical suffix for rare earth minerals is now standard, and in the format just shown (Levinson, 1966).

### Use of Adjectival Modifiers

Adjectival modifiers are used to denote nondominant chemical substitution in an isomorphous series. Their use does not create a new mineral name and therefore does not require IMA approval. Proper usage combines the adjectival form of an element name (separate word) immediately followed by a mineral name—for example, "ferroan glaucophane."

Under this rule a clear distinction is made between terms like "ferroglaucophane," which indicates $Fe>Mg$ and is a mineral name proper, and "ferroan glaucophane," which indicates $Fe<Mg$ and is merely a mineral name with an adjectival modifier.

Avoid the use of nouns as adjectival modifiers because of possible misunderstanding of intent. For example, the modifier "manganese" in "manganese tremolite" may imply either a manganese-rich tremolite or the manganese equivalent of tremolite. Element names should therefore be converted to the adjectival form when they are used as modifiers.

For minerals that can accommodate many substitutions (for example, the amphiboles and pyroxenes), the use of adjectival modifiers, prefixes, and suffixes can be more confusing than enlightening. Attempts to systematize the nomenclature are given in several short-course volumes of the Mineralogical Society of America (Prewitt, 1980; Veblen, 1981; Bailey, 1984). A similar systematization for phyllosilicates is given by Bailey (1980). If no previous nomenclature exists and prefixes, suffixes, or modifiers would only cause confusion, the author should simply use explicit chemical formulas whenever possible.

## New Mineral Descriptions

Before reporting a new mineral species, the author should thoroughly investigate the possibility of a previously published description. The outline of Donnay and Fleischer (1970) is recommended to authors describing new minerals. All proposed new mineral names must be approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association. Approval is needed before the manuscript is published and should be noted on the first page of the manuscript as a footnote immediately after the new mineral name in the title. When naming new minerals, authors should consider possible similarities to already existing mineral names and should consider possible confusion resulting from non-English pronunciation. In naming new rare-earth minerals, the applicable rules should be followed (Levinson, 1966).

# MINERAL RESERVES, RESOURCES, RESOURCE POTENTIAL, AND CERTAINTY

DEFINITIONS OF MINERAL RESERVES, resources, resource potential, and certainty of assessment have been adopted by the Geological Survey and U.S. Bureau of Mines to foster more uniform terminology and more accurate communication. The exact nomenclature used depends on the commodity being described, but the unified terminology can be applied to all commodities.

The terminology of McKelvey (1972) for both discovered and undiscovered mineral resources, modified by Brobst and Pratt (1973, p. 1–8), has been adopted with minor changes for joint use by the U.S. Bureau of Mines and U.S. Geological Survey (1976a, b, 1980). This terminology applies to the description of the mineral endowment of an area. Resource assessment studies evaluate the likelihood of the occurrence of mineral deposits (resources) in terms of levels of mineral resource potential and the certainty of the assessment (Goudarzi, 1984). The likelihood of occurrence is not a measure of the resources themselves; consequently, the McKelvey classification should not be used in assessment studies except for descriptions of identified resources.

## RESERVES AND RESOURCES

The total mineral endowment of an area is divided into two major parts: identified resources and undiscovered resources. These, in turn, are subdivided on the basis of the adequacy of knowledge about the deposits and current economic factors (fig. 21). The definitions of reserve and resource terms as follows are quoted or paraphrased from Geological Survey Circular 831 (U.S. Bureau of Mines and U.S. Geological Survey, 1980).

**Resource.** A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is regarded as feasible, either currently or at some future time.

**Identified resource.** A resource whose location, grade, quality, and quantity are known or can be estimated from specific geologic evidence. Identified resources include economic, marginally economic, and subeconomic resources.

**Undiscovered resources.** Undiscovered bodies of mineral-bearing material whose existence is surmised from broad (regional) knowledge and theory.

**Reserve.** That portion of an identified resource from which a usable mineral or energy commodity can be economically and legally extracted at the time of determination. The term "ore" applies to reserves of some kinds of mineral commodities, generally metallic, but for want of another term it is sometimes applied to nonmetallic commodities.

Definitions given here for "measured," "indicated," and "inferred" resources may be applied to both identified economic resources (reserves) and identified subeconomic resources.

**Measured.** Materials whose quality and quantity have been determined, within a margin of error of less than 20 percent, by quantitative data, including appropriate analyses, from closely spaced and geologically well-known sample sites.

**Indicated.** Materials whose quality and quantity have been estimated partly from analyses and measurements and partly from reasonable geologic inferences.

**Demonstrated.** A collective term for the sum of materials in both measured and indicated resources.

**Inferred.** Materials in identified but unexplored deposits whose quality and quantity have been estimated from geologic projections.

The terms "hypothetical resource" and "speculative resource" apply to undiscovered resources and are useful when estimating resource endowment.

**Hypothetical resources.** Undiscovered materials that may reasonably be expected to exist in known mining districts under known geologic conditions.

**Speculative resources.** Undiscovered materials that may occur in known types of deposits in geologic settings where no previous discoveries have been made or in as-yet-unknown types of deposits that remain to be recognized.

The terms "proved," "probable," and "possible" are commonly used by industry for economic evaluations of ore in specific deposits or districts. "Proved"

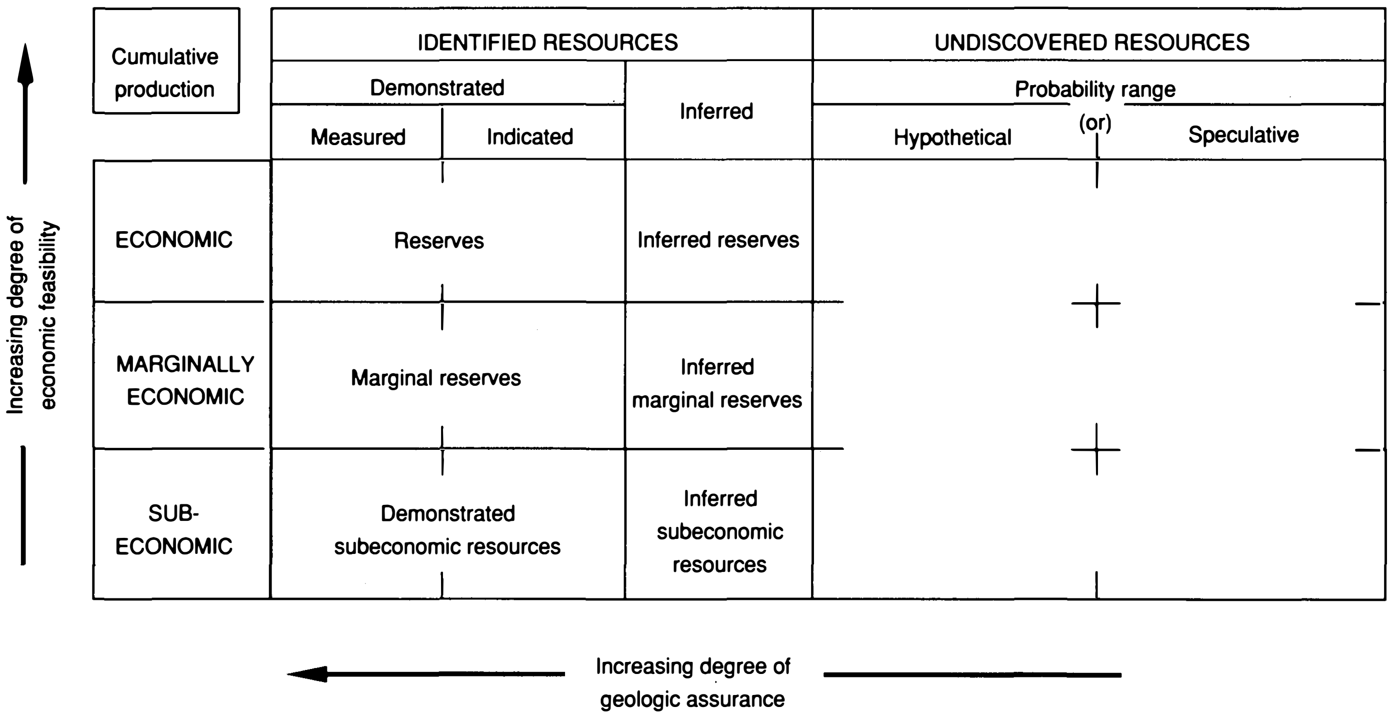



**Figure 21.** Classification of mineral resources (from U.S. Bureau of Mines and U.S. Geological Survey, 1980, p. 5).

corresponds closely to "measured." "Probable" and "possible" usually describe estimates of partly sampled deposits; both fall within the meaning of the term "indicated" as here defined.

The Survey author's estimate of reserves and resources for a district or area should nearly always be presented in such a way as to conceal figures for individual properties. Quotation of published estimates is permissible so long as they are properly ascribed.

## Mineral Resource Potential and Certainty

Mineral-assessment reports use a dual scheme based on two ratings, "resource potential" and "certainty" (fig. 22). The general format for the scheme was suggested by Voelker and others (1979). As shown by figure 22, the level of resource potential expresses the favorability of the area for a given resource; the level of certainty indicates the confidence with which the level of resource potential was assigned (Goudarzi, 1984).

### Levels of Mineral Resource Potential

The definition of mineral resource potential and of the several levels of resource potential follow the suggestions of Taylor and Steven (1983) for use in joint U.S. Geological Survey and U.S. Bureau of Mines assessment reports (Goudarzi, 1984).

**Mineral resource potential** is the likelihood for the occurrence of undiscovered mineral resources in a defined area; it is closely related to mineral-resource favorability. The term "resource potential" is preferred for the description of an area; "resource favorability" is preferred for description of a specific rock mass or geologic environment.

**Low potential** is assigned to areas where geologic, geochemical, and geophysical characteristics define environments in which the existence of resources is unlikely. This broad category embraces areas that have dispersed but insignificantly mineralized rock, as well as areas that have few or no indications of having been mineralized.

**Moderate potential** is assigned to areas (1) where geologic, geochemical, and geophysical characteristics indicate environments favorable for resource occurrence, (2) where interpretations of data indicate a reasonable likelihood of resource accumulation, and (3) where application of knowledge of types of mineral deposits indicates favorable ground for specific types of deposits.

**High potential** is assigned to areas (1) where geologic, geochemical, and geophysical characteristics indicate environments favorable for resource occurrence, (2) where interpretations of data indicate a high degree of likelihood for resource accumulation, (3) where knowledge of types of mineral deposits supports determinations of the presence of resources, and (4) where data indicate that minerals have concentrated in at least a part of the area. Resources or deposits need not be identified for an area to have high resource potential.

**Unknown potential** is assigned to areas where information is inadequate to assign low, moderate, or high levels of potential; this category is generally used for areas that have covering rock units and have inadequate geophysical and geochemical data.

The phrase **"no potential"** should be applied only to a specific kind of resource in a carefully defined area; it should not be used as a summary rating for all commodities in any area.

## Levels of Certainty

The level of certainty applied to a rating of resource potential indicates the degree of confidence with which the rating was assigned. The level of certainty should reflect (1) the adequacy of the geologic, geochemical, and geophysical data available at the time of evaluation, and (2) how well the specific deposit type being evaluated is understood. Generally, the attributes of a mineral-deposit type are determined first, specific requirements for assignment of high, moderate, and low potential are determined next, and the nature and amount of data required for assignment of level of certainty are determined last.

**Level A.** Available information is not adequate to determine the level of mineral resource potential; this level of certainty is assigned when the area is assigned unknown resource potential for a specific commodity.

**Level B.** Available information suggests the level of resource potential; level B is assigned where the general geologic environment is known but key evidence is lacking on such aspects as rock units, structure, activity of resource-forming processes, or expectable types of mineral deposits.

**Level C.** Available information gives a good indication of the level of mineral resource potential; level C is used where geologic environments are clearly defined but where specific evidence is inadequate to evaluate past activity of resource-forming processes (mineralization).

**Level D.** Available information clearly defines the level of mineral resource potential; generally level D is used where geologic environments are clearly defined, activity or lack of activity of resource-forming processes can be ascertained, and data on expectable mineral-deposit types are well understood.

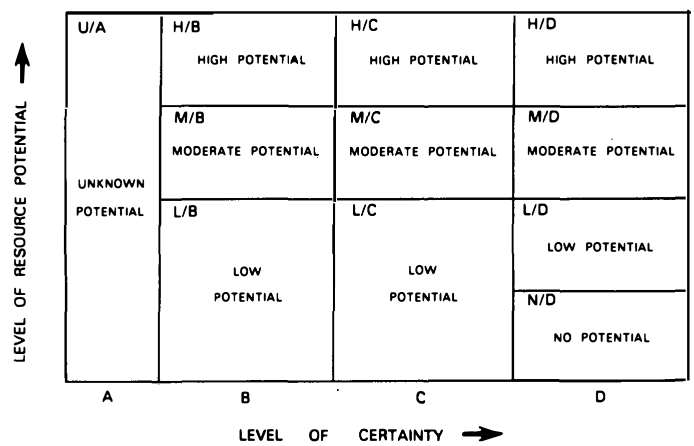



**Figure 22.** Mineral-assessment classification based on level of resource potential versus level of certainty (based on Voelker and others, 1979).

The approach to resource evaluation should be aggressive and basically optimistic—even imaginative and daring. Undiscovered resources will remain undiscovered as long as investigations are limited to an inventory of known deposits or as long as investigators fail to use carefully reasoned geologic predictions to suggest the likelihood of resource occurrences. Conclusions must be based solidly on evidence, the criteria for conclusions must be stated clearly, and an account of the logic used in the analysis must be provided. The assessment should state the date of the assessment: although the rocks change very slowly, our understanding of them may change rapidly.

# PETROLOGIC TERMINOLOGY

PETROGRAPHIC DESCRIPTIONS are essential parts of many geologic reports, but such descriptions are not easy reading, and they demand care to keep them as free as possible from abstruse phraseology. The geologist who includes petrographic descriptions in a geologic report should make them an essential part of the story. Unless a paper is aimed primarily at other petrologists, the author should avoid overly detailed petrographic descriptions. Instead, include only matter that bears directly on the overall purpose of the report. Thus, a report on a mining district is hardly the place to introduce a new rock name or to exhaustively describe all the rocks and thin sections that have been examined. On the other hand, even minute features of host rocks warrant full description if they bear on the origin of the ore deposits or on the search for more ore.

## General Petrologic Terms

General definitions of standard petrologic terminology, including rock textures, fabrics, color, and state of aggregation, are given by Bates and Jackson (1987) and Tomkeieff (1983). Recent additional information on the appearance of certain textures and rock types in thin section may be found in MacKenzie and Guilford (1981), MacKenzie and others (1982), and Adams and others (1984).

## Igneous Rock Names

The Subcommittee on the Systematics of Igneous Rocks of the International Union of Geological Sciences (IUGS) has proposed standards for the use of plutonic and volcanic rock names (Streckeisen, 1967, 1976, 1979). This system is now widely used internationally for the modal and normative classification of igneous rocks. Another useful classification is based solely on chemistry, without regard for modal expression or recalculated norms (De La Roche and others, 1980); authors working with intermediate to mafic igneous rocks or silica-deficient rocks may find this system of classification more useful than that of Streckeisen. STA recommends that authors use one or the other of these systems for naming igneous rocks. In any event, to avoid any misunderstanding, authors should clearly identify whatever system they have used.

## Sedimentary and Metamorphic Rock Names

Nomenclatures of sedimentary and metamorphic rocks have not been standardized. Authors should consult widely used texts in sedimentary and metamorphic petrology for naming these rocks. Also, many review volumes, symposia proceedings, and individual periodical issues devoted to individual rock types provide guidelines on their nomenclature.

## New Names

Petrologists should be chary about proposing new rock names. Henry S. Washington, who himself proposed 31 rock names, spoke many years ago of the host of new names as "impossible to remember and not worth remembering." He once remarked also that he was spending his later years in sackcloth and ashes over his early rock-naming sins, and then related a story about himself. On receiving a paper from England that contained a rock name meaningless to him, he asked Norman L. Bowen if he knew what the Englishman was talking about, and Bowen replied, "You should know, you proposed that name yourself."

## Modifiers

Applying modifiers, such as mineral prefixes, to existing rock names is generally more satisfactory than introducing new names into the literature. In using such modifiers, Survey petrologists should follow a uniform scheme for the use of hyphens, based on the principle that like names are connected by hyphens and unlike names are not. Modifiers used for such terms generally fall into four classes: (1) rock names, (2) mineral names, (3) textural terms, such as porphyritic, gneissic, or vitrophyric, and (4) names expressing kinds of clastic aggregation, such as agglomerate, breccia, or tuff. Names within any one class are hyphenated; others are not:

biotite-pyroxene andesite
albite-epidote-chlorite schist
porphyritic nepheline syenite
trachyte tuff

An unhyphenated compound term should remain unhyphenated when it becomes a unit modifier: "quartz monzonite dike," for example. Expressions such as "granite-syenite contact" or "sandstone-siltstone transition" should be avoided; they seem to refer to single rocks. Instead, say "contact of the granite and the syenite" or "transition from sandstone to siltstone."

Polysyllabic adjectives should be avoided in favor of shorter and simpler terms. Words such as "aphanitic," "melanocratic," and "arenaceous" are not as good as "fine-grained," "dark-colored," and "sandy."

The terms "acid," "basic," and "alkaline" for describing rocks and minerals have been frowned upon since the time of F.W. Clarke. Rocks characterized by quartz are "silicic" rather than "acidic." Rocks are "alkalic," "calcic," "sodic," or "potassic" but not "alkaline." Similarly, the terms "mafic" and "ferromagnesian" are preferred over "basic."

## Petrologic Abbreviations

Authors are urged to follow the mineral symbology of Kretz (1983) when using mineral-phase abbreviations as symbols, subscripts, or superscripts in a manuscript. These symbols (table 3, p. 108) conform to the following guidelines:

1. The mineral symbol should consist of two or three letters, the first capitalized and the other(s) lowercase.
2. The first letter of the symbol should be the same as the first letter of the mineral name; the other letter(s) should be selected from the mineral name, preferably from the consonants.
3. The symbol should not be identical to any symbol of the elements in the periodic table.
4. The symbol should not spell out a common word of any language used in scientific writing.

These guidelines should be followed by authors who intend to compose new symbols for minerals not listed in table 3.

Mineral-phase symbols and mineral-component symbols must be clearly distinguished from one another (Kretz, 1983). Mineral-phase symbols should always begin with uppercase letters; mineral-component symbols should consist solely of lowercase letters; for example, Di = the mineral phase diopside, di = the diopside component in a pyroxene or a melt.

## Rock Analyses and Sample Descriptions

A representative table showing one way to report rock analyses is given by table 10, page 220. To help the reader interpret the analyses, a description of the samples can be provided either by footnotes or by a separate table.

# PALEONTOLOGIC TERMINOLOGY

FOR TAXONOMIC PAPERS, rules of the zoologic and botanic sciences with regard to priorities and other legalities require that fossils be described with scrupulous attention to detail. Clarity and brevity are the goals of descriptive paleontology, as well as of all good scientific writing, but clarity should never be sacrificed for the sake of brevity.

Every species description should contain (1) a brief diagnosis, (2) a full morphologic description, (3) an indication of the types and other specimens used for the description, plus their repositories, (4) accurate information about the locality from which the fossils came, including stratigraphic and geographic detail, (5) comparison with other similar species, and (6) remarks on variability of features. Discussions should include significant results regarding phylogeny, ontogeny, functional morphology, paleoecology, and biostratigraphy.

If a species has been described before, give a synonymy to show the history of usage of names applied to the taxon. If the species is new, give the etymology of the name, plus the type locality.

Species are illustrated, as completely as feasible, with photographs, line drawings, and charts showing morphologic variations.

Descriptive morphologic terms vary from phylum to phylum, and some words have different meanings in different fossil groups. For example, the term "septum" refers to entirely different structures in the foraminifers, corals, brachiopods, cephalopods, ostracodes, and mammals. Proper terminology can be learned from recent pertinent monographs, the "Treatise on Invertebrate Paleontology" (Moore, various dates), and other similar sources.

A sample format for species description:

Generic assignment, describer's name, date
Species name
Plates and figures of illustrations
Synonymy
Diagnosis
Description
Material, including types, with museum numbers and indication of repository
Measurements, with charts and graphs showing variability, where practicable
Occurrence
Discussion and comparison

Generic descriptions are similar to specific ones. Special emphasis is placed on an accurate diagnosis and an unambiguous designation of the type species. Suprageneric assignments should be given where they are not obvious or redundant.

## SYNONYMY

In paleontologic writing, the history of usage of a name is given in a synonymy. Several styles may be used, depending on what the writer wishes to emphasize. Generic synonymies usually first list former usages of the genus in the sense of the writer and then list synonyms, incorrect usages, questionable assignments, and errors. All are in chronologic order. A similar style may be used for species synonymies, although a strictly chronologic listing, with correct and incorrect references in their proper order, is becoming more generally accepted.

In the past, bibliographic references customarily were given for each item in a synonymy, generally because they were not given at the end of the paper. It is now more common for synonymies to be condensed and for full references to be given in the bibliography.

The basic requirement for a synonymy is that it clearly express the history of usage of the name given to a taxon and present the writer's conclusions about the validity of the name. Because this aspect of paleontologic writing often is troublesome to writer and editor alike, examples of several generic synonymy styles are given:

1. The complete form, including reasons for some of the assignments (although it is not essential to give the reasons):

**Genus *PARAPARCHITES*** Ulrich and Bassler, 1906, emend. Scott, 1959

*Paraparchites* Ulrich and Bassler, 1906, Proceedings of the National Museum, v. 30, p. 149. Scott, 1959, Journal of Paleontology, v. 33, no. 4, p. 673.
*Antiparaparchites* Coryell and Rogatz, 1932, American Midland Naturalist, v. 13, no. 6, p. 387. Based on reversal of overlap.
*Ardmorea* Bradfield, 1935, Bulletins of American Paleontology, v. 22, no. 73, p. 138. Based on steinkern.
*Microcoelonella* Coryell and Sohn, 1938, Journal of Paleontology, v. 12, no. 6, p. 597. Based on juvenile.
?*Cyathus* Roth and Skinner, 1930, Cooper, 1941, Illinois State Geological Survey Report of Investigations 77, p. 61.

2. Condensed format; full reference to each paper given in the bibliography:

**Genus *DERBYIA* Waagen, 1884**

*Derbyia* Waagen, 1884, p. 576, 591; Hall and Clarke, 1892, p. 261; Schellwien, 1900, p. 10; Girty, 1909, p. 181; Dunbar and Condra, 1932, p. 75; Sokolskaya, 1960, p. 209.
*Derbyina* Grabau, 1931a, p. 259, 262 (*Graubauellina* Licharew, 1934).
*Grabauellina* Licharew, 1934a, p. 507.
*Derbyaeconcha* Licharew, 1934a, p. 507.
*Plicatoderbya* H. D. Thomas, 1937, p. 13-18.

3. A strictly chronologic format:

**Genus *SYRINGAXON* Lindström, 1882**

1882. *Syringaxon* Lindström, p. 20.
1900. *Laccophyllum* Simpson, p. 201.
1902. *Nichelsonia* Pocta, p. 184. Cited in plate explanations *Alleynia* (*Nichelsonia*).
1928. *Laccophyllum* Simpson. Grabau, p. 82.
1928. *Alleynia* Pocta (*Nichelsonian* Pocta). Grabau, p. 82.
1935. *Syringaxon* Lindström. Butler, p. 117.
1938. *Syringaxon* Lindström (in part). Prantl, p. 21.
1940. *Syringaxon* Lindström. Lang, Smith, and Thomas, p. 129.
1949. *Syringaxon* Lindström. Stumm, p. 10.
1956. *Syringaxon* Lindström. Hill, p. F258.
1962. *Syringaxon* Lindström (in part), Flugel and Free, p. 224.

Similarly, species synonymies can use several styles. Two of these follow, the first according to usage of names and the second according to chronology of references:

***Pentagonia unisulcata* (Conrad)**

*Atrypa unisulcata* Conrad, 1841, p. 56.
*Atrypa uniangulata* Hall, 1861, p. 101.
*Meristella? unisulcata* (Conrad). Hall, 1862, p. 158, pl. 2, figs. 17, 20-23 (not figs. 19, 24, 25).
*Meristella* (*Pentagonia*) *unisulcata* (Conrad), Hall, 1867, p. 309, pl. 50, figs. 18-29 (not figs. 30-35).
Not *Meristella unisulcata* (Conrad). Nettleroth, 1889, p. 99, pl. 15, figs. 9-16.
*Pentagonia unisulcata* (Conrad). Stauffer, 1915, p. 104, 245 (not p. 160, 171, 175, 234); Dunbar, 1919, p. 87, 89; Goldring, 1935, p. 148, figs. 53*B-D*; Butts, 1940, p. 300, 301, 304, 305; Butts, 1941, pl. 115, figs. 17-21, 35; Cooper and others, 1942, chart; Cooper, 1944, p. 333, pl. 127, fig. 27; Oliver, 1954, p. 633, 634, 638-640; Oliver, 1956, p. 1452, 1456, 1462, 1469; Rickard, 1964, chart; Boucot and others, in Moore, 1965, p. M656, pl. 633, figs. 2*a-d* (not figs. 2*e-f*); Oliver and others, 1969, chart.
Not *Pentagonia unisulcata* (Conrad). Savage, 1930, p. 47, 50, 53, 62; Savage, 1931, p. 242, pl. 30, figs. 17, 18.

***Goniatites crenistria* Phillips**

1836. *Goniatites crenistria* Phillips, Illustrations of the geology of Yorkshire, pt. 2, p. 234, pl. 19, figs. 7-9.
1836. *Goniatites vesica* Phillips, Illustrations of the geology of Yorkshire, pt. 2, p. 236, pl. 20, figs. 19-21.
1897. *Glyphioceras incisum* Hyatt (part). Smith, Proceedings of the California Academy of Science, 3d. ser., Geology, v. 1, no. 3, p. 111-121, pl. 13, figs. 1, 2, 6-12, pl. 14, figs. 1-9, pl. 15, figs 1-11 (not pl. 13, figs. 3-5).
1903. *Goniatites crenistria* Phillips (part). Smith, U.S. Geological Survey Monograph 42, p. 68-76, pl. 14, figs. 1, 2, 7-12, pl. 15, figs. 1-9, pl. 16, figs. 1*a-j*, pl. 26, figs. 1-4 (not pl. 10, figs. 12-16, pl. 14, figs. 4-6, pl. 26, fig. 5).
1910. *Goniatites crenistria* Phillips. Grabau and Shimer, North American index fossils, v. 2, p. 141, figs. 1393*f-h*.
1911. *Goniatites choctawensis* Shumard (part). Girty, U.S. Geological Survey Bulletin 439, p. 97-99, pl. 15, figs. 7, 7*a* (not figs. 1-6).
1911. *Goniatites crenistria* Phillips. Girty, U.S. Geological Survey Bulletin 439, p. 99-101, pl. 15, figs. 8, 9.
1924. *Goniatites crenistria* Phillips. Bisat, Proceedings of the Yorkshire Geological Society, v. 20, pt. 1, p. 78-82, pl. 3, figs. 4, 5, pl. 9, fig. 1.
1925. *Glyphioceras crenistria* (Phillips) (part). Schmidt, Preussischen Geologischen Landesanstalt Jahrbuch, v. 45, p. 565, 566, p. 21, figs. 1, 3, pl. 23, fig. 14 (not pl. 2, fig. 2, pl. 23, fig. 13).
1952. *Goniatites crenistria* Phillips. Bisat, Transactions of the Leeds Geological Association, v. 6, pt. 4, p. 173, 174, text fig. 3(*b*).

## A Few Guidelines

Formal generic and specific fossil names are in Latin and are italicized. Informal names and adjectives based on fossil names are not italicized: Pectens, spirifers, bryozoans, productids, Ostreas, foraminifers, and others. All generic and suprageneric names are capitalized. (See also p. 141 for further information on the use of italic in regard to fossil names).

The two parts of species names agree in gender according to rules of classical grammar. Gender does not necessarily indicate the sex of the object in question. Most Latin nouns ending in *-us* are masculine, in *-a* are feminine, and in *-um* are neuter, but there are exceptions. Consult classical grammars when in doubt. Brown's "Composition of Scientific Words" (1954) is indispensible for anyone composing scientific names for use in systematics.

The name of the first describer of a taxon should be included in all references to that taxon, although the name can be omitted from tables and elsewhere, at the discretion of the paleontologist, if earlier reference to the describer is clear.

When a species is assigned to a genus other than the original one, the name of the first describer is placed in parentheses and the reviser's name is added. For example, the proper citation for the olenellid trilobite that was first described as *Olenus thompsoni* by Hall in 1859, but that later was used as the type species of *Olenellus* by Billings, is *Olenellus thompsoni* (Hall) Billings.

Taxonomic rules differ for animals and plants. Anyone writing about fossils should study the two standard nomenclatural guides carefully (Stafleu, 1983; Ride and others, 1985).

Various degrees of certainty in identification of taxa are expressed by modification in citations of fossil names. For example:

| Taxon | Degree of certainty |
|---|---|
| *Spirifer grimesi* Hall | Taxon definitely identified. |
| *Spirifer* cf. *S. grimesi* Hall | Taxon compared with named species. |
| *Spirifer* aff. *S. grimesi* Hall | Taxon has affinities with named species. |
| *Spirifer*? *grimesi* Hall | Species questionably assigned to genus. |
| *Spirifer grimesi* Hall? | Species doubtful, but assigned to correct genus. |
| ?*Spirifer grimesi* Hall | Entire assignment doubtful. |

A species name consists of two parts; the first is the generic part and the second is the trivial part. Despite a clear statement by Schenk and McMasters (1956, p. 13), among others, confusion concerning this basic fact continues.

The name of the original describer of a taxon should not be abbreviated. However, the rules of botanical nomenclature provide for use of standard abbreviations of the names of certain classical botanists.

The English forms of "n. gen.," "n. sp.," "not," "part," "of authors," "undet.," "indet.," and so on, are to be used rather than the Latin forms.

An unpublished name, or "nude" name, is invalid and should not be used in a manuscript unless the description of that species will be published before the manuscript is published.

Generic names may be abbreviated where they are a part of a species name if the full name has been used earlier in the paper and there is no confusion with other generic names having the same initial letter.

Authors who cite systematic identifications and opinions of others should quote accurately and should include original qualifying statements and clear reference to source and date of communication, whether published or unpublished.

In describing species authors must state the nature of the material on which the description is based. Include (1) number and condition of specimens, (2) sex and growth stage where known, (3) measurements of all important morphologic features and indication of variability, and (4) an unambiguous indication of the types, their catalog numbers, and their repository.

Descriptions of taxa may be in complete sentence form or they may be in telegraphic style. As with synonymies, however, a consistent format is used throughout any particular paper.

Authors who are not paleontologists, but who are describing fossils or are quoting or paraphrasing paleontologists on referred fossils, should submit relevant parts of their reports to the Branch of Paleontology and Stratigraphy for inspection early in the review process.

Formats for different journals vary; the suggestions for authors of papers submitted to any specific journal should be followed closely when designing a contribution to that journal. This procedure ultimately avoids grief for writer, critic, and editor alike.

## Numbering Systems for Samples and Specimens

Different institutions use various numbering systems to identify repositories for their fossils, minerals, ores, and rocks. A serial number with the description of a new fossil species can tell the reader where the type specimen is preserved, whether in the paleontologic collections of the U.S. National Museum, the American Museum of Natural History, the Harvard Museum of Comparative Anatomy, or another permanent repository. Similar numbering systems applied by groups within the Survey, and by other groups, are indispensable to future researchers and should be used in published reports wherever applicable. Informal and temporary systems applied in the field on a particular project, or in the laboratory, seldom have a place in a final report. In general, any material of permanent value that will need to be physically retrieved by some future worker should be identified with a meaningful permanent collection number.

By law, all type specimens and significant collections made on projects supported by Federal money must be deposited in the National Collections of the U.S. National Museum, Smithsonian Institution; a logical time to transfer specimens is soon after completion of the project for which the specimens were collected.

Significant specimens such as type fossils or minerals are far more valuable if the exact spots from which they were collected are also recorded permanently. Some scientists understandably hesitate to pinpoint these locations for fear that the remaining material will be removed by others or vandalized. Each researcher must balance the potential damage of disclosing the collecting locality against possible benefits to science. On geologic maps the collecting locality can be shown by symbol. Whether or not a map accompanies a report, the locality should be referred to permanent topographic features, to a land-survey (section, township, and range) system, to latitude and longitude, or to the Universal Transverse Mercator projection grid. Road intersections and the like may prove to be ephemeral.

# ABBREVIATIONS, SIGNS, AND SYMBOLS

ABBREVIATIONS SAVE SPACE and prevent the distraction of needlessly repeated words or phrases. The space saved is usually so small, however, that the use of abbreviations is determined largely by custom, convenience to the reader, and the appearance of the printed page.

In general, few abbreviations should be used in the text of a Survey report, although many may be used in tables and footnotes. The text should be understandable by nonspecialists, and abbreviations should be used without definition only if they are widely understood (for example, such common bibliographic abbreviations as "fig.," "pl.," "p.," and "no.," and other nonbibliographic abbreviations such as "a.m.," "p.m.," "A.D.," and "B.C.").

Uncommon abbreviations must be defined the first time they are used in the main text. The standard Survey format is to enclose the abbreviated form in parentheses immediately following the spelled out form—for example, U.S. Geological Survey (USGS). Follow the same procedure in the abstract if a term is used several times there, and because the abstract must be able to stand alone, repeat the procedure in the main text the first time the abbreviation is used there.

Common sense can help decide when abbreviations are appropriate. Terms used only a few times should not be abbreviated, and abbreviations that might inconvenience the reader should not be used. In general, abbreviations are suitable for often-repeated names of organizations, conferences, congresses, and programs—for example, IGCP, for International Geological Correlation Programme; AGI, for American Geological Institute; also, for widely used instruments or processes—for example, SEM for scanning-electron microscope. Abbreviations are inappropriate for geographic names or geologic terms in Survey reports, no matter how many times such names or terms are used in a paper. Do not, for example, use AB for Appalachian Basin, SAF for San Andreas Fault, or MVTD for Mississippi Valley-type deposits.

Abbreviations are used freely in tables, partly because of tight space limitations. Abbreviations used in tables are defined in bracketed headnotes.

In general, abbreviations for scientific terms and for terms of measurement are not followed by periods; however, a period should be used with the abbreviation for "inch(es)" if the abbreviation might be confused with the preposition "in." A better procedure is to just spell out the word "inch(es)."

## NAMES OF COUNTRIES AND OTHER POLITICAL SUBDIVISIONS

"U.S." is used when "United States" precedes the word "Government" or the name of a Government organization: U.S. Government, U.S. Congress, U.S. Department of the Interior, U.S. Geological Survey. No spaces are left between the letters and periods of "U.S.," but a space precedes the name that follows. In titles, "United States" should be written out whether it is a noun or an adjective. In the text, "United States" should be written out when used as a noun and abbreviated when used as an adjective—for example, "mineral deposits of the United States," *but* "U.S. mineral deposits."

Names of foreign countries, except that of the U.S.S.R. (or SSSR), are not abbreviated, nor are the names of their political subdivisions. "United States" is written out when used in association with the names of other countries, except the U.S.S.R.; thus, British, French, and United States Governments; United States-British talks; *but* U.S.-U.S.S.R. meeting.

## STATES AND POSSESSIONS OF THE UNITED STATES

Names of States of the United States (except Alaska, Hawaii, Idaho, Iowa, Maine, Ohio, and Utah), also the District of Columbia, Puerto Rico, and the Virgin Islands, are abbreviated when they immediately follow a capitalized geographic term; they are spelled out after a lowercased word: Chicago, Ill.; Montgomery County, Md.; Stone Mountain, Ga.; Arlington National Cemetery, Va.; Redstone Arsenal, Ala.; *but* St. Lawrence County magnetite district, New York; Tacoma area, Washington. The names of other insular possessions, trust territories, and such places as Long Island and Staten Island are not abbreviated. Customary abbreviations are used for States in reports; Postal Service abbreviations are used only in "ZIP code" mailing addresses.

| *States and possessions* | *Customary abbre- viations* | *Postal Service abbre- viations* | *States and possessions* | *Customary abbre- viations* | *Postal Service abbre- viations* | *States and possessions* | *Customary abbre- viations* | *Postal Service abbre- viations* |
|---|---|---|---|---|---|---|---|---|
| Alabama | Ala. | AL | Maryland | Md. | MD | Rhode Island | R.I. | RI |
| Alaska | Alaska | AK | Massachusetts | Mass. | MA | South Carolina | S.C. | SC |
| Arizona | Ariz. | AZ | Michigan | Mich. | MI | South Dakota | S. Dak. | SD |
| Arkansas | Ark. | AR | Minnesota | Minn. | MN | Tennessee | Tenn. | TN |
| California | Calif. | CA | Mississippi | Miss. | MS | Texas | Tex. | TX |
| Colorado | Colo. | CO | Missouri | Mo. | MO | Utah | Utah | UT |
| Connecticut | Conn. | CT | Montana | Mont. | MT | Vermont | Vt. | VT |
| Delaware | Del. | DE | Nebraska | Nebr. | NE | Virginia | Va. | VA |
| Florida | Fla. | FL | Nevada | Nev. | NV | Washington | Wash. | WA |
| Georgia | Ga. | GA | New Hampshire | N.H. | NH | West Virginia | W. Va. | WV |
| Hawaii | Hawaii | HI | New Jersey | N.J. | NJ | Wisconsin | Wis. | WI |
| Idaho | Idaho | ID | New Mexico | N. Mex. | NM | Wyoming | Wyo. | WY |
| Illinois | Ill. | IL | New York | N.Y. | NY | | | |
| Indiana | Ind. | IN | North Carolina | N.C. | NC | | | |
| Iowa | Iowa | IA | North Dakota | N. Dak. | ND | | | |
| Kansas | Kans. | KS | Ohio | Ohio | OH | District of Columbia | D.C. | DC |
| Kentucky | Ky. | KY | Oklahoma | Okla. | OK | Guam | Guam | GU |
| Louisiana | La. | LA | Oregon | Oreg. | OR | Puerto Rico | P.R. | PR |
| Maine | Maine | ME | Pennsylvania | Pa. | PA | Virgin Islands | V.I. | VI |

## ACCENTS AND DIACRITICAL MARKS

In Survey publications accents and diacritical marks are used chiefly in the spelling of foreign words. Take care to use them correctly:

´ acute (Orléans)
˚ bolle (Ålesund)
¸ cedilla (français)
ˆ circumflex (côte)
¨ dieresis or umlaut (Nürnberg)
` grave (Asmères)
ˇ hacek (Přibyl)
˛ inverted cedilla (Dąbrowa)
¯ macron (Kyūshu)
/ slash (Rømros)
' soft sign (Arkhangel'sk)
˙ superior dot (sharżysko Kamienna)
˜ tilde (cañon)

## ADDRESSES

The words "street," "avenue," "building," and similar address terms following a name or number are abbreviated in footnotes, tables, leaderwork, and lists, but as parts of names, they are spelled out, even in parentheses, footnotes, tables, and leaderwork: "2912 14th St.," *but* "14th Street Bridge." The words "county," "fort," "mount," "point," and "port" are not abbreviated. "Saint (St.)" and "Sainte (Ste.)" should be abbreviated.

## CHEMICAL ELEMENTS, NAMES, AND SYMBOLS

Chemical names, rather than symbols, should generally be used in text, as discussed in "Chemical Terminology." Names and symbols are given in table 2.

## DATES

Names of months followed by the day, or by the day and year, are usually abbreviated in tables, locality lists, and in parentheses. May, June, and July are always spelled out. Preferred forms for other months are as follows:

| | | |
|---|---|---|
| Jan. | Apr. | Oct. |
| Feb. | Aug. | Nov. |
| Mar. | Sept. | Dec. |

In narrow columns of tables, the names of months may be abbreviated even if they stand alone. Otherwise, the form used in Survey reports is "January 1, 1985."

## GEOCHRONOLOGIC DATING

Article 13 of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), quoted in part below, should be followed for the preferred abbreviations used in geochronologic dating.

> The "present" refers to 1950 AD [sic], and such qualifiers as "ago" or "before the present" are omitted after the value because measurement of the duration from the present to the past is implicit in the designation. In contrast, the duration of a remote interval of geologic time, as a number of years, should not be expressed by the same symbols. Abbreviations for numbers of years, without reference to the present, are informal (e.g., y or yr for years; my, m.y., or m.yr. for millions of years; and so forth, as preference dictates). For example, boundaries of the Late Cretaceous Epoch currently are calibrated at 63 Ma and 96 Ma, but the interval of time represented by this epoch is 33 m.y.

## Table 2. Chemical symbols

[The names and symbols listed below are approved by the International Union of Pure and Applied Chemistry. From the U.S. GPO Style Manual, 1984, p. 157]

| Element | Symbol | Atomic number [1] | Atomic weight | Element | Symbol | Atomic number [1] | Atomic weight |
|---|---|---|---|---|---|---|---|
| Actinium | Ac | 89 | 227.0278 | Molybdenum | Mo | 42 | 95.94 |
| Aluminium | Al | 13 | 26.98154 | Neodymium | Nd | 60 | 144.24 |
| Americium | Am | 95 | (243) | Neon | Ne | 10 | 20.179 |
| Antimony (Stibium). | Sb | 51 | 121.75 | Neptunium | Np | 93 | 237.0482 |
| Argon | Ar | 18 | 39.948 | Nickel | Ni | 28 | 58.69 |
| Arsenic | As | 33 | 74.9216 | Niobium | Nb | 41 | 92.9064 |
| Astatine | At | 85 | (210) | Nitrogen | N | 7 | 14.0067 |
| Barium | Ba | 56 | 137.33 | Nobelium | No | 102 | (259) |
| Berkelium | Bk | 97 | (247) | Osmium | Os | 76 | 190.2 |
| Beryllium | Be | 4 | 9.01218 | Oxygen | O | 8 | 15.9994 |
| Bismuth | Bi | 83 | 208.9804 | Palladium | Pd | 46 | 106.42 |
| Boron | B | 5 | 10.81 | Phosphorus | P | 15 | 30.97376 |
| Bromine | Br | 35 | 79.904 | Platinum | Pt | 78 | 195.08 |
| Cadmium | Cd | 48 | 112.41 | Plutonium | Pu | 94 | (244) |
| Caesium | Cs | 55 | 132.9054 | Polonium | Po | 84 | (209) |
| Calcium | Ca | 20 | 40.08 | Potassium (Kalium). | K | 19 | 39.0983 |
| Californium | Cf | 98 | (251) | Praseodymium | Pr | 59 | 140.9077 |
| Carbon | C | 6 | 12.011 | Promethium | Pm | 61 | (145) |
| Cerium | Ce | 58 | 140.12 | Protactinium | Pa | 91 | 231.0359 |
| Chlorine | Cl | 17 | 35.453 | Radium | Ra | 88 | 226.0254 |
| Chromium | Cr | 24 | 51.996 | Radon | Rn | 86 | (222) |
| Cobalt | Co | 27 | 58.9332 | Rhenium | Re | 75 | 186.207 |
| Copper | Cu | 29 | 63.546 | Rhodium | Rh | 45 | 102.9055 |
| Curium | Cm | 96 | (247) | Rubidium | Rb | 37 | 85.4678 |
| Dysprosium | Dy | 66 | 162.50 | Ruthenium | Ru | 44 | 101.07 |
| Einsteinium | Es | 99 | (252) | Samarium | Sm | 62 | 150.36 |
| Erbium | Er | 68 | 167.26 | Scendium | Sc | 21 | 44.9559 |
| Europium | Eu | 63 | 151.96 | Selenium | Se | 34 | 78.96 |
| Fermium | Fm | 100 | (257) | Silicon | Si | 14 | 28.0855 |
| Fluorine | F | 9 | 18.998403 | Silver | Ag | 47 | 107.8682 |
| Francium | Fr | 87 | (223) | Sodium (Natrium). | Na | 11 | 22.98977 |
| Gadolinium | Gd | 64 | 157.25 | Strontium | Sr | 38 | 87.62 |
| Gallium | Ga | 31 | 69.72 | Sulfur | S | 16 | 32.06 |
| Germanium | Ge | 32 | 72.59 | Tantalum | Ta | 73 | 180.9479 |
| Gold | Au | 79 | 196.9665 | Technetium | Tc | 43 | (98) |
| Hafnium | Hf | 72 | 178.49 | Tellurium | Te | 52 | 127.60 |
| Helium | He | 2 | 4.00260 | Terbium | Tb | 65 | 158.9254 |
| Holmium | Ho | 67 | 164.9304 | Thallium | Tl | 81 | 204.383 |
| Hydrogen | H | 1 | 1.00794 | Thorium | Th | 90 | 232.0381 |
| Indium | In | 49 | 114.82 | Thulium | Tm | 69 | 168.9342 |
| Iodine | I | 53 | 126.9045 | Tin | Sn | 50 | 118.69 |
| Iridium | Ir | 77 | 192.22 | Titanium | Ti | 22 | 47.88 |
| Iron | Fe | 26 | 55.847 | Tungsten (Wolfram). | W | 74 | 183.85 |
| Krypton | Kr | 36 | 83.80 | (Unnilhexium) | (Unh) | 106 | (263) |
| Lanthanum | La | 57 | 138.9055 | (Unnilpentium) | (Unp) | 105 | (262) |
| Lawrencium | Lr | 103 | (260) | (Unnilquadium) | (Unq) | 104 | (261) |
| Lead | Pb | 82 | 207.2 | Uranium | U | 92 | 238.0289 |
| Lithium | Li | 3 | 6.941 | Vanadium | V | 23 | 50.9415 |
| Lutetium | Lu | 71 | 174.967 | Xenon | Xe | 54 | 131.29 |
| Magnesium | Mg | 12 | 24.305 | Ytterbium | Yb | 70 | 173.04 |
| Manganese | Mn | 25 | 54.9380 | Yttrium | Y | 39 | 88.9059 |
| Mendelveium | Md | 101 | (258) | Zinc | Zn | 30 | 65.38 |
| Mercury | Hg | 80 | 200.59 | Zirconium | Zr | 40 | 91.22 |

[1] The atomic weights of many elements are not invariant but depend on the origin and treatment of the material. The values of atomic weight given here apply to elements as they exist naturally on Earth and to certain artificial elements. Values in parentheses are used for radioactive elements whose atomic weights cannot be quoted precisely without knowledge of the origin of the elements. The value given is the atomic mass number of the isotope of that element of longest known half life.

For dating use the following:

ka for kilo-annum ($10^3$ years)
Ma for mega-annum ($10^6$ years)
Ga for giga-annum ($10^9$ years)

Note that ka and kilo are not capitalized (by international convention).

## Land

In describing land divisions subdivided by section, township, and range, use the following forms (omit periods after abbreviated compass directions that immediately precede and close up on figures):

SE¼NW¼ sec. 4, T. 12 S., R. 15 E., of the Boise Meridian
lot 6, NE¼ sec. 4, T. 6 N., R. 1 W.
N½ sec. 20, T. 7 N., R. 2 W., Sixth Principal Meridian
Tps. 9, 10, 11, and 12 S., Rs. 12 and 13 W.
T. 2 S., Rs. 8, 9, and 10 E., sec. 26
T. 3 S., R. 1 E., sec. 34, W½E½, W½, and W½SE¼SE¼ sec. 32 (with or without a township number)

If fractions are spelled out in land descriptions, "half" and "quarter" are used (not "one-half" or "one-quarter"): "south half of T. 47 N., R. 64 E." Avoid breaking a group such as NE¼SE¼ sec. 4 at the end of a line. If a break is unavoidable, make it after the fraction and use no hyphen.

## Latitude and Longitude

The words "latitude" and "longitude" followed by figures are abbreviated (no periods after "lat" and "long"), and the figures are closed up: lat 52°33′05″N., long 13°21′10″E. Avoid breaking latitude and longitude figures at the end of a line. If a break is unavoidable, use a hyphen.

## Measurements

Terms denoting units of measurement should be abbreviated only when preceded by an amount indicated in numerals. Thus, write "3 m high," "6 cm thick," *but* "several meters long," "a few kilometers north."

Over a stratigraphic figure column, use "Meters," "(m)," "Feet," "(feet)," "Ft In," or "(ft in)," depending on the content of the column, whether the term stands by itself or follows another term such as "Thickness," and depending on the amount of space available.

## Minerals

Mineral names are not ordinarily abbreviated in narrative text, but abbreviations may be appropriate on certain maps, in tables, or as symbols, subscripts, or superscripts. Symbols for common minerals are given in table 3.

## Names and Titles

In the names of business firms, the abbreviated forms "Bros.," "Co.," "Corp.," "Inc.," "Ltd.," and "&" should be used if the full legal title need not be preserved. "Company" and "Corporation" are not abbreviated in names of Federal Government units. "Association" and "Manufacturing" are not abbreviated.

Names of railroads should not be abbreviated except in parentheses, footnotes, tables, and leaderwork. Use the correct form "Railroad" or "Railway" ("RR." and "Ry."), depending on the usage of the individual company.

In other than formal usage, a civil, military, or naval title preceding a name is abbreviated if followed by a given name or initials: "Col. H.M. Smith furnished data on the wells"; *but* "Colonel Smith furnished * * *." The titles "Senator" and "Representative" are not abbreviated.

## Number

The abbreviation "no." (lowercase "n") is used for serial numbers and in citing "v." and "no." of a publication: "Journal of Paleontology, v. 10, no. 3." In identifying specimens, wells, drill holes, and the like, however, "number" or "No." is generally superfluous and can be omitted: "specimen 4297," "Government well 6W," "Drill hole 5" *but* "Of all the specimens examined, No. 4297 most clearly illustrated * * *." Do not use the symbol #. Uppercase "N" is used in formal names and in numbered coal beds.

## Percent

The word "percent" should be spelled out in text. In tables, the abbreviation "pct" or the symbol "%" may be used if other terms of measurement are also abbreviated. The symbol "%", however, is not as easily read in small type. "Percent" should be used with numerals: "20 percent." It is preferred to "percentage" for table headings. "Percentage"

**Table 3.** Mineral symbols

[Kretz, 1983; courtesy of the Mineralogical Society of America]

| | |
|---|---|
| Acm | acmite |
| Act | actinolite |
| Agt | aegirine-augite |
| Ak | åkermanite |
| Ab | albite |
| Aln | allanite |
| Alm | almandine |
| Anl | analcime |
| Ant | anatase |
| And | andalusite |
| Adr | andradite |
| Anh | anhydrite |
| Ank | ankerite |
| Ann | annite |
| An | anorthite |
| Atg | antigorite |
| Ath | anthophyllite |
| Ap | apatite |
| Apo | apophyllite |
| Arg | aragonite |
| Arf | arfvedsonite |
| Apy | arsenopyrite |
| Aug | augite |
| Ax | axinite |
| Brt | barite |
| Brl | beryl |
| Bt | biotite |
| Bhm | boehmite |
| Bn | bornite |
| Brk | brookite |
| Brc | brucite |
| Bst | bustamite |
| Cam | Ca clinoamphibole |
| Cpx | Ca clinopyroxene |
| Cal | calcite |
| Ccn | cancrinite |
| Crn | carnegieite |
| Cst | cassiterite |
| Cls | celestite |
| Cbz | chabazite |
| Cc | chalcocite |
| Ccp | chalcopyrite |
| Chl | chlorite |
| Cld | chloritoid |
| Chn | chondrodite |
| Chr | chromite |
| Ccl | chrysocolla |
| Ctl | chrysotile |
| Cen | clinoenstatite |
| Cfs | clinoferrosilite |
| Chu | clinohumite |
| Czo | clinozoisite |
| Crd | cordierite |
| Crn | corundum |
| Cv | covellite |
| Crs | cristobalite |
| Cum | cummingtonite |
| Dsp | diaspore |
| Dg | digenite |
| Di | diopside |
| Dol | dolomite |
| Drv | dravite |
| Eck | eckermannite |
| Ed | edenite |
| Elb | elbaite |
| En | enstatite (ortho) |
| Ep | epidote |
| Fst | fassaite |
| Fa | fayalite |
| Fac | ferroactinolite |
| Fed | ferroedenite |
| Fs | ferrosilite (ortho) |
| Fts | ferrotschermakite |
| Fl | fluorite |
| Fo | forsterite |
| Gn | galena |
| Grt | garnet |
| Ged | gedrite |
| Gh | gehlenite |
| Gbs | gibbsite |
| Glt | glauconite |
| Gln | glaucophane |
| Gt | goethite |
| Gr | graphite |
| Grs | grossular |
| Gru | grunerite |
| Gp | gypsum |
| Hl | halite |
| Hs | hastingsite |
| Hyn | haüyne |
| Hd | hedenbergite |
| Hem | hematite |
| Hc | hercynite |
| Hul | heulandite |
| Hbl | hornblende |
| Hu | humite |
| Ill | illite |
| Ilm | ilmenite |
| Jd | jadeite |
| Jh | johannsenite |
| Krs | kaersutite |
| Kls | kalsilite |
| Kln | kaolinite |
| Ktp | kataphorite |
| Kfs | K feldspar |
| Krn | kornerupine |
| Ky | kyanite |
| Lmt | laumontite |
| Lws | lawsonite |
| Lpd | lepidolite |
| Lct | leucite |
| Lm | limonite |
| Lz | lizardite |
| Lo | loellingite |
| Mgh | maghemite |
| Mkt | magnesiokatophorite |
| Mrb | magnesioriebeckite |
| Mgs | magnesite |
| Mag | magnetite |
| Mrg | margarite |
| Mel | melilite |
| Mc | microcline |
| Mo | molydbenite |
| Mnz | monazite |
| Mtc | monticellite |
| Mnt | montmorillonite |
| Mul | mullite |
| Ms | muscovite |
| Ntr | natrolite |
| Ne | nepheline |
| Nrb | norbergite |
| Nsn | nosean |
| Ol | olivine |
| Omp | omphacite |
| Oam | orthoamphibole |
| Or | orthoclase |
| Opx | orthopyroxene |
| Pg | paragonite |
| Prg | pargasite |
| Pct | pectolite |
| Pn | pentlandite |
| Per | periclase |
| Prv | perovskite |
| Phl | phlogopite |
| Pgt | pigeonite |
| Pl | plagioclase |
| Prh | prehnite |
| Pen | protoenstatite |
| Pmp | pumpellyite |
| Py | pyrite |
| Prp | pyrope |
| Prl | pyrophyllite |
| Po | pyrrhotite |
| Qtz | quartz |
| Rbk | riebeckite |
| Rds | rhodochrosite |
| Rdn | rhodonite |
| Rt | rutile |
| Sa | sanidine |
| Spr | sapphirine |
| Scp | scapolite |
| Srl | schorl |
| Srp | serpentine |
| Sd | siderite |
| Sil | sillimanite |
| Sdl | sodalite |
| Sps | spessartine |
| Sp | sphalerite |
| Spl | spinel |
| Spd | spodumene |
| St | staurolite |
| Stb | stilbite |
| Stp | stilpnomelane |
| Str | strontianite |
| Tlc | talc |
| Tms | thomsonite |
| Ttn | titanite |
| Toz | topaz |
| Tur | tourmaline |
| Tr | tremolite |
| Trd | tridymite |
| Tro | troilite |
| Ts | tschermakite |
| Usp | ulvöspinel |
| Vrm | vermiculite |
| Ves | vesuvianite |
| Wth | witherite |
| Wo | wollastonite |
| Wus | wüstite |
| Zrn | zircon |
| Zo | zoisite |

(synonymous with "proportion") may be used in such phrases as "a small percentage" when proportion is meant. When proportion is not meant, an expression such as "a small part" should be used. "Percentage" may be used with numerals in a phrase such as "5 percentage points."

## ROCKS

The names of rocks are never abbreviated in narrative text, but abbreviations may be appropriate on certain maps or tables; uniformity in such usage is desirable. Unusual abbreviations must be defined to avoid misunderstandings. Common abbreviations are given on page 55.

## TEMPERATURE

Temperature is expressed in figures. Following the practice of the American Society for Testing and Materials "Standard for Metric Practice," STA recommends no space before or after the degree sign (100°C, 212°F).

## TERMS OF DIRECTION

Terms of direction are spelled out in text: "Kanosh is 58 km northwest of Koosharem; both are north of Kanab." In expressions of dip and strike, the terms of direction are abbreviated, and the degree mark is set without space against the figures:

A dip of 10° SE. (or 10° S. 35° E.)
The strike is N. 55° E. (or N. 45°–70° E.)
N. 55°30′25″ E.
*but* "the dip is southeast."

Abbreviated terms of direction are followed by a period:

N., S., NW., SE., NNW., ESE.

## COMMON WORD ABBREVIATIONS

The following abbreviations are commonly used in parenthetical phrases, brackets, footnotes, sidenotes, synonymies, tables, and leaderwork:

abstract(s), abs.
annual, ann.
appendix, app.
approximate(ly), approx.
article(s), art., arts.
association, assoc.
biologic(al), biol.
bulletin, bull.
chapter, chap.
chemical, chem.
communication(s), commun.
edition, editor(s), ed., eds.
figure(s), fig., figs.
formation(s), fm., fms.
geographic(al), geog.
geologic(al), geol.
geophysical, geophys.
hydrographic, hydrog.
hydrologic(al), hydrol.
illustration(s), illus.
investigation(s), inv.
locality, loc.
miscellaneous, misc.
Mount, Mt.
page(s), p.
part(s), pt., pts.
plate(s), pl., pls.
publication(s), pub., pubs.
report(s), rept., repts.
science(s), sci.
section(s), sec., secs.
series, ser.
stratigraphic(al), strat.
topographic(al), topog.
volume, v.
zoologic(al), zool.

## SCIENTIFIC AND ENGINEERING TERMS

Table 4 lists abbreviations, signs, and symbols for scientific and engineering terms likely to be used in Survey reports. Cite meanings in text or appendix. The exact form and style of some symbols may vary with different printers.

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms

[Adapted from lists in STA5 and STA6. For further treatment of abbreviations, see U.S. GPO Style Manual, 1984, chap. 9. For abbreviations on maps, see p. 55; for minerals and normative minerals, see p. 108; for chemical elements, see p. 106]

| | |
|---|---|
| absolute | abs |
| absolute value | $\vert \ \vert$ |
| absorbance | $A$ |
| absorptivity | $a$ |
| absorptivity, molar | $\epsilon$ |
| acceleration, angular | $\alpha$ |
| acceleration, linear | $a$ |
| acre-foot (feet) | acre-ft |
| activity, chemical (absolute) | $\lambda$ |
| activity, chemical (relative) | $a$ |
| activity coefficient | $\gamma$ |
| affinis | aff. |
| alternating current | ac or $\leftrightarrows$ or $\rightleftarrows$ |
| alternating-current (unit modifier) | a-c |
| altitude | alt |
| ampere | A |
| analytical variability | $\xi_a$ |
| angle | $\angle$ |
| angle between | $\wedge$ |
| angle between $a_0$ and $b_0$ in the unit cell | $\gamma$ |
| angle between $a_0$ and $c_0$ in the unit cell | $\beta$ |
| angle between $b_0$ and $c_0$ in the unit cell | $\alpha$ |
| angle between the two optic axes of a biaxial mineral | $2V$ |
| angstrom | Å |
| angular frequency | $\omega$ |
| angular velocity | $\omega$ |
| anhydrous | anhyd |
| antilogarithm | antilog |
| approaches | $\rightarrow$ |
| approximate (tion of) | approx |
| approximately (nearly) equal to | $\approx$ |
| aqueous | aq |
| are (land area) | a |
| area | $A$ or $S$ |
| astronomical unit (in English) | au |
| asymptotically equal to | $\simeq$ |
| atmosphere | atm |
| atomic mass | $m_a$ or $m$ |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| atomic mass of species X | $m$ (X) or $m_x$ |
| atomic number | at. no or $Z$ |
| atomic number of species X | $Z$ (X) or $Z_x$ |
| atomic weight | at wt or $M$ |
| atomic weight of species X | $M$ (X) or $M_x$ |
| automatic data processing | ADP |
| average | avg |
| average (indicated by bar or vinculum over symbol or by angular parentheses) | — or ⟨ ⟩ |
| Avogadro's number | $N$ or $N_A$ |
| avoirdupois | avdp |
| azimuth | az or $\alpha$ |
| barn (area) | b |
| barometer | bar. |
| barrel | bbl |
| barrel per day | bbl/d |
| base of natural logarithms | e |
| baud | Bd |
| Baumé (used with degree symbol) | °Bé |
| becquerel | Bq |
| before present (dates before 1950, in thousands of years) | B.P. |
| bench mark (in illustrations) | BM |
| bench mark (in text) | B.M. |
| Bernoulli number | $B$ |
| Bessel function (first kind, zero order) | $J_0(x)$ |
| Bessel function, hyperbolic (first kind, zero order) | $I_0(x)$ |
| bias | $\delta$ |
| billion gallons per day | Ggal/d |
| billion years | b.y. |
| binary coded decimal | BCD |
| biochemical oxygen demand | BOD |
| bit, byte | b |
| Bohr magneton | $\mu$B |
| boiling point | bp |
| Boltzmann constant | $k$ |
| Boltzmann function | $H$ |
| bottom-withdrawal tube | BW-tube |
| braces | { } |
| brackets | [ ] |
| Bragg angle, glancing angle (2θ is twice the glancing angle in X-ray diffraction) | $\theta$ |
| breadth (width) | $b$ or $B$ |
| Brinell hardness number | Bhn |
| British thermal unit | Btu |
| bushel | bu |
| byte | B |
| calculated | calc |
| calorie | cal |
| candela | cd |
| candela-hour | c·h |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| capacitance | $C$ |
| carat | kt |
| Cartesian coordinates | $x,y,z$ |
| cathode ray | CR |
| cathode-ray tube | CRT |
| Celsius (used with degree symbol) | °C |
| centimeter | cm |
| centimeter-gram-second (system) | CGS |
| centimeter-gram-second (unit) | cgs |
| central processing unit | CPU |
| chemical oxygen demand | COD |
| chemical potential | $\mu$ |
| chi-square statistic | $\chi^2$ |
| circa (about) | ca. |
| circle | ○ |
| circular (shape) | cir |
| citrate-extractable heavy metal | cxHM |
| coefficient | coef |
| cold-extractable copper | cxCu |
| collection(s) (abbreviation used only with numbers) | colln(s). |
| cologarithm | colog |
| compressibility | $\kappa$ |
| concentrate | conc |
| concentrated | concd |
| concentration | concn or $c$ |
| conductance | G |
| conductivity | $\gamma$ |
| confer (to be compared to) | cf. |
| confidence limit, lower, for the population mean | $\mu_L$ |
| confidence limit, upper, for the population mean | $\mu_U$ |
| constant | const |
| constant as defined in text | $K$ |
| continued (abbreviation used only in some tables) | con. |
| Coordinated Universal Time | UTC |
| corner | cor. |
| correlation coefficient | $\rho$ or $r$ |
| cosecant | csc |
| cosecant, hyperbolic | csch |
| cosine | cos |
| cosine, hyperbolic | cosh |
| cotangent | cot |
| cotangent, hyperbolic | coth |
| coulomb | C |
| counts per minute | c/min |
| critical | crit |
| Cross, Iddings, Pirsson, and Washington | CIPW |
| cross section of atoms and nuclei | $\sigma$ |
| crystallographic axes | $a$, $b$, $c$ |
| cubic centimeter | $cm^3$ |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| cumulative frequency | c.f. |
| curie | Ci |
| cutting point in a hypothesis test | $\Omega$ |
| cycle (radio) | c |
| cycles per minute | c/min |
| cycles per second | c/s |
| cylinder | cyl |
| darcy, darcies | D |
| day | d |
| debye unit | D |
| decay constant | $\lambda$ |
| decay constant based on alpha emission | $\lambda_a$ |
| decay constant based on negative beta emission | $\lambda_{\beta}-$ |
| decay constant based on orbital electron capture | $\lambda_{\epsilon}$ or $\lambda_{EC}$ |
| decay constant based on positron emission | $\lambda_{\beta}+$ |
| decay constant based on spontaneous fission | $\lambda_{SF}$ |
| decibel | dB |
| degree | ° |
| degree Celsius | °C |
| degree Fahrenheit | °F |
| degree Rankine | °R |
| degree réamur | °R |
| degrees of freedom | d.f. |
| delta (finite change, incremental variations, difference) | $\Delta$ or $\delta$ |
| density (mass) | $\rho$ |
| density (relative) | $d$ |
| depth | $h$ |
| deuterium | D or $^2$H |
| deutron | d |
| diameter | diam, $D$, or $d$ |
| dielectric constant (permittivity) | $\epsilon$ |
| dielectric flux | $\Psi$ |
| differential, partial | $\partial$ |
| differential thermoanalysis | dta |
| differential, total | d or $d$ |
| dilute | dil |
| direct current | dc or $\rightarrow$ |
| direction of extraordinary ray | E |
| direction of flow | $\rightarrow$ |
| direction of ordinary ray | O |
| discharge; total water discharge; rate of discharge; recharge | $Q$ |
| disintegrations per minute | d/min |
| disintegrations per second | d/s |
| disk operating system | DOS |
| dissociation constant | $K$ |
| dissociation constant, negative logarithm of; –log $K$ | p$K$ |
| dissolved oxygen | DO |
| dissolved solids | DS |
| distilled | dist |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| ditto (the same) | do. |
| divided by | $\div$ |
| dozen | doz |
| dram | dr |
| dropping mercury electrode | dme |
| dry basis | DB |
| dyne | dyn |
| efficiency | eff |
| electric current | $I$ |
| electric-current density | $J$, $j$ |
| electric-field strength | $E$ |
| electric potential | $V$ |
| electromagnetic unit | emu |
| electromotive force | emf or $E'$ |
| electron | e or $e$ |
| electron mass | $m_e$ |
| electron-spin resonance | esr |
| electronvolt | eV |
| electrostatic flux | $\Psi$ |
| electrostatic unit | esu |
| elementary charge | $e$ |
| elevation | elev |
| emendatio (emended) | emend. |
| end point | EP |
| energy | $E$ |
| energy (kinetic) | $E_k$ |
| energy (potential) | $E_v$ |
| enthalpy | $H$ |
| entropy | $S$ |
| entropy (standard state of) | $S°$ |
| ephemeris time | ET |
| equal to | = |
| nearly equal to | $\approx$ |
| not equal to | $\neq$ |
| equation(s) | eq (s) |
| equilibrium constant | $K$ |
| equivalent | equiv. |
| equivalent conductivity | $\wedge$ |
| equivalent uranium | eU |
| equivalent weight | equiv. wt. |
| error function | erf |
| error function (complement to) | erfc |
| Euler number | $E$ |
| ex grupo | ex gr. |
| exchange | $\downarrow\uparrow$ |
| exchangeable-potassium-percentage | EPP |
| exchangeable-sodium-percentage | ESP |
| excited hydrogen atom | H* |
| exponential of | exp, e |
| factorial product | ! |
| Fahrenheit (used with degree symbol) | °F |
| farad | F |
| Faraday's constant (the faraday) | $F$ |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| foot, feet | ft |
| footcandle | fc |
| footlambert | fL |
| foot (feet) per second cubed | $ft/s^3$ |
| foot-pound | ft·lb |
| foot-pound-second (system) | FPS |
| force | $F$ |
| force (moment of) | $M$ |
| formality | $f$ |
| freezing point | fp |
| frequency | $f$ or $v$ |
| frequency (spectroscopy) | $v$ |
| friction, coefficient of | $\mu$ or $f$ |
| Froude number | F |
| $F$-statistic for equality of variances | $F$ |
| fugacity | $f$ |
| function of $x$ | $f\ (x)$ |
| fusion point | fnp |
| gallon | gal |
| gallons per minute | gal/min |
| gamma function | $\Gamma$ |
| gas, as in $H_2O$ (g) | (g) |
| gas constant | $R$ |
| gas liquid partition chromatography | glpc |
| gauss | G |
| Geiger-Müller (unit modifier) | G-M |
| Gibbs free energy, Gibbs function | G |
| Gibbs free energy (standard state) | G° |
| gradient | $\nabla$ |
| grain | gr |
| gram | g |
| gravitational acceleration, acceleration of free fall, local acceleration due to gravity | $g$ |
| gravitational constant | $G$ |
| gray (unit of measure for absorbed dose) | Gy |
| greater than | $>$ |
| much greater than | $>>$ |
| not greater than | $\ngtr$ |
| greater than or equal to | $\geqq$ or $\geq$ |
| Greenwich mean astronomical time | G.m.a.t. |
| Greenwich mean time | G.m.t. |
| gross | gr |
| gross weight | gr. wt. |
| half-life | $T_{1/2}$ |
| half-life reduced | $fT_{1/2}$ |
| haversine | hav |
| head, total | $H$ |
| heat capacity | $C$ |
| heat capacity at constant pressure | $C_P$ |
| heat capacity at constant volume | $C_V$ |
| hectare | ha |
| height | $h$ |
| Helmholtz free energy | $A$ |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| henry, henries | H |
| hertz | Hz |
| high-pressure (unit modifier) | h-p |
| high-pressure metal vapor | HPMV |
| horsepower | hp |
| hour | h |
| hydrogen-ion concentration, negative $\log_{10}$ of | pH |
| hyperbolic functions, inverse, prefix to be added to abbreviation (for example, arcosh) | ar |
| hypothesis (alternative) | $H_1$ |
| hypothesis (null) | $H_0$ |
| identical with | $\equiv$ |
| not identical with | $\not\equiv$ |
| imaginary square root of –1 | i or j |
| inch (period may be used if abbreviation might be confused with the preposition "in") | in |
| inch-pound | in-lb |
| indeterminate | indet. |
| index of refraction | $n$ |
| indices of refraction for biaxial crystals | $n_x$, $n_y$, and $n_z$ or $\alpha$, $\beta$, and $\gamma$ |
| indices of refraction for uniaxial crystals | $n_O$ and $n_E$ or $\omega$ and $\epsilon$ |
| inductance (mutual) | $M$ |
| inductance (self) | $L$ |
| infinity | $\infty$ |
| infrared | ir |
| inside diameter | id |
| integral | $\int$ |
| integral, closed (circuital or contour) | $\oint$ |
| intensity of X-rays reflected from crystallographic planes | $I$ |
| intermediate-pressure (unit modifier) | i-p |
| intersection or logical product | $\cap$ |
| ionization constant | $K$ or $K_i$ |
| irrigation-water classification: $C$ denotes conductivity (electrical); $S$ denotes sodium-adsorption ratio (SAR); numbers denote respective numerical quality classes | $C2–S3$ |
| Jackson turbidity unit | Jtu |
| joule | J |
| joule per kelvin | J/K |
| Joule-Thomson coefficient | $\mu$ |
| kelvin (degree symbol not used) | K |
| kilobyte | K |
| kilohm | k$\Omega$ |
| kilowatthour | kWh |
| K-meson | K |
| knot | kn |
| lambert | L |
| langley | ly |
| Laplacian operator | $\nabla^2$ |
| latitude (abbreviation used only with figures) | lat |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| length | $l$ |
| less than | $<$ |
| much less than | $<<$ |
| not less than | $\nless$ |
| less than or equal to | $\leqq$ or $\leq$ |
| limit of $f(x)$ | $\lim f(x)$ |
| linear alkylsulfonate | LAS |
| liquefied petroleum gas | LPG |
| liquid | liq |
| liquid oxygen | lox |
| liter | L |
| locality, localities (abbreviation used only with numbers) | loc (s). |
| logarithm (common) | log |
| logarithm (natural) | $\log_e$ or ln |
| logical product or intersection | $\cap$ |
| logical sum or union | $\cup$ |
| longitude (abbreviation used only with figures; omit period when "long" is used with "lat"; use period if abbreviation may be confused with the adjective "long") | long |
| longitudinal velocity; *P*-wave velocity | $v_P$ |
| low frequency | LF |
| low-pressure (unit modifier) | l-p |
| lumen | lm |
| luminous flux | $\Phi$ |
| lux | lx |
| magnetic-field strength or intensity | $H$ |
| magnetic flux | $\Phi$ |
| magnetic induction | $B$ |
| Manning's roughness (resistance) coefficient | $n$ |
| mass | $m$ |
| mean sea level | m.s.l. |
| mass number | $A$ |
| mass number of species X | $A(X)$ or $A_x$ |
| matrix; for example $\lVert a_{ij} \rVert$ or $(a_{ij})$ or $A$ | $\lVert\ \rVert$ or ( ) or $A$ |
| matrix, cofactor of element | $a_{ij}A_{ij}$ |
| matrix, conjugate | $A^*$ |
| matrix, determinant of; for example $\lvert a_{ij} \rvert$ | $\lvert\ \rvert$ |
| matrix, identity | $I$ |
| matrix, inverse | $A^{-1}$ |
| matrix, transpose | $A^T$ |
| maximum | max |
| maxwell | Mx |
| mean (statistical) | $\mu$ or $m$ |
| mean life | $\tau$ |
| mean of a linear combination $q$ | $\mu_q$ |
| mean of the lognormal distribution | $\alpha$ |
| mean of the negative binomial distribution | $\theta$ |
| mean of sample means | $\mu_{\bar{w}}$ |
| mean of the variance of sample means | $\mu s^2_{\bar{w}}$ |
| mean sea level | m.s.l. |
| mean square error | M.S.E. |
| megabyte | Mb |
| megohm | M$\Omega$ |
| melting point | mp |
| member of (used with a set and its elements) | $\epsilon$ |
| meta (in organic compounds) | *m* |
| meter | m |
| metric ton | t |
| microGal | $\mu$G |
| micron | $\mu$ |
| mile | mi |
| miles per hour | mi/h or mph |
| Miller indices | *hkl* |
| millimeter of mercury | mmHg |
| million | M |
| million gallons per day | Mgal/d |
| million years | m.y. |
| minimum | min |
| minus | $-$ |
| minus or plus | $\mp$ |
| minute | min |
| minute; prime; foot | $'$ |
| mixture melting point | mmp |
| Modified Mercalli | MM |
| molality, molal (concentration) | $m$ |
| molar concentration of substance B | $c_B$ |
| molar mass of substance B | $M_B$ |
| molarity, molar (concentration) | $M$ |
| mole | mol |
| molecular concentration | $C$ |
| molecular weight | mol wt |
| month | mo |
| motorship | MS |
| multiplied by | $\times$ or $\cdot$ |
| multiplying factor for the geometric mean of lognormally distributed observations | $\psi_n$ |
| multiplying factor for the variance of lognormally distributed observations | $\phi_n$ |
| multispectral scanner | MSS |
| muon | $\mu$ |
| nabla; del; differential vector operator | $\nabla$ |
| natural variability | $\xi_n$ |
| nautical mile | nmi |
| neutrino | $\nu$ |
| neutron | n |
| new genus | n. gen. |
| new series | new ser. |
| new species | n. sp. |
| new variety | n. var. |
| newton | N |
| newton meter | N·m |
| Newtonian gravitational constant | $G$ |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| no data | n.d. |
| no record, not reported | n.r. |
| nomen nudum | nom. nud. |
| normality, normal (concentration) | *N* |
| not available; not applicable | NA. |
| not determined | n.d. |
| nucleon number | *A* |
| number of observations in a population | *N* |
| number of observations (sample size) | *n* |
| number of samples | *k* |
| observation | *w* |
| observed frequency of observations | *O* |
| oersted | Oe |
| ohm | Ω |
| ohm centimeter | Ω·cm |
| ohm meter | Ω·m |
| optical directions in a crystal; also rays of light in these directions and pleochroic colors in these directions | X, Y, Z |
| ortho (in organic compounds) | *o* |
| ounce | oz |
| outside diameter | od |
| oven-dry basis | ODB |
| oxidation-reduction potential | Eh |
| para (in organic compounds) | *p* |
| parsec | pc |
| part(s) | pt(s). |
| part(s) per billion | ppb |
| part(s) per million | ppm |
| part(s) per thousand | ppt or °/₀₀ |
| partial pressure of oxygen or carbon dioxide | $P_{O_2}$, $P_{CO_2}$, or $P\ (O_2)$, $P(CO_2)$ |
| particle-size diameter | ϕ |
| partition function | *Z* |
| pascal | Pa |
| pascal second | Pa·s |
| peck | pk |
| percentage risk of type I error | α |
| percentage risk of type II error | β |
| period | *T* |
| phase | ph |
| phenyl | Ph |
| phot | ph |
| photon | γ |
| pint | pt |
| pi (mathematical constant) | π |
| pion | π |
| Planck constant | *h* |
| plus | + |
| plus or minus | ± |
| poise | P |
| Poisson ratio | ν or μ |
| pooled sample variance | $s_p^2$ |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| population coefficient of variation and of skewness | γ |
| population mean | μ |
| population standard deviation | σ |
| population variance | $\sigma^2$ |
| posterior distribution of a parameter θ | $D_1(\theta)$ |
| potassium-adsorption ratio | PAR |
| potential difference | *V* or *U* |
| pound (mass) | lb |
| pound avoirdupois | lb avdp |
| pound-force | lbf |
| pound-force per square inch | lbf/in$^2$ |
| power | *P* |
| precipitate | ppt or ↓ |
| preparation variability | $\xi_p$ |
| pressure | *P* or *p* |
| primary wave | *P*-wave |
| prior distribution of a parameter θ | $D_o\ (\theta)$ |
| probability of the event *A* | *P(A)* |
| product of a series | Π |
| proportion | : : |
| proportion of successes in a binomial population | θ |
| protium | $^1$H |
| proton | p |
| quantity of electric charge or electricity; quantity of heat; quantity of light | *Q* |
| quart | qt |
| rad | rd |
| radian | rad |
| radiance | *B* |
| radiant emissivity | *J* |
| radiant energy | *Q* |
| radiant energy density | *u* |
| radiant exposure | *H* |
| radiant flux | Φ |
| radiant intensity | *I* |
| radical | √ |
| radio detection and ranging | radar |
| radio frequency | RF |
| radius | *r* or *R* |
| random fluctuation of "experimental error" | *e* |
| random access memory | RAM |
| Range(s) (legal land division) | R(s). |
| rankine (used with degree symbol) | °R |
| ratio; is to (when solidus is used, the word "ratio" should follow; for example, Cu/Ni ratio) | : or / |
| reactance | *X* |
| read-only memory | ROM |
| réaumur (used with degree symbol) | °R |
| refractive index at 20°C, sodium (*D*) line | $n_D^{20}$ |
| relative cumulative frequency | r.c.f. |
| repeating decimal; bar covers part that is to be repeated | $1.\overline{14}$ |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| resistance | $R$ |
| resistivity | $\rho$ |
| return beam vidicon | RBV |
| reversible reaction | $\leftrightarrows$ |
| revolutions per minute | r/min or rpm |
| revolutions per second | r/s or rps |
| Reynolds number | R |
| roentgen (used with degree symbol) | °R |
| roentgen equivalent, man or mammal | rem |
| roentgen equivalent, physical | rep |
| root | $\sqrt{}$ |
| root mean square | rms |
| rubidium acid phthalate | RAP |
| Rydberg constant | $R$ or $Ry$ |
| Rydberg constant for infinite mass | $R_\infty$ |
| salinity (parts per thousand) | ‰ |
| sample coefficient of variation | $C$ |
| sample mean | $\bar{w}$ |
| sample standard deviation | $s$ |
| sample variance | $s^2$ |
| sampling variability | $\xi_s$ |
| saturated calomel electrode | sce |
| secant | sec |
| secant, hyperbolic | sech |
| second (time) | s |
| second; double prime; inch | ″ |
| second-foot | s·ft |
| secondary wave | *S*-wave |
| section(s) (subdivision of Township and Range) | sec(s). |
| sensu lato | s.l. |
| sensu stricto | s.s. |
| shear velocity; *S*-wave velocity | $v_s$ |
| siemens | S |
| sine | sin |
| sine, hyperbolic | sinh |
| sine of the amplitude (an elliptic function) | sn |
| skewness of frequency distribution | sk |
| sodium, line in spectrum of | $D$ |
| sodium-adsorption ratio | SAR |
| solid, as in AgCl(s) | (s) |
| solid angle | $\omega$ |
| solidus (also called virgule, slash) | / |
| soluble | sol |
| solution | soln |
| sound navigation and ranging | sonar |
| spacing of Bragg planes in a crystal | $d$ |
| species (singular) | sp. |
| (plural) | spp. |
| specific gravity | sp gr |
| specific heat | sp ht |
| specific heat capacity | $c$ |
| specific volume | sp vol |

**Table 4.** Abbreviations, signs, and symbols for scientific and engineering terms—Continued

| | |
|---|---|
| square | sq |
| square centimeter | $cm^2$ |
| square root | $\sqrt[2]{}$ |
| standard | std |
| standard deviation | $\sigma$ |
| standard error of laboratory means | $s_x$ |
| standard mean ocean water | SMOW |
| standard state | ° |
| standard state Gibbs free energy | $G°$ |
| standard temperature and pressure | STP |
| standardized normal distribution | s.n.d. |
| station(s) (abbreviation used only with numbers) | sta(s). |
| steradian (solid angle) | sr |
| stokes | St |
| strain, normal or linear | $\epsilon$ |
| strain, shear | $\gamma$ |
| stress, normal | $\sigma$ |
| stress, shear | $\tau$ |
| subgenus | subgen. |
| subset of; is contained in | $\subset$ |
| subspecies | subsp. |
| "Suggestions to Authors" | STA |
| sum | $\Sigma$ |
| sum of squares | SS |
| sum of squares of the replication totals | $T_r^2$ |
| sum of squares of the treatment totals | $T_t^2$ |
| sum total of observations in a sample | $T$ |
| surface tension | $\gamma$ or $\sigma$ |
| tangent | tan |
| tangent, hyperbolic | tanh |
| temperature | temp |
| temperature, in degrees Celsius | $t$ |
| temperature, in kelvins; absolute temperature; thermodynamic temperature | $T$ |
| tesla | T |
| theoretical frequency of observations | $T$ |
| thermogravimetric analysis | tga |
| thickness | $t$ or $d$ |
| thin-layer chromatography | tlc |
| thousand | k |
| thus | sic |
| time | $t$ |
| ton, metric (tonne) | t |
| total (grand) of observations squared | $G^2$ |
| Townships(s) (legal land division) | T., Tps. |
| trace | tr. |
| trace of a matrix (math) | tr |
| transformed observation | $u$ |
| transmittance | $T$ |
| triangle | $\triangle$ |

# NUMBERS

**Arabic versus Roman.** Arabic numbers are generally easier to understand than Roman: 3 or 4 rather than III or IV; 1988 rather than MCMLXXXVIII.

**Beginning of a sentence.** Numbers at the beginning of a sentence are spelled out, but most sentences can be worded so as not to begin with a number. In the sentence "Four thousand eight hundred fifty tons was produced in 1986, and 5,180 tons in 1987," convenience requires that both quantities be expressed in figures. Rewrite as "The production was 4,850 tons in 1986 and 5,180 tons in 1987."

**Compound modifier.** Numbers less than 100 preceding a unit modifier containing a figure are spelled out:

twelve 6-inch guns
two 3/4-inch boards
120 8-inch boards
three 4-foot boulders

**Dates.** In Survey reports dates are given as follows: June 20 (not June 20th), the 20th of June, the 2d or 3d (not 2nd or 3rd). In the Department of Defense the day and month are written "20 June," and in material quoted from that Department the style should not be changed.

For consecutive years use the contracted forms: 1934–35, 1890–91, 1986–87, 1900–10, 1907–8 (but, on a change of century, 1895–1902, and to avoid three ciphers together, 1900–1901). Fiscal years, water years, or meteorological years are written the same way: 1968–77.

A.D. precedes the year; B.C. follows the year: A.D. 937, 254 B.C.; A.D. 937 means anno Domini (in the year of our Lord) 937; 254 B.C. means the 254th year before Christ.

**Decimals.** Decimals are expressed in figures. A zero should be supplied before a decimal point if there is no unit (both in text and in footnotes), and zeros should be omitted after a decimal point unless they indicate exact measurement: 0.25 percent, 90 percent silver. (See p. 119 for discussion of significant figures.)

**Doubled-up numbers.** Avoid doubling up figures as shown in the following example: "The final survey made the total distance of levels run in 1976 38,307 miles." Rewrite as "Including the final survey, the total distance of levels run in 1976 was 38,307 miles."

**Fractions.** Fractions that stand alone are spelled out, but where the fraction is joined to a whole number figures are used: one-eighth, three-fourths, 3½, 1¾ (but ½ page to 1¾ pages).

Write half a mile, a quarter of a mile (not a half mile or ½ mile), but ⅔ mile (1 kilometer).

Figures are used for fractions in a unit modifier: ½-inch pipe, ⅞-point rise, 0.9-inch spacing.

**Indefinite expressions.** Indefinite expressions are spelled out: the early seventies, in the eighties (but the 1980's).

**Large numbers.** In large numbers, the word "million" or a similar group term is spelled out: 20 million, 3 billion, $5 million (but use figures if other numbers in a series are given in figures: "The appropriation in 1952 was $780,000 and in 1953 was $2,000,000").

**Ordinal numbers.** Except in formal writing, in bibliographic citations of an edition of a work, and for day preceding month, figures are used for ordinal numbers beginning with 10th: 82d Congress, 20th century, 49th parallel, 141st meridian.

When ordinal numbers appear in juxtaposition and one of them is 10th or more, figures are used for both: the 1st session of the 82d Congress, the 9th and 10th Congresses.

**Quantities and measurements.** Age, degree, measurement, money, percentage, proportion, time, and similar matters are expressed in figures: 6 years old, 27°, 45 miles, 9 bushels, 24 pages, 16 by (or ×) 24 inches, $1.54, 17 percent, ratio of 1 to 4, scale of 1:62,500, 10 o'clock, 10 p.m., 4:30 p.m. (but four centuries, three decades).

**Related numerical expressions.** Figures are used in a group of two or more related numerical expressions, whether or not each number is less than 10: 2 gold mines, 3 silver mines, and 8 copper mines; 3 wells and 11 springs; tested at 4, 28, and 160 days.

A unit of quantity or measurement, always expressed in figures (except in round numbers), does not affect the use of figures or other related or connected numerical expressions: "The five mines are 20 miles southwest of the town."

**Round numbers.** Round numbers are spelled out: almost a thousand years, nearly a hundred feet, about a hundred wells (but 115 wells).

**Serial numbers.** Figures are used for serial numbers: locality 259, Bulletin 725.

**Singular nouns.** Avoid the common mistake of assigning plural verbs to numbers that have singular contexts, almost always in the passive voice:

Eight hundred feet of sandstone and shale *were* [was] measured. (Not 800 individual feet but a single section of rock totaling 800 feet. Recast as, "They [we, I, she, he] measured 800 feet of sandstone and shale.")

Three million years *were* [was] required to excavate the gorge. (A single time lapse of 3 million years. Try recasting with "gorge" as the subject: "The gorge was excavated in 3 million years.")

Four years *were* [was] spent in the field and 8 years *were* [was] spent in the office. (Problem can be avoided by recasting: Field-work took 4 years; office work took 8.)

See also page 126.

NOTEWORTHY NUMERICAL CONVERSIONS

[A la *Johns Hopkins Magazine*, as conceived by Solomon W. Golomb, University of California]

One-half Soviet press agency = 1 demitasse
Ten cards = 1 decacard
Two thousand mockingbirds = 2 kilomockingbirds
Two tribes = 1 diatribe
One-trillionth dilly = 1 picodilly
One billion antics = 1 gigantic
One-millionth fish = 1 microfiche

Also:

$10^{21}$ picolos = 1 gigolo
$10^{12}$ microphones = 1 megaphone
$10^{3}$ bicycles = 1 kilocycle
10 millipedes = 1 centipede
10 monologues = 5 dialogues
1 milli-Helen = the face that launced 1 ship

# SIGNIFICANT FIGURES

NUMERICAL DATA that are used to record observations or solve problems are seldom exact. The numbers are generally rounded off and, consequently, are estimates of some true value, and the mathematical operations or assumptions involved in the calculations commonly are approximations. In numerical computations, no more than the necessary number of digits should be used; to report results with too many or too few digits may be misleading. To avoid surplus digits, numbers should be rounded off at the point where the figures cease to have real meaning. Conversely, the number of significant figures may be unnecessarily reduced by choosing the less meaningful of several possible methods of calculation. Careful consideration, therefore, should be given to the significant digits and arithmetic involved in each measurement.

The number of significant figures resulting from any calculation involving simple arithmetic operations on measured quantities should not exceed the number of significant figures of the least precise number entering into the calculation. In the calculation itself, one more significant figure may be retained in the more precise numbers than exist in the least precise number.

The digits 1 through 9 are always significant, regardless of their position in a number. The digit 0 is significant when it is between other significant digits but not when it is at the right or left of the number that locates the decimal point, because that location may be changed by changing dimensions—for example, grams to milligrams. At the right of a number, 0 is significant if it indicates actual precision, but not if it is used only to complete a rounded number. For example, the number 0.0046 has only two significant figures, but 4,103 has four significant figures. In a number such as 53,200 we do not know the number of significant figures unless we know whether the zeros at the end were actually determined experimentally. To remove this ambiguity the number may be written as $5.3200 \times 10^4$ if the zeros are significant, and $5.32 \times 10^4$ if they are not. Use of five significant figures indicates that the author knows that the two zeros have real meaning. Nonsignificant zeros should never be used at the right of the decimal part of the number. In tabulating data, an alternative is to list only the significant figures and absorb the superfluous zeros in the general heading, as follows:

| Specimen | Temperature (°C × $10^3$) |
|---|---|
| A | 1.4 |
| B | 2.0 |
| C | 1.8 |
| D | 1.2 |

## ROUNDING OFF NUMBERS

A consistent procedure should be followed in rounding off numbers to *n* significant figures. All digits to the right of the *n*th digit should be discarded, as illustrated in the following six examples of rounded numbers, each of which has only three significant figures:

| Example | Original number | Rounded number |
|---|---|---|
| 1 | 0.32891 | 0.329 |
| 2 | 47,543 | 47,500 |
| 3 | 11.65 | 11.6 |
| 4 | 22.75 | 22.8 |
| 5 | 18.05 | 18.0 |
| 6 | 18.051 | 18.1 |

If the first of the discarded digits is greater than 5, add 1 to the *n*th digit (example 1). If the first of the discarded digits is less than 5, leave the *n*th digit unchanged (example 2). If the first of the discarded digits is 5 and all the following digits are zero, round off to the nearest even number (examples 3–5). If the 5 is followed by any of the digits 1 through 9, add 1 to the *n*th digit (example 6).

If the difference between successive numbers is more important than the total or average, it may be desirable to round consistently in one direction all numbers in which the first dropped digit is followed by zeros only, instead of rounding to the nearest even number.

In presenting numerical data, give only those digits that convey actual information. The last digit should represent the uncertainty in the data. Unless stated otherwise, it is generally assumed that the last significant figure is uncertain by one unit. To illustrate, if the length of a drill core is given as 3.12 cm, true length is implied to be $3.12 \pm 0.01$ and is thus somewhere between 3.11 and 3.13 cm. If the uncertainty in the last figure is appreciably different from one unit, attention can be called to the uncertainty by expressing the measurement at $3.12 \pm 0.03$ cm.

Special problems arise in converting English-to-metric or metric-to-English units. These problems can be avoided if (1) the precision of the original measurement is stated and (2) the author adheres strictly to the concept of significant figures. Most readers will assume that the first-listed number represents the system used for the actual measurement; hence they should not be confused by reconverting the second-listed number. Thus, the measurement "500 ft (152 m)" implies a precision of "500±1 ft," not the "500±3 ft" that would result from converting the 152 m back to feet. (The Survey no longer encourages dual measurements in its formal reports.)

## Absolute and Relative Errors

The absolute error of a number or measurement generally is defined as the numerical difference between the true value and the approximate value as given by the number or measurement. The relative error can be defined as the absolute error divided by the true value of the quantity. The true index of a measurement is expressed by the relative error, which in turn is indicated by the number of significant figures required to express the measurement. For this reason, the number of significant figures is vitally important in reporting measured or computed quantities.

The following example[1] illustrates the difference between absolute and relative errors: Assume that the length of a carefully prepared core of rock 2 inches long has been measured to the nearest thousandth of an inch and that a mile of railroad track has been measured to the nearest foot. The absolute errors are 0.0005 inches for the core and 0.5 ft for the track, whereas the relative errors are, respectively,

$$\frac{0.0005}{2}=\frac{1}{4{,}000} \text{ and } \frac{0.5}{5{,}280}=\frac{1}{10{,}560}.$$

The track measurement is relatively better.

## Arithmetic Operations

A simple arithmetic operation, such as addition or multiplication, may affect the number of significant figures in the result. In addition and subtraction, the placement of the decimal point is important in the retention of significant figures. The general rule can be illustrated thus: Suppose you want to add the numbers 120.632, 8.14, 980.3, and 1,401.0023, each number being correct to its last figure. Inasmuch as the third number listed is correct only to the first decimal place, it is meaningless to retain more than two decimal places in the other numbers. Consequently,

$$\begin{array}{r} 120.63 \\ 8.14 \\ 980.3 \\ \underline{1{,}401.00} \\ 2{,}510.07 \end{array}$$

and the result is rounded to 2,510.1, or to five significant figures. Note that only one decimal place is retained in the sum and that the number of significant figures in the sum is less than the number of significant figures in two of the original numbers. The procedure of rounding off applies to measurements but not to whole numbers that are correct to the last digit. If the whole numbers in the example given above applied to individual persons or digits and represented counts that were correct to the last digit, they would be shown as:

$$\begin{array}{r} 120 \\ 8 \\ 980 \\ \underline{1{,}401} \\ 2{,}509 \end{array}$$

and the total would not be rounded off.

If small numbers are added to (or subtracted from) large numbers of limited accuracy, the total should retain no more significant figures than are justified by the accuracy of the larger numbers. For example, in adding 356,000 (good to only three figures) and 1,420 (good also to three figures), the sum is 357,000, not 357,420. The figures that are dropped are within the limits of error of the larger number and are meaningless in the sum. By the same reasoning, the addition of a very large group of numbers of limited accuracy cannot produce a total more accurate than the respective items. Therefore, if several hundred objects have been weighed individually with an accuracy of three figures, the total weight of all the objects should be rounded off to three significant figures.

In subtraction, the number of significant figures in the difference may be considerably reduced if the numbers are close to each other in numerical value. Suppose 0.1189 is subtracted from 0.1204. The difference is 0.0015, which contains only two significant figures.

In the multiplication or division of two or more approximate numbers of different accuracies, the more accurate numbers should be rounded off so as to contain one more significant figure than the least accurate number. In this procedure, the error of the product is due almost entirely to the error of the least accurate number. Therefore, the final result should be given to as many significant figures as are contained in the least accurate number, and no more. As illustrations, two calculations may be given:

$$103.24 \times 0.0081 = 103 \times 0.0081 = 0.83$$

and

$$\frac{56.3}{2.23612} = \frac{56.3}{2.236} = 25.2.$$

In computing with logarithms, no more decimals need be retained in the mantissa of the logarithm than the number of significant figures in the numerical factors that enter the computation. Thus, log 352.3 = 2.5469. It is sometimes easier to use logarithms directly from the tables without rounding off, but the results of computation should never be presented as being more accurate than the original data.

## Misusing Significant Figures

A result cannot be more accurate than the data used to obtain it. Thus the number of significant figures of the result cannot be greater than is justified by the least accurate number entering into the calculation. Despite this rule, many published data contain incorrect significant figures.

Many estimates of ore reserves are carried to as many as six significant figures—for example, 123,415 tons. Such a number gives a spurious impression of accuracy, if not a suspicion that the estimator is incompetent. To see the fallacy, just consider how reserve tonnages are calculated. The estimated volume, which is usually determined from drill-hole information, is multiplied by the density of the ore. At best, the volume can be determined accurately to only three significant figures, and probably to no more than two. The density of the ore may be correct to two significant figures. Consequently, the calculation of the estimated tonnage can produce no more than two significant figures. The figure in the foregoing example should be given as 120,000 tons.

Again, the depth to a geologic structure, as computed from gravity determinations, might be given as 13,016 ft. If, as is usual, this figure was calculated on the assumption of a density contrast for the ore body good to only two significant figures, the figure should be reported as "about 13,000 ft."

Reports on results of chemical analyses provide yet another illustration. Typically the results might be reported as 1,061.39 for $SO_4$, 880.90 for Na, and 205.62 for Cl, all in milligrams per liter (mg/L). Each of these numbers contains five or six significant figures, whereas the analytical procedures used justified only two or three. Moreover, concentrations of more than 1,000 mg/L are customarily reported to only three significant figures; for concentrations between 10 and 1,000 mg/L only whole numbers are reported. It follows that the above results should be listed as 1,060, 881, and 206 mg/L.

Certain other field measurements, some of them crude, are improperly reported to a greater number of significant figures than would be justified by even the most refined laboratory methods. In these, as well as in laboratory measurements, care should be taken to use only as many significant figures as are justified.

Some published stratigraphic measurements[1] indicate unrealistic accuracies. The calculated thickness of a sedimentary formation of Tertiary age might be given as 14,633 ft, but if the top and bottom are as ill defined as most Tertiary units, a more acceptable figure would be "about 15,000 ft." Calculations of the thickness of such rock units based on measurements of strike and dip along a measured traverse inevitably contain many uncertainties (exact amount and direction of dip, magnetic declination, nature of exposure, and others), which are almost impossible to evaluate and which limit the acceptable value to a few significant figures. Mining geologists have been known to pace the length of an adit but to use a steel tape to measure the last few feet and to record the total distance in fractions of a foot. So too have stratigraphers been known to measure the poorly exposed parts of a section by hand leveling but to measure cliff-forming beds by tape and then to construct a columnar section in which some units, and the total thickness, are reported in inches or even in fractions of an inch.

[1]STA 7 was in press before the Survey adopted the policy of using metric units in all its formal reports.

# THE METRIC SYSTEM

THE METRIC CONVERSION ACT OF 1975—P.L. 94–168, amended by P.L. 100–418 (August 23, 1988)—stated that the policy of the United States is to designate the metric system as the preferred system of weights and measures for United States trade and commerce. Reference is to the International System of Unit(s) or SI (from the French "Le Système International d'Unités") as modified by the Secretary of Commerce for use in the United States.

SI differs from earlier versions of the metric system in that (1) the base units are more accurately defined and (2) specific directives and guidelines are provided for use of prefixes and for the development of combined or derived units. SI and the history of its development are described in National Bureau of Standards Special Publication 330 (as revised). Other helpful and authoritative references for the use of SI are Publication E380 (as revised) of the American Society for Testing and Materials; Publication 268 (as revised) of the American National Standards Institute/Institute of Electrical and Electronic Engineers; Publication 85–1, Metric Editorial Guide (fourth edition revised), April 1985, American National Metric Council; and Federal Standard 376A, Preferred Metric Units for General Use by the Federal Government, General Services Administration.

Aside from the fact that SI units simplify measurements and calculations, a major scientific advantage of SI is that it eases the exchange of data in the many disciplines that have used inch/pound (U.S. customary) units of measure. The term "inch/pound units" not only includes units based on the inch and the pound commonly used in the United States but also includes all other (nonmetric) units not considered part of SI.

In adopting the Metric Conservation Act, the United States officially expressed its intent to join other nations in the use of SI. The amended act expressly stated that the transition to the use of the metric system by the Federal Government shall be implemented by the end of fiscal year 1992, except to the extent that such use is impractical or is likely to cause significant inefficiencies.

To ensure timely and effective compliance with P.L. 94–168, the U.S. Geological Survey would be ready by FY 1991 to begin extending the requirement to cover all new scientific reports published in the official book series, provided the requirement does not conflict with cooperators' requirements nor detract from the clarity of reports directed to mixed audiences (interdisciplinary scientists, legislators, technical personnel such as engineers, and nonscientific personnel such as planners and the general public).

All other publications series contain subject matter of differing technical complexity directed to readers of varying technical sophistication. Products run the gamut from lay-reader, information-type releases to complex mathematical treatises, and the selection of either SI, inch/pound, or dual units for a publication in one of these series is the author's responsibility—with guidance from appropriate Division staff. The decision to use a system of units should be made in the planning stage of a publication and not when project activities are near completion. This decision is especially important where SI or dual units are to be used, because it enables project personnel to familiarize themselves with what may be a new suite of units, and it improves the accuracy of published data. If dual units are used, the numbers used first should be the ones that the measurements were made in. The Survey, however, discourages dual usage.

In light of the transition to SI, the use of conversion tables is encouraged in Survey publications to expose readers to SI and to help familiarize readers with the SI units that correspond to the inch/pound units commonly used by the Survey.

The most often read SI and inch/pound units, and factors for their conversion, are given in table 5 (less common conversions are found in most good dictionaries).

**Table 5.** Conversion factors for SI (metric) and inch/pound (U.S. customary) units of measurement ►

[SI (International System of Units) a modernized metric system of measurement. An asterisk after the last digit of the factor indicates that the conversion factor is exact and that all subsequent digits are zero; all other conversion factors have been rounded to four significant digits. Use of hectare (ha) as an alternative name for square hectometer ($hm^2$) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter ($dm^3$) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter. Metric ton (t) as a name for megagram (Mg) should be restricted to commercial usage, and no prefixes should be used with it]

**Table 5.** Conversion factors for SI (metric) and inch/pound (U.S. customary) units of measurement—Continued

*A. Factors for converting SI metric units to inch/pound units*

| To convert from | To | Multiply by |
|---|---|---|
| | **Length** | |
| millimeter (mm) | inch (in) | 0.03937 |
| meter (m) | foot (ft) | 3.281 |
| | yard (yd) | 1.094 |
| kilometer (km) | mile (mi) | 0.6214 |
| | mile, nautical (nmi) | 0.5400 |
| | **Area** | |
| meter$^2$ (m$^2$) | foot$^2$ (ft$^2$) | 10.76 |
| | yard$^2$ (yd$^2$) | 1.196 |
| | acre | 0.0002471 |
| hectometer$^2$ (km$^2$) | acre | 2.471 |
| kilometer$^2$ (km$^2$) | mile$^2$ (mi$^2$) | 0.3861 |
| | **Volume** | |
| centimeter$^3$ (cm$^3$) | inch$^3$ (in$^3$) | 0.06102 |
| decimeter$^3$ (dm$^3$) | inch$^3$ (in$^3$) | 61.02 |
| | pint (pt) | 2.113 |
| | quart (qt) | 1.057 |
| | gallon (gal) | 0.2642 |
| | foot$^3$(ft$^3$) | 0.03531 |
| meter$^3$ (m$^3$) | foot$^3$ (ft$^3$) | 35.31 |
| | yard$^3$ (yd$^3$) | 1.308 |
| | gallon (gal) | 264.2 |
| | barrel (bbl), (petroleum, 1 bbl=42 gal) | 6.290 |
| | acre-foot (acre-ft) | 0.0008107 |
| hectometer$^3$ (hm$^3$) | acre-foot (acre-ft) | 810.7 |
| kilometer$^3$ (km$^3$) | mile$^3$ (mi$^3$) | 0.2399 |
| | **Volume per unit time (includes flow)** | |
| decimeter$^3$ per second (dm$^3$/s) | foot$^3$ per second (ft$^3$/s) | 0.03531 |
| | gallon per minute (gal/min) | 15.85 |
| | barrel per day (bbl/d), (petroleum) | 543.4 |
| meter$^3$ per second (m$^3$/s) | foot$^3$ per second (ft$^3$/s) | 35.31 |
| | gallon per minute (gal/min) | 15,850 |
| | **Mass** | |
| gram (g) | ounce avoirdupois (oz avdp) | 0.03527 |
| kilogram (kg) | pound avoirdupois (lb avdp) | 2.205 |
| megagram (Mg) | ton, short (2,000 lb) | 1.102 |
| | ton, long (2,240 lb) | 0.9842 |
| | **Pressure** | |
| kilopascal (kPa) | pound-force per inch$^2$ (lbf/in$^2$) | 0.1450 |
| | atmosphere, standard (atm) | 0.009869 |
| | bar | 0.01* |
| | inch of mercury at 60°F (in Hg) | 0.2961 |
| | **Temperature** | |
| kelvin (K) | degree Fahrenheit (°F) | [1] |
| degree Celsius (°C) | degree Fahrenheit (°F) | [2] |

[1]Temp °F=1.8 temp K−459.67. [2]Temp °F=1.8 temp °C+32.

**Table 5.** Conversion factors for SI (metric) and inch/pound (U.S. customary) units of measurement—Continued

*B. Factors for converting inch/pound units to SI metric units*

| To convert from | To | Multiply by |
|---|---|---|
| | **Length** | |
| inch (in) | millimeter (mm) | 25.4* |
| foot (ft) | meter (m) | 0.3048 |
| yard (yd) | meter (m) | 0.9144* |
| mile (mi) | kilometer (km) | 1.609 |
| mile, nautical (nmi) | kilometer (km) | 1.852* |
| | **Area** | |
| foot$^2$ (ft$^2$) | meter$^2$ (m$^2$) | 0.09290 |
| yard$^2$ (yd$^2$) | meter$^2$ (m$^2$) | 0.8361 |
| acre | meter$^2$ (m$^2$) | 4,047 |
| | hectometer$^2$ (hm$^2$) | 0.4047 |
| mile$^2$ (mi$^2$) | kilometer$^2$ (km$^2$) | 2.590 |
| | **Volume** | |
| inch$^3$ (in$^3$) | centimeter$^3$ (cm$^3$) | 16.39 |
| | decimeter$^3$ (dm$^3$) | 0.01639 |
| foot$^3$ (ft$^3$) | decimeter$^3$ (dm$^3$) | 28.32 |
| | meter$^3$ (m$^3$) | 0.02832 |
| yard$^3$ (yd$^3$) | meter$^3$ (m$^3$) | 0.7646 |
| pint (pt) | decimeter$^3$ (dm$^3$) | 0.4732 |
| quart (qt) | decimeter$^3$ (dm$^3$) | 0.9464 |
| gallon (gal) | decimeter$^3$ (dm$^3$) | 3.785 |
| | meter$^3$ (m$^3$) | 0.003785 |
| barrel (bbl), (petroleum, 1 bbl=42 gal) | meter$^3$ (m$^3$) | 0.1590 |
| acre-foot (acre-ft) | meter$^3$ (m$^3$) | 1,233 |
| | hectometer$^3$ (hm$^3$) | 0.001233 |
| mile$^3$ (mi$^3$) | kilometer$^3$ (km$^3$) | 4.168 |
| | **Volume per unit time (includes flow)** | |
| foot$^3$ per second (ft$^3$/s) | decimeter$^3$ per second (dm$^3$/s) | 28.32 |
| | meter$^3$ per second (m$^3$/s) | 0.02832 |
| gallon per minute (gal/min) | decimeter$^3$ per second (dm$^3$/s) | 0.06309 |
| | meter$^3$ per second (m$^3$/s) | 0.00006309 |
| barrel per day (bbl/d), (petroleum) | decimeter$^3$ per second (dm$^3$/s) | 0.001840 |
| | **Mass** | |
| ounce avoirdupois (oz avdp) | gram (g) | 28.35 |
| pound avoirdupois (lb avdp) | kilogram (kg) | 0.4536 |
| ton, short (2,000 lb) | megagram (Mg) | 0.9072 |
| ton, long (2,240 lb) | megagram (Mg) | 1.016 |
| | **Pressure** | |
| pound-force per inch$^2$ (lbf/in$^2$) | kilopascal (kPa) | 6.895 |
| atmosphere, standard (atm) | kilopascal (kPa) | 101.3 |
| bar | kilopascal (kPa) | 100.* |
| inch of mercury at 60°F (in Hg) | kilopascal (kPa) | 3.377 |
| | **Temperature** | |
| degree Fahrenheit (°F) | kelvin (K) | [3] |
| degree Fahrenheit (°F) | degree Celsius (°C) | [4] |

[3]Temp K=(temp °F+459.67)/1.8. [4]Temp °C=(temp °F−32)/1.8.

# SUGGESTIONS AS TO EXPRESSION

## Unity, Coherence, and Emphasis

A scientific report is an exposition of facts, inferences, conclusions, and, often, arguments and criticisms. The report should be clear enough that the reader cannot mistake its meaning, simple enough to be easily understood by the intended readership, and concise enough to avoid padding and needless repetition. Good exposition has unity, coherence, and emphasis. Unity comes from oneness and completeness in thought: A sentence may be simple, compound, or complex, but every word, phrase, or clause should help develop that one thought. Coherence means that words are understandably put together. Emphasis relates to proper stress.

Unity asks that you as a writer of scientific reports direct every sentence, paragraph, and chapter toward the stated subject of your report. Avoid paragraphs that are mere collections of sentences; ideally, each paragraph should have one central thought, and each sentence should lead toward that thought. Topic sentences are valuable aids to unity, both for the reader and for the writer. Topic sentences inform the reader that a new thought follows, and they help the writer adhere to that single thought. Besides using topic sentences, you can heighten interest and enhance comprehension without sacrificing unity by skillfully introducing variety into sentence length and phrasing.

Coherence requires that all parts of your report be logically arranged: Words, phrases, and clauses should lead the reader forward through sentences into paragraphs and through paragraphs into logical groupings under suitable topic headings and chapters. You can also gain coherence by ending statements with transitional words, phrases, or sentences that summarize what has been said and point toward what is to come. You can relate sentences or paragraphs to one another by repeating significant words or phrases used before. If a discussion is long, a brief transition paragraph will help you maintain coherence.

Emphasis can be gained through literary devices such as changes in voice, variety in sentence length and structure, and careful choice of words. Make the beginning and ending of a paragraph not so long or so complicated as to lose unity or so short as to lose coherence.

## Common Grammatical Problems

Because many excellent books on grammar are available in libraries and book stores, STA focuses mainly on grammatical problems that commonly have appeared in Survey manuscripts. Some problems recur over and over. Careful attention to grammar saves the time of authors, reviewers, and editors alike, but careless attention to the basic principles of grammar takes time from everyone.

### Problems With Sentence Structure

Two types of problems are common in structuring complete sentences: (1) Ending too soon—a sentence fragment—before a complete thought has been conveyed and (2) ending too late—a run-on sentence—after more than one idea has been expressed without the appropriate connectives of grammar and punctuation.

#### Sentence Fragments

A complete sentence must have at least one independent clause—that is, a group of words that contains a subject and a verb, stands by itself, and makes sense. "The sandstone is interbedded with shale" is an independent clause; ended with a period, it also is a sentence. If a word such as "although" is added at the beginning, the sentence is no longer independent: "Although the sandstone is interbedded with shale" is a sentence fragment that needs further qualification: "Although the sandstone is interbedded with shale, the shale is only a minor constituent of the formation." The "although" clause has become dependent; its meaning is incomplete until it is followed by a second, independent clause. Sentence fragments usually result from the addition of a qualifying word or words at the beginning of the clause; for example, "in which," "when," "to" plus a verb, or "if." Few Survey authors, of course, would compose a sentence fragment, but such fragments often appear inadvertently in manuscript revisions. To recognize one, ask yourself if the sentence element contains a subject, a verb, and a thought that can stand alone. If not, you have a sentence fragment.

### Run-On Sentences

At the opposite extreme from sentence fragments, and more common, are run-on sentences. These take two forms, comma splices and fused sentences. In the comma splice, two independent clauses are joined by a comma: "Another interesting study was by Stephanic (1981), his primary objective was to compare the geochemistry of the two types of deposits." Two independent clauses cannot be joined by a mere comma. A coordinating conjunction (and, but, or, for, nor, so, yet, still) must be added immediately after the comma, or the comma must be replaced by a semicolon or by a period and a capital letter. The comma-splice sentence in the preceding example becomes a fused run-on sentence simply by omitting the comma and running the ideas together. Correct the error by inserting a coordinating conjunction to compound the sentence, or replace the pronoun "his" by "whose" to make the second clause dependent on the first.

## Lack of Agreement Between Sentence Elements

In grammar, agreement involves singular or plural forms of two or more words that function together. Lack of agreement comes in two forms: (1) noun subjects that disagree with their verbs and (2) pronouns that disagree with their antecedents. Both forms diminish the quality of the writing.

### Subject/Verb Disagreements

Subject/verb disagreements flourish in complicated sentences. Few people would write "Mechanical problems *appears* to be a major reason for the poor data," because the singular verb "appears" next to the plural subject "problems" does violence to the ear. Intervening phrases between subject and verb, however, can trick the ear by placing distance between the two sentence elements. Thus, one author wrote, "Mechanical problems with the inclinometer *appears* to be a major reason for the poor data." The prepositional phrase, "with the inclinometer," and the singular form of the word "inclinometer" tricked the author into composing the disagreement.

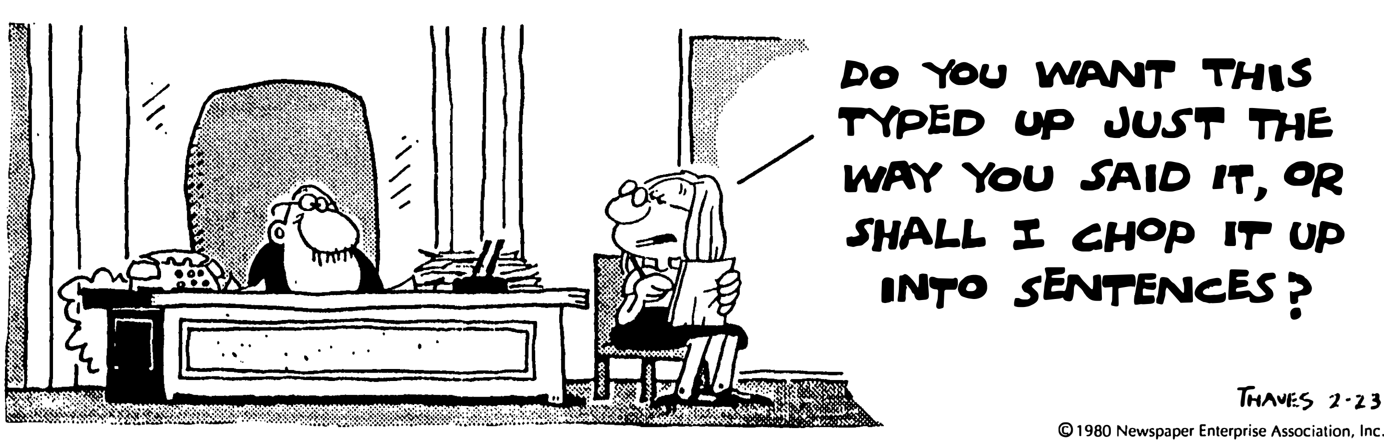
A second type of subject-verb disagreement involves compound singular subjects—the so-called 1 + 1 agreement problem. "The composition of each sample was examined carefully" would nearly always be written correctly, but if a second singular subject is added, the likelihood of error increases greatly, even for experienced writers: "The composition and texture of each sample *was* [were] examined carefully." Because each noun is singular, the writer took them to be one subject and was misled into using a singular verb. Remembering that $1+1=2$ may reinforce your perception of the need for a plural verb.

### Plural/Singular Verbs and Singular/Plural Predicate Nouns

This awkward problem of verb/noun agreement generally involves "is" or "are" as the principal verb, but it is easily remedied by (1) subordinating "is" or "are" to another verb, (2) substituting a stronger verb, or (3) changing the number (singular or plural) of one of the elements.

Delete words in italic; add those in brackets:

> This matrix is [made up] chiefly [of] microphenocrysts of plagioclase and hornblende. ("Consists" would be better than "is made up.")
>
> Eolian strata of the Weber *are* [compose] the chief petroleum reservoir.
>
> The red beds of the Catskill Formation are *a* North American counterpart[s] of the Old Red Sandstone.
>
> In some populated areas the uraniferous waters or the deposits themselves may *be* [present] a significant natural environmental hazard. (Or, delete "a" and pluralize "hazard" to make the verb and noun agree.)
>
> The Wasatch Mountains are a narrow upfaulted range. (Rewrite as, "The Wasatch Mountains are narrow and upfaulted," or substitute a transitive verb: "The Wasatch Mountains form a narrow, upfaulted range.")



The Dillon Mesa Tuff is crystal-poor rhyolite containing fine-grained phenocrysts that locally underlie the outflow Sapinero Mesa Tuff. (The "that" clause wrongly modifies "phenocrysts." Rewrite as "The Dillon Mesa Tuff, a crystal-poor rhyolite containing fine-grained phenocrysts, locally underlies the outflow Sapinero Mesa Tuff.")

Much of its extent is defined by a zone of faults and a well-marked fault scarp, which has been described in detail by Gilbert. (Inasmuch as both "zone of faults" and "well-defined fault scarp" are objects of the first preposition "by," the reader naturally connects the "which" clause to both of them. Just delete "which has been" and the preceding comma to clear up the difficulty.)

### Pronoun Disagreements

Pronouns are words that substitute for nouns; antecedents are those nouns. Pronouns that disagree with their antecedents appear in many manuscripts. The following sentence illustrates the problem: "Large-scale pyroclastic eruptions began about 49 m.y. ago; this included the activity that is represented by ash-flow tuffs at Surrey Ridge and in Long Valley." "Eruptions" is the antecedent of the pronoun "this." Because "eruptions" is plural, its substitute pronoun must be the plural form "these." Even the pronoun "these," used by itself as above, has a vague connotation; a clearer, more forceful phrasing would repeat "eruptions" in the clause "these eruptions included * * *."

### Problems With Collectives and Their Verbs

Certain nouns and pronouns called "collectives" may take either singular or plural verbs as predicates, depending on the meaning being conveyed. If the noun or pronoun is viewed collectively as a unit, its verb should be singular; if viewed as separate items, the verb should be plural. The following sentences are correct:

The number of men employed was greater in 1985.

A large number of the men were injured. ("Many men * * *" would be better.)

He thinks that 30 cents is a high price.

Three dimes were placed on the table.

About 3,000 tons was produced in 1934. ("About 3,000 tons" means a quantity weighing, in all, about 3,000 tons; it does not mean about 3,000 neat parcels each containing exactly a ton.)

At this place, 9 meters of sandstone is exposed.

A series of studies was begun. (Emphasis on "series.")

The United States protects its natural resources. (Although the term "United States" is treated as a plural in the Constitution, it is generally used elsewhere in the singular.)

"None" is singular when it means "no one," "no person," or "nobody." It is plural when it means "no persons" or "no things." "No one" may be substituted for "none" in some sentences to express the singular.

None of the mines were open.

None of the ore contains gold.

None were injured.

No one was injured. (Emphatic: Not one was injured.)

"Each" and "every" are usually singular in usage.

Each man will stand his post.

Every species is represented.

## ELIMINATING INDEFINITE ANTECEDENTS

The term "indefinite antecedent" refers to a phrasing in which the antecedent of the pronoun is ambiguous. In some such sentences the pronoun may vaguely represent two or more different nouns: "Bill's father left home when he was 6 years old." Consider the following example: "Close to the faults, however, the folds are tighter, the fold limbs are steeply dipping, and *they* display bedding-plane schistosity." Whether "they" refers to "folds" or "fold limbs" is unclear to anyone but the author, and even if an analysis of the context could clarify the meaning, the reader's train of thought has already been derailed. Change to, "Close to the faults, however, the folds are tighter, they display bedding-plane schistosity, and their limbs dip steeply." (See p. 165 regarding the use of the verb "display.")

Your familiarity as author with the subject matter makes the indefinite antecedent an easy pitfall. One of the commonest misused pronouns is the word "this," and its ambiguity in writing stems from author familiarity: "Low-grade regional metamorphism, folding, and thrust faulting affected the pre-Tertiary rocks during Jurassic and Cretaceous time. *This* ended with regional intrusion of granodioritic stocks and batholiths in the eastern part of the study area. To the north, *this* resulted in northeast-trending folds." The antecedent of "this" in these sentences is unclear. Although the sequence of events may have been clear to the author, the unsuspecting reader must try to puzzle out what the author meant; most readers will just shrug and move on. Whenever the word "this" appears in a manuscript, ask yourself, "This what?" If the answer is unclear, you as author or reviewer should add the appropriate noun, or recast the sentence.

"Some" is another word to watch. If "some" is intended as a pronoun but has no clear antecedent, the reader may take it to be an adjective modifying the word that follows, and the result can be ambiguous.

> Since no one wants a high-level nuclear waste dump, some doubt that a compromise can be reached.

The above statement can be read as a sentence fragment, with "some" serving as an adjective modifying "doubt." To clear up the ambiguity, the writer should subordinate "some" to a noun such as "people." Then the sentence would make sense: "* * * some people doubt that * * *." (Also, "Because" would be a better starter word than "Since.")

## MODIFIERS

Sentences should be written with an eye to the best placement of modifying words and phrases. The subject, predicate, and object shape the framework of the sentence; the modifiers—adjectives, adverbs, participles, and descriptive phrases and clauses—add detail and meaning. In using modifiers, carefully choose the best words available to express your meanings and carefully put them in the most appropriate places. For clarity, put them as close as possible to the words they modify, and remember that the most emphatic positions in a sentence are at the beginning and end.

In the following sentence, the modifying phrases are right after the nouns they modify: "Removal of salt by extrusion, solution, or lateral flowage partly destroyed these folds, either by causing collapse along faults or by causing general subsidence." Note that the emphasis is at the beginning on "removal of salt." The phrase "by extrusion, solution, or lateral flowage" has a position of lesser importance. Placing "general subsidence" at the end gives it emphasis also.

Writers are often exhorted to use "exact" words to express their meanings, but few words really have "exact" meanings. Even some of the commonest words need a full column of 6-point type just to explain their dictionary definitions; to have exact meanings, words must be used skillfully in relation to one another. To choose appropriate modifying words and phrases, you need access to a good dictionary, to relevant glossaries and lexicons, and to any of the many good word-use books available in the library or marketplace.

### Misplaced Modifiers

Misplaced modifiers sometimes provide unintended comic relief. A newspaper caption explained that a nanny-in-training was "feeding and diapering a baby with educational toys." A list of unusual explanations given to a life insurance company by accident claimants included "I had been driving my car for 40 years when I fell asleep at the wheel and had the accident," and "I was on my way to the doctor's with rear end trouble when my universal joint gave way causing me to have an accident." Laugh, but do not cast the first stone. Geoscience writing, of course, hardly ever contains misplaced phrases, but when it does, the result is more often pathetic than laughable: "The samples were preserved for analysis in a paraffin-sealed flask." "Remnants correlated with this pediment are plentiful in the southern part of the San Juan Basin, according to Parker, lying 90–120 m below the Scottsville erosion surface and 30–60 m above modern drainage." "The howling of coyotes is often heard by field personnel, as these animals frequently stray into the area." "Because of its huge size, oceanographic information is inadequate in many places."

Errors of modification are common in everyday oral and written language. Ask yourself if phrases are really next to what you intend them to modify and if they do in fact modify the appropriate subject. Pay particular attention to beginnings and endings of sentences, where misplaced (and dangling) modifiers are most likely to be. The proper placement of phrases within the context of a sentence must be a conscious decision. Modifiers belong next to the words they modify. Consider the following sentence:

**Misplaced modifier.** Example 1:

> We also present a plausible model for the origin of the ore deposits at the Sun Valley mine, Pitkin County, Colo., which until now has lacked a satisfactory explanation.

Because the phrase beginning with "which" is placed immediately after "Colorado," this sentence must be taken to say that either the Sun Valley mine, or Colorado, lacked a satisfactory explanation until now. "Which" clauses are often appended to sentences as added inspiration when the creative juices are flowing, but they sometimes end up in the wrong place. The intended meaning could be clarified in several ways. Two possibilities follow:

> **Suggested alternative 1:** We also present the first plausible model for the origin of the ore deposits at the Sun Valley mine, Pitkin County, Colo.

**Suggested alternative 2:** We also present a plausible model for the origin of the ore deposits at the Sun Valley mine, Pitkin County, Colo. No one had previously studied the origin of the deposits.

Notice that in the second alternative we gained additional information, with little increase in length over the original version.

**Misplaced modifier.** Example 2:

Because they are highly sensitive to changes of temperature and salinity, paleontologists use them as indicators of the environment that was present when they died.

Recast the above sentence yourself to straighten out the antecedents and put the paleontologists in their proper place. Then, try this one from "The New Yorker": "At the Battle of Antietam a careless Confederate officer used a piece of paper containing General Lee's orders to wrap his cigars."

## Dangling Modifiers

Dangling modifiers differ from misplaced modifiers, not in their placement in the sentence but in having no antecedent to modify. They have no real grammatical relationship to the sentence, despite the intentions of their authors. Two examples illustrate the problem:

**Dangling modifier.** Example 1:

By comparing the fence diagram with the resistivity log profiles in figure 5, it is evident that injected freshwater is most efficiently transmitted through the highly permeable zones.

If you write an "-ing" phrase like this one, ask yourself who is doing the comparing. According to the phrasing in example 1, "it" is making the comparison, but "it" (an indefinite pronoun) is incapable of comparison, so the initial phrase dangles. This sentence can be revised either to eliminate the need for a subject of the modifying phrase or to add the appropriate subject.

**Suggested alternative 1:** A comparison of the fence diagram with the resistivity log profiles in figure 5 shows that injected freshwater is transmitted most efficiently through the highly permeable zones.

**Suggested alternative 2:** By comparing the fence diagram with the resistivity log profiles in figure 5, we learned that injected freshwater is transmitted most efficiently through the highly permeable zones.

**Dangling modifier.** Example 2:

As a field investigator working in the Desert Southwest, your paraphernalia should include two pairs of stout leather boots.

("As a field investigator" is an unintended modifier of the subject, "paraphernalia.")

**Suggested alternative:** As a field investigator working in the Desert Southwest, you should include two pairs of stout leather boots in your paraphernalia.

Here is a parallel to example 2: "As a first impression, the Sparks fault appears to have moved more than once." And one more: "As a baboon who grew up wild in the jungle, I realized that Wiki has special nutritional needs."

Even careful writers are sometimes trapped by dangling modifiers, especially by participles. A few more examples and their remedies may be helpful; correct the errors by inserting the missing words modified or by restructuring the sentences. Delete the words in italic; add those in brackets.

On closer inspection, chattermarks were observed. (Write, "Closer inspection showed chattermarks.")

Going seaward the boulders became smaller. (Just delete "Going" and change "became" to "were."

The [roughly tabular] western part of the ore body *has a roughly tabular shape dipping* [dips] southeast.

*Judging from* the dip of the tuff [indicates that] a small hill has been buried here.

None of the old openings are accessible, but *judging from* material on the dumps [indicates that] the ore was massive magnetite.

*Going downward* the till *becomes* [is] less oxidized [at depth].

Crossing to the other side, the peak came into full view. (The peak didn't cross to the other side, the viewer did. Try, "From the other side, the peak is in full view.")

And one from a morning paper:

On his way home, Bill was mugged, robbed, and left for dead. Going to work the next morning, he was found by a lady lying in a snowbank.

## Other Misplaced Words and Phrases

Try to keep related words and phrases together. Watch out for misplaced adverbs and adverbial phrases, especially "only," "principally," "mainly," "chiefly," "alone," "also," and "too." In the following sentences, delete the words in italic and add the words in brackets:

Their presence can *only* be determined [only] by tests.

The sediments were [derived] principally *derived* from quartzite. (Sentence is strengthened by not splitting the verb.)

In the following statement it is not clear which part of the sentence "when the time came" modifies:

> I told him when the time came I would do it. (Write, "When the time came, I told him I would do it," or "I told him I would do it when the time came," according to the meaning intended.)

The sentence, "They suspended operations as the weather became colder and moved south," says that the weather moved south. Write, "As the weather became colder, they suspended operations and moved south," or "they suspended operations and moved south as the weather became colder."

Prepositional phrases also may be misplaced, as in the following examples:

> *Under such conditions* it is easy to see that the commercial development of these deposits [under such conditions] * * *.

> *In Indiana* writers have classified the rocks [in Indiana] as Utica or Eden.

> *On level 2* it is reported that considerable realgar and orpiment were found [on level 2].

> Fossils [from Indiana] were described *from Indiana.*

> *From the ice* water overloaded with glacial debris discharged westward [from the ice]. (Inserting a comma after "ice" is not a good remedy for poor construction.)

Adjectival expressions are misplaced occasionally or are misused for adverbs as well as misplaced.

> *A careful sample of* this rock was [carefully sampled] *taken* for chemical analysis.

> The granite was intruded during the *great* period of [great] structural deformation.

> Leaves [little] room for *little* doubt.

> The *luxuriant* gray green of the [luxuriant] sagebrush.

> *Tilted* edges of [tilted] sandstone strata.

> The *most prevalent* region of [most prevalent] cloudbursts.

> A [dark] coarsely porphyritic rock of *dark* granular texture. (It is the rock, not the texture, that is dark.)

> Two altered thin vitreous tuff beds. (Change to read "two thin beds of altered vitreous tuff.")

The sentence "There is a band of coarsely crystalline limestone carrying bunches of garnet-pyrite rock from place to place" presents an absurd picture. Better write, "A layer of coarsely crystalline limestone contains sporadic [or scattered] bunches of garnet-pyrite rock." Note that "layer" replaces "band," which refers simply to the visible edge of a layer.

The statement "Care should be taken to see whether such wells are contaminated by frequent analysis" slanders the analyst. Change to, "Analyze the water frequently to see if such wells are contaminated."

In general a phrase that applies equally to two or more items should follow the first item, not the last. Don't keep the reader in suspense:

> * * * mountainous in the western part [of the quadrangle] and level in the eastern part *of the quadrangle.*

> The thickness ranges from 215 meters at the east side [of the area] to perhaps 500 meters at the west side *of the area.*

> The upper coal bed is as thick [as the lower bed], if not thicker *than the lower.*

### Dangling Non Sequiturs

Dangling non sequiturs are phrases out of context but meant to be modifiers; most of them are participles. They have no logical relationship to what they are attached:

> Formerly mined in southern Greenland, cryolite occurs in limited quantity near Pikes Peak, El Paso County, Colorado.

> Much of it is perfectly transparent, the oval grains being a half a centimeter in diameter.

> Douglas-fir grows between altitudes of 2,000–2,400 meters, the individuals averaging 40–50 centimeters in diameter.

> Born in Schenectady, she graduated with honors from Boston University.

> The discharge of the spring is about 8 gallons a minute, its temperature being 90°F.

> Home of the Air Force Academy, Colorado Springs received 17 centimeters of rain in less than 5 hours.

### Troublesome Participles

In many sentences a participle can be replaced by a restrictive relative clause to gain emphasis. Delete words in italic:

> A gravel-floored plain *sloping* [that slopes] gently toward the southeast * * *.

> All thick coal beds *cropping out* [that crop out] in this field * * *.

Other improvements involving participles are indicated as follows. Delete words in italic:

> They are therefore regarded as *being* of the same geologic age.

> The basal formation of the group here *occurs resting* [rests] upon the Tejon Formation.

These dikes *were found cutting* [cut both] the granitic rocks and *were noted cutting* the aplite dikes.

Remnants of quartzite *occur perched along* [cap] the crest of the ridge.

The cliff *rises facing* [faces] the river.

## Uncoordinated Sentence Elements

Clauses within sentences are normally joined by conjunctions or by various forms of punctuation. Independent clauses are joined by coordinating conjunctions (*and*, *but*, *for*, *or*), which are words that connect equal or coordinate elements. A dependent clause linked to an independent clause should be joined by a subordinating conjunction (such as *after*, *although*, *because*, *unless*, *when*, and *whereas*). A clause that amplifies or restricts the meaning of another clause should be introduced by an adverbial conjunction (for example, *consequently*, *however*, *nevertheless*, *therefore*, and *thus*). Selecting the appropriate conjunction depends on the intended meaning. A coordinating conjunction should be used only between clauses of equal importance; if one clause is more important, the other should be introduced by a subordinating conjunction. If two clauses contain equally important information but are not simple equivalents, one of the clauses should begin with an adverbial conjunction. The following examples should help clarify these distinctions:

**Faulty coordination:** The formation exhibits characteristics suggestive of a fluvial environment, and it is red.

The color of the formation in this example is not coordinate with the depositional environment. Eliminate the second clause by incorporating the information into the first clause or by changing the second clause into a parenthetical phrase. (Also, the verb "exhibits" is a bit overblown for characteristics that merely suggest.)

**Suggested alternative:** The formation, which is red, has characteristics that suggest fluvial deposition.

The revised sentence contains the same information, but its emphasis is stronger.

Misused conjunctions may confuse the intention of the sentence. In the next example, the idea that the two clauses present equivalent pieces of information is incorrect:

**Faulty coordination:** Zircon is the only original rock constituent that remains stable throughout the cycle of alunite alteration, and biotite and Fe-oxide minerals are pseudomorphed by $TiO_2$.

These two clauses present noncoordinate ideas; the implied contrast between the two pieces of information would be expressed better by substituting the adverbial conjunction "whereas" for "and" or by just dropping the "and" and starting a new sentence with "biotite."

## Incomplete Comparisons

If a sentence attempts to compare two incomparable things, the resulting grammatical problem is called an incomplete comparison. The problem is common because the true nature of the comparison seems obvious to the writer. Consider the following sentence:

**Faulty comparison:** The producing wells in this part of the basin are similar to the Williston Basin.

The writer's intention of comparing wells in one basin with wells in another basin has been ineptly compressed.

**Suggested alternative:** Producing wells in this part of the basin are similar to those (*or* * * * are similar to wells * * *) in the Williston Basin.

Incomplete comparisons are also illustrated by the following sentences: "The average dip of the Lyons Sandstone is less than the Pierre Shale." (One dip can be compared with another, but not with a formation.) "No density measurements were made of the south slide; however, prefailure density should have been about the same as the north slide." (Density cannot be compared to a landslide.) In making any comparison, be sure that the structure of the sentence leads to a comparison of like things.

## Problems With Poorly Chosen Adverbs, Prepositions, and Infinitives

### Adverbs

An adverb is a word that modifies a verb, an adjective, or another adverb. Many of them end with "ly" (nearly, hardly, largely, poorly, usually). Adverbs are easily misused, particularly the common adverb "where." "Where" should relate to the idea of place, but it is often used incorrectly for "when." Some writers use "where" for "on which," "in which," or "for which."

**Faulty choice of "where":** Where a number of ponds in a landslide seem to have been formed at about the same time, such a date might represent a time of significant slide movement.

Here the word "where" was inaccurately intended to connote time; change it to "when."

**Suggested alternative:** When several ponds on a landslide apparently formed at about the same time, the date of their formation might have been a time of significant slide movement. (Better yet, change "when" to "if.")

### Prepositions

Prepositions, like adverbs, make for fuzzy writing if used carelessly. Commonly confused prepositions include "with," "of," "for," "from," and "in." "With," misused as a conjunction, troubles many writers who have little difficulty with most other prepositions. In the following example "with" inaccurately connects "environment" to "movements":

> Deposition of the upper San Rafael Group in northwest New Mexico took place in a quiescent environment *with* only broad regional movements.
>
> **Possible alternative:** Deposition of the upper San Rafael Group in northwest New Mexico took place in a quiescent environment during a time of broad regional movements.

For a better rewrite, get rid of "deposition", "took place," "a time," and the prepositions "of" and "in." Recast as follows:

> The upper San Rafael Group accumulated quietly in northwest New Mexico during broad regional movements.

"With" is also often taken to mean "and" or "but" plus "having" or "using." In the following sentence, "with" wrongly takes the place of the conjunction "and":

> The faults have been indurated and tilted, with some slight folding. Change to: The rocks have been indurated, tilted, and slightly folded.

In the following sentence, "with" is used improperly to qualify the water's clarity: "The water is very clear *with* a faint bluish tinge." Change to: "The water is very clear but has a faint bluish tinge." ("But has" suggests a limitation on clarity not conveyed by "with.")

"With" may also trick you into wordiness and faulty logic:

> The top of the mountain is flat *with* a smooth descent to the west. (The top cannot descend.) Change to: The flat-topped mountain slopes smoothly west.

Further indiscretions with "with":

| Change this | To this |
|---|---|
| The mechanic advised the man with the broken cylinder head to report it to the company's regional office. | The mechanic advised the man to report the broken cylinder head to the company's regional office. |
| The surface of the bedrock is fairly even with depressions representing temporary channels of the shifting creek. | The surface of the bedrock is fairly even but contains depressions * * *. |
| A fine-grained rock with blotches of bright pink color * * *. | A fine-grained rock blotched with bright pink * * *. |
| The conglomerate pebbles are well rounded with a very loose cement. | The conglomerate pebbles are well rounded and loosely cemented. |
| He discusses the geology of the county with descriptions of 19 mining districts. | He discusses the geology of the county and of 19 mining districts within it. |

You should be aware that "without" may be as misused as "with." If you find "with" or "without" in your writing, doublecheck to make sure you should not be using a conjunction instead.

### Prepositions Doubled Up

The use of a preposition following a verb to express an idea that can be conveyed by some other verb alone may lead to the undesirable doubling of prepositions. Examples of undesirable doubling and tripling of prepositions follow:

> The conditions *met with* [observed, confronted] in the field * * *.
>
> A large production is not *to be looked for* [expected] from these deposits.
>
> A thickness of *from* 1 to 2 meters * * *.
>
> An estimate of the cost of *operation of* [operating] the filter * * *. (In most such phrases, a noun ending in "tion," and the "of" following it, should be replaced by a gerund as in the preceding example.)
>
> Following the discovery of the character of this deposit * * *. (Write, "After the character of this deposit was discovered * * *.")
>
> Each of the veins has been drifted on for from 15 to 20 meters. (Write, "Drifts have been run 15 to 20 meters along each vein.")

### Infinitives

Writers trying to express ideas succinctly occasionally misuse infinitives ("to" plus a verb): "A Grand Junction man was killed this morning to raise the traffic toll for the year to 273." Newspaper journalists face the intense pressure of daily deadlines, but Survey writers lack such excuses:

> He hiked all day only to learn that he was on the wrong ridge. (Write, "He hiked all day before learning that * * *.")

> An eruption of Mount St. Helens *occurred* this morning *to blanket all of* [blanketed] the northwestern United States with ash. (Note that "occurred" and "all of" in the previous sentence are superfluous.)

And a heading dredged up by Robert L. Bates of "Geotimes":

> Portrait of First President to Hang at Association Headquarters.

## EFFECTIVE PUNCTUATION

Try to imagine a written communication without punctuation. Punctuation clarifies communication by conveying to the reader the stops and stress points intended by the writer. A good writer uses punctuation for the same purpose that a good speaker uses gestures, facial expressions, voice tone, and inflections. Points of law have been decided on the placement of a comma.

Frank C. Calkins, a long-time Survey geologist who had a penchant for improving the writing of others, once expressed the relationship of punctuation to cadence as the musiclike quality that gives writing balance and flow. The cadence a musician creates through the use of eighth, quarter, half, and whole rests is analogous to a writer's artful use of commas, semicolons, colons, periods, dashes, and parentheses. The cadence of the sentence controls accent and timing, which together influence the reader's understanding. Effective punctuation clarifies writing; ineffective punctuation clouds it.

Punctuation is purely functional; it clarifies writing by (1) grouping related words, (2) separating unrelated words, (3) enclosing parenthetical words, and (4) emphasizing important words. The Survey's attitude toward punctuation is based on the principle that if punctuation does not clarify the text it should be omitted and that the sole aim of punctuation marks should be to clarify the author's thoughts (U.S. GPO Style Manual, 1984, p. 117). If a sentence cannot be so punctuated as to make the author's thoughts clear, the sentence probably needs to be rephrased.

### THE COMMA

Commas mark brief pauses in the flow of ideas, like quarter rests in music. Needless commas break the flow and rhythm of the sentence, but commas missing where needed cause ambiguity or misunderstanding.

Some guidelines:

1. After any introductory phrase or clause, a comma is needed if its absence forces the reader to back up and reread the sentence to understand the intended meaning:

| **Change this** | **To this** |
|---|---|
| During periods of intense rain water from the claypit flows through this ranch. | During periods of intense rain, water from the claypit flows through this ranch. |
| Where data are inaccurate or insufficient results deviate from what is expected. | Where data are inaccurate or insufficient, results deviate from what is expected. |
| After cooling the sample is reweighed and ground to 80 mesh. | After cooling, the sample is reweighed and ground to 80 mesh. |

2. An introductory participial phrase should be set off by a comma:

> Spreading toward natural and manmade depressions, the sediments settled in stream valleys, drainage ditches, borrow pits, and lakes.
>
> Deflected by natural obstructions, the lava stream turned eastward.

3. Commas are required between the parallel words, phrases, or clauses of a series:

> The deposit consists of clay, sand, and gravel.
>
> The upper coal is 53 cm thick, the parting 30 cm, and the lower coal 46 cm.

Some writers mistakenly assume that the comma before the final "and" is unneeded because the "and" signals the end of the series, but this notion can cause trouble, especially in technical writing, as follows:

> The complex consists of three conformable, well-layered units of gabbro, diorite and granodiorite and granophyre.

Without another comma this sentence lacks clarity. The units could be (1) gabbro, (2) diorite, and (3) granodiorite and granophyre, or they could be (1) gabbro, (2) diorite and granodiorite, and (3) granophyre. A comma placed before the proper "and" removes the ambiguity.

If members of a series contain commas, a semicolon between the members may be needed for clarity:

> The order of deposition was quartz and pyrite; massive galena, sphalerite, and pyrite; brown carbonates and quartz; and small amounts of all those named, together with fluorite, barite, calcite, and kaolin.

4. Commas are needed between two or more adjectives of equal rank (parallel, or coordinate, adjectives) that precede the word(s) modified. (If "and" can be inserted between the adjectives or

if their order can be reversed with no change in meaning, the adjectives are parallel and should be separated by a comma.)

| **Parallel** | **Nonparallel** |
|---|---|
| hard, impermeable subsoil | hard clay subsoil |
| a brief, interesting account | a brief typewritten account |
| short, swift streams | short tributary streams |
| long, tedious spell of dry weather | long dry spell |
| freezing, driving rains | heavy spring rains |
| perceptible, strong ground motion | strong lateral ground motion |
| silty, clayey sand | yellowish-gray clayey sand |

5. Parenthetical words, phrases, and clauses are usually set off by commas.

   Parentheses or dashes may be used to indicate stronger, longer, or more abrupt breaks in thought. Parentheses within parentheses should be avoided.

   Identical punctuation marks are needed on both sides of the parenthetical expression, unless the expression is at the end of the sentence: two commas, for instance, or two dashes—not a single comma or a comma and a dash.

| **Change this** | **To this** |
|---|---|
| Several individual flows, each thicker than 25 meters have been traced for more than 160 kilometers. | Several individual flows, each thicker than 25 meters, have been traced for more than 160 kilometers. |
| The President, in his energy message to the Congress recommended that this program go forward. | The President, in his energy message to the Congress, recommended that this program go forward. |

   Expressions introduced by "together with," "as well as," and "in addition to" are parenthetical and should be set off by commas.

   Commas are needed between more than two items of run-in numbered or lettered series:

   Damage resulted from (1) vibration, (2) ground cracking, (3) subsidence, and (4) sea waves.

6. The independent clauses of a compound sentence may or may not need separation by commas, or semicolons, depending on their length and complexity:

   **Without:** Where the drainage went is problematical but it almost certainly turned west.

   **With:** A south-flowing course toward the White River looks plausible on a planimetric map, but geomorphic evidence is against it.

   But: The coordinate conjunctions "for" and "as" need a preceding comma to avoid being read as prepositions. If "because" is used instead of "for" or "as," the comma may not be needed.

| **Change this** | **To this** |
|---|---|
| The arching of the deck probably pulled the piling upward for the connections between the stringers and the piles were strong. | The arching of the deck probably pulled the piling upward, for the connections between the stringers and the piles were strong. Or: The arching of the deck probably pulled the piling upward because the connections * * *. |

7. No punctuation is needed after items in a vertical list, whether numbered or unnumbered, unless the items are complete sentences or clauses:

   During our trip we saw many interesting sights:
   Washington Monument
   Statue of Liberty
   Mount Vernon
   Natural Bridge
   Lee's birthplace
   Shenandoah Valley

   But:

$$P = \tfrac{1}{2}\gamma H^2 Kp$$

   where
   $P$ is force per horizontal foot of bulkhead,
   $\gamma$ the unit weight,
   $H$ the height along the bulkhead,
   and
   $Kp$ the passive pressure coefficient.

8. A comma is needed between an adjective and an adverb modifying another adjective or a participle:

   Standard, nationally recognized units of measure * * *.

9. A secondary clause beginning with "so," "then," or "yet" may need separating punctuation, and a comma may suffice.

   Field relations indicate divergent geomorphic histories for the two formations, yet over broad areas they are nearly coextensive.

10. Survey style specifies the following uses or omissions of commas in relation to dates, names, places, and numbers:

   Wilmington, Del., was the site of the convention.

   July 4, 1776, was the date.

   July 1776 was the time.

The river flooded in June and July 1975.

The river flooded between March 6 and April 15, 1975.

The address of the U.S. Geological Survey's National Center is 12201 Sunrise Valley Drive, Reston, VA 22092.

Water-Supply Paper 2022, page 2632 (this usage applies to all serial numbers); *but,*

2,632 pages, 92,485 kilometers

Henry Smith, Jr., chairman; John Smith II

11. An unneeded or a misplaced comma is as confusing as an omitted one. Commas should not separate a subject from its verb, a verb from its object, a preposition from its object, or an adjective from its noun. (A parenthetical expression is not considered to be a grammatical separation.) The comma in the following sentence separates a subject and its verb:

    A national program aimed at reducing hazards to life and property and at minimizing disruption of governmental and private activities, is spelled out in a newly published report. (Either insert a comma after "program" or delete the comma after "activities.")

    Compound predicates and compound complementary infinitives, each consisting of no more than two elements, generally need no commas. The commas in the following sentences should be omitted:

    The Center staff also provides assistance to users, and conducts training courses in remote sensing.

    The final statement was filed with the Council of Environmental Quality, and was made available to the public in June.

    Scientific personnel are available to answer queries, and to explain how the Survey conducts mapping investigations.

12. A comma may be used to prevent a misreading or to add emphasis. This rule provides the flexibility authors may need to occasionally sidestep the previous rules, as below:

    The movements of the shorelines were affected by sedimentation and subsidence, and were preserved as transgressive/regressive cycles.

    Dependent clauses are not normally preceded by commas, but because the preceding sentence contains an "and" before and after "subsidence," the comma after "subsidence" aids readability. In effect, the second clause then becomes a parenthetical add-on at the end of the sentence. This rationale does not mean that the rules should be violated on whim, but it does suggest that the rules may be bent to enhance clarity.

## The Semicolon

Returning to Calkins' musical analogy, you can equate the semicolon with the half rest; it demands a longer pause than the comma. Use it, therefore, when you want a more significant stop than a comma, or when the comma is already serving a lower level function. Rules for the use of semicolons thus dovetail with rules for the use of commas. The first rule applies to punctuating a series:

1. Use a semicolon to separate items in a series if individual items already contain commas:

    Much of the unit is red, pink, or gray; medium to coarse grained; and equigranular or slightly porphyritic.

    The first items of the series, "red, pink, or gray" are separated by commas. If you also used a comma to separate "gray" from "medium," the relationship between those elements would be confusing. Note also that once the need for the semicolon is dictated by internal commas, you must use semicolons in parallel fashion throughout the series—even if no other elements contain commas. If the sentence becomes unwieldy, it might be grasped more easily if written as follows: "Much of the unit is (1) red, pink, or gray, (2) medium to coarse grained, and (3) equigranular or slightly porphyritic."

2. Use a semicolon to separate two independent clauses not joined by a coordinate conjunction:

    Only tungsten and tin are sufficiently concentrated to be potential resources; other elements shown in figures 4–6 are possible "pathfinder" elements for exploring other prospects.

    In the above construction, the semicolon links two closely related but complete thoughts. The closer the link, the better it is to keep the ideas within the same sentence structure—joined, that is, by a semicolon instead of a period. A comma-splice run-on sentence, which is a mild illiteracy, would result if a comma were used in this construction.

3. Use a semicolon to separate two independent clauses joined by a coordinate conjunction if either of the clauses contains at least two commas. As in a series, the commas are already serving one function (here, marking pauses within a clause);

the semicolon, therefore, must serve a function normally assigned to the comma:

> In some populated areas, such as the Lake Tahoe Basin or the Colorado Front Range, the uraniferous waters or the deposits themselves may be significant natural environmental hazards; and further study is needed to determine the severity of the problem.

The nonrestrictive phrase starting with "such as," set off by the required pair of commas, dictates the need for the semicolon before the conjunction "and." The same rule would apply if the two commas were in the second clause. If you are uncomfortable with this use of the semicolon—and many writers are—you may avoid it by simply eliminating the coordinate conjunction "and" (rule 2) or by putting a period after "hazards" and beginning a new sentence with "further."

4. Use a semicolon before adverbial conjunctions that begin a second or subsequent clauses.
   These are the more common adverbial conjuctions:

| | |
|---|---|
| accordingly | moreover |
| besides | nevertheless |
| consequently | still |
| furthermore | therefore |
| hence | thus |
| however | |

> In-place rock was sampled whenever possible; however, most plugs were taken from cores or from boulders around quarries or construction-site borrow pits.

Note that "however" is preceded by a semicolon and followed by a comma; this punctuation is standard treatment for adverbial conjunctions. If a comma were used to splice this sentence together, a run-on sentence would result. The clue to avoiding the problem is in recognizing adverbial conjunctions. Rather than joining two clauses in a coordinate fashion, the adverbial conjunction both links and modifies.

Because "however" is used widely as an adverbial conjunction in technical reports, its use as a standard adverb also needs mention. So used, it is treated like any other nonrestrictive element:

> In-place rock was sampled whenever possible; most plugs, however, were taken from cores or from boulders around quarries or construction-site borrow pits.

In these two examples, the key difference in the use of "however" is its function in the sentence: As an adverbial conjunction, it introduces a new clause; as an adverb, it qualifies a statement being made within a clause. The second example reads more smoothly than the first, because "however" follows rather than precedes the subject it qualifies, "most plugs." The sentence would be even smoother, though less arresting, if "but" were used instead of "however," as a simple coordinating conjunction:

> In-place rock was sampled *whenever* [wherever] possible, but most plugs were taken from cores or from boulders around quarries * * *. (Note the substitution of "wherever," signifying place, for "whenever," signifying time.)

5. Words and phrases such as "for example," "that is," and "namely," which introduce an enumeration or explanation, are preceded by a semicolon and followed by a comma:

> Simple physical and mathematical modeling is useful in investigating the general characteristics of a broad class of geothermal systems; for example, vapor-dominated or hot-water systems.

This construction is least disruptive at the end of a sentence. If the context requires that it be embedded within the sentence, setting it off in dashes or parentheses is better than the punctuation just described.

## The Period

Periods are used after letters or numbers denoting items in vertical series, after abbreviations unless otherwise specified, in decimals, and after the captions of text illustrations, but not after titles or subtitles. Write: SW1/4 sec. 13, T. 2 S., R. 23 E.; N. 40° W., 35° SE. The period provides a more emphatic stop than either the comma or the semicolon. It indicates that an idea is complete. Any writer who recognizes a complete statement uses the period quite naturally, but if its proper use is in doubt, see discussion of "Sentence Fragments" and "Run-On Sentences."

## The Exclamation Point

The exclamation point is rarely used in technical writing (and practically never in Survey reports). Its use there tends to irritate the reader and suggests a certain immaturity on the part of the writer. Technical subject matter, moreover, does not lend itself to such emphasis, and even if it did, the use of the exclamation point is a bit histrionic for the objectives and style of technical writing. Emphasis is better gained through effective rhetoric. In a popular publication directed to a nontechnical readership, its use might rarely be justified, but its effectiveness is related to its not being overdone. An exclamation point must convey great emotion, anguish, force, excitement, or stress; for example, "Please be careful!" "No, not now!" "Help!" "Yes, yes!" and "The volcano is erupting!" Even to convey heightened emotion, the slight understatement of a period may express the poignancy more effectively: "When one experiences a storm like this and sees the consequences, exaggeration is difficult—and pointless." If the words themselves suffice to show the tone, the exclamation point is not called for (Fowler, 1965, p. 590).

## The Colon

The colon is a handy punctuation mark because it tells the reader that a statement just read will be amplified immediately after the colon. This function, discussed in rule 1 below, is the most common use of the colon.

1. The colon is used after an introductory statement that conveys the idea that something is to follow.

   > The following is a list of observations summarizing the laboratory results:
   >
   > I regard the two surfaces as one, displaced by faulting, for the following reasons:

   In the above examples a period would be an acceptable substitute, but the colon makes the connection more precise and more emphatic: The reader is thereby prepared for the "list of observations" and the "following reasons."

   If the statement that precedes the colon is incomplete, the colon is generally inappropriate: Either the statement must be finished, or the colon must not be used. Rare exceptions seldom appear in technical reports, but here is an example: "Gold and silver: That's what won the West!"

   But do avoid the following trap: "Factors controlling distribution of stromatolites are: total quantity of sediment, rate of sediment movement, and wave action." Here the colon is unneeded and incorrect because the clause before the colon is an incomplete thought.

2. A colon can be used to separate two independent clauses, the second of which amplifies the first. In this usage, a colon functions in the same way as a dash—it is no more correct than a semicolon or a period, but it more precisely defines the connection between the two independent clauses. The first word following the colon is not capitalized if the matter following it is merely a supplementary remark made to clarify the meaning, as follows:

   > Contact relations within the complex indicate that the granodiorite was the last intrusive phase: it cuts the diorite and tonalite.

   Here the colon clearly signals that what follows will prove that the granodiorite was the last intrusive rock. Although the colon is not required, it is informative. If the statement following the colon is a grammatically complete sentence that can stand alone, many American writers will capitalize the first word.

3. A colon is used after the introduction to a long quotation. Long quotations have minimal use in technical writing, but when one is repeated, the colon is appropriate.

## The Dash

The dash is an emphatic and versatile punctuation mark, but it should be used with restraint. Overuse dilutes its effectiveness and even antagonizes some readers—there are those who love it and those who do not—but when not overdone, its use can be very effective.

The dash and the colon are often used interchangeably—some writers use the dash when, in fact, the colon is more apt. The dash, however, does have three major uses. The first is most common in technical writing:

1. A pair of dashes is used to emphasize a nonrestrictive phrase or clause. In this construction, paired dashes replace the paired commas that would be standard usage. Keep in mind that the information enclosed by the dashes will receive particular attention from the reader. The following example shows how these dashes might be used:

   > Another attribute of the Mowry Shale—a diagnostic one, and an unmistakable clue to the identity of the formation—is the presence of countless well-preserved fish scales found with little effort on nearly every outcrop.

   Use of dashes allows two major ideas to be conveyed in the above sentence—both what the attribute is and the writer's perception of its significance. The result is a sentence that is strong and effective.

   In other examples, the dash is justified by the context of the sentence. If several commas are used in more than one function, the dash may prevent misreading:

| Change this | To this |
|---|---|
| There are shore deposits, gravel, sand, and clay, but marine sediments underlie them. | There are shore deposits—gravel, sand, and clay—but marine sediments underlie them. |

On first reading, "shore deposits" appears to be the first of a series of four items; the reader must reread the sentence to recognize that the final three items are a subset of the first. Although "gravel, sand, and clay" do not require emphasis in this sentence, this construction both emphasizes and clarifies the relationship between the ideas. Parentheses could have been used, but they would have deemphasized the enclosed matter.

2. The dash is used before a word that sums up a preceding series. This use of the dash parallels the second use of the colon: It is an artful punctuation. A minor rearrangement of the sentence would eliminate its need, but the dash effectively conveys the appropriate emphasis:

> The close association with chemogenic units and rocks indicative of pauses in active volcanism, the simple mineral assemblage, and the rhyolite doming in some localities—all suggest that the stratiform sulfides developed through fumarolic activity.

If you eliminate "all," the dash will have to go too. The present construction, however, allows the reader to pause and absorb the material preceding the dash before reading on to its significance.

3. A dash is used to indicate an afterthought or an abrupt change in thought. This use requires caution. It rarely is acceptable in technical writing but it can be very effective:

> Then, when downcutting resumed, the soft fill was removed preferentially and buried promontories such as Kings Point were exhumed—an ancient Tertiary landscape faithfully, if incompletely, restored.

Consideration of readership is important when you construct and punctuate sentences. Artful uses of the dash and the colon can appeal to those readers who appreciate both what you say and how you say it.

## Parentheses

Parentheses (which always come in pairs) are used to enclose disconnected elements. Their function parallels that of paired commas and paired dashes, but parentheses deemphasize the enclosed matter; dashes have the opposite effect—they emphasize. Commas, being neutral, merely separate.

In Survey writing (and in most other technical reports) parentheses are used chiefly to set off bibliographic citations and references to figures and tables. They also set off (1) numbers or (a) letters identifying items of a run-in series.

## The Hyphen

The hyphen is widely used in technical writing, but it can be ambiguous and confusing. Principles outlined below may help avert problems:

### In Syllable Breaks

Word breaks at the ends of lines of type should be made only between syllables, and any good contemporary dictionary will show where the syllable breaks are. Syllable breaks are ignored in some computer-set type, and though the resulting errors may be amusing, they are always distractive and should always be corrected in galley or page proof.

### In Unit Modifiers

A unit modifier is made from two or more words that together qualify the meaning of a noun; for example, "zero-frequency limit," "pale-green shale," and "water-oil flow." If the words must work in tandem to be meaningful, use a hyphen. If each word individually modifies the noun, omit the hyphen. The following basic rules apply:

1. Words functioning as unit modifiers (that precede the noun modified) are generally hyphenated.

    a 6- to 10-m-thick unit
    five-spot homogeneous system
    five- and nine-point finite-difference grids
    chimney- and halo-like anomalies (better to say "chimneylike" and "halolike" anomalies)
    log-interpreted lithology
    oil-bearing shale
    cliff-forming sandstone
    fine-grained, thin-bedded sandstone
    blue-green algae
    dark-gray shale

    Omission of the hyphen can change the meaning (p. 146).

2. The same words used as compound predicate adjectives (following the verb) are not hyphenated.

   The shale is oil bearing.

   The sandstone is fine grained and thin bedded.

3. Do hyphenate unit modifiers that follow the noun in inverted sentences (often used in map explanations and measured sections).

   Sandstone, fine-grained and thin-bedded
   Shale, oil-bearing

4. A two-word unit modifier is not hyphenated if the first word is an adverb ending in "ly," but adverbs that might be mistaken for adjectives should be followed by a hyphen.

   Finely crystalline limestone
   Widely spaced joints
   Very clean outcrop
   Well-defined aquifer
   Poorly defined surface

5. The hyphen is not used if the first word of a three-word unit modifier is an adverb that modifies the second word, or if the first two words are adverbs.

   Very fine grained sandstone
   Very well defined surface
   Unusually well preserved specimen

6. Common adverbs that cannot be mistaken for adjectives need not be hyphenated.

   Too much turbidity
   Almost empty pool

7. If the words of the unit modifier commonly go together, hyphenation is unnecessary. Ask yourself if you are improving the readability of your sentence by adding hyphens.

   High school student
   Rare earth element
   Mother Lode Belt
   Solid waste disposal

8. The intent of hyphenation in unit modifiers is to aid readability; a hyphen is unnecessary if the meaning is clear without it.

Rules may seem arbitrary, but they are based on clarity and readability. Rules 7 and 8 are deliberately vague, because the decision to use a hyphen is sometimes a matter of judgment. Additional rules 9–13 from the U.S. GPO Style Manual (1984, p. 75–79) apply to many Survey manuscripts:

9. Do not use a hyphen in a unit modifier consisting of a foreign phrase.

   in situ sample
   ex officio member
   per diem allowance
   prima facie evidence

   *But*, "They did not believe in-vitro fertilization was feasible" needs a hyphen to avoid temporary misreading.

10. Use a hyphen or hyphens to prevent mispronunciation, to ensure a definite accent on each element of the compound, or to avoid ambiguity.

    un-ionized (as distinguished from unionized)
    non-quartz-bearing rock
    non-civil-service position

11. Use a hyphen between the elements of compound numbers from twenty-one to ninety-nine and in adjective compounds having numerical first elements.

    twenty-one
    2-meter rattlesnake
    two-sided question
    thirty- (30-) day period

12. Do not use a hyphen in scientific terms used as unit modifiers if no hyphen appears in their original form. (For hyphenating petrologic terms, see "Petrologic Terminology," p. 98)

    carbon dioxide content
    methyl bromide solution
    equivalent uranium content
    quartz monzonite stock
    *but*, iron-oxide-stained zone

13. Use as one word compass directions consisting of two points, but use a hyphen after the first point when three points are combined

    northeast
    north-northeast

14. Use a hyphen between numerical values when "from * * * to" is not used. (Substitute an en dash for the hyphen in typeset copy.)

    from 3 to 6 m
    3–6 m

## Slash or Virgule

Any ambiguity that interrupts the reader's train of thought diminishes comprehension. Hyphens may cause ambiguity, because they are used to join words as well as to separate them. If a hyphen causes ambiguity, a slash may add clarity. Consider the "Green-Snake divide": Here the hyphen seems to punctuate a unit modifier, "Green Snake," but the intention is to indicate the divide between the Green and Snake Rivers. "Green/Snake divide" would be clearer. Confusion is compounded if three or more words are involved: "Sunbeam-Sand Wash Basin area" seems to say that "Sunbeam-Sand" is a unit modifier of "Wash Basin." In "dry oak-hickory savannah," the expression is obscure unless a slash replaces the hyphen. Another example further illustrates the point: "a slump-debris-flow complex." Because "debris-flow" as a unit modifier of "complex" requires a hyphen, an additional hyphen after "slump" obscures the meaning, but a slash clarifies it: "a slump/debris-flow complex." Rephrasing with prepositions may add clarity but also adds words and tends to be cumbersome, especially if used repeatedly in the same or in succeeding paragraphs: "a complex of slumps and debris-flows."

Use a slash to substitute for "per" (m/km, $ft^3/s$, gal/min).

## The Apostrophe

1. **In the possessive case**

   The apostrophe is used chiefly to form possessives, indicate contractions, and create certain plurals. The possessive case of a singular or plural noun ending in "s" or with an "s" sound is formed by adding an apostrophe only: boss', bosses', Reynolds', Reynoldses', Ph.D.s', and Cos.'. To show possession in compound nouns, add an "s" to the last word only: secretary-treasurer's position, David Brown III's report.

   Remember that the apostrophe is omitted from the possessive pronouns its, yours, theirs, ours, and hers.

   The possessive form is added to the last element of a series to show joint possession—Tyler, Moore, and York's experiment—but to each element to show separate possession—author's, technical reviewer's, or editor's opinion. The singular possessive case is used in such general terms as fuller's earth and miner's inch.

2. **In contractions**

   Contractions are rarely used in formal technical writing, but the contraction "it's" and the possessive "its" are commonly confused in Survey manuscripts.

3. **In plurals**

   Despite a trend in contemporary writing toward eliminating the apostrophe from certain plurals, STA follows the U.S. GPO Style Manual (1984, p. 118, rule 8.11) in its use of coined plurals of letters, figures, and symbols, such as 1920's, Btu's, a's, 7's, T's, and 2×4's. On the other hand, adding apostrophes to the plurals of common or proper nouns not in the possessive case is a clumsy error: assorted opal's; elephant's on the move; dined with the Smith's.

## Brackets

One primary function of brackets is to indicate information added to the work of another writer. This information is generally added in either of two places: in quotations or in references. Occasionally a quotation will be introduced by a pronoun that does not provide a clear referent for the reader. Brackets can be used to add the referent, as in the following example:

> The Federal Government should, as a matter of policy, actively and vigorously seek to take maximum feasible advantage of the opportunities provided by this [information resources management] technological revolution.

In references, brackets are used to indicate additional information that is not available on the title page of the publication. This information might be the actual date of publication as compared to the imprint date, an English translation of a foreign language title, or an indication that a particular cited article is an abstract.

The Survey also uses brackets to enclose headnotes in tables and measured sections.

## Points of Ellipsis

Ellipsis is the omission of words necessary for complete grammatical construction but unnecessary for comprehension in the context of a sentence. Ellipsis (pl. ellipses) is also used in the omission of material from quotations. The Survey advocates a series of three asterisks separated by spaces (in preference to a series of three periods) to indicate points of ellipsis (* * *). Asterisks avoid the confusion that period ellipses cause at the end of a sentence. Four periods in a row could mean that the ellipsis either precedes or follows the end of the sentence, but when three asterisks and a period are used, the end of the sentence is obvious. Few people outside the Federal Government use asterisks, but their meaning in context is self-evident.

### Quotation Marks

In Survey style, quotation marks are used to enclose (1) direct quotations, (2) titles of publications named in text, (3) words spoken of as words, (4) letters spoken of as letters, (5) words used ironically or out of context, and (6) misnomers. At the ends of quotes, the comma and the final period are placed inside quotation marks. Other punctuation marks are placed inside the quotation marks only if they are part of the matter quoted.

If the quoted matter consists of more than one paragraph, you should place quotation marks at the beginning of each paragraph and at the end of the quotation. The editor may remove the quotes and mark the copy for type different from the rest of the text. You may omit nonpertinent parts of quoted matter, but the omission should be indicated by ellipsis marks (* * *), and the result should be a complete sentence.

Omission of a complete paragraph should be indicated by a line of seven asterisks separated by spaces across the page or column.

Matter following "entitled," "the word," "the term," "marked," "designated," "classified," "named," and "signed" is usually enclosed in quotation marks. Matter following "known as" and "so-called" is usually not enclosed in quotation marks. For example:

> The term "silt" refers to unconsolidated rock particles finer than sand and coarser than clay. The so-called bottom load refers to the larger particles that move on or near the bed of the stream.

Further examples of appropriate use of quotation marks are given in the U.S. GPO Style Manual (1984, p. 131):

> After the word "treaty," insert a comma.
> Of what does the item "miscellaneous debts" consist?
> The document will be marked "Exhibit 21"; *but* The document may be made exhibit 2.
> The check was endorsed "John Adamson."
> It was signed "John."
> Beryllium is known as glucinium in some European countries.
> The so-called investigating body met * * *.

Quotation marks should not be used in lieu of apology—to say, in effect, that a particular word probably isn't the best available, but that time was not available to find one more suitable. Nor should quotes be used with condescension—to indicate that you know the word isn't quite right, but fear the reader may not know unless tipped off.

## Style

Try to preserve an author's style if he is an author and has a style.

*Wolcott Gibbs*

Style is more easily recognized than defined. You may recognize it in people, places, and things without knowing why. Some have style; some have not. Style in writing is the way thoughts are put into words, the form of expression as distinguished from the content. As a technical writer, you may never achieve style in a literary sense, but your goal should be to write clearly enough to be understood and smoothly enough to avoid stylistic quirks. Technical writing should be dispassionate and unobtrusive. If your readers are overly conscious of how you express yourself, your message will fall short. Being clearly understood is the best test of good technical writing style.

Style is hard to categorize because it is more judgmental than grammatical. Writing can be grammatically flawless but without style, and a writer may relish a phrasing that a reader finds offensive. Good style should have a certain grace and elegance that the reader senses subconsciously. The basic elements of style can be learned, and understanding them helps authors and editors alike uphold the quality of Survey writing.

### Emphasis

To express thoughts effectively, you may need to emphasize different parts of a sentence. Some common ways are given below.

#### Position

Important ideas should have important positions—positions that command attention. Unimportant ideas should be subordinated. The most emphatic positions in the sentence are the beginning and the end, especially the end. Readers naturally stress the words immediately preceding and following punctuation marks. The only objection to ending a sentence with a preposition is that an unimportant or weak word is placed in a position of emphasis. A sentence ended with a preposition, however, may be better than an unnatural or awkward sentence phrased to avoid such an ending.

### Order

Deviation from the usual order attracts attention. In some sentences emphasis can be changed by just transposing a word or phrase:

> Gold mining has been the leading industry of the region for many years. (Emphasis on gold mining.)
>
> For many years gold mining has been the leading industry of the region. (Emphasis on many years.)
>
> The leading industry of the region has long been gold mining. (Emphasis on leading industry.)
>
> In this region gold mining has long been the leading industry. (Emphasis on region.)

### Voice

The active and passive voices are discussed further on page 142. Two points, however, relate directly to the subject of emphasis: (1) The passive voice, on the whole, is less emphatic than the active, and (2) whatever emphasis the passive voice has is imparted to the object acted upon rather than to the agent of the action. "The sandstone is cut obliquely by the fault" (passive voice) emphasizes the sandstone and is not as strong overall as "The fault obliquely cuts the sandstone" (active voice).

### Specific Terms

Specific and concrete terms are more emphatic than general and abstract terms.

### Italic

Italic type is used chiefly to differentiate or highlight certain words or phrases. In manuscript, it is indicated by underlining. In scientific writing, italic should not be used for emphasis; composition should be so phrased that emphasis requires no typographic assistance. Similarly, boldface type should not be used for mere emphasis either.

The following are examples of what is printed in italic:

- *See* and *see also*, in indexes and glossaries
- *In* and *of* in certain reference citations
- Sideheads in text
- Names of vessels, aircraft, and spacecraft
- Letter symbols in mathematical equations
- Most letter symbols used in physics.

Letters used for subordinating figure numbers for maps and other illustrations, or in text to refer to such numbers, are set in italic without periods and are capitalized if so shown in copy—for example "(fig. 1*A*)."

Scientific names of genera, species, and subspecies or varieties of organisms are ordinarily italicized, but in italic matter they are set in roman: *Productus*, *Inoceramus fragilis*, *Ostrea congesta* Conrad, *Bulimina elongata subulata*. If italic is unavailable on the office printer, such names may be printed in a suitable typeface different from that used in the text, following recommendations of the International Code of Zoological Nomenclature (Stoll and others, 1964, p. 143; Ride and others, 1985). Underlining, for example, is more commonly available on word processors than italic and is equally appropriate for camera-ready copy. One typeface should be used throughout. Names of families and higher groups are ordinarily printed in roman: Brachiopoda, Mollusca, Foraminifera.

Chemical symbols and foreign words are printed in roman, even in italic matter.

## Variety in Sentence Length and Type

Monotonous sentence structure reduces the effectiveness of a report. You can achieve variety in sentence length or form by interspersing simple, complex, and compound sentences, by changing the word order, by using meaningful connectives, and by avoiding excessive use of participial phrases.

Some authorities advocate short, snappy sentences, but too little variety in length—either short or long—yields flaccid prose. Too many short, choppy sentences tend to irritate the reader, but one long sentence after another befogs the reader's mind. Good writing needs a mixture of sentence lengths to provide cadence, add emphasis, and heighten interest. The longer the sentence, the greater the risk of convolution, but regardless of length, the train of thought is broken if the reader is forced to analyze the sentence structure to unravel its meaning. Long sentences of themselves need not be hard to read. The late Survey grammarian-geologist Frank Calkins once pointed out that a sentence may be long without being involved, or involved without being long, but an involved sentence always seems longer than it really is. One short sentence in a series of longer ones will catch extra stress. So will the converse. By varying sentence lengths, therefore, you can effectively control emphasis. To check for appropriate length, read the words aloud, listening for their clarity, flow, and cadence. Whispering the words to yourself is almost as effective. A reminder: The most emphatic places in a sentence are at the beginning and the end, where the eye lingers longest. The important words belong there.

### Four Types of Sentences

To enhance style, sentences should vary in form as well as length. Regardless of length, every sentence can be classified into one of four types: simple, compound, complex, or compound-complex.

**Simple.** A simple sentence contains one independent clause consisting of at least one subject and one verb: "The ground shook." Simple sentences thus can be spare in form, but they can also have associated objects and linkages: "The ground appeared to be stable." (Here the phrase "appeared to be" links the subject to "stable.") Simple sentences can also be quite involved: "The striking contrast between the simplicity and symmetry of spheres and the apparent chaos of the universe has attracted men to spherical bodies since the dawn of abstract perception." Short sentences likely are simple sentences, but simple sentences are not necessarily short.

**Compound.** A compound sentence consists of two or more simple sentences joined by a coordinating conjunction (and, but, for, or, yet, so) or a semicolon. When a reviewer suggests a need to coordinate ideas, the compound sentence is a possible approach. Like the simple sentence, a compound sentence can be rather simple or rather complicated in form. A simple example: "The northeastern margin of the batholith steepens with depth, and in the lowest exposed parts it is nearly vertical." A more complicated example: "The two coal dumps near Engleside are shown on the map because the steep angle of repose poses [ugh] a threat of landslide, and they contribute smoke, suspended solids, and odor to the atmosphere, as well as suspended and dissolved minerals to the streams and ground water." This sentence needs help. Each clause introduces multiple thoughts ineptly strung together.

**Complex.** Complex sentences convey ideas that have unequal relationships—one independent clause linked to one or more dependent clauses. Certain ideas are thus subordinated to others that the writer regards as more essential. If the expressed idea is uncomplicated, the dependent clause can be short: "The basal unit is the Anza Formation, which is a coarse conglomerate about 350 m thick." The author chose to emphasize the idea that the basal unit is the Anza Formation. Greater stress could be added by placing "Formation" last: "The basal unit, which is a coarse conglomerate about 350 m thick, is the Anza Formation."

Complex sentences often contain fairly involved ideas, sometimes to their detriment: "Because the ship selected for the program, the *Glomar Conception*, lacked dynamic positioning capability, its anchoring capacity determined the maximum water depth in which drilling could take place." Inserting "the *Glomar Conception*" into the middle of the first clause broke the rhythm of the sentence. Two separate sentences, one simple and one complex, would be better: "The ship selected for the program was the *Glomar Conception*. Because it lacked dynamic positioning capability, its anchoring capacity determined the maximum water depth in which drilling could take place." Complex sentences communicate involved ideas and provide variety in style, but their construction needs care.

**Compound-complex.** The compound-complex sentence is potentially the longest and most complicated sentence type, and it therefore contains pitfalls for both the writer and the reader. Combining the two previous sentence types, it consists of two or more independent clauses, and one or more dependent clauses. Although such a sentence can be unmanageable, and sometimes is, it can also be clear and bright: "As the mass arched through the air, it quickly chilled on the outside, and a hardened skin formed around the still-hot plastic core." The following sentence, at the other extreme, is neither clear nor bright: "These feldspars differ from the saussurite pseudomorphs occurring in some of the rocks transitional to the quartz diorites, although even these saussuritic feldspars are probably due to hydrous solutions, inasmuch as zoisite is a hydrous silicate, and they suggest, if they do not demand, dynamic processes for their formation." A danger of the compound-complex form thus is that the sentence may be so dense with poorly expressed ideas that the reader cannot easily interpret the message. Note that "occurring" is superfluous in the above example and should have been left out.

### Active Versus Passive Voice

Voice refers to the relationship between a transitive verb and the subject of the sentence either as actor or as recipient of the action. If the subject is the actor, the voice is active: "Jane measured the section." If the subject is the recipient, the voice is passive: "The section was measured by Jane." Note that the passive form requires an auxiliary verb (was), which adds an extra word to the sentence, and a preposition (by), which adds another. Saving a few words here and there makes little difference to the preparation cost of the report, but it can greatly improve the style and readability. The following sentence gains both style and readability by a change of voice: "*As a result of* determining the hydrological units, *a clearer* [clarified our] understanding of stratigraphy *was achieved.*

In another simple example, "I did the experiment," the voice again is active. The pronoun subject "I" is the actor who did the experimenting. In the passive voice, "The experiment was done by me," the noun subject, "experiment," received the action of the verb, and the actor was relegated to a flabby prepositional phrase tacked onto the end of the sentence. If the whole discussion centers around the experiment, however, it would be silly not to make "experiment" the subject of the sentence, even in the passive voice. To do otherwise would jar the reader. The passive voice requires more words to say the same thing, but it is less personal than the active voice and is more anonymous and hence is less committal: "These rocks are thought to be overturned" doesn't say who thinks so; it lets the writer off the hook. It also is more modest than "I think these rocks are overturned," and it is less assertive than, simply, "These rocks are overturned," but it also is less forthright and less forceful. Good technical writing should have a blending of voices, but the active should predominate. In any event, the subject matter of a report needs emphasis, not its author.

### Passive Voice and Personal Pronouns, First and Third Person

Some writers conscientiously use the passive voice or the third person to avoid using the pronouns "I" or "we" (first person) on the grounds that such usage is somehow boastful. The first person is more straightforward than the third, and avoiding an appropriate "I" risks a stodgy, overly formal style. Referring to yourself as "the author," 'the writer," or "the senior author" smacks of false humility. "The author" or "the writer," moreover, can be ambiguous or even misleading if another author has just been mentioned: "Gillespie's report mentioned several occurrences of chalcopyrite, but their exact locations were unknown to the writer."

On the other hand, some authors overuse the first person in a way that seems arrogant or self-congratulatory. Survey editors try to be openminded about authors' preferences; use either person, first or third, but do not use them both in the same report. If you find yourself struggling to avoid the first person, use it, but if it appears on every page, or more than once or twice on a single page, rephrasing may be appropriate.

## Enhancing Clarity

### That, Which, Who, Whom, and Whose in Restrictive and Nonrestrictive Clauses

> THAT, *relative pronoun*. . .The two kinds of relative clause, to one of which *that* and to the other of which *which* is appropriate, are the defining and the nondefining; and if writers would agree to regard *that* as the defining relative pronoun, and *which* as the nondefining, there would be much gain both in lucidity and in ease.
>
> *H. W. Fowler*

Some misunderstanding and argument cloud the distinctions in the use of the relative pronouns "that" and "which." As a relative pronoun, "that" is used only to introduce restrictive (distinguishing or defining) clauses: "Oviparous animals are those that lay eggs." The essence of the sentence is lost if the "that" clause is deleted. "Which" is used to introduce nonrestrictive (informing or parenthetical) clauses: "Oviparous animals, which include birds and most reptiles, are those that lay eggs." Delete the "which" clause and the sentence still makes sense. Many good writers use "which" to introduce restrictive clauses, but in so doing they lose an element of precision and style in their writing. In the following jingle, substitute "which" for "that" and note the loss of style; it becomes just a bit prissy.

> This is the house that Jack built.
> This is the cow with the crumpled horn
> That tossed the dog
> That worried the cat
> That killed the rat
> That ate the malt
> That lay in the house that Jack built.

Similarly, "These are the times that try men's souls" is a powerful statement; substitute "which" for "that" and feel the loss of strength.

Some otherwise great writers have been inveterate whichers, but STA urges Survey writers to observe the distinctions anyway, not just to help preserve the purity of the language but to maintain the clarity of their writing.

Some authors are elegant variationists. They throw in an occasional "which" just for the sake of euphony, or they alternate between "that" and "which" in a litany of inelegance. Try it with "The house that Jack built."

In some constructions, either "that" or "which" is appropriate, depending on the intent of the writer:

> **Restrictive.** "The peak that is capped with quartzite is the highest in the range." (Here the capping of quartzite distinguishes the highest peak from lesser ones capped with something else.)
>
> **Nonrestrictive.** "The peak, which is capped with quartzite, is the highest in the range." (Here the capping of quartzite is merely added information, incidental to the statement of fact.)

In both examples, the whole issue can be sidestepped without a loss of good grammar by just omitting "that is" or "which is': "The peak capped with quartzite is the highest in the range." The sense of the clause is restrictive unless "capped with quartzite" is set off by commas.

In another example that could be either restrictive or nonrestrictive, "Periodically, much of Browns Park was flooded by lake waters that deposited blankets of sand and clay," the author wanted to emphasize the fact that the lake waters were depositing sand and clay. They were not just any old lake waters.

The pronouns "who" and "whom" are acceptable substitutes for "that" or "which" but only as applied to persons, not to animals, for which they are unidiomatic:

> This is the maiden all forlorn *that* [who] milked the cow with the crumpled horn.

"Whose," however, is an idiomatic substitute for persons, animals, and inanimate objects, and its use can enhance clarity:

> This is the dog *the mistress of which* [whose mistress] milked the cow.
>
> The peak *of which the* [whose] summit is quartzite * * *.

The use of "which" in a restrictive clause occasionally adds something to a sentence, at least if an emotional or a melodramatic effect is desired: "It is for us the living, rather, to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced." Frank Calkins called this construction the "running which," and it isn't preceded by a comma, but such an effect is seldom sought in scientific works. More often, "which" is used simply out of habit, or because the writer is unaware of the distinction. "Which" used in a restrictive sense is not a cardinal sin, but the precision of the sentence is diminished if the distinction is not observed.

### Parenthetical Expressions

Parenthetical expressions are nonrestrictive interjections and hence are not essential to the grammatical completeness of a sentence. They can range from single words or short verbless phrases to long independent clauses or complete sentences set off by commas, dashes, brackets, or parentheses. They offer flexibility, therefore, in conveying information and in varying your writing style, but for the same reasons, they can easily confuse the reader. If they are lengthy, or are carelessly placed, they force the reader to backtrack to pick up the essential thread of the sentence: "Five flatcars carrying U.S. Mail, as well as the toe of the landslide, came to rest in the Weber River."

For easy reading, put parenthetical expressions at logical breaks in the sentence—before, between, or after independent clauses, not in the middle of them. Place them after prepositional phrases or after participial phrases. Avoid interjections (unless unusual impact is desired) in the middle of a clause, where they will jar the reader. Sentences read more smoothly if such breaks are at logical breathing places. Additional information is sometimes better presented in a separate sentence rather than in a parenthetical expression.

### Parallel Construction

Parallel construction is one of the author's strongest tools for writing clearly and forcefully. Sentence elements that are parallel or coordinate in meaning should also be parallel or coordinate in style.

The following sentence elements signal the need for parallel construction:

1. Coordinate conjunctions ("and," "but," "or," sometimes "for," "nor," "yet"). A shift in verb tense, voice, or mood, after a coordinate conjunction, violates the principle of parallelism and may also create other difficulties:

| **Change this:** | **To this:** |
|---|---|
| Tours of the facility will begin following the ceremony on Friday and continuing through Saturday. | Tours of the facility will begin on Friday following the ceremony and will continue through Saturday. |
| Limestone in massive beds and thin layers of sandstone | Limestone in massive beds; sandstone in thin beds |

2. Correlative conjunctions ("both * * * and"; "either * * * or"; "if * * * then"; "neither * * * nor"; "not only * * * but also"). If a verb follows one, a verb should follow the other; if a prepositional phrase follows one, a prepositional phrase should follow the other. Repair of faulty parallelism may require only transposition or addition of a word or two.

> Mr. Small *both* talked [both] longer and more rapidly than I had expected.
>
> To the northeast, the sandstone bed *both* became [both] thicker and coarser grained. ("Both" adds little to either of the above sentences and could be omitted.)
>
> *Either* the water was [either] too turbulent or too shallow for such bottom-dwelling species.
>
> *Either* you will [either] report on time or be penalized for your absence.
>
> This nation *not only* has achieved great things [not only] in science but also in the arts.
>
> The program *not only* aimed at development of techniques that [not only] would be useful in the present emergency but also would improve the efficiency of normal operations.

3. "And which," "and who," "and that," "but which," "but who," and "but that" need a preceding "which," "who," or "that."

| Change this | To this |
|---|---|
| This district, the largest and which contains the principal mine, is in the western part of the county. | This district, which is the largest and which contains the principal mine, is in the western part of the county. |

4. Items in a list, in a reading column of a table, and in a description of a process should be in parallel format.

| Change this | To this |
|---|---|
| a. Laboratory equipment should be assembled. | a. Assemble laboratory equipment. |
| b. Then arrange samples in proper sequence. | b. Arrange samples in proper sequence. |
| c. Tests are run. | c. Run tests. |
| d. We recommend that results then be recorded. | d. Record results. |

5. Items in a series.

| Change this | To this |
|---|---|
| The content of CRIB was based on user response, individual discussions, and by certain requirements of the GYPSY program. | The content of CRIB was based on user response, individual discussions, and certain requirements of the GYPSY program. Or: * * * on user response, on individual discussions, and on certain requirements of the GYPSY program. |
| The Department of the Interior had 15 Skylab experiments in which its scientists were principal investigators, co-investigators on 4 other experiments, including one experiment with the Italian Geological Survey. | Scientists of the Department of the Interior were principal investigators on 15 Skylab experiments and were co-investigators on 4 other experiments, including one with the Italian Geological Survey. |

6. Expressions of comparison and contrast.

| Change this | To this |
|---|---|
| The instruments on Skylab were more complex than the ERTS payload. | The instruments on Skylab were more complex than those on ERTS. |

**Faulty parallelism.** Florida deposits were discovered in 1888, in Tennessee in 1894, and in the Western United States in 1906.

If you don't believe the previous sentence has faulty parallelism, substitute "phosphate" for "Florida" to see the flaw.

**Suggested alternative.** Deposits were discovered in Florida in 1888, in Tennessee in 1894, and in the Western United States in 1906.

Parallelism is flawed if a series includes items that do not really belong. Consider the following example:

**Faulty parallelism.** Abstracts are selected on the basis of geologic significance, amount of new information, broad interest, and in the case of section meetings there must be relevance to the section's geographic coverage.

The first three elements of the preceding sentence express parallelism through a series of noun phrases, but the "and" introduces an unrelated independent clause. The three items preceding "and" relate to something other than section meetings, and they rightly belong in a parallel series, but the final item does not. The problem can be remedied as follows:

**Suggested alternative.** Abstracts for the national meeting are selected for geologic significance, new information, and broad interest; abstracts for section meetings must additionally be relevant to the section's geographic coverage.

The use of the word "additionally" in the previous sentence conveys the idea that abstracts for section meetings must meet the criteria for abstracts for the national meeting as well.

**More examples of faulty parallelism.** The following sentences are clumsy or misleading because they fail to observe parallelism. Words in italic should be deleted; words in brackets should be added. Read each sentence first with the italic, then as corrected.

The average growing season *according to the Ennis record* is 98 days [at Ennis] and longer at the other stations.

The district has a moderate climate, in winter not very cold and *not excessively hot* in summer [not excessively hot].

The veins pinch out in one direction and *in the other* pass under the glacier [in the other].

These leaves range in length from 6 to 9.5 cm and [in width] from 4 to 7.5 cm *in width.*

The boundary between the belts is fairly distinct in [some] places and *in places* indefinite [in others].

The biotite replaced albite and quartz extensively and *sparingly replaced* hornblende [sparingly].

The layers of shale are much thinner than the *chert* layers [of chert].

Estimating the potential value of power sites and [the] storage *capacities* [capacity] of reservoir sites * * *. ("Storage capacity" is an abstract term like "potential value.")

> The replacement of pyrite by chalcocite would result in an increase in volume; the replacement of chalcocite by pyrite would *occur with a slight volume decrease* [result in a slight decrease].

A change in form of a phrase or clause may be taken by some readers to indicate a difference in idea, but in the immediately preceding example the only difference is between "increase" and "slight decrease." The two clauses are parallel and should be expressed in the same form. Also, the phrasing would be stronger if "would result in" were changed to "would cause"—a change from intransitive mode to transitive.

For clarity, sentences that contain coordinate information should be written in parallel form also:

> The Madison Limestone forms sheer cliffs. The underlying Lodore Shale forms rubbly slopes.

### Excessively Long Unit Modifiers

Authors should avoid clumsy unit modifiers intended to save space but more likely to confuse the reader. Read, for example, the following: "It is shown by this simple study that advances must be made in both earthquake-prediction capability, and in ground-motion and structural-response-estimation technology, for the costs associated with long-term design and planning decisions to be significantly reduced." Aside from all the other stylistic problems in this sentence, the overuse of the unit modifier diminishes clarity and hampers the comprehension of the reader. Few readers are likely to grasp the meaning of this sentence without regressing more than once.

The following clever phrases gleaned chiefly from the columns of Robert L. Bates can be clarified simply by recasting with prepositional phrases or by inserting appropriate hyphens.

Multidisciplinary Sinkhole Conference
  (Change to: Multidisciplinary Conference on Sinkholes)
Heavy crude trained personnel
  (Change to: Personnel trained in [refining?] heavy crude)
Endangered Mammalian Dictionary
  (Change to: Dictionary of Endangered Mammals)
Caribbean Plate Steering Group
  (This example is too precious to alter)
Regional Climate Coordinating Office
  (This example is too ambiguous to remedy without additional information)
Underwater Mining Institute
Abnormal Subsurface Pore Pressure Symposium
Abandoned Mine Reclamation Project
Small horsepower salesman
First carnivorous dinosaur eggs
Closed loop Earth coupled heat pump
High Altitude Health Conference
Low rank coal study
Underground Operators Conference
Boring Late Cambrian organisms
Horizontal boring machine operator

Avoid using nouns as adjectives, especially in unit modifiers:

Ocean Disposal Symposium
Copper acetate ammonia solution method
The natural gas production report

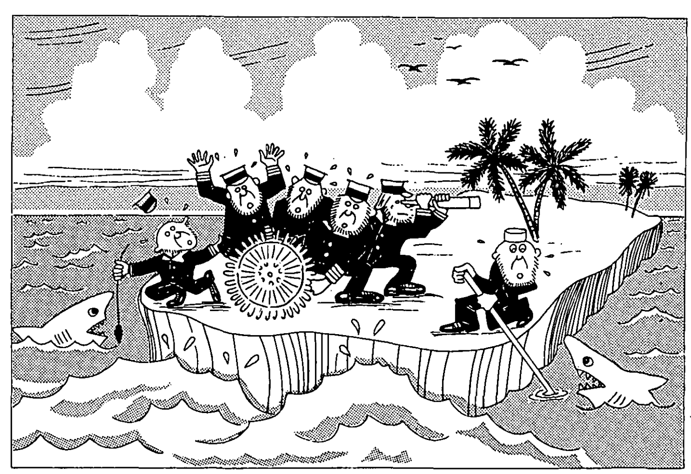
### Split Infinitives

The split infinitive, in which "to" is separated from its verb by an adverb (or by several other words), is generally awkward and unnecessary. It is justified, however, if (1) placing the adverb before the "to" or after the verb causes a more cumbersome construction or (2) the result otherwise is ambiguous:

> "Our intent is to further strengthen the embankment" is much better than the ambiguous revision, "Our intent is further to strengthen the embankment." (Further intent, or further strengthen?)

Don't hesitate to split an infinitive to avoid ambiguity or to improve the flow of a sentence, but infinitives in many manuscripts are split without reason, and most such sentences thus lose emphasis:

> To slowly accumulate (to accumulate slowly, *and* to have slowly accumulated)
>
> To violently erupt (to erupt violently, *but not* violently to erupt)
>
> It was difficult to locally distinguish one tuff from another. (Locally, it was difficult to distinguish * * *.)



"Caribbean Plate Steering Group."

### Terminal Prepositions

Some writers studiously avoid placing prepositions at the ends of sentences to the extent that their phrasing becomes stilted and unidiomatic. Most terminal prepositions can be avoided gracefully by recasting, but recasting an already adequate sentence may be more trouble than most writers are willing to put up with. Fowler (1965, p. 473–475), in fact, devoted nearly a page and a half defending terminal prepositions and cited many examples of their appropriate use. The chief objection to ending a sentence with a preposition is that a place of emphasis in the sentence is lost to a weak or unimportant word.

### Repetition and Synonyms

Appropriate word choice is essential to clarity. If a word has two (or more) possible meanings (many have), avoid using it for both in the same paragraph or in nearby paragraphs. Avoid homonyms. A short word is better than a long one if it has the same nuance, and repeating a short, familiar word is less distracting to the reader than repeating a long or uncommon one. Substituting a synonym may be appropriate, but the writer should not resort to elegant variation just to avoid repetition; unless the synonymy is obvious the reader may be diverted from the main thought. In technical writing, precise terms should be repeated for clarity and emphasis. If one term is substituted for another, the reader is temporarily distracted, as in the following example: "Andesine and augite, the essential minerals, are usually found in the proportion of 3 of the plagioclase to 1 of the pyroxene." The reader is forced to equate andesine with plagioclase and augite with pyroxene. Revise the sentence to avoid the substitution: "The proportion of the essential minerals is usually 3 andesine to 1 augite."

### Acronyms

Acronyms are troublesome for most readers and should be avoided. If an acronym is widely understood (radar, sonar, NATO, NASA) its use may be acceptable, but some reports are loaded with obscure acronyms that few readers can keep straight. Saving space is insufficient justification for a loss of clarity. Well-known acronyms or abbreviations are appropriate in Survey reports for often-repeated names of organizations and the like but not for geographic names or geologic terms. The Survey, for example, disapproves of UWTB for Utah-Wyoming Thrust Belt or QFS for quartzo-feldspathic schist.

**Ten Steps Toward Clarity**

1. Be concise.
   Delete needless words.
2. Choose the right word carefully.
   Favor the short word over the long.
3. Do not needlessly repeat words, phrases, or ideas.
   Do repeat what is needed for clarity.
4. Favor the active voice over the passive.
5. Be specific.
   Use concrete terms; avoid abstract nouns (shun "tion").
6. Avoid dangling modifiers.
   Place modifiers as near as possible to what they modify.
7. Take care in the placement of parenthetical phrases.
8. Avoid shifts in subject, number, tense, voice, or viewpoint.
9. Express parallel thoughts through parallel construction.
10. Arrange thoughts logically.
    Work from the simple to the more complex.

### Conciseness

> Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph should contain no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecssary parts.
>
> *William Strunk*

Insecurity about subject matter sometimes leads to wordiness, but a flood of words will not hide technical inadequacies. Know your subject before you start to write, then get to the point. George Otis Smith, fourth Director of the U.S. Geological Survey, was a champion of plain language. In 1921, he addressed the following plea:

> This brings me to a third reason for our use of highly technical language; we too often try to overdress our thoughts. Just as there is a somewhat prevalent notion that clothes make the man, so we subconsciously believe that words make the idea. We follow the precept, "To be scientific, use scientific terms," and in so doing we deceive ourselves. I do not wish to be unduly autobiographic in this analysis, but to show my true sympathy for those whose practices I denounce, I confess that I, too, have had the unhappy experience of stripping the technical words from what looked like a good-sized geological deduction only to find that the naked idea was rather small and not my own. It is also a common experience to make the sad discovery that a piece of involved and obscure writing is simply the product of roundabout reasoning or twisted thinking. Our own words fool us, and unconsciously we cover up with long words or tangled rhetoric our lack of plain thinking.

The attitudes of a society are reflected in its writing styles, and our fast-paced society has little time for stylistic niceties. The following statement met standards of style in 1921, but most readers today would find it boring, if not foolish: "So keen were his observational powers in the geological direction that he was finally inveigled into deserting the purely scientific realm which he had so auspiciously entered in Brazil, Iowa, Illinois, and Kansas, and on the Hayden surveys in Idaho, Wyoming, Colorado, and New Mexico, and into expending his superior powers on the more remunerative economic aspects." Simpler language would be more appropriate today: "He was a highly talented, widely traveled research geologist, but the promise of financial gain lured him from research into industry." Ideas should not be overly compressed, but to convey ideas clearly and directly, the writer should scrupulously eliminate unnecessary words.

### Expletives

In grammar, expletives are filler words or phrases such as "There are" and "It is" that substitute for the real subject of a sentence or for the object of the verb. Expletives put the real subject into a subordinate place in the sentence, generally add words needlessly, and hence generally weaken the vigor and clarity of your writing. They can project an informality, however, that sometimes is desired.

### Gunning's Fog Index

Several years ago Gunning (1968) devised a "fog index" as a test of readability and as a way to see where your own writing stands against the writing of others. Slightly modified here, the fog index is simply a factoring of sentence length and word length, ignoring intangibles such as grammar and rhetoric. It shows how sentence length and word length directly affect comprehension—the longer the sentence and its words, the harder they are to read. An index of 8 equals an 8th grade reading level; 12 equals 12th grade or high-school senior level. Try it out, using several sentences or paragraphs taken at random from your own report.

First, measure the average length of sentences in the passage by dividing the number of words in the passage by the number of sentences. Independent clauses—joined by "and," "but," some other conjunction, or a semicolon—should be counted as separate sentences.

Next, find the percentage of "hard words" by counting the number of words per 100 containing three or more syllables. Unusual acronyms and abbreviations should be counted as hard words. Don't count capitalized nouns, and don't count verb forms that have three syllables merely because they end with suffixes "ed" or "es" (such as "disgusted" or "sentences"). Use your own judgment about hyphenated words.

Finally, get the fog index by just adding the average number of words per sentence to the percentage of hard words and multiplying by 0.4 as follows:

$$F = 0.4 \times (l + h)$$

where

$F$ is the fog index,
$l$ is the average length of sentences, and
$h$ is the percentage of hard words.

An index of 13 or more means that your copy exceeds the danger line of reading difficulty for most readers in the general public. Copy with a fog index of 13 or more runs the risk of being ignored or misunderstood by many people. Popular reports should range near 12. (The first two paragraphs of this section have an index of 12.) Table 6 below compares Gunning's fog index with various reading levels.

**Table 6.** The fog index by reading level

| Fog index | Reading level: By grade | Reading level: By magazine |
|---|---|---|
| 17 | College graduate | |
| 16 | College senior | Most technical reports |
| 15 | College junior | in this range but no |
| 14 | College sophmore | popular magazines |
| 13 | College freshman | |
| Danger line for most readers | | |
| 12 | High-school senior | "Atlantic Monthly" |
| 11 | | "Time" and "Newsweek" |
| 10 | | "Reader's Digest" |
| 9 | High-school freshman | Popular magazines off |
| 8 | 8th grade | the rack |
| 7 | 7th grade | "True Confessions" |
| 6 | 6th grade | Comics |

Many passages in technical journals exceed 20. Some abstracts reach 30, and at that level are hard reading, even for the professional peers of their authors. The following excerpt from a Survey Professional Paper has a fog index of about 14 and is fairly easy going. Polysyllables are italicized.

The Phosphoria Formation *accumulated* in a large shelving *embayment* bordered by lands of low relief that *contributed* little *detritus* to the sea. Cold, phosphate-rich waters upwelled into this basin from the ocean *reservoir* to the south or southwest. *Phosphorite* was deposited from these *ascending* waters, *probably* in depths of 1,000 to 200 meters, as their pH increased along with increase in *temperature* and decrease in partial pressure of $CO_2$. *Carbonates* were *precipitated* from these waters when they reached more shallow depths, at a somewhat higher pH. The phosphate-rich water nurtured a *luxuriant* growth of *phytoplankton*, as well as higher forms of plant and animal life, some remains of which were *concentrated* with fine-grained *materials* in deeper waters away from shore. Part of the phosphate and probably some of the fine-grained silica in the *formation* were *concentrated* by these *organisms*.

Even if you are writing for a scholarly journal you will do well to pay attention to sentence lengths and polysyllables. If your intended readership is nontechnical (a "popular report"), try to judge its reading level in terms of table 6.

## Coherence in the Report

### Topic Sentences

Coherence is essential at every level of a report, from the sentence to the paragraph, to the chapter, to the entirety. If the message is to reach the reader, ideas must follow a logical order that excludes extraneous thoughts. Transitional devices such as topic sentences help supply coherence by linking sentences and paragraphs together. These in turn are the building blocks of a coherent report.

A unified paragraph contains a clearly defined topic sentence and the necessary supporting detail. (Note that the previous sentence is a topic sentence; it clues in the reader as to what will follow and at the same time puts a restriction on the subject matter.) If a topic sentence is too general, the paragraph will lack direction. If it is too specific, the paragraph will lack room to develop. Too many paragraphs in Survey reports have no topic sentence at all; they just string out the facts with little apparent connection—they are just aggregates of marginally related sentences.

Most topic sentences are at the beginning of paragraphs, and that is where they belong, but some are placed at the end, where they serve either as summary statements or as transitions to the next paragraph. At the beginning a topic sentence should at least hint at what will follow, so the reader can anticipate the supporting details. This arrangement introduces the reader to the topic of each paragraph. A chapter may have a topic sentence also, or a topic paragraph. But if the paragraph starts out with specifics and ends with a summation—the deductive or who-done-it approach—the reader may fail to see the linkage or may have to regress and reread to see it.

### Paragraph Organization

Besides having a topic sentence that defines the subject matter, each paragraph should be internally organized. Four major patterns are possible: (1) decreasing importance, (2) increasing importance, (3) time, and (4) place. A paragraph organized in terms of decreasing importance begins with the topic sentence, followed by a description of the evidence ranked from most to least significant. Conversely, the pattern of increasing importance builds the evidence to support the concluding topic sentence or summation.

Much geologic writing is organized by time or place, such as studies focused on geologic time and studies that are site specific. The content of a paragraph cannot always be organized so easily, but the writer should aim for a coherent structure and a logical order.

### Paragraph Length

Authors should cultivate a feeling for paragraph length. Many paragraphs are too long, commonly because of weak topic sentences. Paragraphs should be logical units of thought and should not be broken simply because of length, but if a paragraph extends over more than one manuscript page, its stated subject should be critically reexamined; the reader may be better served by a forceful introductory paragraph (a topic paragraph) and several subsequent paragraphs developing specific aspects of the subject. Several short paragraphs are easier to assimilate than a long one. Besides, readers need occasional breaks to collect their thoughts and catch their breath. The readers' comprehension is enhanced even more by a careful interweaving of long and short paragraphs joined by appropriate transitional devices to provide coherence.

One-sentence paragraphs are suspect. If such a sentence-paragraph logically follows the paragraph that precedes it, you should see if it is more effective as part of that paragraph, or as part of the one that follows. One-sentence paragraphs are used occasionally to emphasize an idea or to serve as a transition between two otherwise unrelated paragraphs, and in rare instances such emphasis is justified, but before using a one-sentence paragraph as a transition, you should rethink the organizational structure.

### Transitions and Coherence

Coherence is improved through the use of (1) transitional devices, (2) parallel constructions, and (3) key words. Transitions are designed to link ideas through the careful use of words, phrases, and sentences. Some overzealous reviewers eliminate what they perceive as extraneous verbiage by deleting transitions that are needed for coherence. Transitions cannot solve every problem of coherence, but they can help the writer make logical connections between ideas whose relation is not otherwise apparent to the reader. Some useful transitional words are listed at the top of the next page.

**Addition:** additionally, again, also, and, besides, equally important, finally, further, furthermore, in addition, last, moreover, next.
**Comparison:** also, in comparison, in like manner, likewise, similarly, too.
**Concession:** admittedly, although, granted, of course, to be sure, true, given that.
**Conclusion:** finally, in any event, in conclusion, to conclude.
**Contrast:** but, however, nevertheless, notwithstanding, on the contrary, on the other hand, still, whereas, yet.
**Emphasis:** as has been stated, as I have said, chiefly, indeed, in fact, in other words, in particular, most important, note that.
**Example:** as an illustration, for example, for instance, specifically, such as, that is.
**Place:** adjacent, behind, beyond, by, elsewhere, here, in the background, near, on the other side, opposite, there.
**Result:** accordingly, as a result, consequently, hence, therefore, thus, so.
**Summary:** in brief, in other words, in short, in summary, to sum up.
**Time:** afterward, at length, after [some period of time], before, during, immediately, in the meantime, later, meanwhile, soon, until.

Parallel constructions (p. 144) add coherence within a sentence or a paragraph by tightly relating coordinate ideas. Related words, phrases, and clauses need similar vocabulary, structure, and logic.

Key words repeated from one sentence to the next or from the end of one paragraph to the beginning of the next help connect related ideas. Synonyms do not serve that purpose, and if they are used as word substitutes, take care to avoid derailing the reader; make sure their connection is clear. The personal pronouns *I*, *you*, *he*, *she*, *it*, *we*, and *they* are effective substitutes for nouns, but they rarely function well as key words. The demonstrative adjectives *this*, *that*, *these*, and *those* can point back to particular nouns if their antecedents are unmistakable.

## Coined Verbs

Most verbs in *-ize* are inelegant. Sir Alan Herbert has compared them to lavatory fittings, useful in their proper place but not to be multiplied beyond what is necessary for practical purposes.

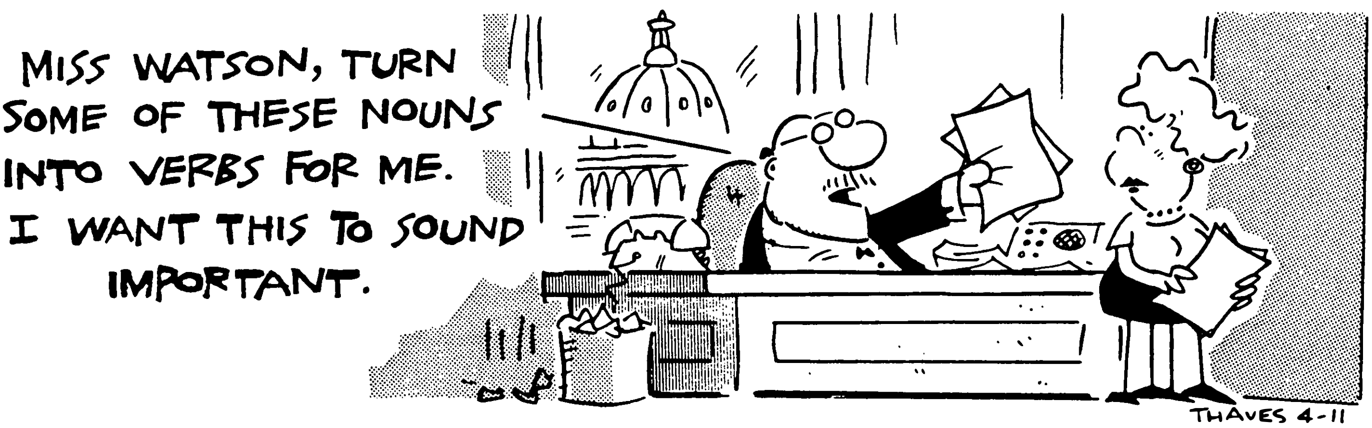
*H. W. Fowler*

English is a dynamic language, and change has always been inherent in its growth. Not all change, however, improves the language. Some writers, especially in the media, the military, and the bureaucracy, introduce new word forms whether they are needed or not, often out of sloth, and the resulting proliferation seldom enhances either the richness of the language or its clarity. "Destruct" is a pitiable example from the space program. "Input" and "access," both as verbs, are two of many contributions from computer language where perhaps they should remain. So, also the verb "keyboard." Many long-standing nouns used in Survey reports are unacceptable as verbs, and although some may gain acceptance through long use, the Survey is not an appropriate agent for their nurture. Many will vanish unassisted from the idiom. Some such verbs are formed by affixing "ize" to the noun or adjective—words such as "prioritize" (ugh). Thousands of standard words (crystallize, itemize, digitize), as well as some abominations (finalize), have thus entered the language. "Finalize" became fashionable in the 1960's, over spirited opposition from wordsmiths. Survey authors can hardly judge what current coinages deserve to survive. Rather, authors should heed the advice of "The American Heritage Dictionary" (Second College Edition), regarding the suffix "-ize": "New coinages of this sort should be used with great caution until they have passed the tests of utility, permanence, and acceptance by good writers."

Recently coined words ending in "ize" are not alone among offensive verbs; new creations appear often in the earth sciences. "Young," for example, is a good adjective but an unacceptable verb, and to write that something "youngs to the east" will offend most readers. One author described rocks that "had been boudinaged" during regional deformation. Similarly, "contact metamorphism" is a recognized geologic process, but its acceptability as a noun does not justify its use as a verb: "The magma contact-metamorphosed the igneous rock." The favorite abomination of one Survey editor is "complexify" but, except right here, it is not likely to see print in a Survey publication.

Simply using nouns as verbs can obfuscate clarity also. For example, the headline "CHINA PROTESTS FUEL REFORM DEBATE" has two possible unrelated meanings. The unsuspecting reader is sure to take "PROTESTS" to be the verb and read the sentence accordingly, but the intended verb is "FUEL," which is likely to be taken as a noun. "PROTESTS," meant to be a plural noun, is the intended subject, whereas the apparent subject, "CHINA," is meant to be a proper adjective modifying the noun "PROTESTS." Now reread the sentence and catch its real meaning.

Authors should also avoid usages that distort the true meanings of words and that thereby rob the





language of its clarity and acuity. Students of plate tectonics have seized "collide" and "collision" to signify processes that bear little relationship to the true meaning of the words. We, alas, are probably stuck with continental "collisions," but such portrayals can only cause confusion in the minds of laymen. Disneyesque depictions aside, truer if less colorful meanings would be conveyed by "join," "merge," "converge," "contact," "abut," "press against," "occlude," or "override."

### Abstract Nouns in the Subject of the Sentence

Abstract nouns are less offensive than newly coined "ize" verbs, but they are more pervasive, and their widespread use is among the commonest and most crippling stylistic faults in technical writing. In particular, turning active verbs into abstract nouns ending in "tion" puts the wrong word into the subject nominative and compels the writer to find a substitute verb—nearly always a weak one. Survey grammarian Frank Calkins used to admonish young writers to "shun tion."

As a writer you should consider whether an abstract or a concrete noun makes a better subject and should decide which choice strengthens the verb. In the following examples, the writers have converted strong, active verbs into abstract nouns for their subjects and have been forced to substitute weak, inappropriate verbs for their predicates, such as "occurred," "accomplished," "transpired," or "performed." Delete the words in italic and add those in brackets:

The *mapping of the* area was *accomplished* [mapped] by Smith and Jones.

*The principal production* [Most of the ore] was mined from the Nevada property. (You cannot mine "production.")

The *exploration of the* region was *carried out* [explored] by Smith.

During this epoch *aggradation of* the lowlands may have *transpired* [been aggraded].

Thus *a sudden inundation of* the desert would [suddenly] be *accomplished* [inundated].

*Capitalization of* the initial letters of formal geologic names [have been capitalized] *was adopted* by the Survey *in* [since] 1961.

*Modifications may be made to* existing formal names [may be modified] if evidence is *presented in a* published *report.*

The *movement of the* ore solutions here must have *been* [moved] very slow[ly].

The *formation of the* ore deposits *occurred* [were formed] just after the igneous intrusions. (Or better yet: The ore was deposited just after the igneous rocks were intruded.)

*Confirmation of* these reports cannot be *obtained* [confirmed].

The *selection, equipment, and maintenance of* stream-gaging stations are *performed* [selected, equipped, and maintained] according to standard methods.

*The principal use of* sheet mica is *in the manufacture of* [used principally in making] electrical apparatus.

*Examination of* the prospect could not be *made* [examined].

Slippage may *occur in association* [be associated] with volcanic activity. (Better yet: Slippage may result from volcanic activity.)

Because many mid-Paleozoic complexes are undeformed, *it has been possible to obtain a reasonably good understanding of* their tectonic setting [is reasonably well understood.]

*Computation of* the fractal dimension would be *done* [computed] in the Branch of Geophysics.

*Internal deformation of* the Moine rocks *was accomplished* [were deformed] primarily by northwest-directed ductile thrusting.

Other lines of evidence for the weakness of fracture zones come from geologic studies. (Change to: Geologic studies yield other evidence for * * *.)

In the sentence "Barite and intense silicification usually always accompany the ore" the compound subject links together a mineral, which perhaps accompanied the ore, and a process, which ended long ago. Change "intense silicification" to "intensely silicified rock." Whatever idea the writer had in mind by "usually always," the expression is objectionable, and the conditions would be better described by deleting "always."

## Forgetting Your Subject

Some writers seem to forget their subject before they finish the sentence.

> Its flow is large and is reported to be excellent for drinking. (The flow [of the spring] is so many gallons a minute; it is the water, not the flow, that is excellent.)
>
> The "rimrock," which surrounds Billings, Park City, and the intermediate area, is the popular designation for this scarp. (A "designation" cannot surround an area. There is more than one way to correct this sentence; it might be rewritten "This scarp, which surrounds * * *, is popularly called the rimrock.")
>
> The average thickness of the shale partings is about 1 millimeter but is extremely variable. (How could an average be variable? Write "The thickness * * * averages about 1 millimeter but is extremely variable.")
>
> Muscovite is possibly unstable in the presence of hornblende and occurs as biotite, plagioclase, and quartz. (Wow!)
>
> Although the rock has been greatly altered by weathering, the decomposition is believed [to be] rather superficial and is regarded as affording entirely adequate foundations. (Decomposition seems hardly an "adequate" foundation for a dam.)
>
> The principal granite district of this group of States is at Salida, Chaffee County, and is sold for monumental stone. (The granite, not the district, is sold.)
>
> The French deposits have been largely Government owned and have been sold through the German-French cartel. (It is the potash mined from the deposits that has been sold, not the deposits.)
>
> Cattle, poisoned by selenium-rich foliage, prompted scientists of the Department of Agriculture to investigate * * *.

## Modified Subject Misapplied

A phrase that qualifies or relates to the subject applies until a new subject is introduced, but in many sentences such a phrase is inadvertently applied to an unrelated part of the sentence.

> For full development the tree seems to require considerable water and probably deserves its reputation as an indicator of underground water. (The phrase "for full development" does not apply to the second clause and should be transposed after "considerable water.")
>
> The individual grains in the coarser limestone are as much as a millimeter in diameter and average 0.02 millimeter in the finer grained beds. (Write "The individual grains * * * are as much as a millimeter in diameter, but those in the finer grained beds average 0.02 millimeter.")
>
> Its generally dark color is somewhat somber for building stone but makes a very substantial structure. (The dark color does not affect its durability. Put a comma after "building stone" and insert "the rock" after "but.")
>
> During the summer a pool of water forms on the ice and gradually freezes again during the winter. (Change to read: A pool of water forms on the ice during the summer and gradually refreezes during the winter.)
>
> No lead and manganese were reported in these analyses and were evidently negligible. (One can assume that "no lead and manganese" would be negligible. Write "Lead and manganese were not reported in these analyses.")
>
> Very little sulfide is present in the main ore shoot, but it is abundant along the margins. (It is sulfide, not "very little sulfide," that is abundant. Write "Sulfide is scarce in the main ore shoot but is abundant along the margins.")

## Undesirable Change in Construction

Many compound or complex sentences switch ineptly from the active voice to the passive in midsentence. For clarity, continuity, and parallelism the voices of verbs should be the same:

> Surface water percolates downward until [it reaches] the zone of saturation *is reached.*
>
> These vugs carry no gold and [do not affect] the tenor of the vein *has not been affected by them.*
>
> The workings were closed and *examination of them* could not be *made* [examined].
>
> The rocks show both bedding and cleavage, but *the amount of* [not much] metamorphism *has not gone far.* (Also, delete the comma.)

## Undesirable Alliteration

Alliteration, the repetition of initial word sounds, may have a positive impact on the reader but is more likely to draw attention from the substance of the message to the style. A few egregious examples:

Larger and longer lived lakes
Famous fossil-fish formation
Crustal movements that crushed and crumpled
Further fissuring, faulting, and fracturing
Well-waterworn polygonous pebbles
Low-lying lands that lie
Shattered and scattered through the shale
Saturated silts sliding slowly seaward
Somewhat similar series of sediments

## Loose Versus Tight Language

Loose language is appropriate in some contexts, but the greater precision of tight wording is better for technical reports. A few examples:

| **Loose** | **Tight** |
|---|---|
| a number of | several, a few |
| accountable for | the cause of |
| essentially | principally, mostly |
| evidenced | showed, indicated |
| grows | becomes |
| improve | increase |
| in case of | if |
| in the vicinity of, in the neighborhood of | about, near, nearly |
| majority | most |
| open, close | begin, end |
| over, under | more than, less than |
| provided, provided that | if |
| ranges up to | is as much as |
| various | many, several |

## Meaningless Redundancies

Commonly heard redundancies are sometimes used unthinkingly, as follows:

| | |
|---|---|
| actual measurement | join together |
| advance planning | metric unit of measure |
| age dating | low-lying depression |
| bisect into two parts | originally of * * * origin |
| completely absent | preliminary preparations |
| completely surrounded | refer back |
| down dropped | relative proportion |
| downward direction | repeated repetition |
| dropped down | Rio Grande River |
| erroneous misconception | rise up, sink down |
| feeling of euphoria | Sierra Nevada Mountains |
| first began | surrounded on all sides |
| first initiated | throughout the entire |
| green in color | underground cavern |

Perhaps you can add more examples from your own list.

## Prepositions in Idiomatic Expressions

Idiomatic expressions are word groupings that are unique to a language or culture. Some cannot be explained logically, but they are part of conventional usage. A few common prepositional idioms are listed below:

**Compare:** x **with** y (similar things), x **to** y (different things)

**Conform: to** practice, **to** a design; conformable **to,** in conformity **with**

**Contrast (verb):** x **with** y

**Contrast (noun): between** x and y; x placed in contrast **with** y

**Correspond: to** (things), **with** (persons)

**Differ:** An object differs **from** another object, a person differs **with** something or someone ("I beg to differ with you.")

**Different: from** (not **than**)

**Independent: of** (not **from**)

**Overlain: by** (not **with**)

## Foreign Words

Foreign words are unlikely to add anything to a scientific report that is not better expressed and understood in English. Many readers, perhaps most, cannot translate or define "viz," "i.e.," "e.g.," and "et al." "In place" is generally better than "in situ." "Etc." is meaningless in most constructions and is improper in the following examples:

> Deposits of this type occur in several mines—for example, the Telegraph, Commercial, [and] Old Jordan, *etc.*
>
> The solution contained mineralizers, such as fluorine, [and] boron, *etc.* (Delete the comma after "fluorine.")
>
> The glacial features that give variety to the surface, such as moraines, kames, [and] eskers, *etc.*, are described.

On the other hand, a few foreign words that have no appropriate English equivalents have been adopted as technical terms—words such as arête, bajada, boudinage, couloir, felsenmeer, inselberg, lahar, moulin, and roche moutonnée.

## Vogue Words and Trite Phrases

Vogue expressions intended to enliven reports or add sophistication may have the opposite effect. Through overuse they lose effectiveness; even worse, they may foster subconscious antagonisms, or by leaping from the page, may distract the reader's attention from the thoughts that the author hoped to convey. Though some vogue words may endure, the writer of scientific reports is hardly the proper judge of idiomatic trends. Trite words and phrases, such as "timeframe," "viable," "point in time," "might well be," "window of opportunity," and "impact" (in some connotations as a verb), will pass out of use, and we can rejoice in their passing, but we must be on guard against new ones springing forth. "Model" has become a prevalent substitute for "conjecture" or "postulate"—the working hypothesis of times past is the working model of today. "Metastable," from physical chemistry, has been adopted by geomorphologists. "Powerful tool" had a spate of fashion among earth scientists in the 1980's. If you suspect that a word is trite, it surely is.

## Stilted and Showy Language

Some authors seem to believe that writing is enhanced by obscure phrasing and that the best means to that end is stilted and showy language, what George Otis Smith called "the wordy sins of scientists." These authors never "go" anywhere; they invariably "proceed." Rather than "start" new projects, they "initiate" them. They "encounter" fossils, "inaugurate" new programs, and "conduct" field trips. The engineer who remarked that "Repairs are a very manually intensive effort," meant that they must be done by hand. The mapper who wrote that "Contact relationships are poorly constrained due to talus-block slopes" meant that the contacts are covered with talus.

Bernard H. Lane, in his revised and enlarged STA 4, noted that authors only occasionally recognize these faults in their own writing. (Faults are easier to see in the writing of others.) One writer changed "hydropneumatothermal contact action" to "hot solutions" in his own manuscript and thereby deprived his reviewer of the vicarious pleasure.

Pedantic phrases in some technical reports seem designed to flaunt learning or to hide shortcomings by overwhelming the reader. Other sincere but misguided attempts at precision are likely to be seen as priggish distractions. If a choice can be made between a polysyllabic Latin derivative and a simple Anglo-Saxon word, between a long word and a short one, the latter is almost always more effective. Use the big word if it is precisely and uniquely right, but try to save your reader's train of thought and a needless trip to the dictionary. Use "palynomorphs" if you must, but if you are talking about pollen grains, say "pollen grains." In the words of one sage, eschew obfuscation. Economy in words serves two purposes: It enhances readability, and it cuts printing costs. If a word must be repeated, a short word diverts the reader's attention less than a long one.

Here are a few stilted words, with suggested alternatives. As George Otis Smith once said, "It takes years for some geologists to break the fetters of this scholastic habit."

| | | | |
|---|---|---|---|
| abstruse phrases | vague words | interdigitate | interfinger |
| allochthon | upper plate | limited | small, few |
| appellation | name | numerous | many |
| approximate | about | palynomorph | pollen grain |
| arenaceous | sandy | pelite | clay, shale |
| argillaceous | shaly | peruse | read |
| autochthon | lower plate | plication | fold |
| conduct | lead, do | psammite | sandstone |
| congeliturbation | frost action | psephite | conglomerate |
| display | show | riparian border | riverbank |
| employ | use | secure, obtain | get |
| exhibit | show | terrestrial gastropod | land snail |
| ignimbrite | welded tuff | transect | cut across |
| inaugurate, initiate | start, begin | verge | bend, turn, move |

## Care With Metaphors and Similes

Samuel Goldwyn, late master of the neatly turned phrase, once said that anyone who makes atom bombs is fooling with dynamite. He also said that people who visit psychiatrists should have their heads examined. Metaphors and similes used sparingly may add meaning and color to some scientific reports, but they must be used with care: "carpeted with grass," yes, "carpeted with boulders," no; and like fine old scotch, they should not be mixed.

## Pathetic Fallacy

Ascribing human traits or feelings to inanimate objects—what Ruskin called the "pathetic fallacy"—is inappropriate in scientific reports. Mountains neither enjoy uplift nor suffer degradation, tides are never restless, and skies are never angry, at least not in reports of the USGS.

## Sexist Pronouns

Variations of the pronoun "he" are unacceptable to many people when referred collectively to both masculine and feminine genders and should be avoided in that context in Survey reports. The noun "geologist," for example, has no implied gender—it may be either masculine or feminine—but "he" is inherently masculine, despite the remonstrations of some grammarians. "He" can be avoided gracefully by careful grammatical construction. Contrived, tricky artifices to cover both genders should be avoided: He/she, she or he, s/he, his/hers, his or hers, him/her and him-or-her sometimes appear in technical reports, but they tend to distract or annoy the reader, especially if used repeatedly. Moreover, by making curt little bows to feminism, they are condescendingly sexist (Johnson, 1983).

Sexist pronouns can be avoided in various ways. In the following examples the bracketed words should be added; the italicized words or letters should be deleted.

1. Use plurals instead of singulars:

    Before beginning to write *the* author[s] should familiarize *himself* [themselves] with the literature.

2. Change the person of the subject and pronoun from third person (he) to second (you); second person may be inappropriate in technical reports, but it often is useful in nontechnical writing:

    Before beginning to write *the author* [you] should familiarize *himself* [yourself] with the literature.

3. Use the imperative mood; the imperative serves the same purpose as second person but more forcefully:

    *The author should* [Be] familiar*ize* *himself* with the literature before beginning to write.

4. Change the voice of the verb from active to passive. The passive voice should not be overdone, but its occasional use can have a positive effect on the reader:

| **Change this** | **To this** |
| --- | --- |
| An author should not think that because he has studied thin sections of all the rocks of a district it is necessary to publish exhaustive descriptions of them. | An author should not think that because all the rocks of a district have been studied in thin section, exhaustive descriptions must be published. |

    The recast version, by switching to the passive voice, has fewer words and the added virtue of parallel construction. It does not specify, however, that the author studied the sections. Some advantages and disadvantages of the passive voice are discussed on page 142.

5. Insert a participle:

    The author may follow the same procedure before *he turns* [turning] the report in for review.

6. Simply omit the offending words where the meaning is clear without them and recast the sentence, substituting applicable articles for pronouns and deleting other unneeded words:

    *In* this section *are* outlined[s] *the* successive steps *that an author will* normally follow[ed] in planning and writing *his* [a] report, beginning when an investigation is authorized and ending with *his* final review. [Included are] suggestions *are also offered* that *he* may *find* [be] useful at different stages.

    Procedure 6 also has the merit of yielding tighter, crisper writing (34 words instead of 44).

## Ellipsis

Ellipsis, the omission of words where the reader is expected to understand the meaning without them, can tighten and freshen style or obscure the meaning. Use ellipsis to avoid distractive repetitions, but be careful to avoid ambiguities or illiteracies.

Many good writers use ellipsis instinctively. In "Much Ado About Nothing," "The fashion wears out more apparel than the man," the Bard's meaning is perfectly clear without repeating "wears out" or adding "does," but in the following sentence, "Fred was more interested in the fossils than his wife [was]," the bracketed verb is needed for clarity.

Conversely, studied avoidance of ellipsis is fairly common in Survey manuscripts, probably in the mistaken belief that clarity is thereby gained. In the sentence, "Graphs present some kinds of data more concisely than *does* any other format," the word "does" adds little more than awkwardness to the sentence. "Does" would be less awkward if it followed "format," but its presence there is not needed for clarity.

# Choosing the Right Word

Whenever we come upon one of those intensely right words in a book or a newspaper the resulting effect is physical as well as spiritual, and electrically prompt.

*Mark Twain*

EVEN THOUGH SEVERAL WORDS may be synonymous, they all have different shades of meaning. Authors should carefully choose the word that best conveys the intended message. Technical writers sometimes fail to distinguish shades of meaning, or they brush aside careful word choices in the haste to set down their scientific concepts. If a word is uncommon, double check its spelling and meaning or risk passing a flawed message to the reader.

The following words and phrases are stumbling blocks for many Survey authors:

**A, an**

"An" should precede "h" words only if the "h" is silent: an heir, an herb, an honor, or an hour, but a historic event. In contemporary American usage almost all beginning h's are pronounced.

**About, approximately, on the order of**

"About" is nearly always better than "approximately," but "approximately" is preferable if fairly accurate figures are being given. "On the order of" should be used only with an established order of intensity, magnitude, or velocity. It should not be substituted for "about."

**Absent, lacking**

"Absent" means simply not present or missing ("absent without leave"), but "lacking" implies need or requirement. "Data are lacking" could mean that they are unavailable but seems to say we want more. Absence is a factual condition or observational statement, as in the following examples:

> Sandstone beds are *lacking* [absent] from the lowermost section.
>
> Samples containing evidence of secondary mineralization are *lacking* [unavailable, not found].

The lack of an item, as opposed to its mere absence, reflects more human than natural factors; the scientist is concerned with the existence of facts, which should dictate the choice of words. If no evidence exists, then say so directly.

**Accuracy, precision**

A measurement can be precise without being accurate. Precision relates to values reported in very small increments; accuracy reflects the correctness of those values. A stratigraphic measurement to the nearest tenth of a meter is very precise but is not necessarily accurate. In statistics, "accuracy" is the agreement of a measured or computed value with the absolute or true value; "precision" is the degree of coincidence of repeated measurements of a single quantity. (See also section on "Significant Figures," p. 119.)

**Align, alignment**

"Align" and "alignment" should refer to things being in a line: "The stakes were precisely aligned." The author who said the minerals are aligned N. 30° E. meant that their long axes are oriented in that direction, not that they are one behind another. The alternative spelling "aline" is no longer used in Government reports.

**All of**

The word "of" in the phrase "all of" is generally superfluous. As a popular idiom "all of" emphasizes totality, as "How many of the rocks did you see?" "I saw all of them." The best usage omits the "of" as needless, preferring "I saw them all." I saw all (not, all of) the specimens. Include "of," however, with pronouns, as "all of it," "of whom," "of which," "of them."

The foregoing judgment is based on the assumption that the word "of" is a partitive in phrases like "some of," "many of," "one of"—that is, a term implying partition or denoting a part—whereas in "all of," no expression of partition is intended. "The whole of" has been criticized on the same grounds.

You may say "the whole staff accompanied the Chief Hydrologist" or (for emphasis) "the whole of the staff," but it would be better to say "the entire staff" or "all members of the staff," not "all of the members of the staff." "Take it all" is better than "Take all of it."

But "of" after "all" should not be mechanically cut out. In the phrase "Many *but not all* of these fragments are rounded" the italicized words may be superfluous, but whether or not they are cut out, the "of" should stand.

**Although, whereas**

"Although" means "regardless of the fact that," and "whereas" suggests "but at the same time" or "while on the contrary." A clear contrast between two statements is implicit in "whereas" but is not implicit in "although." ("Jack was short and fat, whereas Jill was tall and skinny." "Although gypsum is soft, talc is even softer.")

**Altitude, elevation**

Both terms may refer to height above sea level, but "elevation" may also mean uplift in a geologic sense. To avoid ambiguity, use "altitude" in geologic reports to indicate height above sea level and use "elevation" to mean uplift. Because "elevation," however, is widely used by engineers and topographers to mean altitude, Survey reports directed to such readers may follow that usage. Consistency is essential; do not use "altitude" and "elevation" interchangeably within a report, and do not use "elevation" for "uplift" if you also use it to mean "altitude."

**And (or)**

The legalistic "and (or)" is not erroneous but is frowned upon by grammarians and should be avoided. The slash (and/or) serves the same purpose no better. "Or" or "and" alone may suffice to make the meaning clear; "or both" may be added.

> In some places the succession of shale beds is interrupted by lenses of sand or gravel.
>
> The sequence may include limestone or sandstone, or both.

**Apparent, evident, obvious**

"Obvious" means so easily perceived or seen that it cannot be missed. "Evident" denotes the existence of visible signs, all pointing to one conclusion. "Apparent" goes one step beyond "evident" and implies visible signs and some reasoning, as in "The absurdity of their contention is apparent to one who knows the effects produced by the same causes in the past."

**Appears, seems**

"Appears" in its primary sense means to come into view, as in "As one travels westward the mountain appears over the horizon." "Appears" also means to give an impression and therefore approximates "seems," as in "It seems (appears) clear that the rock was originally a sandstone." "Seems" may suggest something in opposition to fact, however, as in "The rock seems to be gray, but in good light it is seen to be buff." If you wish to maintain a distinction between "appears" and "seems," you should follow the first definition above.

**Area, region, section**

"Area" and "region" are common geographic descriptors. Use "region" for larger geographic units and "area" for smaller ones. Usage should be consistent; the "region" of one paragraph should not become the "area" of another. "Section" is best reserved for land sections, cross sections, and thin sections.

**As, since, because**

"As" and "since" are sometimes used as conjunctions interchangeably with "because," but the result can be ambiguous if the reader takes the meaning to be "after," "when," or "at the time that." In the following examples, "as" and "since" are ambiguous:

> The levees were sandbagged *since* [because] all the creeks were in flood.
>
> *Since* [when, or because] you left the door ajar, the house filled up with flies.
>
> *Since* [because] the Snow Storm Mine ceased production and the Lost Packer Mine shipped only a few cars of matte, the increase during the year was due to * * *.
>
> *As* [because] the hillside was logged off, avalanching increased.

"Because" is the most specific conjunction used to express cause or reason—it indicates unequivocal causal relationship. "Since" is sometimes used in place of "because," but its principal connotation of time confuses the usage, particularly in introductory clauses: "*Since*" [Because] a tidal wave was forecast, people fled to higher ground."

**As much as, up to**

"As much as" is better than "up to" for describing an upper limit. "Up to" implies a position in space and logically should be coupled with a preceding "from." (See also "Range.")

**As well as, and**

"As well as" is used in a parenthetical sense to give slightly less emphasis to what follows it compared with what precedes it; if no such subordination is intended, "and" should be used instead. The parenthetical construction does not affect the number (singular or plural) of the verb, so awkward phrasing can result: "Quartz, as well as microcline and oligoclase, is a major constituent" doesn't sound as good as "Quartz, microcline, and oligoclase are major constituents."

**Assume, presume, postulate**

In the sense of suppose, "presume," which is similar to "assume," expresses what the presumer believes until it is proved wrong, and the presumption should be based on experience, theory, or logic. "Assume" perhaps should mean to take for granted, and with less reason for doing so than to take that which is presumed; it emphasizes the arbitrary acceptance of something as true. "Postulate," in the sense of suppose, means to assume, especially as a basis for argument. Webster says, "One can assume * * * at any point in a course of reasoning, but one postulates something or lays down a proposition as a postulate only as the groundwork for a single argument, or for a chain of reasoning, or for a system of thought." In considering "postulate," scientific writers might ponder whether they actually mean that word or, perhaps, "infer" or "conjecture."

**Assure, ensure, insure**

"Assure" means to encourage. "Ensure" means to make certain. "Insure" should be used when referring to underwriting a loss.

**Audience, readership**

"Audience" is used widely as a synonym of "readership," but its derivation is from the Latin verb "to hear." Although "audience" has come to mean one's public or readership, it is better reserved for august gatherings in lecture halls or meetings with the Director.

**Balance, remainder, rest**

"Balance" is properly used to denote the difference between two amounts when their comparison is in one's mind. Without this idea of comparison, "rest" or "remainder" is the better word. "Rest" is preferred to "remainder" when there is no implication of subtraction, depletion, or deduction. If such an implication does exist, as in "Two faults trend northeast, but the rest trend east," either word is correct, though "remainder" is a bit stilted. "Remainder" seems preferable in describing laboratory analyses even when that which remains is not thought of in terms of amount, weight, or the like, but "rest" has the virtue of being shorter.

**Based on, on the basis of**

Carefully distinguish the participial phrase "based on" from the prepositional phrase "on the basis of." "Based on" modifies the noun in the main clause of the sentence; "on the basis of" modifies the verb.

> *Based on* [On the basis of] measurements made on photographs, Brown estimates * * *. (Brown is not based on photogrammetic measurements, the estimates are.)
>
> Brown's estimates were based on measurements made on photographs.

Even when grammatically correct, a "basis" phrase may be less desirable than a concrete phrase.

> *The rocks on the basis of* [If classified by] size of grain [the rocks] may be divided into sandstones and conglomerates. (Also, "grain size" would be better than "size of grain.")
>
> The conclusions stated seem to be warranted *on the basis of* [by] the data presented.

**Beside, besides**

In some senses these are interchangeable. "Beside" means by the side of. "Besides" means in addition to or other than. Some writers prefer "in addition to" over "besides" where an adding to or union with something is meant; "besides" may not be as clear here, because it may be taken to mean "other than" in the sense of except.

**Between, among**

Strictly speaking, "between" requires two objects; "among," more than two. However, current usage permits use of "between" with more than two objects when each item is considered in relation to each of the others.

**Both, different**

"Both" and "different" are useful words, but they are not needed in these sentences:

> *Both* branch chief and project leader will depart in opposite directions.
>
> They are *both* alike.
>
> The Survey occupies more than 30 *different* buildings.
>
> The motorship brings mail and freight to the *different* towns in the region.
>
> Samantha Harper and Bill Macy have married and *both* are honeymooning in Hawaii.

**Calculate, compute, determine, estimate**

"Calculate" and "compute" are used to describe mathematical determinations. "Calculate" hints at sophisticated mathematical operations; "compute" suggests straightforward arithmetic. "Determine" means to find out exactly. "Estimate" may involve calculations or computations, but it also implies use of judgment and a result that is not necessarily exact.

**Can, could; may, might**

"Can" suggests the ability to do something. "May" expresses permission ("Mother, mother, may I go") or possibility ("These rocks may have been folded more than once"). "Could" and "might," respectively, are the past tenses of these two verbs, but all four words are also treated as subjunctive verbs that can convey ideas in present or future time. "Can" and "may" have positive connotations, whereas "could" and "might" imply that the ability or permission required to do something is unlikely:

> This outcrop can be studied. (Studying it is feasible)
>
> This outcrop could be studied. (If certain criteria were met)
>
> This outcrop may be studied. (You have permission to do so)
>
> This outcrop might be studied. (Chances are less likely that it will be studied or that permission will be granted)

**Case, instance**

Authors should guard against these words. *In* most *cases they* [of them] are superfluous, and *in* some *instances they* are misleading; they commonly add needless words.

**Case, instance**—Continued

The author who wrote, "Specimens in some cases exhibit veins of calcite" meant simply "some specimens," not museum pieces. Catch the double meaning here: "Splendent prisms of hornblende were displayed in only one case; in every other case the rocks were propylitic." See also "Display, exhibit."

Other improper or superfluous usages:

> In some *cases* [places] the lowlands contain lakes, the most conspicuous *instance* being Crystal Lake.
>
> *In a few instances* [Locally], as at Chimney Pond * * *.
>
> One such case formed a cinder cone. (How could a case form a cinder cone?)
>
> In several cases the casing has been pulled.
>
> In case of a malfunction of the pump * * *. (If the pump fails)

**Centered around, at, in, on, upon**

Because "center" refers to a central point or focus, "centered around" is illogical and should not be used. "Centered at, in, on," or "upon" are all acceptable alternatives.

**Character, conditions, purposes**

In many sentences these words take up space without adding anything to the meaning. If the extraneous words are eliminated, the expression is more forceful, as in the following examples. Delete the words in italic: "The surface is *of a* very uneven *character*." "With proper drainage *conditions*, the land could be made more suitable for farming *purposes*."

**Characteristic, distinctive, typical**

"Characteristic" distinguishes that which identifies some particular thing. "Distinctive" emphasizes that which sets something apart. "Typical" expresses the qualities of a representative example.

**Collide, collision** (see p. 151)

**Commonly, generally, typically, usually**

"Commonly" refers to something that is frequent or ordinarily so. "Generally" refers to something that is extensive but not universal. "Typically" refers to something that applies to most members of a class. "Usually" has a temporal connotation for something that is customary or regular but not universal; it should not be confused with "generally."

**Comparative(ly), relative(ly)**

Some writers use "comparative(ly)" and "relative(ly)" to hedge otherwise-positive statements and thereby diminish the effectiveness of their writing ("Discharge was *comparatively* rapid." "The eruptions were *relatively* small."). Neither term is properly used without a comparison: "Compared with the great eruption of 1815, these eruptions were relatively small."

## Compass directions

Terms of compass direction, such as "west," "western," "westerly," and "westward," should not be used indiscriminately. The adjectives "west" and "western" may both be used, but each should be used consistently. Indefinite or general terms of broad application may end in "ern," as "in the western part of the district"; terms of definite designation need not, as "west bank, west side."

"West" is an adverb also, as in the sentence "The fault strikes west" (or "westward"). Use "west" to indicate approximate direction, meaning anywhere between west-northwest and west-southwest. Exact direction is better expressed by saying "due west" or by giving the deviation in degrees, as "N. 75° W." Puzzles in direction appear in many reports:

> About 13 kilometers north and a little west of Weatherford.
>
> About 160 kilometers south of west of this * * *.
>
> In a ravine 2.5 kilometers west and a short distance north of Hanover.

If a place cannot be reached by a diagonal (few places can), say "Drive 10 miles north and then 2 miles east."

The adjective "westerly" is used properly in such phrases as "westerly dip, direction, trend." Its use as an adverb is less desirable; STA suggests "westward":

> The fault extends indefinitely *westerly* [westward].
>
> The stream here turns *westerly* [westward]. (Not "westwardly" or "to the westward.")

The "westerly wind" means the wind that blows from the west.

"Westward" also is both an adjective and an adverb. It is used properly in the unit modifiers "westward dipping, trending, flowing" (but west-dipping might be better). "Westward" is used as an adverb in "extends westward." The adverb "westward" means toward the west or in a general westerly direction. In the sentence "Clay is abundant in this formation at Newton and westward," the latter part would be better if written "at and west of Newton."

## Compose, comprise, consist, constitute, include

Authors often stumble over these terms. "Comprise," besides being a bit stuffy, is so widely misused that you might better avoid it entirely. A safe guideline for authors: Excise "comprise" should it arise.

The whole "comprises" the parts; for example, "The formation *comprises* [consists of] limestone and shale." The parts "compose" or "constitute" the whole, as in "Limestone and shale compose [constitute] the formation." Never write "is comprised of"; the passive form "is composed of" can be substituted for "comprises" or "consists of," but the result is a weaker sentence: "The formation *is composed of* [consists of] limestone

**Compose, comprise, consist, constitute, include**—Continued

and shale. In contrast to all these terms, "include"indicates an incomplete listing of constituents: "The formation includes limestone and shale" implies that other constituents not mentioned are included also.

**Conclude, deduce, imply, infer**

"Conclude" means to reach a decision or an agreement as a logical result of interpreting evidence. "Deduce" means to derive an inference from a principle. "Infer" is similar to "deduce" but is not so strong a statement. The difference between "infer" and "imply" rests on the writer-reader relationship: The reader infers or concludes something from an implied statement by the writer. To imply something is to state it indirectly, to hint, or to suggest. "Imply" and "infer" should not be used interchangeably.

**Conduct**

"Conduct" is a good verb for leading an orchestra but is stilted for a field trip or a research project and, moreover, is often superfluous: "Exploration and development should be *conducted in an* orderly and careful *fashion.*" "Jones *conducted research on* [researched] the evolution of the Desmoinesian Foraminifera."

**Conspicuous, prominent**

In the sense of being immediately noticeable, "conspicuous" and "prominent" are synonyms. The root meaning of "prominent," however, is to jut out or project above a level or beyond a surface, and when that meaning is intended, a clear distinction between these two terms should be observed. Rock colors and bedding planes may be conspicuous; a volcanic cone may be both conspicuous and prominent.

**Continual, continuous**

"Continual" relates only to time and applies to something that goes on incessantly or that recurs unceasingly. "Continuous" refers to uninterrupted action in time or unbroken extent in space.

**Crop out, outcrop**

Use "crop(s) out" as a verb; use "outcrop" as a noun. "Outcrop" used as a verb is easily misread: "The rock outcrops at three places in the study area * * * " is an example that brings the reader up short, wondering what comes next.

**Crossbedded, cross-laminated, cross-stratified**

The AGI Glossary and Webster's Third International Dictionary hyphenate all these words, but the Survey and the GPO Style Manual write "crossbedded" as one word. "Cross-laminated" vs. "crosslaminated" is writer's choice, but "crosslaminated" looks a bit awkward. "Cross-stratified" should always be hyphenated to avoid tripling the s's.

**Data, facts, information**

The term "data" generally refers to organized information used to answer questions or reach conclusions. Data are often used to verify "facts." "Information" is knowledge gained in any way, whether through study, experience, or hearsay; its connotation is more general than "data," though the terms are sometimes used interchangeably. "Data" is the plural of "datum" and should not be used in a singular sense in Survey reports. "Datums," however, is correct for bench marks and time markers.

**Deplete, enrich**

"Deplete" means "decrease the supply of" or "deprive of something essential to existence"; "enrich" means "add to or improve by addition." Thus, one can have "an enriched [depleted] granite" or "a granite enriched [depleted] in calcium." The converse is not possible; calcium cannot be depleted in granite. The phrasing may be further simplified by using a unit modifier: Ca-poor, quartz-rich granite.

**Despite, in spite of, notwithstanding**

All three terms indicate opposition of varying intensity to contrary forms or circumstances. "Notwithstanding" suggests the weakest opposition, "despite" is stronger, and "in spite of" is strongest.

**Determined to be**

"Determined to be" appears in many manuscripts, but watch out for this pitfall (see p. 142, 143): "Determined to be" can be either (1) intransitive or (2) transitive passive voice, as in the following:

(1) King was determined to be successful.

(2) The Uinta Mountain Group was determined to be Precambrian.

**Develop, development**

"Develop" in many manuscripts is intended to mean acquire, deposit, exploit, form, grow, mine, occur, work, or various other verbs that fail to gel in the minds of their writers. Here are a few uses and misuses:

> In this district ore bodies of considerable *importance* [value?] have been *developed* [formed? worked?].
>
> Here the vein is *developed in greater thickness* [thicker].
>
> The *large development* [great thickness] of Triassic sediments in this region * * *.
>
> It is possible that its development was in Tertiary time. (Write, "It may have formed in Tertiary time.")
>
> There is much lateral variation in the *development* [thickness? character? composition?] of even the most persistent strata.
>
> Salt pseudomorphs are *more prominently developed* [more abundant? more conspicuous? more nearly perfect?] on the south slope of the mountains.
>
> *In its typical development* [Typically] the formation is a series of dark clay shales.
>
> Neither the limestone nor the sandstone is *developed with sufficient uniformity* [sufficiently uniform] to be traced *for considerable distance* [very far].
>
> In some places the quartz *is developed in* [forms] anhedral grains.
>
> Here the century plants attain their *greatest development* [largest size?].
>
> These plants are here *present in less abundance and in more stunted development* [smaller and less abundant].

In the mining industry "develop" and "development" have explicit meaning. To develop a mining property is to open up the ore bodies. The work done for these purposes is development or

**Develop, development**—Continued

development work. "Developed" and "development" are used properly in the following sentences:

> It is the only deposit that has been developed.
>
> The development of the deposit will soon *be undertaken* [start].

Even in the above examples, however, the sentences would gain clarity by a more informative choice of words.

In water-well construction "develop" and "development" have a particular meaning also, although more explicit words might add clarity. To develop a well is to remove fine-grained material from the walls of a drill hole to improve yield. In ground-water parlance, "develop" and "development" refer to exploitation of ground water:

> Large supplies of ground water are developed in this area.
>
> The ground-water development in this area is intensive.

**Display, exhibit**

Save both words for museums, art shows, and department store windows. "Display" and "exhibit" appear interchangeably in many papers whose authors fail to search out more meaningful, less trite words. "Webster's Third New International Dictionary," equates display with "an unfolding, stretching out, spreading out, or otherwise showing in full detail or to best advantage (displaying the new fabrics to the buyers)." "Exhibit" applies to putting forward prominently, openly, or conspicuously to attract rather than merely permit attention and inspection ("He exhibited with peculiar pride two cream-colored mules"—Willa Cather). Other meanings include "show off" and "show with ostentation."

Now try to visualize a fault exhibiting very little drag, a rock exhibiting poorly developed fracture cleavage, or a thin section displaying eutaxitic texture. If you can believe some authors, quartzite may even exhibit vague cross stratification or dim outlines of hopper crystals.

**Distinctive** (see "Characteristic")

**Dominant, predominant; dominate, predominate**

"Dominant" and "predominant" both mean that which exercises principal control, but "predominant" can also mean having greatest influence or authority at a given time. The verb forms, "dominate" and "predominate," are synonymous, so the shorter form is better.

**Doubled-up auxiliary verbs**

Mark Twain, in his book "A Tramp Abroad," wrote:

> Harris said that if the best writer in the world once got the slovenly habit of "doubling up his have's" he could never get rid of it—that is to say, if a man gets the habit of saying "I should have liked to have known more about it," instead of saying "I should have liked to know more about it," his disease is incurable.

**Doubled-up auxiliary verbs**—Con.

Doubled-up "have," "has," and other auxiliary verbs are seen in rough drafts of some manuscripts, as in the following sentences:

> This gravel *has the appearance of having* [apparently has] been deposited by moving water and *has a strong resemblance to* [strongly resembles] the Gila conglomerate.

> The known geologic history of the region *may be said to have been begun* [began] in Silurian time.

On the other hand, "to be" is often omitted where it should be used, as in these sentences:

> Cap Glacier is reported [to be] a thin névé field.

> The submarine topography appears [to be] chiefly the result of glacial erosion.

"Have" and "has" should be used as principal verbs only with thoughtful discrimination. "Has" should be used in place of "contains" in the sentence "This water contains a higher mineral content," but "have" and "has" are used undesirably in the following sentences:

> The deep erosion gives evidence that the rocks *have a* [are of] considerable age.

> The alluvial soil *has* [contains] much sand and gravel.

> The rocks *have a flesh color* [are flesh colored].

> The sample had *had no exposure* [not been exposed] to the air.

**Dramatic**

"Dramatic" means theatrically representing human character or behavior. Its attribution to striking natural phenomena such as earthquakes, volcanic eruptions, or fault offsets is an anthropomorphism. Such events or features would be better described as "great" or " significant," or they should be described by some other appropriate scientific term.

**Drainage basin, drainage divide, watershed**

"Watershed" once meant just the divide separating one drainage basin from another. Now it also means catchment area or drainage basin, even though such usage can be ambiguous. "Drainage basin" is a better term to indicate the area drained. "Drainage divide" refers to the boundary between one drainage area and another. "Drainage" should not be used as shorthand for "drainage basin."

**Due to, owing to**

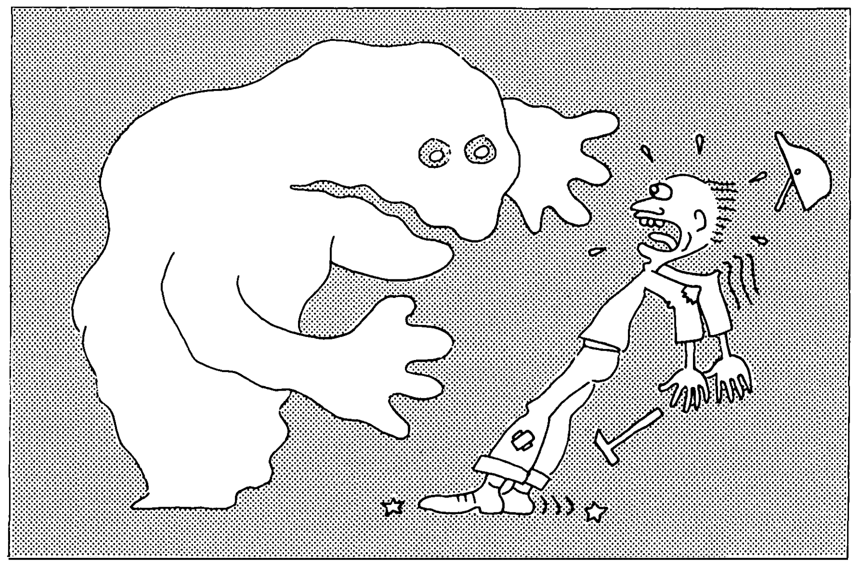
STA recommends that authors adhere to the traditional use of "due to" only as a predicate adjective following a linking verb: "The uplift was [due to] *owing to* movement in the underlying plate." Many modern writers inelegantly use "due to" as an adverbial modifier by simply dropping "owing to" from their vocabularies: "Landsliding was instantaneous *due to* [, owing to] liquefaction of saturated silt." "*Due to* [Owing to] the rugged terrain, the fault trace was very crooked." (Better yet, "Because of the rugged terrain, * * *" or "On account of * * *.") "Because of" is clearly better than "due to the fact that" or "owing to the fact that." Although the adverbial use of "due to" is common, it is deplored by most grammarians.

**Employ, use, utilize**

"Employ" and "use" are generally interchangeable, except that "employ" is stuffier. "Utilize" and "employ" are equally pompous, but "utilize" implies a practical or profitable use. "Employ" also means "to hire," so its use in a different sense may cause momentary misunderstanding in the mind of the reader: "We employed a block and tackle to remove the specimens."

**Encounter**

"Encounter" means to meet unexpectedly; to come face to face; to oppose, confront, or contest—a meeting with hostile forces. "Encounter" is a favorite verb of writers who prefer a longer, more impressive-sounding word than "meet" or "find." It has little place in technical literature except for dramatic effect, which doesn't belong there either. Better alternatives are "meet" and "find."



"Kaye first encountered xonotlite deep in the workings of the Puerto Rican mine."

**Essential, essentially**

"Essential" means part of the nature or essence of something—a basic or indispensable property. It should not substitute for "almost," "chiefly," "in effect," "mainly," "most of," "principally," or "virtually": "The formation is *essentially* [mostly] limestone" or "Most of the formation is limestone." To describe a mineral as "essential" is correct if you mean that the mineral is invariably part of a particular rock.

**Evidence, evidenced**

"Evidence" is overused by some scientists-cum-mystery writers. The writer who said, "No fossil evidence was found," meant "No fossils were found." Another writer who said, "In this limestone pebbles were in evidence," should have said, "This limestone contained pebbles" (and would thereby have strengthened the sentence with a straightforward transitive verb).

"Evidenced," the past tense of a verb best avoided, is not as meaningful as "shown," "indicated," or "proved."

**Exhibit** (see "Display")

**Expressions of indefinite time and place** (see also "While" and "Time words, * * *")

Careful writers reserve adverbial words and phrases such as "at times," "often," "sometimes," "when," and "while" for expressions relating to time.

| **Change this** | **To this** |
| --- | --- |
| These phenocrysts are often deeply corroded. | Many of these phenocrysts are deeply corroded. |

**Following**

"Following" is used appropriately as an adjective in the sense of "succeeding": "The analyses are given in the following table." "They left the following day." The participle "following" should be avoided, however, in the sense of "after": "*Following* [after] the earthquake, a series of smaller shocks rattled the Bay Area." "O'Brien left the ship following his dinner." "Kellerman went West following a prolonged illness."

**Former, latter**

"Former" and "latter" are so often misused that many careful writers decline to use them at all. Do not use them if the reader will have to look back to find what they mean. "Former" and "latter" cannot be used, of course, for more than two antecedents, as in "The granite consists of quartz, orthoclase, and biotite, the former constituting two-thirds of the rock." Some writers use these words without reason, as in the following sentences:

> The quartz veins lie near bodies of muscovite-biotite granite, *the latter being* [which is] probably the youngest rock in the region.
>
> The mines and the smelter were operated until the first of November, the *latter* [smelter] treating an average of 360 tons daily. (In this construction, "latter" seems to refer to "November.")
>
> Most such deposits contain calcite, and where they carry copper-iron sulfides, the latter will oxidize to carbonates, silicates, and oxides. (Write, "Most such deposits contain calcite, and any copper-iron sulfides they carry will oxidize * * *.")

Some meanings can only be guessed or inferred from the context:

> The concentration of the sulfide ion is so greatly affected by change of acidity that *the latter* [this change] is the principal factor determining the precipitation of sulfides.
>
> One of the purposes of the reconnaissance was to examine certain prospects containing ores of uranium and vanadium, and it is to *the latter* [these ores] that this report is confined. (The context shows that "the latter" means the ores of both uranium and vanadium, not just vanadium, and not "certain prospects.")
>
> The house and chimney swing with different periods under the impulse imparted by the ground, and the *latter* [chimney] is broken off, usually at the roof line. (As written, "latter" refers to "ground.")

"Former" and "latter" have no proper antecedents in the following sentences:

> I have seen all the phenomena herein described but have minutely studied only small parts of them. It would be impossible for any one person to do the latter unless it were made a life task.

**Former, latter**—Continued

> In color the chrysocolla ranges from reddish brown to brownish black; in a few places it is light blue. The *latter* [blue chrysocolla] has a vitreous luster and is crystallized, but the *former is* [brown varieties are] dull and in most places amorphous. ("In color" is superfluous in the first sentence.)

**Found to be, known to be, seen to be**

The word "found" intrudes without reason in "These rocks are *found* exposed at many places" and "The principal lakes *found* in this region * * *." In the sentence "These lands *are known to* contain valuable deposits," the words in italic may be easily spared. "Known to be," 'found to be," and "seen to be" are generally superfluous, as in the sentences "The St. Peter sandstone is *known to be* jointed in places"; "In this region the deposits are *found to be* more arenaceous." On the other hand, these phrases may be improperly omitted where they are required to complete the sense of a statement, as "Under the microscope the grains of sand are [seen to be] coated with iron." "The rich ore, when examined closely, *contains* [is seen to contain] fine-grained drusy quartz." "Under the lens, the tuff *has* [is seen to have] a eutaxitic texture." (The texture is eutaxitic whether you see it or not, but it is seen to be eutaxitic under the lens.)

**Grow**

"Grow" should not be used to indicate changed conditions not involving growth: "The rocks *grow* [are] larger toward the apex of the fan." "Downstream they *grow* [become] progressively smaller." (Some rocks may grow larger, as by accretion, but none grow smaller.)

**Horizon**

The term "horizon" denotes mere position, and its use for "bed" or "stratum" is improper. A horizon has no thickness, being merely a stratigraphic level or plane. In the following sentences "horizon" is used improperly:

> This *horizon* [interval] is about 1 meter thick.
>
> Several thin *horizons* [beds] stand out from the rest.
>
> The total thickness of the *horizon that carries the conglomerate* [conglomeratic beds] is 6 meters.

By virtue of conventional usage, however, "horizon" is applied in soil terminology to soil zones having thickness: "A, B, or C horizon" refers to a specific soil zone.

**"-ic" and "-ical"**

The preference today is the shorter ending (hydrologic, hydrographic) but no strong justification supports such choice. Except for conventional expressions (Geologic Division, Geological Survey), consistency within a report should govern usage. "Historic," however, signifies momentous or ominous ("On this historic occasion"); "historical" means within the human cultural record and thus more accurately describes such natural events as earthquakes and volcanic eruptions, most of which were prehistoric.

**Important, interesting**

Some Survey writers overuse these words. "Important" should not be used for "large," "abundant," "conspicuous," "valuable," or any other term of indefinite meaning. What is interesting to one investigator may be uninteresting to another. For clarity, you should point out *why* something is interesting or important; then the need for either word may disappear, as follows:

> The *most important* [best? easiest? most traveled?] route across the quadrangle
>
> The most *important* [productive] aquifer
>
> The most *interesting* [complex?] microfold

**Inaugurate**

Used every fourth year on or about January 20. For Survey projects and programs, "begin" and "start" are better.

**Initiate**

Used appropriately in some technical reports, perhaps, but generally is better applied to occult ceremonies in secret societies.

**In question**

Some authors write "in question" about matters that are not in question at all. Instead of "the landslide in question," write "the landslide just mentioned" or "this landslide."

**In situ**

"In situ" has wide usage in some technical fields and has specific connotations in terms such as in situ density, in situ temperature, and in situ theory, but for most purposes, "in place" is more meaningful and less stilted.

**Intermittent, occasional, sporadic**

"Intermittent" means starting and stopping at intervals. "Occasional" implies a randomness to something happening from time to time. "Sporadic" has a similar sense of randomness, but it also can refer to location (sporadic outcrops).

**Interval**

Use "interval" in its usual sense of time or space—a span of time between the recurrence of things or a space between objects. Do not write "glacial interval" for "glacial period." "Interval" is also used to mean the thickness between horizons, as in "The rocks in this interval are sandstone and shale." It should be applied to the thickness, not to the rocks themselves. A well log or a measured section may include a covered, concealed, or missing interval.

**It**

We couldn't do without this very useful pronoun, but beware of grammatical pitfalls. As an impersonal pronoun, "it" often acts as an expletive that lacks an antecedent and takes the place of the subject: "It is snowing." It may also take the place of and disagree in number with the true subject: "*It was* the ammonoids *that* dominated in the Cretaceous, but *it was* the nautiloids *that* survived into the Tertiary." (For a simpler construction, delete the words in italic.)

When using "it" as a personal pronoun, take care to assure its proper antecedence, and avoid using "it" in two senses that might be confusing in the same sentence:

**It—Continued**

It has not been possible to identify it with any of the described forms, and it seems to be so distinct that it is probable that additional examples could be recognized. (The first and fourth "its" are expletives; the second and third are personal pronouns.)

If the contaminated ground water reaches the town water supply, it may spread pollution throughout the community. (Here the intended antecedent of "it" was "contaminated ground water" but could as easily have been "town water supply.")

**It is apparent, clear, evident, or obvious that**

These phrases are somewhat patronizing and tend to antagonize the reader. What seems obvious to the writer, moreover, may be obscure to the reader. If something is obvious or apparent, perhaps it need not be said.

**Its, it's**

"Its" is the possessive of "it." "It's" is the contraction of "it is."

**Keyboard, keyboarding**

"Keyboard" and "keyboarding" fill a need beyond the words "type" and "typing" in regard to the use of computers for word processing, computer typesetting, computer graphics, and desktop publishing. Type a letter, yes, but keyboard the data for the digitizer. Keyboarding is more than mere typing.

**Kind, type**

"Kind" is the better word in reference to a general group or category. "Type" is better in reference to a specific group or category.

**Last year, this year**

Avoid these vague references. By the time your report is published, "last year" may be several years past. Be specific; cite the appropriate date.

**Latter** (see "Former")

**Lie, lay**

"Lie," meaning to recline or be situated, is an intransitive verb, which therefore takes no direct object: "Now I shall lie down to sleep." Its forms are lie, lying, lay, and lain: "The sandstone lies on the shale." "They lay undisturbed for thousands of years." "They had lain there for centuries."

The transitive verb "lay," meaning to put, place, or prepare, requires a direct object: "Now I lay *me* down to sleep." "Lay that pistol down." The forms of "lay" are lay, laying, and laid. "Lie" and "lay" are confusing because of their similarities and seeming contradictions. The past tense of "lie" is the same as the present tense of "lay": "Last night as I lay on my pillow"; "Lay (place) your head upon the pillow." "She then laid her eggs in the carefully prepared nest where they lay until hatched by the warm sun."

**Limited**

"Limited" should be used in the sense of "confined" but should not be used in the sense of "few," "meager," "scanty," "short," "slight," or "small."

Rainfall in this arid region is therefore *limited* [scanty].

Their interest in the fauna was *limited* [slight].

**Limited**—Continued

He had *limited* [few] interests other than ammonites.

Now available for a *limited* [short] time only.

But its use is proper in the following constructions:

His interest in the fauna was limited to the ammonites.

Sandbags piled along the railway limited the floodwaters to the eastern part of town.

**Located, situated**

"Located" and "situated" are generally superfluous, as in the following sentences:

One of the domes is *located* in sec. 31; the other is *located* in secs. 3 and 4.

South of the axis of the principal anticline *there* is *situated* a small syncline.

The outcrops are *situated* on the shore *and in* close *proximity* to deep water.

The largest of these outliers is *situated* 2 miles *to the* southeast*ward* of the canyon.

This field is *located* 5 kilometers north of Bristol.

"Locate," however, is properly used in setting well sites, surveying section corners, and recovering books missing from the library.

**Majority, most**

"Majority" means the greater part of something, but some of its connotations relate to populations of people, election results, reaching legal age, and the rank of major. "Most," which is shorter and has no such connotations, is better for indicating greater degree, number, quantity, or size. Write "most of the grains," not "the majority of the grains."

**Many, several, various, numerous**

"Many" means an indefinite large number; more than a few. "Numerous" and "many" are close synonyms, but "many" is better because it is shorter. "Several" means more than two or three but fewer than many. "Various" is often misused for "many" or "several" in sentences such as "Various attempts were made to recover the gold," and "Native arsenic was found at various places." "Various" is better used in the sense of unlike or different: "Native arsenic is found in various settings." (See also "Various, different.")

**Mineralization**

Any of the many processes by which minerals form. Its use as a synonym for "deposit" is prevalent but ungrammatical ("tion" is the process, not the product). "They then drifted on the hanging wall in hope of finding richer *mineralization* [ore]."

**More or less**

"More or less" is overworked by many Survey authors, is less direct than "about," "almost," or "nearly," and is occasionally erroneous, as in the following impossibilities:

more or less vertical
more or less less unique
more or less intact
more or less inert
more or less surrounded

**Myself, herself, himself**

Omar Khayyám to the contrary ("Myself when young did eagerly frequent * * *"), using the reflexive pronoun is poor form when the ordinary pronouns "I" or "me" will do:

> The area was visited by William Jones and *myself* [me] in July.
>
> Jones and *myself* [I] visited the area in July.
>
> After a few perfunctory remarks the chairman introduced *myself* [me] to the audience.

**Number of**

"A number of" usually connotes "several" or "not many," but it literally is ambiguous. Use "a few" or "several." If you know the actual number, use it, even with "about" to indicate uncertainty.

**Occur**

"Occur" is the refuge of writers who lack the time or imagination to think of a more appropriate verb. Note the following limp sentences:

> Trees *occur* [grow, flourish] on the north-facing slopes.
>
> Waterfowl *occur* [gather] here in great numbers.
>
> The mines *occur* [are] in Breathitt County.
>
> *A well-exposed occurrence of* dolomite sheared by faulting *occurs* [is well exposed, crops out] near Boulder Creek.
>
> Dikes with variable morphologies occur in the study area. (Change to: Dikes in the study area have varied morphologies.)
>
> *Exposures of* the most richly fossiliferous Lower Ordovician strata in the United States *occur* [are exposed] about 80 km west of Delta, Utah. (Better yet, substitute the active verb "crop out.")

**Occurrence**

"Occurrence" is best used, if at all, to mean something that takes place, such as an event, happening, or incident (for example, "mode of occurrence"). "Occurrence" has been used inaccurately in many geologic reports to connote a mineral deposit itself, especially a deposit of indefinite but low concentration or value, as opposed to an exploitable resource. (See section on "Mineral Reserves, Resources, Resource Potential, and Certainty," p. 95).

**Over, under, more than, less than**

"Over" and "under" are used in some phrases where "more than" and "less than" or "fewer than" would be better. The use of "over" in the sense of "more than" and of "under" in the sense of "less than" or "fewer than" is not grammatically erroneous, but "over" and "under" should not be used where they might be confusing, as in some of the following sentences:

> The dolomite dips eastward under over 6 meters of muscovite-biotite schist.
>
> Even under the best condition it was not profitable to mine coal under 2 feet thick or over 200 miles from market. (Here, "under" has also been used in two different senses in one sentence.)
>
> The burning has advanced along the coal bed for *over* [a distance of more than] 300 meters *and under* [beneath] 300 meters of overlying material.

**Over, under, more than, less than—** Continued

> The ore generally lies *under* [beneath] more than 6 meters, and in some places *over* [more than] 30 meters, of sand and clay overburden. (Better yet, write: The ore generally lies beneath more than 6 meters of sand and clay, and in some places more than 30 meters.)

"Upward of" is also used undesirably for "more than," as in "The project will cost upward of a million dollars." "Better than" in the same sense has a barbarous double meaning.

"Over" or "above" may be misleading in such sentences as "Oxidation extends to depths *above* [of more than] 640 meters." (A better rewrite would be: "Oxidation extends deeper than 640 meters.")

**Part, portion, partly, and partially**

"Portion" suggests an assigned or allotted part: "Take your portion and go." If that implication is not intended, the preference is for "part." Choose the shorter, simpler word. Some writers use "partially" when "partly" would be better, although "partly" and "partially" are not strict synonyms. "Partly" is better in reference to part of a whole, as in "The valley is partly filled with alluvium." "Partially" is better when the meaning is "to a certain degree or measure," as in "The Leadville Limestone was partially metamorphosed" or "This outcrop has been partially weathered." Many readers may not detect the subtlety. "Partial" and "partially" also may imply partiality or bias.

**Percent, percentage (proportion)**

Survey style forbids use of "percent" except with a numeral, as "4 percent copper." By this usage, "a large percent" is incorrect; the correct phrase would be "a large percentage." "Percentage" is synonymous with "proportion"; it should not be used when no proportion is being expressed:

> The greater *percentage* [part] of the soil of the area is of glacial origin.

"Percent" is preferred to "percentage" for table headings. If other terms, such as "meters" and "centimeters," are abbreviated in a table, "percent" may be abbreviated as "pct"; it is not abbreviated in text. The symbol "%" may also be used in tables, but in small type it is not as easily read as "pct."

**Precision** (see "Accuracy, precision")

**Present, presence**

"Present" and "presence" are favorites of many writers but are generally superfluous, as in the following sentences:

> The undulating strata mark one of the many local unconformities *present* in the arkose.

> Here cacti are *present in greater abundance* [more abundant] than on the plateau.

> In most of its facies quartz is the most abundant mineral *present*.

> The metallic minerals *present* in the ores * * *.

> Blocks of sandstone are *present* scattered over the surface.

**Present, presence**—Continued

In this area there are several irregularities *present*. (This area has several irregularities.)

Some of the zinc *present* in the ores is saved.

*The presence of* open channels that extend downward to caverns may be seen at several places.

*The presence of the* other sulfides of copper were not noted in the district. (Wrong subject but right verb).

**Prominent** (see "Conspicuous")

**Quite, rather, somewhat**

These vague descriptors are best avoided in technical writing.

**Range** (see also "Vary")

Loose comparisons can be made to well-known objects ("melon-size boulders"; "larger than a bread box"), but specific ranges require expressed limits. When "range" is used, the prepositions "from" and "to" must also be used, and for literacy the adverbial phrases "in thickness," "in length," "in width," and so on must be used instead of the adjectives "thick," "long," or "wide." "The dikes range in thickness from 0.5 to 5 m." Contrast that with "The dike is 5 m thick." The use of "range" requires two limits—don't say, "ranges up to * * *." If only the upper limit is stated, alternative phrasing should be used, such as "is as much as" or "reach a maximum of."

"Vary," rather than "range," should be used for changes or fluctuations such as those related to flow, stream width, tidal levels, turbidity, or salinity: "The water level in the well varies yearly and seasonally; during the spring the level normally ranges from 10 to 15 m below ground surface."

Take care in the use of "zero," as zero is significant when it is stated in a measurement. A reader who is told that "Two coal beds are separated by 0 to 10 cm of bone" may wonder how much separation is made by 0 cm of bone. However, in the sentence, "The Livesay Shale ranges from 0 to 7 m in thickness," it is clear that the formation is locally nonexistent.

**Rare, scanty, scarce, sparse**

"Rare" denotes something very uncommon or few in total number: "rare old coins"; "rare and endangered species"; "rarely euhedral."

"Scanty" implies bare sufficiency or an inadequate quantity: "scanty rainfall."

"Scarce" applies to ordinary things locally not abundant: "Outcrops are scarce in the deeply weathered saprolite."

"Sparse" means spread thinly: "sparse crystals of pyroxene"; "sparse gray hairs on a shiny balding pate."

**Sample, sample No., sample number**

Drop the "No." or "number." "Sample 00," "specimen 00," or "drillhole 00" is the preferred usage in text, tables, and figures. "Sample No." is an acceptable column head in a table, however.

**Several** (see "Many, several, various, numerous")

**Secure**

"Secure" is appropriate usage for activities related to battening hatches, bolting doors, or guaranteeing the blessings of liberty to ourselves and our posterity but is stilted for getting concert tickets, seats at the ball game, or specimens for analysis. ("Did you secure the specimens?" "Yes, I locked them in the vault.")

**Significant** (see also "Important, interesting")

Many Survey writers misuse this word, which means "important, having a meaning;" it does not mean "large." "Significant amounts of calcium are present in the rocks" should be rewritten as "Calcium content of the rocks is high."

**Since** (see "As, since, because")

**So, so that**

"So" by itself is a coordinating conjunction used to join clauses of equal rank: "The laboratory results were inconclusive, so I requested more tests." When used as a subordinating conjunction (as when introducing a clause that gives the reason for an action), "so" should be followed by "that": "We have described our results in detail so that the basis for our interpretation will be clear."

**Structure, structural feature**

In geology, the term "structure" is properly applied to the spatial relationships of rocks. "Structure" should not be used synonymously for "structural feature" nor for such features as "fold," "fault," "anticline," "syncline," "pipe," "neck," or "batholith." Note the following indiscretions:

> The producing *structures* [folds] are two closed anticlines.
>
> Surprisingly, the *structure* [anticline] has been found [to be] barren of oil and gas in the Tensleep and Phosphoria Formations.
>
> There has been considerable speculation as to the type of fold that exists on this structure. [The structure of this fold has been the subject of considerable speculation.]

**Superfluous prepositions—at, from, of, on, to, with**

The use of a verb plus a preposition to express an idea that may be conveyed by some other verb alone may lead to the undesirable doubling of prepositions:

> This can be *dispensed with* [spared] with advantage.
>
> The conditions *met with* [observed, faced] in the field.
>
> A large production is not to be *looked for* [expected] from these deposits.
>
> Placer mining has been *carried on* [done] on this stream. (Or better yet: Placer deposits have been mined from this stream.)

In "a thickness of from 2 to 4 meters" the "from" should be omitted. So also, in "The water rises to within 3 meters of the surface," the "to" is superfluous. Prepositions are doubled or tripled badly in the following sentences:

> Each of the veins has been drifted on for from 15 to 20 meters. (Drifts have been run 15–20 meters on each vein).

**Superfluous prepositions—at, from, of, on, to, with**—Continued

This well was *brought in* [completed] in 1986.

This is equivalent to coal of *at least* $50 [or more] a ton.

A newscast stating that "The march will reach the State line in *from between* 12–15 hours" used three prepositions where one would have sufficed.

"Of" is superfluous after "permit," as in the phrase "too poorly preserved to permit *of* identification."

"Of" is multiplied needlessly in many phrases, as in "An estimate of the cost of *the operation of* [operating] the filter." In most such phrases a noun ending in "tion" and the "of" following it should be replaced by a gerund, ending in "ing." Many phrases in which "of" is repeated can be rewritten with advantage. "Following the discovery of the character of this deposit" means "After the character of this deposit was discovered."

**Terrain, terrane**

"Terrain" refers to a topographic or geographic landscape configuration—for example, a "hilly terrain," a "wooded terrain." "Terrane" refers to a lithologic or geologic areal expanse—for example, a "metamorphic terrane," a "basaltic terrane." If in doubt about either usage, find an appropriate substitute, as neither term is indispensable.

**That, which** (see p. 143)

**There are, it is**

Expletives such as "There are," "There were," and "It is" are effective in some constructions, but more commonly they (1) subordinate the real subject, (2) add needless words, and (3) diminish the strength of the sentence. Merely deleting the expletive and inserting the weak verb "is" or "exists" is not apt to improve the sentence. In the following examples, active verbs have been substituted to strengthen the constructions.

There has been some faulting subsequent to the deposition of the ore. (Recast as, "Some faulting followed the deposition of the ore.")

*It is the belief of* the project geologist [believes] that the alignment is on a landslide.

*There are* many other primary minerals contain*ing* phosphorus.

*There were* in that same country prospectors *abiding* [lived] in the hills.

There is a probability that some of the veins may have had their gold content increased by enrichment. (Recast as, "The gold content of some veins may have been enriched.")

There are valuable deposits in this area. (Recast as "This area contains valuable deposits" not "Valuable deposits exist in this area.")

An initial "There is" or "There are" may undesirably detach a sentence from the preceding one, as in the following example:

The Niagara is mainly a light-gray dolomite. *There are* [It contains] both thick and thin beds and, at certain horizons, *there is* considerable chert.

**There are, it is**—Continued

Some appropriate usages:

It is raining!

There is still hope.

It is, sir, as I have said, a small college, and yet there are those who love it.

Once upon a time there were three bears.

**Thick, thickness**

The phrase "in thickness" and not the adjective "thick" must be used after "ranges." Write, "The bed ranges from 12 to 15 meters in thickness," "The bed ranges in thickness from 12 to 15 meters," or "The bed is 12 to 15 meters thick."

**This, these, those**

The demonstrative pronouns "this," "these," and "those" should not be used alone if (1) their antecedents are in doubt, (2) no antecedents have been expressed, or (3) the reader must back up—even momentarily—to find their antecedents. Lacking other clues, the reader will tend to link a pronoun to the nearest available noun, as follows:

Twenty-nine master's theses dealing with various aspects of the geology were produced by students. These are on file [the theses, not the students] at the university library.

The rocks contain numerous drusy cavities. In these, minerals of later age have been deposited. (Repeat "cavities" after "these" and add a comma.)

**Time words, place, and state of being**

If words (mostly adverbs) that strictly speaking denote time are used to denote place or state, the bewildered reader is forced to reread the construction to get the author's meaning:

The pebbles are usually gray, but sometimes they are pink.

While the fault was buried by alluvium we were able to locate it by trenching.

These phenocrysts are often corroded.

Usually these rocks are right-side up.

| Time words | Intended to mean | Time words | Intended to mean |
|---|---|---|---|
| Always | Everywhere | Sometimes | In places, some of |
| Frequently, often | Commonly, many of | Usually | Commonly, most of |
| Now and then | Here and there | When | Where |
| Occasionally | Locally | While | Although, whereas |
| Since | Inasmuch as | | |

More examples and how to fix them:

[Many of] These fissures *often* intersect.

[Some of] These crystals are *sometimes* a centimeter or more in diameter.

[Some of] The volcanoes are *sometimes* practically extinct.

The complexity of the folding is *sometimes* very marked [at some places]. (Better: Locally, the folding is very complex.)

Pyrite is less common than marcasite, although it does occur *at times* [at some places]. (The second clause is redundant and should be omitted.)

**Time words, place, and state of being**—Continued

These rocks are *nearly always* red [at most places].

[Many of] These terraces are *frequently* covered with gravel.

[Few of] These pebbles *almost never* have striated faces.

The moraine is *seldom* less than a kilometer wide [in few places].

"When" is often misused for "where," as in the following sentences:

*When* [Where] the thickness is greatest it is 75 meters.

The ore was richest *when* [where] it was most altered.

**Toward, towards**

Identical meanings, but "toward" is more common in American usage. Use either, but be consistent.

**Typical**

"Typical" should mean just what it says: that which typifies. Don't illustrate the best outcrop in the quadrangle, for example, and caption it "Typical exposure of the Gunflint Shale" if the Gunflint typically forms a covered slope.

**Undertake**

Appropriate in funeral arrangements but stilted in technical writing.

**Unique**

"Unique" means one of a kind; it is absolute, not relative. Don't say "less, more, more or less, or most unique."

**Value**

"Value" in its abstract sense means the worth or desirability of something. In "Lead and zinc values are nearly equal, and their total exceeds the value of gold," the reader is uncertain as to whether "values" refers to the percentage of the metals or to dollar value. To say "About 50 meters below level 6 the ore carried high values in silver and gold, some lead, and 10 to 25 percent excess silica" is ambiguous. In mathematics and statistics, "value" means any particular quantitative determination, as the different values of a variable.

**Various, different** (see also "Many, several, various, numerous")

"Various," meaning "different" or "diverse," is misused for "many" or "several" in the following sentences:

Gold has been found on the beach and *various* [several] attempts have been made to recover it. (Unless various methods were used.)

Native arsenic was found at *various* [several] places.

"The rocks are of various colors" is correct, but "The rocks are variously colored" would be better (so as to eliminate the awkward "are of").

"Different" is sometimes used carelessly, as in "I telephoned him different times" when the writer meant only "I telephoned him several times." "Different" is sometimes used inappropriately, as in the following sentences:

The ore is associated with *different* [several] mineral groupings.

*Different* [Several] phyla are represented.

**Various, different**—Continued

"Different" may be used properly if degree of difference is to be expressed, as in "very different phyla," (but "diverse phyla" would be clearer).

**Vary, variable** (see also "Range")

The verb "vary" has both an intransitive sense ("Iron contents vary in samples of the ore") and a transitive sense ("Vary the flow rate by adjusting the valve"). A "variable," strictly speaking, is an abstract mathematical quantity whose value can be arbitrarily set. A physical parameter may assume varying values in repeated measurements, but it is not freely variable. Note the different meanings of variable:

> Lava flows of *variable* [varied] composition.
>
> *Variable* [Varied] phosphorous contents.
>
> Fracture characteristics of rocks under variable stress conditions (in the laboratory).
>
> Analyses using *variable* [varied] reagent concentrations.
>
> The gold-silver values *are variable* [vary] in samples from Homestead Peak.
>
> *A variety of* [Various] minerals * * *.

**Verbal, oral**

"Verbal" refers to words. It is commonly used improperly for "oral," which means "spoken." "Verbal" is properly used in the sentence "The differences between the two accounts are only verbal"—that is, the ideas are practically alike, but the words are different. Communications of unpublished information should be called "written" or "oral" but not "verbal." In the following example "verbal" is used correctly:

> The text contained two explanations, one verbal and the other mathematical.

**Very, much**

The critics of *very* have a way of going too far and damning the laudable.
*H.W. Fowler*

"Very" is a useful intensifier in some contexts (very fine sand, very coarse sand; "I am very grateful"; "He is the very model of a modern major general"), but it should be used with caution in others ("The destruction was *very* appalling" is less effective prose than just "The destruction was appalling"). Overuse of "very" minimizes its value as an intensifier.

"Very" used with absolutes or superlatives is meaningless or cloddish (very unique, very highest, very unanimous, very meaningless).

As a modifier of past participles, "much" should generally be used instead of "very": Though the andesite was not *very* [much] faulted [was little faulted?], it was *very* [much] altered.

"Very," however, is a proper intensifier of "much": "Are the rocks much faulted?" "Yes, very much so."

**Vicinity of, neighborhood of**

"In the vicinity of" and "in the neighborhood of" are sometimes used unnecessarily for "about" or "nearly," as in the following sentences:

**Vicinity of, neighborhood of**—Con.

The cost of production is *in the vicinity of* [about] 50 percent of the selling price.

Its population is *in the neighborhood of* [about] 1,500.

**While**

For clarity use "while" to mean contemporaneity—"at the time that," but not to mean "although," "whereas," "and," or "but."

Appropriate:
Jones mapped while Martin napped.

Inappropriate:
Martin spent 2 weeks resolving geologic problems *while* [whereas] Jones spent a month studying the coal. (Did time move faster for Jones?)

Also:
*While* [Although] the fault was buried by alluvium we found its trace by trenching.

*While* [Although] work is progressing it is not completed.

Most of the precipitation falls as snow during the winter months *while* thunderstorms are common during the summer. (Change "while" to "although" or "but" and place a comma after "months.")

**Watershed** (see "Drainage basin")

**With** (see p. 131, under "Prepositions")

**Needless words and phrases**

Many sentences can be strengthened by just deleting needless words and phrases. Like the troublemakers noted in the previous section, the common redundancies shown here in italic are easily rectified.

Throughout *the whole of* the Mesozoic Era.

Throughout the *entire* area.

A series of parallel ridges resembling in *their* form * * *.

The problem is *a* difficult *one*.

There can be no doubt *but* that it is Cretaceous.

The Survey has not *as* yet finished its work in this region.

*As yet* no ore bodies of this type have [yet] been exploited.

The conditions were favorable for landslides *to occur*. (Or better yet: The conditions favored landslides.)

Equally *as* well.

It occurs in *disseminated* grains scattered through the rock.

Most of the intrusive masses are *of* large *size*.

The rock is dark green *in color*.

*An* innumerable *number of* tiny veins.

**Needless words and phrases—**
Continued

Contemporaneous *in age.*

The beds do not crop out *at the surface.*

This lies *on the* southwest *side* of the line of the fault. (Or better yet: * * * of the fault line.)

The *color of the* fluorspar is dull green.

A report giving the results of the work is in *process of* preparation.

*Subsequent to the formation of* [After] the Pleistocene terraces [were formed] *there has been* considerable phosphate [was] deposited *along the streams* in the *form of* flood plains and bars *of* [along] the present streams.

No *side* streams enter Red River from the north.

*At its base* the formation lies on a remarkably even surface of granite.

About a mile *in a* northwest*erly direction from* [of] Fort Bayard.

Lenticular *in character.*

Grass Creek almost bisects the basin *into two parts.*

In every respect except size the Ashe County deposits are exactly like *those exhibited by* the Cranberry deposit.

The *down*-dropped block. (An up-dropped block would be peculiar. Write "downthrown block" or "downfaulted block.")

The ores are of igneous origin *originally.* (Or: The ores are igneous.)

—the highest at 365 meters and others *at lower levels* down to about 300 meters above sea level. (Others than the highest would, of course, be "at lower levels." The "above sea level" should be transposed after "365 meters"—with the first item to which it applies, rather than the last—to read as follows: —the highest 365 meters above sea level and others down to about 300 meters.)

In addition another similar dike. (If it is "another," it is "in addition"; if it is "similar," it can't be the same one and therefore must be "another." "A similar dike" tells the whole story.

**Needless words and phrases—**
Continued

The phrases "as already stated" or "as described above" are generally unnecessary. Repetition of a statement in another connection may be perfectly justifiable, but the reader need not be reminded that it is a repetition—in fact, the reader may not realize it unless told so by the author. If you wish to refer to a place where a statement is given in more detail, the form "as explained in detail on page 00" or simply "(see p. 00)" may be used, but remember that you or your editor will have to scrupulously check all such entries in the page proof before final printing.

Introductory phrases, such as "It may be said that * * *," "It might be stated that * * *," "Concerning this matter it may be borne in mind that * * *," "In this connection the statement may be made that * * *," "With respect to the occurrence of these ores it has been found that * * *," can generally be replaced by single words, as in the following sentence: "*There can be little doubt that* this fissure is [undoubtedly] the prolongation of a fault *of the same character as the one* [like that] already described." If you write "It is important to note that * * *," the reader may wonder if the rest of the report is not important enough to note.

"During the winter months" or "in the summertime" are commonly used for "during the winter" or "in summer." Necessities of rhyme and meter may justify "the good old summertime," but Survey reports are not written in metrical form.

"When *I* use a word," Humpty Dumpty said, in a rather scornful tone, " It means just what I choose it to mean—neither more nor less."

*Lewis Carrol*

# PREPARING MAPS AND OTHER ILLUSTRATIONS

THE TERM "ILLUSTRATION" is used here in a broad sense to include all geologic, geophysical, geochemical, hydrologic, and derivative maps and cross sections, mine maps, diagrams, pen-and-ink or wash sketches, columnar sections, correlation diagrams, charts, graphs, fossil plates, photographs, projection slides, engineering drawings, and computer-generated graphics. Most of the following suggestions apply directly to illustrations intended for Survey book publications or for Survey maps, charts, and atlases. Suggestions that may seem arbitrary are based on long experience and practice. Emphasis is on author preparation and author interactions with map or text editors and illustrators (graphics specialists and cartographic technicians).

Every illustration in a scientific report should either (1) give the reader a visual impression, (2) clarify something said in the text, or (3) portray facts that are discussed in the text. A visual impression made by a photograph of an outcrop, for example, supports mental images, and a geologic map provides the facts on which the words are based. Regardless of the type of report, no illustration belongs there unless it serves one of these purposes.

The author, map or text editor, and illustrator together are responsible for preparing final copy for the printer. This copy must be neat, well planned, well prepared, and uncluttered if it is to make published illustrations of professional quality. Experience shows that well-prepared copy costs no more in time and money than slipshod work. Commonly the cost is less, because expensive corrections and revisions are avoided.

Because of their obvious interdependence, authors, editors, and illustrators must work together to achieve their joint objectives. You as author should seek advice from map editors or illustrators early in the planning stage of the project; advice on such things as adequate base-map material and compilation techniques can save later grief and delay.

Authors who lack access to professional map editors and illustrators have special problems. For a given journal, read the journal's publication requirements and examine recent issues to learn what makes a good illustration and satisfactory copy. Most journals accept only finished illustrations ready for the printer. Few scientists have the technical or artistic skills to prepare finished illustrations beyond simple line drawings and photographs. Some of us acquire such skills by study and practice and by seeking advice from experts, but most of us must rely on professional illustrators, especially to prepare copy for colored maps that require perfectly registered color patterns. In any event, you are well advised to seek professional help early in the preparation process. New techniques are developing rapidly for author-prepared copy and computer-generated graphics.

## PLANNING

For planning purposes maps and other illustrations for Survey reports can be broadly classified as plates or sheets and figures. A plate, as here arbitrarily defined, is any illustration larger at publication size than two facing pages. Thus, at this stage, maps that stand by themselves in the various series are considered to be plates or sheets. A figure is any illustration that can be printed within the area of two facing pages or printed as a subordinate illustration on a map sheet. Photographs of fossils or groups of fossils, however, are usually labeled as plates in Survey reports even though they are printed at page size. These distinctions are helpful to bear in mind when you fill out your "Author's Check List," Form 9-1517, shown in figure 23.

When you are planning to submit manuscripts for the Survey's various publication series, or for outside journals, you should know about limitations as to (1) image size, (2) number and size of illustrations, (3) the use of plates, (4) color, and (5) reproduction processes. Contact a map editor, illustrator, or journal editor, or study recent examples of the publication. You should also try to anticipate your needs for photographs, base maps, and other compilation materials early in the project. After your fieldwork is completed may be too late.

### COST CONSIDERATIONS

Illustrations should be planned along with the research project itself or soon thereafter. By using the preliminary project description and a rough outline of your ultimate report, you can estimate the kinds and numbers of illustrations needed. For more detailed planning, you should then consult with a map editor and other advisors. This planning should explore—

1. Proposed publication series—options and constraints
2. Need and justification for multicolor plates and figures
3. Need for separate plates to be inserted in a pocket
4. Alternative of publishing some or all plates in a separate map series
5. Dimensions of figures
6. Base-map requirements (see section on "Base-Map Needs," below).

If you understand the relative costs of various printing methods, as a guide toward the most acceptable form for an illustration, you may forestall publication delays. In general, linecuts (figures that can be printed directly with the text) cost little if any more than composing and printing text; halftones of black-and-white photographs cost only a little more than text or linecuts, unless they are printed on special paper or require special screening. Duotone prints, for example, cost more than single-screen prints but provide richer tonal values. Color halftones and multicolor maps cost much more than black and white (unless the publisher has a multicolor press—then the increased cost per unit is minimal).

Any plate is more expensive and time consuming to prepare than a figure; color plates are much more expensive to print and handle than simple text and figures. These cost considerations shrink with large editions such as those of popular magazines, but they are very real for scientific reports of a few thousand copies that require precise color registration. The use of color in Survey publications is overseen by the Congressional Joint Committee on Printing, which delegates its authority to the Survey's Office of Scientific Publications.

In some Survey reports prepared for the general public, such as reports on national parks or monuments, color photographs of geologic features are encouraged as being more meaningful to the reader than black-and white photographs. In some crowded diagrams, clutter can be reduced by the substitution of a single color, such as blue or red, for some of the black lines or patterns. Other illustrations may also warrant color—photomicrographs of rock thin sections, for example—but any use of color in photographs or other illustrations must be justified in writing; prior tentative approval by the Office of Scientific Publications may avoid wasted work.

## Planning Maps

A first consideration is scale—the optimum scale needed to show the details required by the aims of the project. The scale normally determines what base map will be required. Another consideration is the availability of a topographic base and its clarity at the scale of publication. In the past, planimetric bases were used when topographic maps were unavailable. Modern topographic maps are now available for most of the Nation, and interpretation of modern geologic maps is based on information supplied by the topographic base. Planimetric bases should be avoided unless intended for a simplified black-and-white illustration. How much drainage and culture are necessary? Certain maps—the Geologic Quadrangle (GQ) Map, for example—are published only on standard topographic quadrangles. You should not be parsimonious about color, because it enhances readibility, but color will not be approved unless it is necessary for clarity. Much thought must go into early planning for complex full-color maps.

## Base-Map Needs

Before a mapping project is started, the project chief and supervisor determine the mapping and publication scales. The mapping and publication scales are selected on the basis of the amount of data required to solve the geologic problem. The publication scale is generally easily chosen if published topographic base maps are available, but some geologic problems may be resolvable only at larger scales. Regional relationships, on the other hand, may be depicted best on mosaicked bases of several topographic maps reduced perhaps as much as 50 percent or, if available, on one of the 1:100,000-scale topographic maps. Base maps reduced more than 50 percent are generally illegible and unusable. Rarely, for some maps, a planimetric base may suffice.

Every effort should be made to judge accurately how much detail is needed to solve the geologic problem efficiently; to plot excessive detail wastes time in mapping, in then selecting data to retain or delete, and in final drafting. For some projects, the modern 1:100,000-scale topographic base maps provide adequate detail; for others a 1:24,000-scale base is needed. Supervisors and map editors recommend that compilation and publication scales be the same.

For accurate registration, your final map compilation is plotted on scale-stable material. In planning a project, allow adequate time for preparation of the scale-stable base. Even more lead time is needed if the base is to be a mosaic of several topographic sheets, if the scale is to be different from that of the original base maps, or if the reproducible source material is stored elsewhere than at your regional headquarters. The map editor can advise you on the types of stable materials that are available. Most mappers compile on scale-stable greenline copies of the base map.

### Planning Text Figures

Text figures should be carefully planned to ensure the most effective graphic communication possible. Illustrations serve to demonstrate relations that cannot be described as clearly by written words or to relate more detail than words can effectively portray. Discuss plans for illustrations with the publication staff in advance.

Figures may be published either "bottom title" or "side title." In bottom-title figures the top of the figure is toward the top of the page, and the caption is printed beneath the figure parallel to the text. In side-title figures the figure and caption are turned sideways on the page. Small figures can be printed column width. Use side-title figures only when necessary, because they are awkward for the reader and they detract from the composition of the report; consider (1) redesigning or reproportioning such drawings or photographs, (2) using bleeds (extending the photograph to the edge of the page, to the gutter, or both) for oversized photographs, (3) placing explanations or captions on facing pages, or (4) using page-and-a-half or two-page spreads across facing pages. Such layouts can enhance composition and interest.

### Image Sizes

Standard image sizes for figures and plates are given on the back side of the "Author's Check List" for illustrations, Form 9-1517 (fig. 23).

## Special Requirements

### Maps

Map data should be compiled directly on a stable base. Linework should be drafted in black ink or scribed. The original compilation must not be colored, because it is not easily reproduced. A paper or plastic print should be colored as a "mill" copy for reviewers, map editors, and illustrators.

Scribing is an alternative to inking. For scribing, the base map is printed on scale-stable scribe-coat material, which is ordered through a map editor. Linework is then engraved with a scribing tool. Once the technique is mastered, scribing is rapid, neat, and accurate, and if linework meets publication standards, a major step in map preparation is saved. For review copy the scribed linework is combined photographically with a screened or green base ordered by a map editor. For review purposes and as a guide for illustrators, a paper or plastic copy of the combined inked or scribed original map is then colored as a check copy. You as author cannot adequately check your own work without carefully coloring it out. Do not color the original.

Programs for microcomputers are readily available to assist earth scientists and illustrators in compiling and drafting of maps and illustrations. Lines, symbols, and codes for patterns and colors can be digitized in their proper positions on plots; screen graphics are used to assist digitizing and editing but are not primary tools in design. Electronic plotters, responding to the digital files, can plot the map or illustration at the scale or size selected. Such computer-assisted drafting saves an author much time in making corrections and copies for editing; ultimately, publication is accelerated by using the data files. Programs vary in their capabilities and complexities of use. Consult with a map editor or cartographic expert for advice on which program and equipment are best suited to needs of your map or illustration. (See also p. 224.)

#### Contacts, Faults, and Fold Axes

Contacts, faults, and fold axes are normally drawn or scribed as solid lines. Dashed or dotted contact lines and faults are also generally shown on maps. Standards that define the use of solid, dashed, and dotted lines are available from a map editor. A line guide for the illustrator is required, such as a colored pencil line on a black-and-white print, showing exactly what line segments are to be dashed and what are to be dotted. If most contacts on a geologic map are approximate (most are), all should be shown as solid lines and the explanation should state "Contact—Approximately located" or "Approximate contact." Individual contact relations can also be explained in the descriptions of the formations.

Faults may be drafted as solid, dashed, or dotted lines, based on established standards, and mappers must exercise discriminating care in using the correct line to depict actual field conditions. A solid line designates a known fault accurately located within the scale limitations of the map. A dashed line may designate a known fault approximately located or an inferred fault. Queries can be added to express doubt beyond what is implied by mere inference. A dotted line is used only for a concealed fault; for example, if a surficial deposit such as alluvium or talus laps against bedrock along a fault line but is not involved in the faulting, the line should be dotted; a solid or dashed line would imply that the alluvium or talus had been faulted. Similarly, if a fault is shown by a dotted line through any unit, the fault must pass beneath the unit.

### Lithologic Patterns

Authors who plan to use lithologic patterns on an illustration should consult the map editor and illustrator. Lithologic patterns rarely are overprinted on full-color geologic maps. They appear more commonly on cross sections. If so, authors should supply exact copy on a registered, scale-stable overlay. Because such patterns follow structure and must be drafted by hand, author copy is used if possible. Lithologic patterns generally should be avoided because they are time consuming to draft, they clutter the map, and they obscure the base. Lithologic patterns are commonly used in columnar sections, however, and are available for that purpose in ready-made, adhesive-backed form. Computer programs are available, also, that will plot lithologic patterns in log form.

### Map Explanations

Authors should scan recently published maps for guidance in preparing map explanations. Check with your map editor. The explanation must include all information needed to understand the illustration, which in turn must stand alone without reference to the text or to another illustration.

Two types of explanations are used with geologic maps published by the Survey—short and expanded. The two types differ only in the amount of stratigraphic and lithologic detail. Both types usually consist of a "Correlation of Map Units," a "Description [or a "List] of Map Units," and a list of line and point symbols used on the map. In either event, the "Description of Map Units" must include the names of the rock-stratigraphic units and their assigned systems.

The short "Description of Map Units" includes the names of the mapped groups, formations, or members but either no lithologic description or a brief description limited to the major lithology. Short explanations commonly depend on an accompanying book, pamphlet, or graphic columnar section for lithologic details.

Where space is available, an expanded "Description of Map Units" giving stratigraphic detail is desirable. Detail may include information such as lithologic content, color, grain size, bedding characteristics, porosity, permeability, fracture characteristics, mineral or fossil content, remanent magnetization, and thickness. Correlation with other units, nature of contacts, radiometric or other age determinations, and sources of specific information (citations) may be provided. The length and detail are limited only by the size of the map and the number of map units. If the explanation will not fit, a second map sheet or a pamphlet may be added.

Explanations having many map units cause special problems in form and layout. Look to recently published maps for guidance, such as State maps and 1:250,000-scale maps, and consult with map editors and representatives of your Geologic Names Unit.

Suggestions for the treatment of stratigraphic symbols and the arrangement and format of map-unit boxes in map explanations are given in the section on stratigraphic descriptions (p. 49).

Stratigraphic details in the explanation should be limited to data from within the map area, although brief correlations with rock units in adjacent areas may be appropriate. References may be included. Descriptions should use telegraphic style; nonessential articles ("a," "an," "the") may be deleted; complete sentences are unnecessary. To separate ideas, periods or semicolons may be better than conjunctions. Let brevity and good judgment decide. The description may be paragraphed. Periods are omitted at the end of each entry or paragraph.

The order of describing lithology may differ from map to map, but it should be consistent within a given "Description of Map Units." If entries are fairly short and no lithology predominates, normal word order reads more smoothly than inverted order ("Sandy green shale and silty gray sandstone"), but if an entry is long and has a string of modifiers, inverted sentence structure is easier to follow:

> **Curtis Formation (Jurassic)**—Interbedded sandstone, shale, and limestone. Sandstone, light-gray, fine- to coarse-grained, poorly sorted, and thickly bedded. Shale, pale-green, * * *. Limestone, * * *.

Features that characterize a unit, such as color, permeability, or gradations in grain size, also modify the lithologic term; other information follows (magnetization, fossil or mineral content, age, and so on). The order in which these subsidiary features are listed may depend on their significance in the mind of the author, but usage should be consistent throughout the description.

### Map Symbols

All symbols on the map must be explained. Symbols other than stratigraphic map symbols (such as planar and linear features) are usually explained below the column of map-unit boxes, but if space dictates, they can be grouped elsewhere on the map sheet. Conventional symbols for outcrops, contacts, faults, folds, linear features, bedding attitudes, foliation, cleavage, joints, isopleths, ore and rock alterations, mine devel-

Form 9-1517
(March 1987)

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

**This form must be completed by author and attached to manuscript copy of each line drawing, photograph, map or plate for USGS publication**

## AUTHOR'S CHECK LIST

SERIES: P.P.☐ W.S.P.☐ BULL.☐ CIRC.☐ T.W.I.☐ SPEC.☐ GQ☐ I☐ MF☐ GP☐ MR☐ OM☐ OC☐ HA☐ JR☐ C☐ A☐

DIVISION: GEOLOGIC☐ WATER RESOURCES☐ NATIONAL MAPPING☐ OTHER________

TITLE OF REPORT________

AUTHOR(S):________

**LINE DRAWING**
**(Attach caption)**

Illustration number:____

**RECOMMENDED PUBLICATION SIZE:**
Page width ☐ Side title ☐
Column width ☐ Facing pages ☐

**RECOMMENDED PRINTING COLORS:**
BASE:
Screened black ☐ Black ☐
Drainage
Screened black ☐ Blue ☐
GEOLOGIC/HYDROLOGIC DATA:
Black and white ☐ Multicolor ☐
Black and ________

**TYPE OF SCALE:**
American standard ☐ Metric ☐
Both of above ☐

**ORIGINAL MATERIAL:**
Scribecoat ☐ Cronaflex ☐
Paper ☐ Other:________
Original material is in____pieces.
Original material compiled at
1:________
Illustration has ☐ has not ☐ been previously published. If it has, give complete reference and copy right permission:
________

Illustration to be compared with another illustration☐ Number of other illustration:____
Original material enclosed ☐
Original material available from:________

**PHOTOGRAPH/FOSSIL PLATE**
**(Attach caption)**

Illustration number:____

**RECOMMENDED PUBLICATION SIZE:**
Page width ☐ Side title ☐
Column width ☐ Facing pages ☐

**RECOMMENDED PRINTING COLORS:**
BLACK AND WHITE:
150-line screen ☐
300-line screen (fossil plate ☐)
COLOR:
(Must be justified in separate memorandum)
Duotone ☐ Multicolor ☐
Other:________

**CROPPING:**
Crop lines on edge of print ☐
Crop lines on transparent overlay ☐
Use full image ☐
Symbols, contacts, etc. to be added as shown on registered overlay☐

**SCALE OF PHOTOGRAPH SHOWN:**
By object in photograph ☐
On border of print ☐
In caption ☐

**ORIGINAL MATERIAL:**
Glossy print☐ Negative☐ Transparency ☐
Negative unavailable ☐
Negative available ☐
Location:________

**SOURCE OF PHOTOGRAPH:**
Author ☐
Other source with permission, proper credit, and copyright ☐

**MAP/PLATE**
**(Attach caption)**

Map/Plate number:____

**RECOMMENDED PUBLICATION SCALE:**
1:________

**RECOMMENDED PRINTING COLORS:**
BASE:
Culture: Screened Black ☐ Black ☐
Topo: Screened Black ☐ Brown ☐
Drainage: Screened Black ☐ Blue☐
Road fill-land net: Screened Black ☐ Red ☐
Purple revisions: Not needed ☐
Screened Black ☐
Photomosaic ☐ Color________
GEOLOGIC/HYDROLOGIC DATA:
Black and white ☐ Multicolor ☐
Black and ________
Match color on previously printed map ☐
Reference:________

**ORIGINAL MATERIAL:**
Scribecoat ☐ Cronaflex ☐ paper ☐
Other:________
Original material is in____pieces.
Original material compiled at
1:________
Illustration has ☐ has not ☐ been previously published. If it has, please give complete reference and copyright permission:________

Match adjacent map ☐
Reference:________
Base map material enclosed ☐
Base map material available from:
________

SPECIAL INSTRUCTIONS: See other side ☐

Front

**Figure 23.**—"Author's Check List," front and back (Form 9-1517, revised March 1987). The original sheet (8½ × 11 inches on yellow paper) must be completed for each illustration to be published in a Survey report.

## THE FOLLOWING IS GENERAL INFORMATION MADE AVAILABLE TO AUTHORS TO HELP EXPEDITE REPORTS DURING CARTOGRAPHIC PREPARATION

**MAXIMUM PUBLICATION ILLUSTRATION SIZES IN INCHES (PICAS) FOR BOOK REPORTS**

| PROFESSIONAL PAPER | CIRCULAR, BULLETIN, WATER-SUPPLY PAPER, AND TWI |
|---|---|
| Bottom title | Bottom title |
| 7⅛" x 8½" (43 x 51) | 6⅞" x 8⅝" (41½ x 52) |
| Side title | Side title |
| 9" x 6⅝" (54 x 40) | 9¼" x 6⅜" (55 x 38½) |
| Column width bottom title | Column width bottom title |
| 3½" x 8½" (21 x 51) | 3¼" x 8⅝" (20 x 52) |

**STANDARD FILM AND IMAGE SIZES AND ALLDIS PUNCH NUMBERS FOR PLATES**

| Film size | Image size ** | 1* | 2* | 3 | 4 |
|---|---|---|---|---|---|
| 42" x 58" | 40" x 56" | 56 | 39 | 59 | 43 |
| 34" x 44" | 32" x 42" | 45 | 31 | 41 | 35 |
| 30" x 42" | 28" x 40" | 39 | 29 | 43 | 27 |
| 24" x 30" | 22" x 28" | 31 | 17 | 27 | 29 |

* Top of plate

**Maximum image press size for the USGS printing plant is 41½" x 57". Plates exceeding these dimensions must have OSP approval for printing by a private contractor.

**RECOMMENDED PUBLICATION SCALES FOR PLATES**

| | | |
|---|---|---|
| 1:20,000 (Puerto Rico) | 1:125,000 | 1:25,000 |
| 1:24,000 | 1:250,000 | 1:31,680 |
| 1:62,500 | 1:500,000 | 1:50,000 |
| 1:63,360 (Alaska) | 1:100,000 | |

**PHOTOGRAPHS**

1. Submit glossy print at publication scale or indicate by crop lines to bring to publication scale.
2. 300-line screen to be used for fossil plates and where fine detail is essential.
3. Do not write on the front or back of photographs; avoid using paper clips, especially on the image area. Scale should be drawn outside of image area.
4. Use registered overlay to show line and symbol placement. Never draw on photographic prints.
5. Do not mount with glue, tape, or permanent attaching materials.
6. Do not place any kind of tape over image area.
7. Register all overlays by corner ticks or other marks; indicate top if not obvious.
8. NOTE: Original negatives of all photographs published in USGS reports are sent to the Photo Library, Denver, Colorado, by the Branch of Technical Reports.

**SPECIAL INSTRUCTIONS:**

Reverse

opment, and oil, gas, and water wells are shown in "Cartographic and Digital Standards for Earth Science Publications—Principles, Symbols, Colors, Patterns, Codes, and Formats" (Reynolds and others, in press).

One way to organize an explanation of symbols is to list them in this order: patterns (other than those for map-unit symbols), line symbols (contacts, faults, folds, isograds, structure contours), planar symbols (strike and dip of bedding or other features), linear symbols (bearing and plunge of lineations or other features), and point symbols (such as quarries, mines, and sample localities), but the order may be altered for emphasis.

If linework is dashed, dotted, or both, be sure it is explained. If planar and linear features are shown in inclined, vertical, or horizontal positions, be sure each case is shown separately. The point here is to do everything possible to keep the reader from having to guess what the symbols are showing. Special map symbols may be devised as needed, with the concurrence of the editor or illustrator. Such a unique symbol must be identified in the explanation.

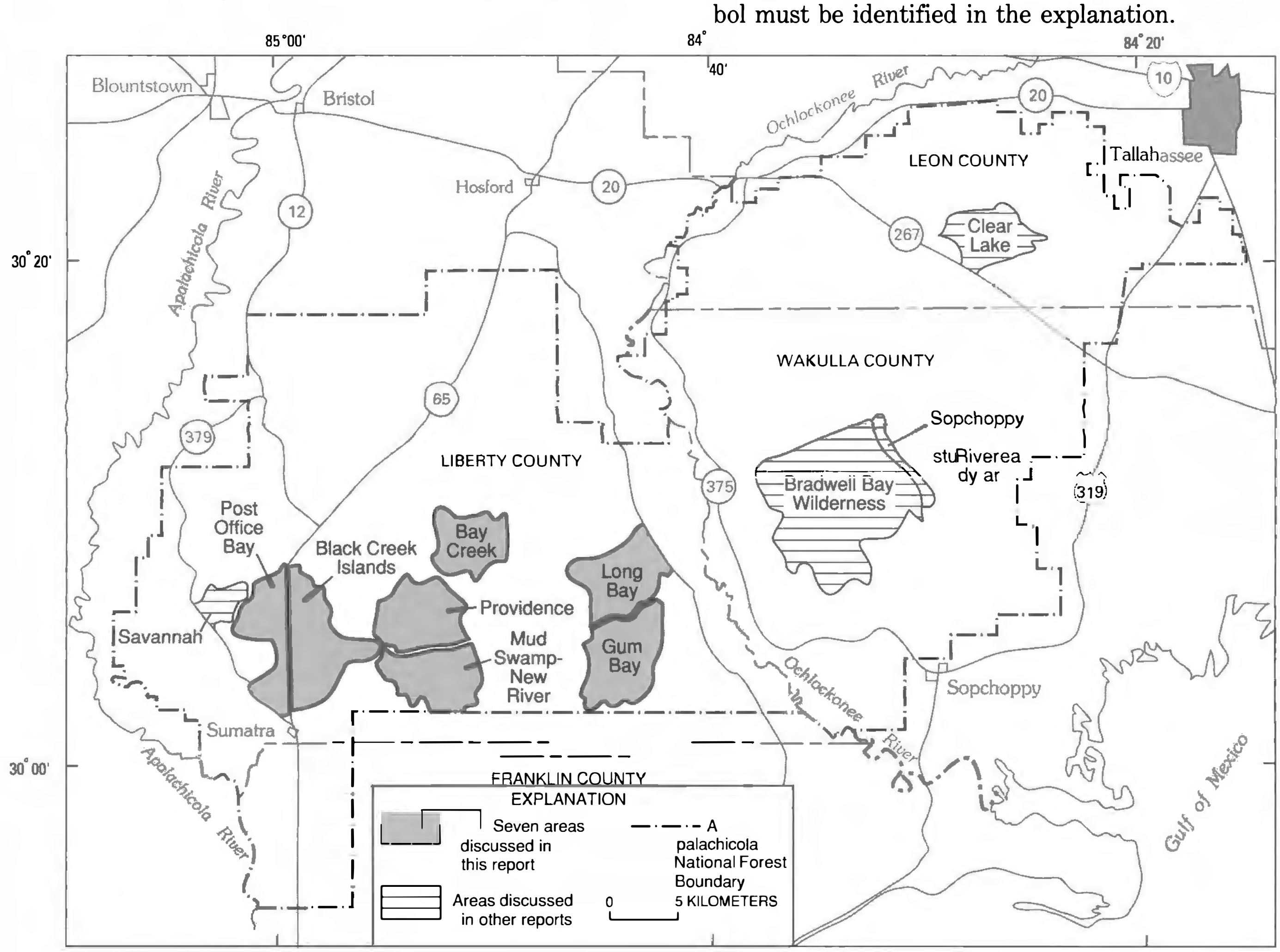



**Figure 24 (above).** Special-purpose index map showing location of the roadless and wilderness areas in the Apalachicola National Forest, Liberty, Leon, Franklin, and Wakulla Counties, Florida. Map shows latitude and longtitude, rake scale, towns, roads, and county lines.

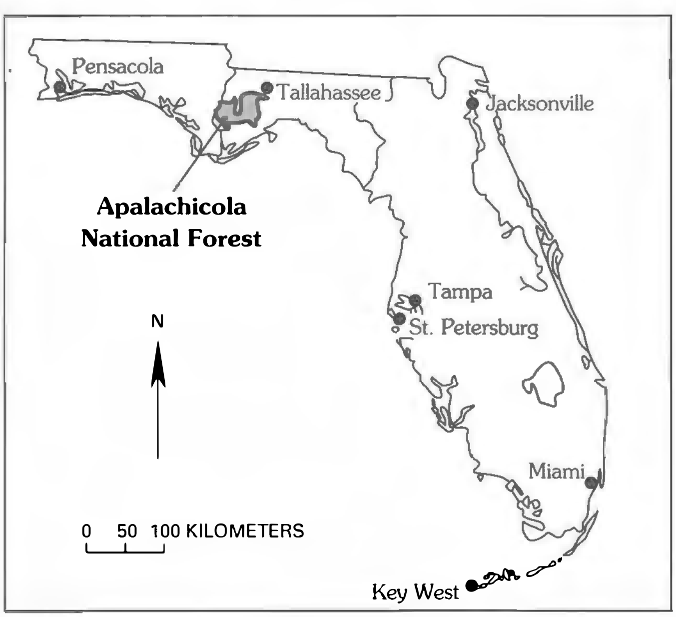
**Figure 25 (opposite page).** Location map accompanies map above. Shows location of the Apalachicola National Forest, scale, and north arrow.

## Index Maps

Most book reports, journal articles, and plate-size maps include an index map to locate the area of the report geographically. A second index map may be needed to locate geographic and structural features mentioned in the text. Index maps range widely in complexity. A complex one should show latitude and longitude or townships and ranges, a rake scale, and perhaps a north arrow. It may show minimal drainage, cultural features such as major towns, county lines, roads, and minimal topography. A township grid alone is rarely adequate, because readers relate better geographically to towns, streams, and roads, although for some reports—those on oil fields, for example-townships and ranges are more useful to the map user than latitude and longitude. If the map includes all or parts of several counties or States, their names should be on the index map. The report area should be identified by pattern, color, or outline.

Most plate-size maps include a small outline map of the State or States enclosing the map area, showing the area in color, pattern, or black silhouette. Additional index maps may be used to show such things as sources of information, sample localities, credits for areas of mapping, published maps of adjacent areas, and regional structural trends. If the map is in color, the index map may be printed in some or all of the same colors, as needed. Examples of index maps shown in figures 24–28 illustrate their range of diversity.

If a figure shows latitude and longitude coordinates on an outline of an area, but no other geographic or cultural data, the figure is simply termed an index, rather than an index map.



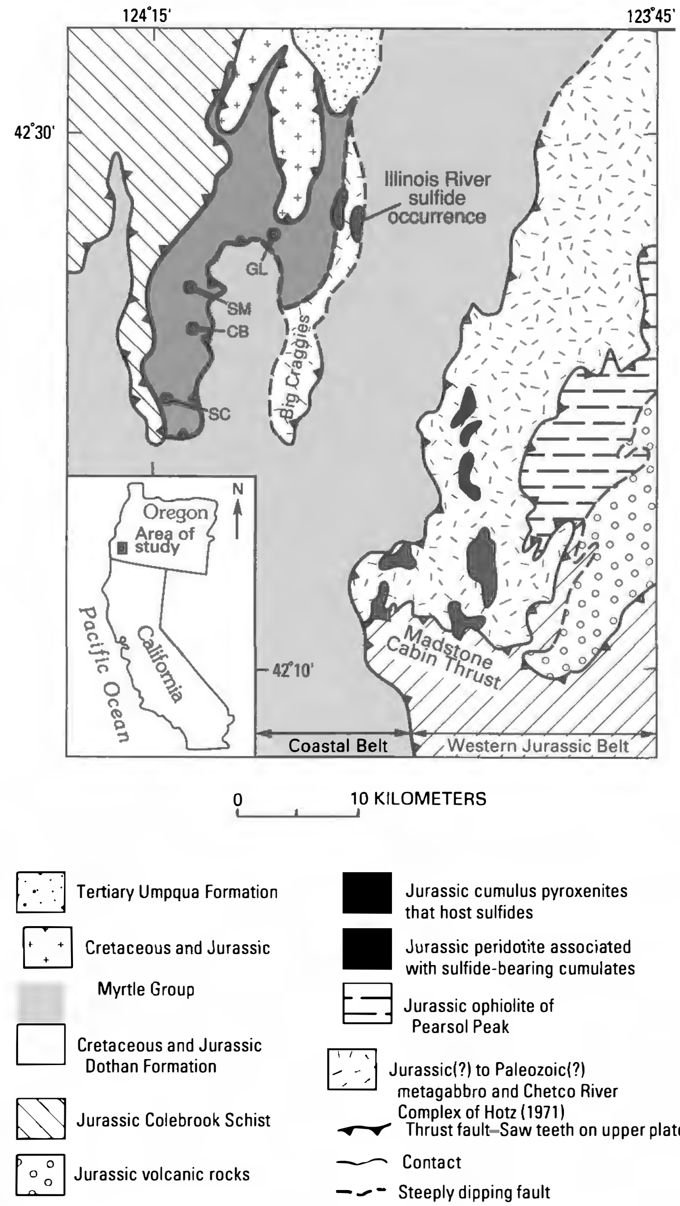




**Figure 26 (above).** Special-purpose index map showing geologic setting of the Illinois River sulfide occurrence. SC, Snow Camp Mountain; CB, Collier Butte; SM, Saddle Mountain; and GL, Game Lake. Shows use of two maps to locate study area, latitude and longitude, north arrow, and generalized geology.

## Mine Maps

Detailed geologic mine maps (not plans or plan maps) are expensive to prepare. Regardless of form of publication, a geologic mine map should have a complete explanation and all the other requisites of a geologic map: north arrow, scale, location in terms of latitude and longitude ticks or of section, township, and range, or some other geographic coordinate system. Notes leadered to points of pertinent observations may take the place of a lengthy explanation; such notes should be in telegraphic style but without abbreviations except for units of measure.

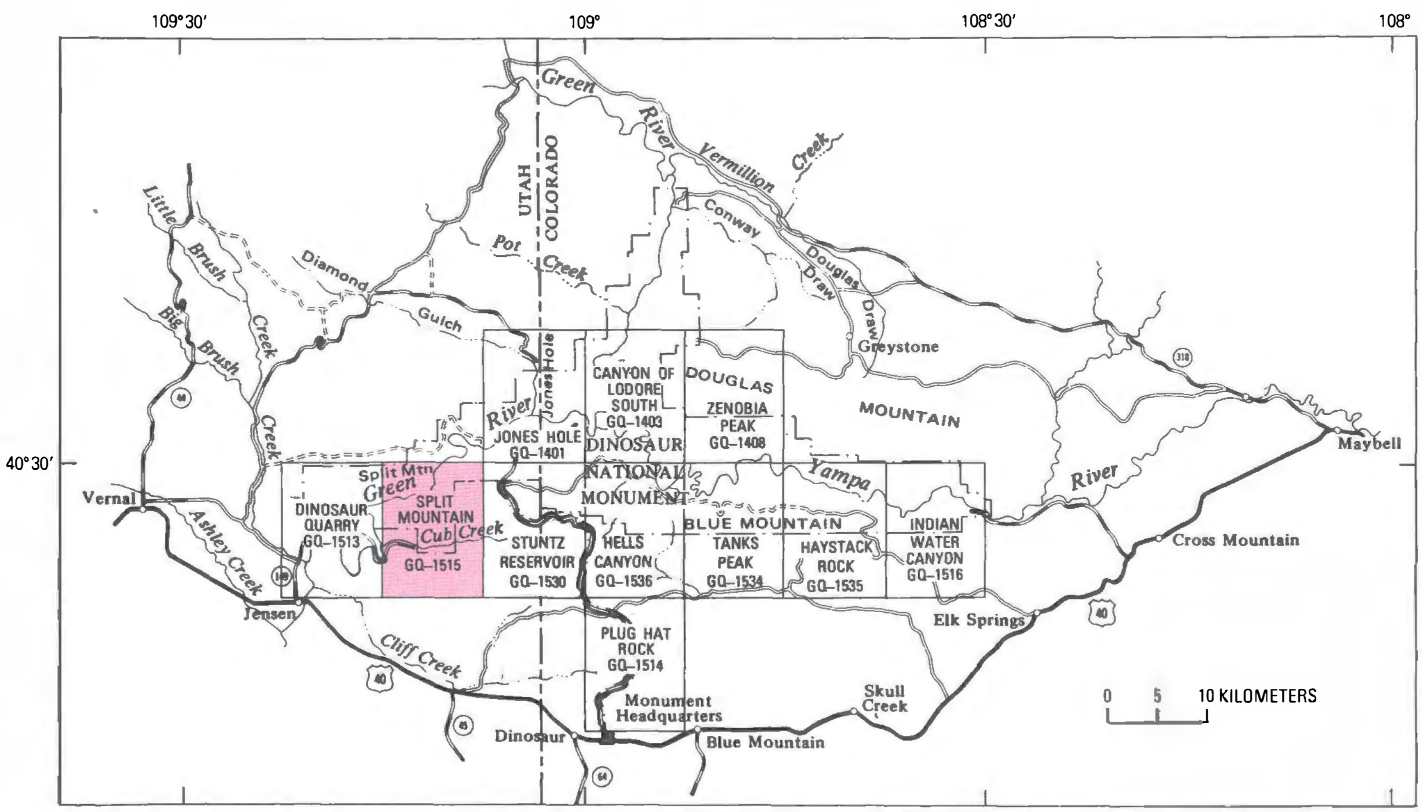
If a series of maps of various levels of a mine is to be published, all the maps should be at the same scale. If some of the maps are too large to be printed on a single page or facing pages, they all can perhaps be grouped in a logical and easily understandable fashion on an oversize plate. Color may be used to depict ore, other mineralized areas, or geologic features if such things cannot be shown clearly by black-and-white patterns.

Mine levels are sometimes designated in either of two ways: (1) A numeric designation such as "100 level" is appropriate if a designation is merely a numbering system for mine levels not separated by precise intervals or elevations below a datum; (2) "100-foot level" is appropriate if a company designation also is a surveyed or precise elevation. If a mining company itself uses both systems, either is acceptable, but only one should be used in a given report. If needed to be shown, names for levels or other workings, such as "main haulage level," should be used as applied by the mine operator.

## Cross Sections

Cross sections should depict scientifically or economically important relationships where structural data are sufficient to allow for reasonable subsurface extrapolations. No more sections should be submitted for publication than are needed to show the inferred relationships. Cross sections should show significant facts and inferences that are better visualized graphically than verbally.

Structural data show best and with least distortion in sections drawn perpendicular to prevailing structural trends. Oblique sections distort dips and thicknesses. Sections need extend only far enough to show relevant structural details; they need not extend across the entire map. They should be oriented to read from either west to east or south to north and should be at the same scale as the map. If several sections are drawn to illustrate through-going structural features common to all, however, all sections should be oriented alike to maintain structural continuity, regardless of the viewer's orientation.




MAP SHOWING LOCATION OF SPLIT MOUNTAIN QUADRANGLE AND OTHER GEOLOGIC QUADRANGLE MAPS IN THE AREA

**Figure 27.** An index map identifying several published Geologic Quadrangle Maps and their geographic settings, including drainage and major highways and roads.

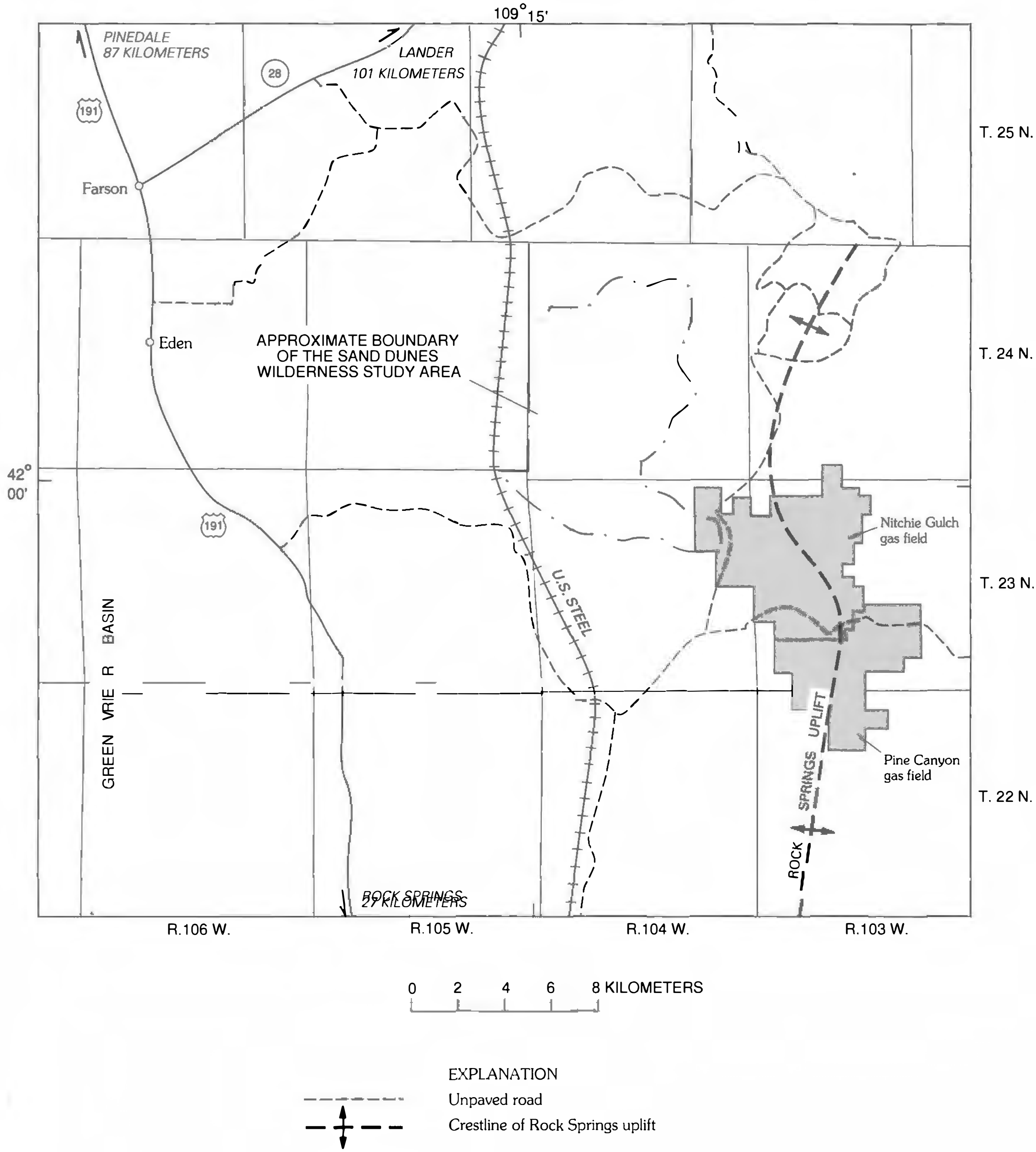



**Figure 28.** Index map of the Sand Dunes Wilderness Study Area, Sweetwater County, Wyo. Shows latitude and longitude, townships and ranges, roads and highways, and other features of interest.

### Exaggerated Sections

Exaggerated vertical scales are sometimes used to show geomorphic, lithologic, stratigraphic, or structural details. They are useful in depicting thin surficial deposits. The exaggeration should be no more than needed to show the detail, and all sections having the same exaggeration should be grouped, where possible, on the same plate. The thickness of thin units can be exaggerated for the purpose of illustration, or thin units may be lumped in a cross section if they cannot be shown at scale. In general, however, avoid exaggeration.

Exaggerated vertical scale causes apparent structural distortions if dips exceed a few degrees, and illogical or impossible apparent structural relationships may result. Exaggerated scales, therefore, should be limited to sections through flat-lying rocks, and a note should be added (below the lower left margin) to call attention to the distortion. A true-scale profile published above an exaggerated section may be helpful.

### Patterns and Lines

Lithologic patterns should be used sparingly on cross sections, because they must be individually drafted or scribed to follow structure, and because they are expensive and often difficult for the illustrator to prepare. All contacts in the cross section, though inherently interpretive, are shown as solid lines. Queries can be inserted in contact lines to express doubt. Faults may be shown as solid, dashed, and queried lines, but not dotted. If a fault or contact is projected above ground profile to show structure, it is dashed. If color is needed to clarify restored (projected above ground) parts of a cross section, that color should be omitted from a narrow band immediately above the ground profile.

## Fence Diagrams

Fence diagrams show stratigraphic interrelation and structure by means of intersecting crossing sections drafted in true geographic projection. Properly constructed, they can present geologic interpretations very clearly, but care is needed to avoid projection errors in apparent dip, thickness, and slope. The height and orientation of the sections, moreover, affect the chosen direction of view and the optimal distance apart of the sections. Fence diagrams are difficult to prepare correctly, are expensive to draft for publication, and have few advantages over well-planned conventional sections.

## Page-Size Maps

For many reports, page-size maps contain scientific and geographic information needed by the reader to understand the text. In preparing page-size maps, your first focus should be on (1) initial decisions about size, scale, and time requirements; (2) materials; and (3) overview of the components of the map.

Page-size maps often are troublesome for you as author to prepare, for critics and editors to review, and for the graphic artist to draft. Consideration must be given to the final "look" of the map, especially if you wish timely drafting and publication. Careful planning can forestall vexing bottlenecks in preparing the artwork by enabling the graphic artist to use most or all of your author-prepared copy, or at least to correctly interpret your copy. Many sources of help exist for authors who don't know how to get started or even where to ask about time, standards, and quality. Consult with map editors and graphics specialists for advice on materials, design, and format.

### Initial Decisions

At the outset, a rough draft of the map may be helpful, at the desired publication size and with all intended geographic detail. This visual aid will help you choose the scale, base needs, and other elements of the illustration. The following questions then may be asked.

1. *Is the map based on previously published work or is it based on new mapping?*
   A previously published source map probably will be of a different scale, may be in color, and may be too detailed or too generalized for the intended illustration, or the map may be new work never before published. The distinctions should be kept in mind before drafting begins.

2. *What are the size limitations?*
   The size of the map is dependent on the maximum image size allowed by the intended publication. Consult a map editor about in-house reports, or the journal editor outside. Most likely, you will have a choice between bottom-title, side-title, and column-title orientations on the page; the choice may depend on the widest dimension of the map. Some layouts can be spread over two pages, or a map can be on one page and its explanation on a facing page. Look at prior publications for examples. See the reverse side of Form 9-1517 ("Author's Check List") for specific dimensions. Authors may try to save publication time and cost by avoiding oversized (larger than page-size) illustrations, but be sure that what you are attempting is feasible.

3. *What is the ideal scale?*

   You need to know the scale (and implications) of the available base maps. The Survey has many standard base-map products at scales of 1:24,000, 1:100,000, 1:250,000, and 1:500,000 and some smaller scales for maps of larger parts of the United States. Some maps are available at 1:50,000. Scale choice depends on the problem to be solved or character of the data to be presented. For best results, compile at or close to publication scale.

4. *What are the time constraints?*

   Time may be short on the cutting edge of science, where the results of your research are in immediate demand, but try to allow adequate time to prepare your illustrations. Be familiar with the production cycle so that time is available to properly draft your map. To judge production time, talk to a map editor or graphics specialist or to the editor of the outside journal and work out a production schedule that meets all deadlines.

## Materials

A map editor or graphics specialist can help you decide what is needed for compilation. All the items described in this section, except basic drafting tools and supplies, are available through the Branches of Technical Reports (BTRs). Instructions on preparing artwork are outside the scope of this section, but a few words about basic materials should be remembered.

**Base maps.** Once you have decided on the size and scale of the illustration, ask a map editor about base-map materials. Map editors keep them on hand, or they can order appropriate base negatives or mosaics. The map editor will order a sheet of scale-stable frosted plastic with the base map printed in non-photographic green (a "greenline"). An order for base materials can take several weeks to fill, so allow for the extra time. The greenline will have registration holes punched near its margins; these holes are needed to register any overlays to the greenline.

If no suitable base map exists, you may have to prepare one yourself, perhaps by finding an available map at the next closest scale and transferring the desired features onto a clean sheet of scale-stable material. Include the geographic coordinates. Towns, drainages, roads, and physiographic depictions are helpful but are optional. An enlarging-reducing photocopier or projector will make this job easier.

**Overlays.** In preparing a figure, you can use overlays to separate information plotted on the original artwork. For example, consider figure 29, which shows the location of Wilderness Lands in the State of Arizona in relation to the geology and shows the State outline, geographic coordinates, counties, and major population centers. One overlay would have the Wilderness Lands, shown here in gray. Another overlay would show the lithologic units and still another would show drill holes, outcrops, and lines of geologic cross sections. Compiling all these layers of information on one sheet of material would present difficulties for both reviewers and the drafter who must interpret your copy. Take care to avoid duplicating information. Overlays should always be compiled on scale-stable material (the same material as a greenline) registered to the greenline or skeletal base map. Decide in advance what information can be grouped together.

**Pens and inks.** For the cleanest linework, use a technical pen filled with carbon-base black ink specially developed for inking on plastic and less than a year old. Avoid india ink, pencil, ballpoint pen, fountain pen, or felt-tip pen—these will yield less satisfactory results and may not photograph well. Scribing is a good alternative to pen and ink.

**Lettering, symbols, and patterns.** Lettering and symbols can be hand drafted with pen and ink or can be applied with adhesive-backed drafting products. Choose the latter method if your illustration is to be camera ready. Scan a variety of USGS publications to decide what styles and sizes of type to use and what symbols are standard for the map features you will show.

Choice of patterns is somewhat subjective; what looks best to you may violate the sensibilities of a graphic specialist. A map editor or graphics specialist can help you decide which patterns are best and which to use, if any. Remember that patterns are substitutes for color on a page-size map and must be selected just as carefully. Avoid patterns that may cause unwanted moire effects or that inhibit legibility. Try to choose tints of gray or small, densely spaced pattern elements rather than stripes or large, widely spaced elements.

## Components of Page-Size Geologic Maps

**Geographic coordinates and neatline.** Unless the map scale is very large, geographic coordinates should be plotted. Once these are plotted, a neatline (or boundary) of the map area can be added. The coordinate ticks should be projected to the neatline and their values placed beside them, outside the neatline, to the left and top of the map. Coordinate intersection crosshairs can be plotted inside the map area if desired, but drawing the entire grid inside the map area detracts from the legibility. Other applicable

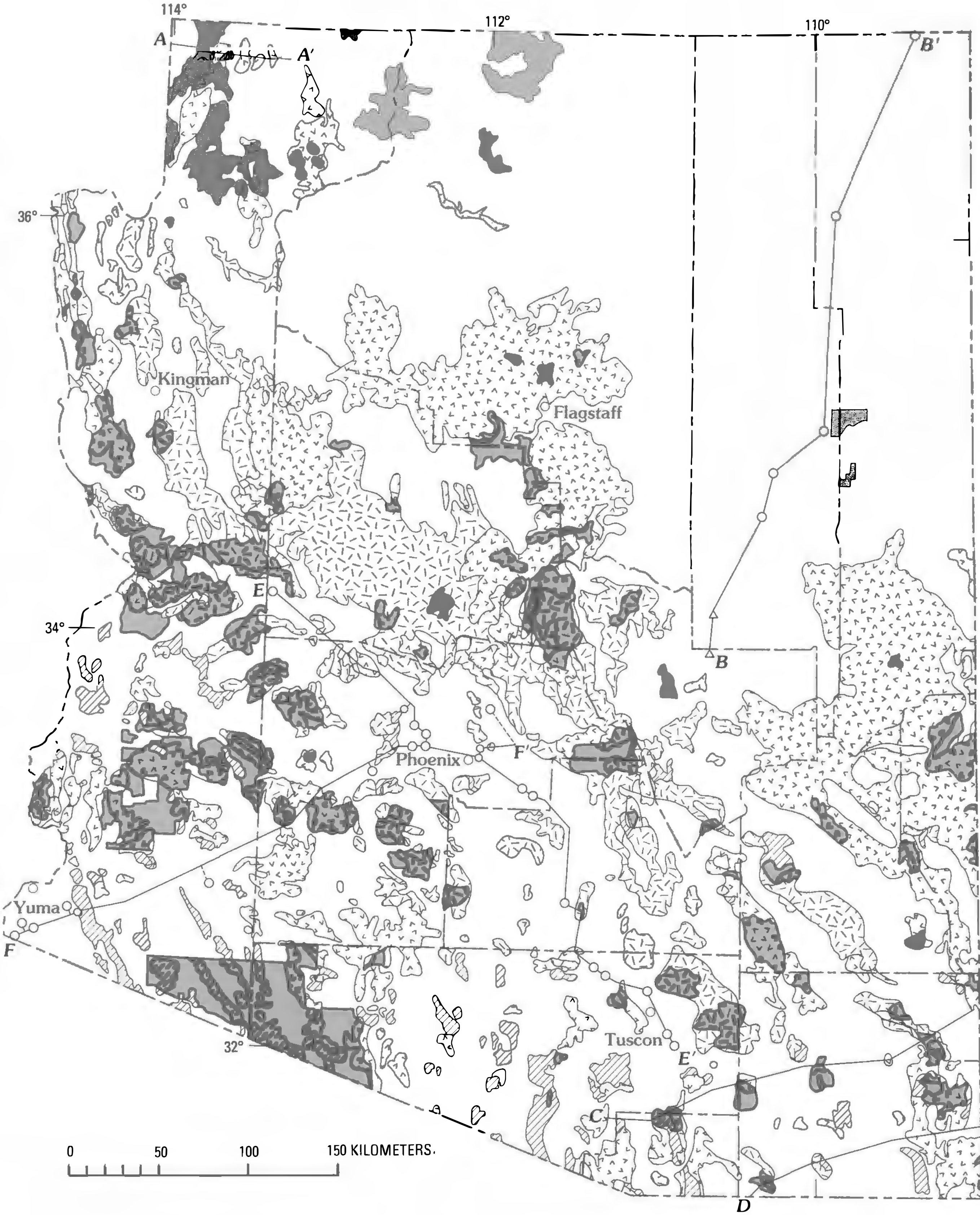
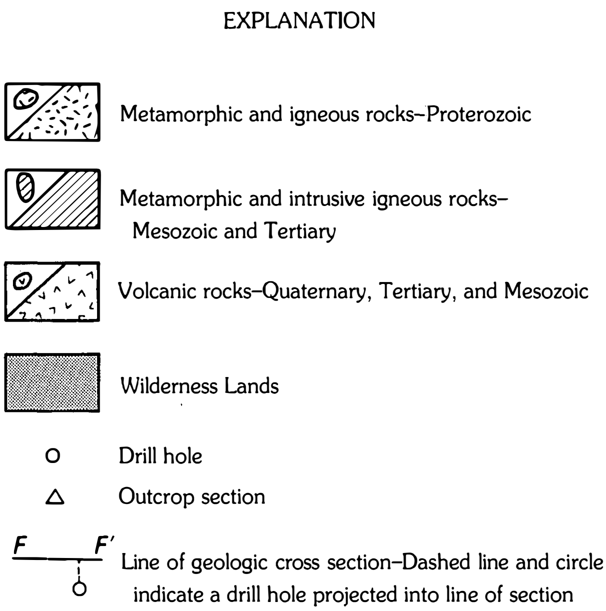



**Figure 29.** Major outcrops of igneous and metamorphic rocks and lines of cross sections.




coordinate system ticks can be added around the neatline, such as UTM coordinates, State grid values, and public land surveys (township and range).

**Scale.** Every map must have a scale. If the scale is a standard Survey scale, and no enlargement or reduction is planned in the printing, use the standard bar scale. If an odd scale will result from enlargement or reduction, use a rake scale. If your report uses both English and metric units, the map should have both English and metric scales.

**Base-map credit note.** Always acknowledge the source for the base map, the publication (and photorevision) date, and the original scale if it differs from your illustration. Wording such as "Base from U.S. Geological Survey, 1:250,000, 1966" is a common way to phrase a credit note, but check with a map editor if you are unsure. The credit note should identify the projection of the base map. Knowledge of the base-map projection is essential for map users who incorporate the map data in a digital information base.

**Mapping credit note.** Always acknowledge the mappers. If the mapping was done by you, the author, the credit note should state when the mapping was done. If the mapping was modified from someone else's work, the note should read "modified from * * *" If the mapping exactly duplicates another person's work, a proper reference citation should be given in the credit note (be sure to get copyright permission from private sources). Field assistance should be acknowledged here also.

**Index or location map.** If space on the page permits, an appropriate index or location map should accompany the page-size map.

**Explanation.** The explanation of a page-size map should include a list of map units (giving the map-unit symbols, names, and ages) and an explanation of map symbols. If space allows, a brief description of the units may spare the readers from having to hunt through the text to find the basics of each. Every illustration in a report should stand on its own. Each symbol in the explanation, whether a line, point, or pattern, should be explained.

**Flexibility.** Keep in mind that these guidelines are flexible. The space requirements of a particular illustration often dictate the amount of flexibility. Figures 30, 31, and 32 are examples of page-size geologic maps that show a good balance between the scale and detail and a thoughtful selection of patterns.

## Stratigraphic Sections, Lithologic Columnar Sections, and Well Logs

Authors preparing stratigraphic sections, columnar sections, and well logs should be mindful of publication scale. Copy should be drafted at publication scale or only slightly larger (not more than 20 percent) so that original, carefully done linework can be used without redrafting; then the illustrator needs only to add type for column headings, explanations, and titles. Illustrators may have difficulty redrafting poorly done, fine detail. Authors should check the technical standards and consult with a map editor or illustrator on line weights and special symbols. Lithologic symbols used in a graphic column must be explained separately unless the description of each unit is printed clearly beside the column. The vertical scale as published should equal some even unit of an engineer's or metric scale. Published widths of columns should be not less than 1 cm nor more than 2. (See also p. 55 and 58, fig. 14.)

Special logs, such as electric, radioactivity, resistivity, and many others, are normally prepared by the author personally or under the author's immediate supervision, with the expectation that they will be photographed and used for final publication copy. Only the author can judge what degree of generalization is acceptable.

Color printing is unnecessary for most graphic logs and sections. Carefully selected black-and-white patterns and distinctive contrasting line weights will adequately portray most data.

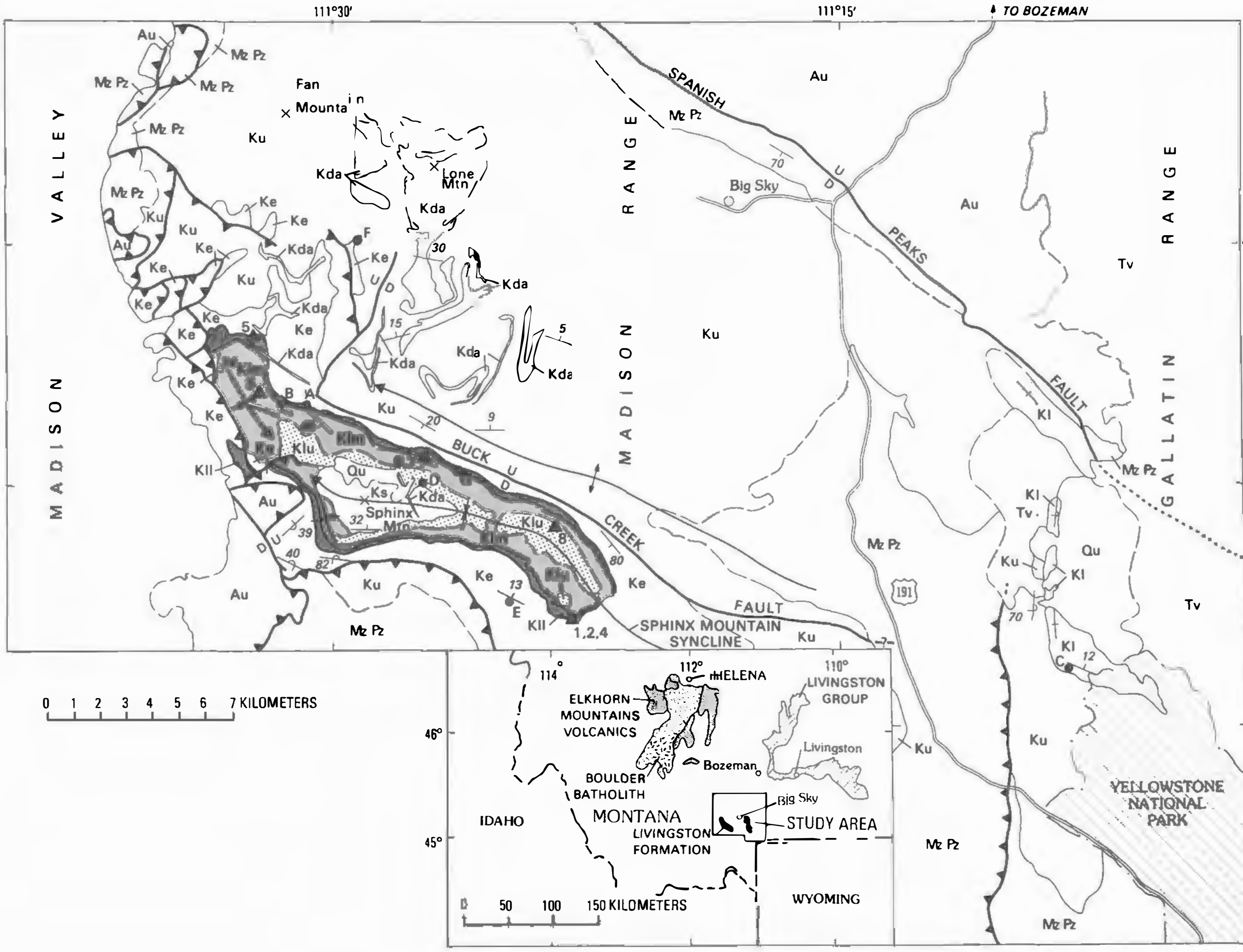



**Figure 30.** Geologic map showing outcrop areas of Livingston Formation in the Madison and Gallatin Ranges, locations of paleontological collections (A–G), and sample sites of igneous rocks (1–8).

## Computer Graphics

Computer graphics offer a rapidly growing field of illustration. Techniques are constantly being updated, so you may wish to ask the advice of an expert in planning and preparing computer-generated maps and other graphics at an early stage of the project. Some computer plots may require extensive touchup or redrafting. The most successful package presently used by USGS authors is the GSMAP/GSDRAW package developed by Selner and others (1986). Computer graphics suitable for lecture slides can be photographed directly from the video screen or can be produced from a program designed for that purpose.

## Photographs

Photographs submitted as figures should be essen-tial to the clarity of the text. Effective photography requires sharp focus and good contrast. Well-chosen and adequately captioned photographs are among the best and least expensive illustrations to prepare and print. If you submit more photographs than necessary, in the mistaken belief that a certain proportion will be arbitrarily rejected by the editors, you will waste everyone's time.

### Black-and-White Prints

The mill copy of the photograph should be printed at about publication scale and at about the correct tonal value for printing. Review prints should be close to publication size so that the reviewers and editors can verify that the photographs show what they intend to show. Prints from copiers may be unacceptable for review. You should retain all negatives with your other original illustrations until they are requested by the publication staff.

EXPLANATION Unconsolidated

Qu sedimentary rocks (Quaternary) Volcanic rocks,

Tv undivided (Tertiary)

Kda Dacitic intrusive rocks (Upper Cretaceous)

Ks Sphinx Conglomerate (Upper Cretaceous)

Klu Livingston Formation, upper member (Upper Cretaceous)

Klm Livingston Formation, middle member (Upper Cretaceous)

Livingston Formation, lower member (Upper Cretaceous)

Kl Livingston Formation, undivided (Upper Cretaceous)

Ku In Gallatin Range, Cretaceous rocks older than Livingston Formation; in Madison Range, Cretaceous rocks older than Virgelle Sandstone, and unmapped areas of Cretaceous Dacitic intrusive rocks (Upper Cretaceous)

Ke (?)Everts Formation and Virgelle Sandstone, undivided (Upper Cretaceous)

MzPz Sedimentary rocks, undivided (Mesozoic and Paleozoic)

Au Metamorphic rocks, undivided (Archean)

Contact— Dashed where approximately located

U D Fault U, upthrown side; D, downthrown side

Thrust fault— Saw teeth on upper plate

Anticline— Showing trace of axial surface and direction of plunge

Syncline— Showing trace of axial surface and direction of plunge

Bedding

40 Inclined

70 Overturned Fossil

B locality Igneous rock

3 locality

If you wish to publish a photograph but do not have a negative, a high-quality copy negative should be made, especially if only one print of the picture is available. If you wish to publish a black-and-white photograph from a color slide or color print, a black-and-white negative and a print at publication size should be prepared for review and publication. Color originals, however, seldom make black-and-white prints of quality equal to black-and-white originals.

### Color Prints

The mill copy for a photograph to be printed in color should be a color print of about publication size and of the desired color balance. The printer will use the mill copy as a guide to cropping and color reproduction. The original—preferably a first-generation color transparency, a high-quality original print, or color negative, in that order—furnished to the printer should be marked "To be returned to USGS Photographic Library." Note that a color negative requires the printer to make a suitable print from which the color separations are made. These extra steps do not ensure quality printing.

### Special Requirements

If a long, narrow picture is intended for a book report, such as a panoramic view made from three or four photographs, it is better printed as a bottom-title figure across two pages and as a center spread than as a side-title figure. An oversize photograph might fit best on a page as a bleed. If as much as 4 millimeters can be cropped from each side without loss to the picture, the printer can easily bleed the photograph to the edges of the page. A bled photograph on a single page of a professional paper can be as much as 60 percent larger in total area than the conventional-size, page-width photograph of the same image. Bled photographs have high pictorial impact, but if overused they lose much of their effect.

Mounting photographs for the printer should generally be left to a graphics expert. Instructions follow for preparing photographs for review:

1. Submit photographic prints at publication scale. Use crop lines on translucent overlays to bring to publication scale or to delete extraneous parts of the image; composition is almost always improved by cropping, but do not trim along crop lines; submit a print of the complete negative.
2. Request 300-line screen only for fossil plates or other prints that require fine detail. Stereopairs, for example, require fine screening because the viewing stereoscope enlarges and emphasizes the dot pattern of the halftone print. Consult with a graphics specialist. Photomicrographs are usually printed in a fine (200-line) screen to preserve fine detail. In any event, justify the need for fine screening.
3. Do not write or draw on photographic prints, front or back, and do not use paper clips. A scale, if any, should be drawn in rough draft outside the image area or on an overlay; the illustrator can decide its final placement with your concurrence.
4. Use a registered overlay to show line and symbol placement. To register overlays, use corner ticks; indicate top.
5. Do not mount with staples, tape, or adhesive material.
6. Do not place tape of any kind over the image area.

Instructions to the photographer concerning cropping, dodging to bring out detail, or other custom treatment for photographs may be placed on the mill copy, on a translucent overlay of the mill copy, or on the back of the "Author's Check List" (Form 9-1517).

### Captions for Photographs

To be meaningful, captions must adequately describe what is shown. "View of Heart Mountain," for example, is insufficient. The location, the direction in which the photograph was taken, a reference to the

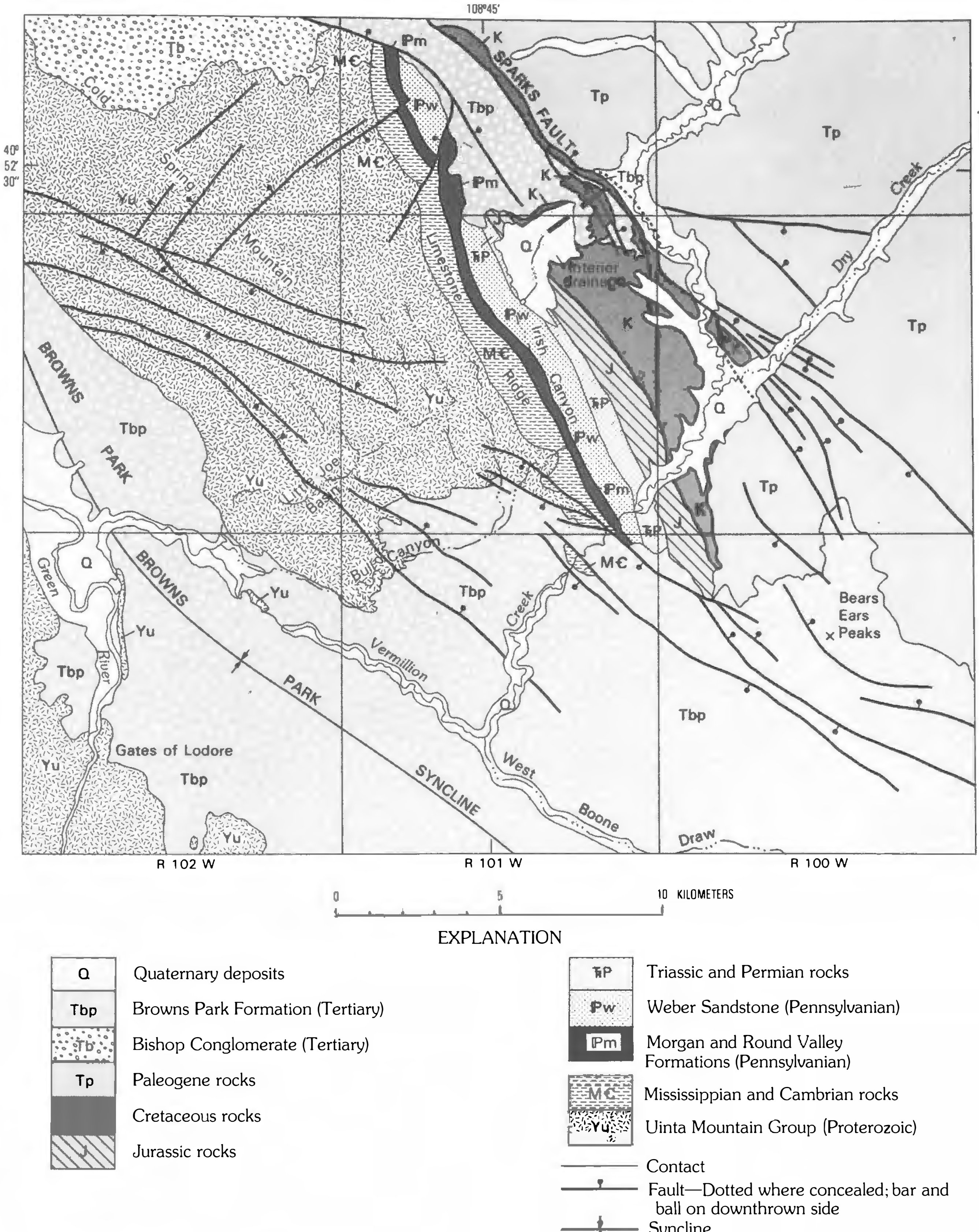



**Figure 31.** Geologic map of Vermillion Creek area affected by the beheading of Irish Canyon. Heavy dashes mark wind gap at head of Irish Canyon.

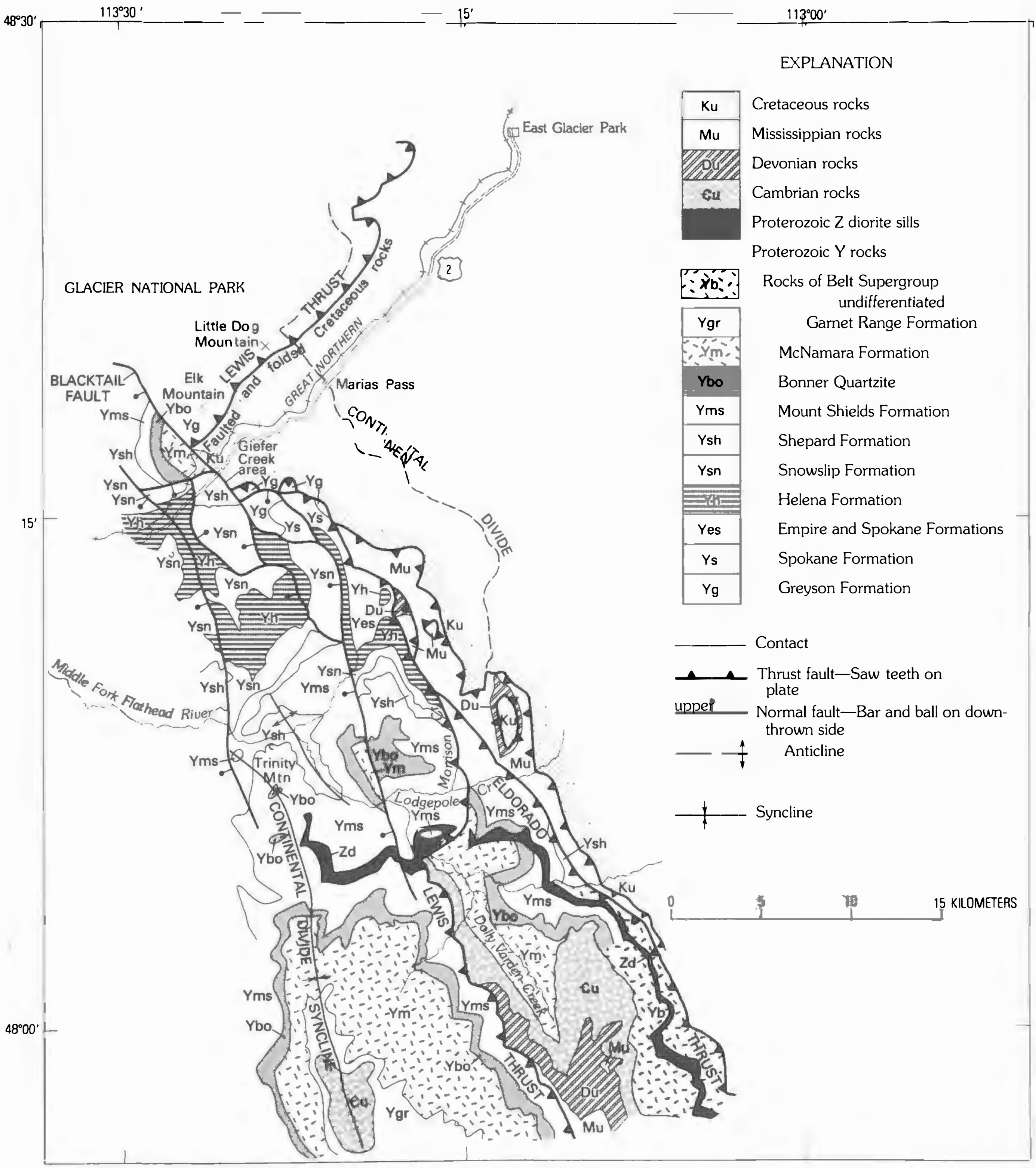



**Figure 32.** Part of a geologic map of the Lewis and Eldorado thrust plates from the southern part of Glacier National Park (shown) to Steamboat Mountain (not shown).

scale of the photograph, if not obvious, and an explanation of any symbols shown on the overlay are essential parts of the caption. The date of photography may be included if relevant. Credit the source, if it is not you.

### Irrelevancies

Manmade structures such as head frames, drill rigs, or machinery are not normally acceptable as illustrations unless they relate specifically to the subject matter of the report. A photograph of a discovery well, for example, has little relevance.

### Photographs on Oversize Plates and Maps

Black-and-white and color photographs occasionally are published on oversize plates and on map-series reports. These must be justified, because the quality of reproduction on map sheets may not preserve fine detail. If several photographs are to appear on the same sheet, they will reproduce best if they all have about the same tonal intensity and contrast; if not, some may be washed out, others may be crisp and clear, and still others may be too dark.

### Drawings from Photographs

Geologic relationships may not be obvious on photographs, and printed overlays showing those relationships may obscure what geology is shown. A sketch prepared from a photograph can often better portray the information. A simple line drawing beneath the photograph, or instead of the photograph, can show the significant features better than words. Submit the original photograph and a rough sketch on a translucent overlay to guide the illustrator. High-contrast photographs can be shot as unscreened linecuts in place of line drawings for special effect, but this technique does not ordinarily lend itself to geologic subjects.

### Fossil Plates

Authors who prepare tentative layouts for proposed fossil plates should check recent publications for style and should work closely with the illustrator in their preparation. Some authors may prefer to do the plates themselves; if so, an illustrator can give technical advice for preparing, arranging, and mounting the parts.

### Aerial Photographs

If aerial photographs or prints from remote sensors such as Landsat multispectral images are to be used as illustrations, their source, identification number, and date should be a part of the caption. Single aerial photographs present no special problems. Aerial photographs that are to appear as stereopairs do present problems and must be precisely mounted for stereoviewing. Many readers, moreover, cannot see stereoscopically without special equipment. Stereopairs should be submitted at publication size, and you as author should work closely with your illustrator in mounting them.

For aerial photographs, the general rule of orienting north toward the top of the page may be waived. Aerial photographs filmed in the Northern Hemisphere have a natural light source in the southern quadrant, whereas the source of light at ground level commonly is from above—that is, from apparent north. Relief features, therefore, may appear inverted on aerial photographs; ridges appear as valleys and craters appear as domes. This troublesome illusion may be averted by orienting the photograph so that south is toward the top or side of the page. A north arrow and scale should always be added.

### Shaded-Relief Maps from Photographs

Inexpensive shaded-relief maps for use as index maps can be made by photographing the back of plastic raised-relief maps with a light source in the lower right quadrant (southeast). When the negative is printed, the light source appears to be in the upper left (Stacy, 1962, p. D165). The front of the plastic map should be photographed with flat overhead light at the same scale and at the same time to provide a guide for the illustrator to add geographic or geologic overlays to the final illustration.

## Frontispieces

A Survey book publication may rarely contain a frontispiece to illustrate the general subject of a report and set the general tone. It may be a panorama of the area or a sketch. If you have an outstanding picture of a more specific nature, it too may be suitable. Color may be approved, but it requires specific justification.

## Cover Art and Other Special Artwork

Many but not most Survey book publications feature cover art, particularly reports aimed at the general public or at a nontechnical readership. Simple, tastefully drawn linework that relates clearly to the subject matter of the report is especially fitting; the range of possibilities is wide. If you are a talented artist, your own work may be used, but the cover more likely will be designed and executed by a professional artist after you have made the necessary arrangements through your publication people. Similarly, unobtrusive artwork may be used for special effect in the body of the report. Such artwork is used most commonly in popularly oriented reports to help project an appropriate mood or to serve as attractive space fillers at the ends of paragraphs or chapters.

## Graphs and Diagrams

Graph scales commonly used in Survey publications include arithmetic, logarithmic, semilogarithmic, and probability scales, shown by a grid of lines across the diagram or merely by ticks along the vertical and horizontal axes. If extension of the grid across the graph is important to the reader, the graph or diagram should be outlined and ticked on all four sides. The grid should be extended to include all data shown on the graph.

Scales are generally labeled only along the left and bottom axes. Scale numbers normally should increase from bottom to top and from left to right. Captions for axes are all in capital letters; they should be complete and should include the unit of measure, as "XX, IN PERCENT." All symbols used on a graph must appear in an explanation or figure caption or be labeled on the graph.

Graphs and diagrams enhance reader comprehension by using points, lines, shadings, patterns, colors, numbers, and symbols to summarize and analyze data that otherwise might be buried in lengthy narratives or tabulations. Variety is limited only by your imagination and ingenuity.

### Preparing Graphs and Diagrams for Review

Time spent in preparing neat, legible review (mill) copy will be made up in the review and production processes. Nonphotographic blue grid lines on base material will make for better review copy than other colors such as orange, which tend to overpower the data in xerographic prints. Bear in mind that you should retain your original copy until it is requested by your publication staff.

Required elements of a graph that are most commonly overlooked are identified on figure 33.

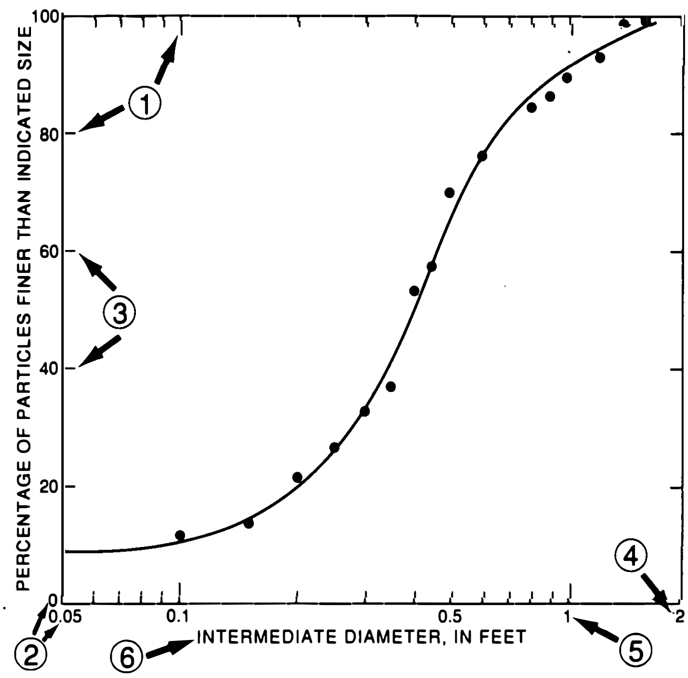



**Figure 33.** Elements of a graph.

1. Grid ticks should appear on all four sides of graph, inside the graph boundaries.
2. Tick values should be labeled across bottom and left side of graph, unless graph is multiscale.
3. Scale increments should be uniform (except on log and probability scales) and, ideally, should extend from one labeled increment to the next. Labeled increments should cover the full range of the data.
4. When, because of space limitations, it is impractical to extend the graph to the next labeled tick of the scale increment being used, the scale can be switched to accommodate the data; the switch in scale must be labeled at the corners of the graphs.
5. Ticks for log scales should be labeled at each cycle (for example, 0.1, 1, 10, 100, and so forth). Intermediate ticks must be added for clarity and may be labeled if necessary.
6. *X* and *Y* axis labels should be in uppercase, including what the axis represents and the unit of measure.

Unit of measure is spelled out in all Survey publications. For example:

DISCHARGE, IN CUBIC METERS PER SECOND

However, if you are submitting an article to a journal that insists on using accepted abbreviations (for example, $ft^3/s$, mg/L), use these on axis labels and throughout your text consistently.

Figures 34–54 show some types of graphs and diagrams that commonly appear in Survey reports.

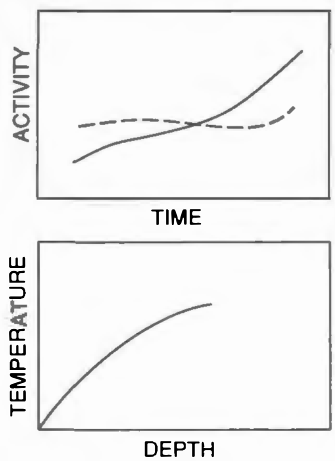



**Figure 34.** Curve or line graph.

Emphasizes trend or rate of relatively continuous data by connecting plotted data points. Differing line symbols distinguishing various properties may become cluttered if more than three line symbols are to be compared, and multiple graphs may then be necessary, or color or screening might be needed to enhance readability. This curve is commonly used to show variation trends of two or more properties, as in isochron plots and equilibrium diagrams.

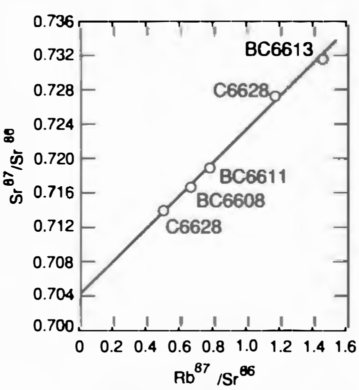



**Figure 35.** An isochron plot.

Plotted on a line graph. Example shows Rb/Sr ratios and positions of samples on plotted line.

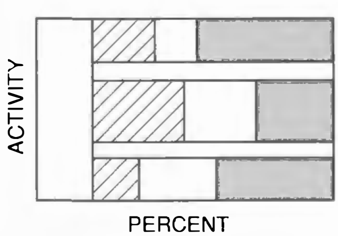



**Figure 36.** Horizontal bar graph.

Emphasizes volume of data and best shows percentages. When used to compare different items simul-taneously, it has only one numerical scale, because no time scale is needed. Bars representing plotted data should be arranged in order of magnitude.


**Figure 37.** Column or vertical bar graph.

Emphasizes fluctuating magnitudes of data for one item at different times. Bars may be subdivided by patterns, tones, or colors to represent component parts of the total by the heights of those parts of the columns.

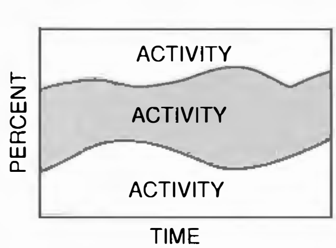



**Figure 38.** Surface or band graph.

Emphasizes amount of data. Various values placed in layers one above another form a cumulative total. The graph is especially effective for showing com-ponents but should not be used if sharply fluc-tuating data distort other components.

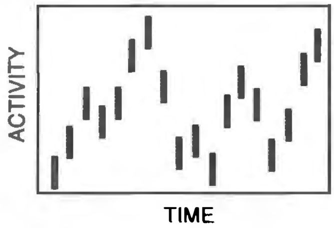



**Figure 39.** Symbol graph. Emphasizes general trends of data. Symbols unconnected by lines represent data. Possible applications could be (1) symbols plotted as data points, where a trend line is not possible or desired, or (2) a series of vertical bars, each bar showing the maximum and minimum values of some data such as monthly mean water levels for a period of time.

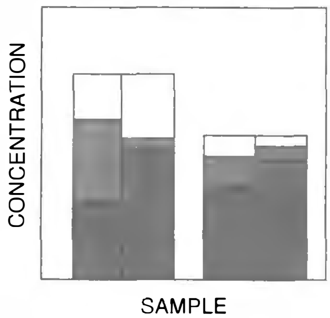



**Figure 40.** Collins diagram. Used in water analysis to show total solute concentration and the proportions assigned to each principal ionic species. Each analysis is represented by a vertical bar graph whose total height is proportional to the total concentration of anions or cations. The bar is divided into a left half representing cations and a right half representing anions. Each half is then divided by horizontal lines to show concentrations of the major ions, which are identified by distinctive patterns, tones, or colors. The lengths of the cation and anion halves should be equal.

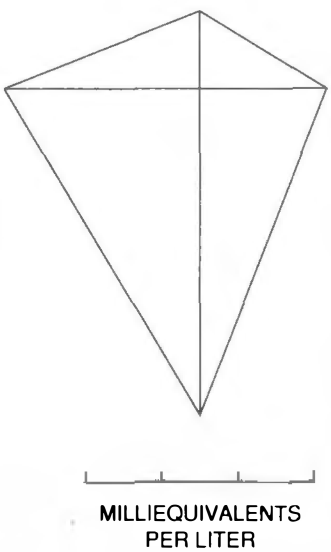



**Figure 41.** Kite diagram. Concentrations of cations and anions, or other properties, are represented on rectangular coordinates. The length of each coordinate line from center corresponds to the concentration of constituents, in milliequivalents per liter. Once the ends of the four coordinate lines are connected, thereby forming a distinctive shape, the patterns for different water types can be easily and quickly compared visually.

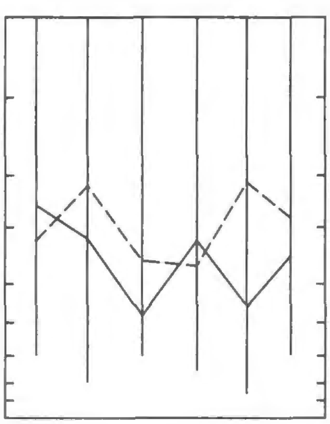


**Figure 42.** Nomograph. Depicts one or a group of analyses. Lines on the interior scales of the nomograph represent concen-trations of ions in milligrams per liter. Scales for milliequivalents per liter at the left and right sides of the nomograph have the advantage of showing the relationship to scales for milligrams per liter. Waters of similar composition plot as near-parallel lines.

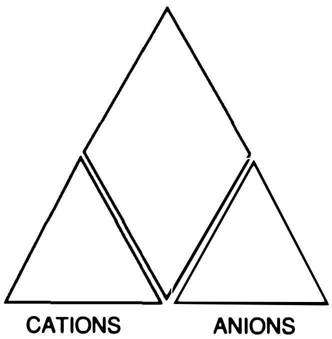



**Figure 43.** Piper diagram. In water analyses, indicates the essential chemical character by single-point plottings of cations and anions on trilinear coordinates. The proportions of cations and anions are plotted in each of the lower triangles; then the points are extended into the central diamond-shaped field. The intersection of the projections represents the composition of water with respect to the combination of ions shown.

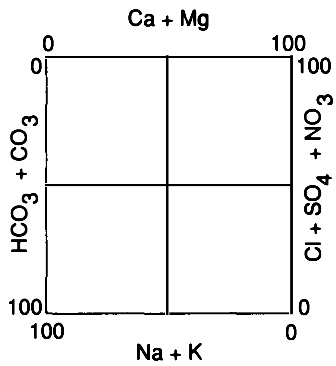



**Figure 44.** Modified Piper diagram. Indicates the essential chemical character of a water sample, or group of samples, by the location of plotted points within a square diagram. Concentrations of the ions for each water sample are in milliequivalents per liter; points are plotted in percentages of total anions. Thus, the sum of cations (Ca + Mg) + (Na + K) equals 100 percent and the sum of anions equals 100 percent.

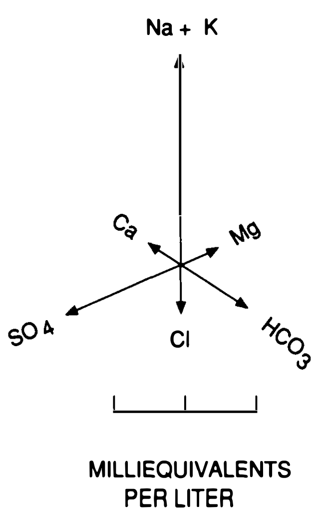



**Figure 45.** Radiating-vectors diagram. Uses a system of plotting analyses by radiating vectors. The length of each of the six vectors from the center represents the concentration of principal ionic species, in milliequivalents per liter. A scale of units must be included with each diagram. A summation of the lengths of the arrows for cations should equal the lengths for the anions.

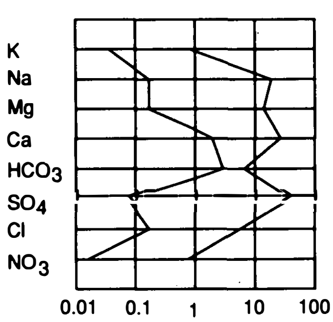



**Figure 46.** Semilog concentration graph (Ropes diagram). Each of a set of parallel horizontal log-scale axes corresponds to a selected constituent or variable. On each axis are plotted the distribution, minimum, mean, and maximum values for the variables selected. Straight lines drawn to connect the low values and the high values of all variables give a characteristic shape to the "distribution" of the selected group of data.

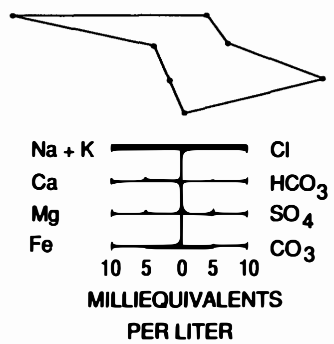



**Figure 47.** Stiff diagram.

Forms a distinctive pattern that can be used to show water composition differences or similarities. Four horizontal lines extending on each side of a vertical line form a grid on which cations are plotted to the left and anions plotted to the right. The plotted points are connected by lines to form a closed pattern that characterizes the analyzed water. The width of the pattern is an approximate indication of total ionic content.

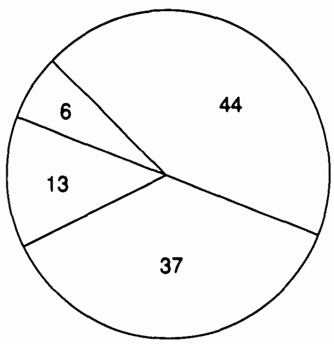



**Figure 48.** Circular (pie) diagram.

Emphasizes subdivisions of a whole. This diagram is commonly used to show percentages, but it can also be drawn with a scale for the radii. Values are easily perceived, but graphs are easier to interpret quantitatively than pie diagrams because the eye can judge linear distances easier than radial ones. Important subdivisions can be screened or patterned in black and white or set off in color.

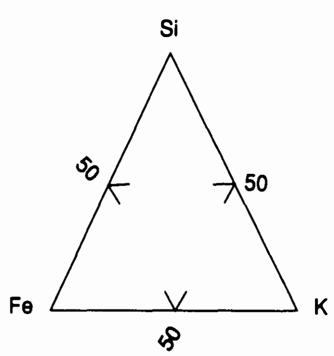



**Figure 49.** Triangular diagram.

Shows a percentage composition in terms of relative amounts of three components.

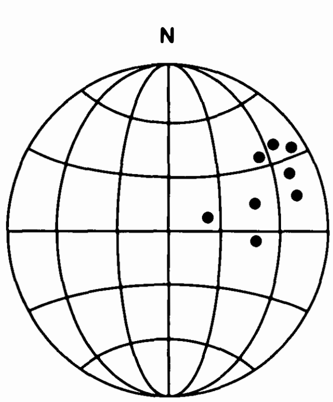



**Figure 50.** Schmidt equal-area projection.

Shows azimuths measured clockwise from north and about a point directly beneath the observer (if grid is deleted, center point is shown by a "+" and north is ticked).

**Combination graphs.** Two or more of the preceding graph forms can be combined to compare additional components, as shown by figures 51–54.

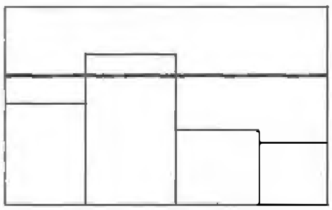


**Figure 51.** A vertical bar and straight horizontal line combination.

Useful for measuring performance against a goal or standard, such as annual precipitation by bars and average annual precipitation by a horizontal line.

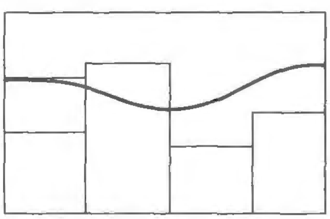


**Figure 52.** A combination of vertical bars and a curved line.

Useful for showing variables such as water use and population, or precipitation and water levels in wells.

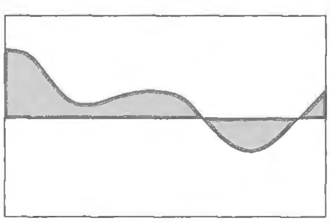


**Figure 53.** A curved line and straight horizontal line.

Can be combined to compare monthly or annual precipitation with an average or cumulative depar-ture from average.

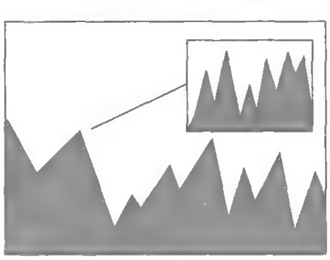


**Figure 54.** An inset.

Smaller graph superimposed on a larger one magnifies part of the data lost in the range of the larger graph. The informative value of this presentation lies in a different or more comprehensive view of the data.

### Engineering Drawings

Circuit diagrams, working drawings for laboratory apparatus, patent drawings (which are usually exploded drawings of a working model), and so on may be required in some scientific reports. Before attempting such a drawing, you should consult a professional engineering draftsman or a knowledgeable illustrator.

### Slides and Viewgraphs

Although color transparencies and viewgraphs are not ordinarily used as illustrations, they are important visual aids for oral presentation, and many organizations have prepared manuals for their preparation. Among the best are those by the American Association of Petroleum Geologists (1970) and Allen (1977).

## Preparation of Author Copy

Author's original copy for every illustration should be neat, clear, and accurate. Few authors are able to prepare finished copy ready for printing, so most illustrations are redrafted. Author-prepared copy is used, however, in the MF series (p. 3) and in many Bulletins and Circulars. Stratigraphic sections generally are printed directly from author copy also. Final preparation follows Director's approval for publication, but you should consult your map editor or illustrator early enough to ensure that your copy (mill copy) is adequate for technical reviewers, editors, and illustrators. Illustrations are generally prepared in final form at publication scale.

Your original copy should be in black ink, or it should be scribed. Colored inks or photographically reproducible pencil should be used only with the concurrence of your map editor. Make lines no heavier than necessary; an author's overly heavy lines leave the exact placement of final fine lines up to the illustrator, who should not have to make such judgments. If your lines are too light, however, they may not be picked up on scribe coats or proof prints. Legible hand-lettering is preferred for your author's copy; the illustrator will place final lettering.

Stick-on ("zip") patterns are used on some maps and cross sections. Choice of patterns is usually left to the map editor and illustrator, though you may suggest styles and preferences. Review and mill copies of illustrations should include both uncolored and hand-colored copy prints of the original drawings, whether they are to be printed in color or in black and white. Distinctive and contrasting colors work best. Never color the originals. A note may be attached to the "Author's Check List" for plates, figures, and photographs (fig. 23) to suggest which units should be emphasized, what colors are preferred, and what published maps should be matched in final reproduction.

Illustrations must be complete when they leave your hands. Show all lines, symbols, numerals, letters, words, and limits of areas to be patterned or colored, and explain all symbols on the illustration. Each illustration should be able to stand alone without reference to the text or to any other illustration for explanations of its symbols. Illustrators will put your material into publishable form, but they cannot be expected to supply missing lines or interpret ill-prepared work.

### Titles and Captions of Illustrations

Titles and captions of illustrations should be both informative and concise. For a separately published illustration such as a map, the title should be short, but it also should express content and location. Explanatory material belongs on the illustration itself, not in the title. Captions for text figures are set in type by the typesetter; they may be longer than those for plates and may include explanatory material, but they should not take the place of text.

For each illustration a figure number and complete caption are typed double spaced on a separate page at the end of the manuscript; a duplicate caption is attached to the mill copy of the illustration. To guide the editor and the typesetter, the phrase "**FIGURE x.--NEAR HERE**" is inserted in the text at the end of the paragraph that contains the chief reference to the figure. Leave a blank line above and below. (See also p. 254.) The figure or plate number is also placed on the mill copy of the illustration to identify the illustration if title and mill copy should become separated.

The following factors control the content and form of titles:

1. Kind of illustration. In book reports the kind of illustration (map, photograph, diagram) is indicated in the list of illustrations in the contents of the report but is generally omitted in the figure caption itself. In separately published illustrations, the kind of illustration must appear in the title: "Geologic Map of the * * *." Although a map may contain secondary illustrative items such as cross sections, columnar sections, or diagrams, the map title ordinarily does not mention them. Essential subordinate or specialized data, however, can be mentioned by such additions as "* * * and structure," "* * * and cross sections," "* * * showing sample localities."

2. Geographic location. Titles of separately published maps must include quadrangle name, if applicable, county or region, and State(s). Complete geographic location (county, State) is not needed in titles of figures bound within a publication unless the figures portray only part of or more than the entire area studied.

3. Qualifications. If special conditions affect the character of a map, qualifying adjectives may be used, such as "preliminary," "sketch," "generalized," "reconnaissance," "surficial," or "bedrock."

4. Multisheet maps and separately printed texts. If a map is to be printed as more than one sheet (for example, if it includes special data to be printed separately—not simply an oversize map that requires more than one sheet to go through the press) or if it includes a pamphlet text, a common title that applies to all parts must appear on each part. The individual parts should be identified also by subtitles.

5. Reference locations. The illustration itself should not be confused either in caption or in text with the physical actualities it represents. Thus:

| Incorrect | Correct |
|---|---|
| The west side of figure 2 is within 56 kilometers of the easternmost sedimentary rocks of the western Nevada Mesozoic province * * *. | The area shown in the left side of figure 2 is within 56 kilometers * * *. |
| A trace of the fault is exposed 8 kilometers north of figure 5. | A trace of the fault is exposed 8 kilometers north of the area shown in figure 5. |

6. Verbal scale, ratio scale, and magnification. These should not be given in a caption, because the scale may be changed in or after cartographic preparation. (Draw a rake scale on the figure or on a translucent overlay and register it to the photograph or photomicrograph for drafting by an illustrator.) Fossil plates are exceptions; the scale of each specimen is given in the caption, which commonly is on the page facing the plate. If a photograph contains no easily recognized object, such as a hammer or a person, the size of some other recognizable object should be noted in the caption. On oblique aerial photographs such an object might be a segment of a road, the face of a cliff, or even the distance across the front of the picture.

7. Map-unit and other symbols. These must be described in an explanation or in the caption. Symbols should not be used in the text, except in parentheses to clarify a unit name; for example, "Tertiary intrusive rocks (Ti)."

### Use of Abbreviations

All words should be spelled out in the body of a map or figure, with the following exceptions:

1. Geographic names. The generic noun (as mountain, mount, river, canyon, creek) may be abbreviated on the map if clutter is reduced by using the abbreviation.
2. Geologic names. Nouns such as sandstone, conglomerate, and group may be abbreviated to fit into available space. See page 55.
3. No period is used in the body of an illustration after an abbreviated word.
4. Well names. Words such as "Company," "Corporation," and "Brothers" may be abbreviated.

Abbreviations are discussed at greater length in the section on abbreviations, signs, and symbols beginning on page 104.

## Final Check of Maps and Other Illustrations Before Review

Draft copies of most illustrations are likely to contain small discrepancies and omissions, regardless of your careful preparations. The following checklist should help obviate most problems. It should also be helpful to you as a reviewer, as well as an author.

Authors, technical reviewers, and map editors should carefully check each illustration for possible errors of omission or commission. The checklist applies particularly to geologic maps and cross sections, but many of the items apply to other illustrations as well. All items do not apply to all illustrations.

1. **Completeness**
   - ——All units are labeled on the map and cross sections and are noted in the explanation.
   - ——All geologic symbols on the map appear in the explanation.
   - ——All geologic units in the explanation are shown on the map. Subsurface units that appear only in cross sections need not appear in the explanation if the names of the units can be spelled out on the sections themselves.

—Positions of cross sections are shown by ruled lines on map.
—All formal geographic names within the map area that are referred to in the text are shown on the map. Newly approved geographic names may be added to the base map only if the date of the domestic names decision is supplied. Unapproved or informal names are not shown on the map.

2. **Correctness**
   —Plotting is accurate. Linework is compatible with topographic or planimetric base.
   —Geographic and geologic names are spelled correctly in the text and agree with spellings on the map and explanation.
   —Locations, directions, and dimensions agree between text, maps, and cross sections.
   —Geologic names and ages on the map explanation agree with the text.
   —Dips as projected in cross sections agree with those on the map.
   —All features on the map are legible at the publication scale.

3. **Scale**
   —Shown graphically in International System (SI) units; some maps may require both SI and inch-pound units (see p. 122 for policy).
   —Ratio scale (such as 1:24,000) is not shown on illustrations that may be enlarged or reduced for printing.

4. **Topographic contour interval and datum**
   —Shown beneath scale.

5. **Caption**
   —Title is succinct but definitive. For a series map or a plate, the term "map," "cross section," or other suitably descriptive term is included. "Geology of the Blank Quadrangle" is not acceptable, but "Geologic Map of the Blank Quadrangle" is.

6. **Authorship**
   —Shown beneath the title of a series map; shown in the geologic credit note in a book publication, text figure, or plate. Affiliation is shown for non-Survey coauthors.

7. **Geologic credit**
   —Authors, compilers, and contributors are named; dates of mapping are given. A source index may be substituted. If a published geologic map is used as a base, its author(s) must be credited and a full citation listed. Place at bottom right.

8. **Base credit**
   —Source, date, and map projection at bottom left.

9. **Cooperative note**
   —Sponsor or cooperating organizations are shown at the top center of the map sheet (on series maps) and on map plates of areas in foreign countries. If the cooperating organization expresses no preference, the wording to be used is "Prepared in cooperation with * * *."

10. **Marginal data**
    —True and magnetic north and numerical declination are shown (will be added by illustrator if a standard base map is used). Magnetic north and declination are unnecessary on page-size maps, and they are omitted from maps that show aeromagnetic contours, because of possible confusion as to whether the declination is that of the date of the base, the date of the data collection, or the date of publication of the map. On page-size maps the true north arrow is unnecessary if latitude and longitude ticks and values are shown and north is to the top of the map.
    —Latitude, longitude, townships, ranges, and geographic reference points or grids are shown by labeled tick marks.
    —Vertical scale and exaggeration, if any, appear on sections.

11. **"Author's Check List" for plates, figures, and photographs** (Form 9-1517)
    —List is complete. Doublecheck notes for illustrators regarding colors and important map units.

## TECHNICAL REVIEW OF AUTHOR COPY

When your report and its illustrations are ready to go forward, the next step is their technical (peer) review. Routing procedures vary somewhat from one organizational unit of the Survey to another, and the actual mechanics of review vary with every report and each reviewer, but certain steps and actions are common to all. Guidelines are given in the section on reviewing maps and cross sections, and you as author may profit from a careful scan of the suggestions offered therein (p. 230).

The original drawing or compilation should not be submitted for review. Rather, a legible mill copy produced by an office copier will be reviewed and approved for publication; the editors and illustrators will rely on this copy for guidance in ordering and placing type for the final version. The illustrator, however, will trace the original—not the mill copy—for placement and position of all linework and symbols. Any discrepancies in linework between the original and the mill copy, therefore, will delay preparation until those matters are resolved. You must make all corrections on both the original and the mill copy or note on the mill copy that the original is to be followed. Blurred, reduced, or otherwise illegible prints of illustrations may cause your reviewers to react negatively to the entire report. The time and expense of preparing final copy of illustrations for publication are affected by the quality of the mill copy.

## AUTHOR RESPONSE TO TECHNICAL REVIEW

The sole purpose of review is to ferret out weaknesses and upgrade the quality of the report. You as author must respond to all questions and comments on the mill copy and make changes as necessary. As with edited text, every query by technical reviewers or map editors should be answered adequately, either by appropriate changes in the illustrations or by replying in writing and striking the query mark. If the reviewed copy is heavily marked, you should supply a new mill copy and transmit it to the next person or office listed on the routing sheet, with the already reviewed copy, the reviewer's comments, and your replies. The new mill copy need not be colored out again if few changes have been made, but any changes involving color must be indicated on the colored copy, which must accompany the new mill copy.

## TRANSMITTAL FOR APPROVAL AND PREPARATION

Mill copies of illustrations must be transmitted with manuscript text but in a separate package at the back of the text; they should not be inserted in text. You should gather together in one place all original material for the report. Hold original line drawings and photographic negatives until they are requested by publication staff for use in final preparation. This step normally follows Director's approval.

A list of illustrations must also be included, even though it may remain unpublished. The list should show, for each illustration, the type (map, diagram, photograph, or other), a unique short title (caption) that is easily related to the illustration, and the manuscript page number of the principal reference to the illustration. The list should be typed in the same order as the principal references in the text, which need not necessarily be their first mention. The original list goes in the manuscript after the table of contents; a copy goes with the illustrations package.

Descriptive captions for each illustration are typed on separate pages (one caption per page) assembled at the end of the manuscript, after the list of references. A duplicate caption is attached to the mill copy of each illustration in the illustrations package, along with a completed "Author's Check List" (Form 9-1517) for plates, figures, and photographs. All this seems complicated, but it in fact is very simple and important; Form 9-1517 contains instructions for the illustrator. (Do not cut the caption out or paste it to the mill copy.) Mill copies of figures and captions are then placed at the end of the text (not interleaved) for forwarding to technical reviewers. To alert the editor and the typesetter, each illustration should have a locating reference in the manuscript at the end of the paragraph containing the principal reference, such as:

**"FIGURE X.--NEAR HERE"**

If you revise and retype a caption after review, attach the new version to the edited caption and return both with the mill copy.

Except for photographic plates of fossils and for illustrations larger than double-page size, you should designate all illustrations as figures, numbered consecutively as the manuscript is prepared. Once a number is assigned in a long, complex report, you would be wise not to change it except to correct an obvious error, such as a duplication. Numbering changes during the evolution of the manuscript are apt to cause errors. Don't renumber figures just because you change their order of appearance in the text; that order may be changed again before you finish the manuscript, or a figure may be added or deleted. The best time to renumber figures is just before the manuscript is transmitted for Director's approval. Special instructions as to placement of figures in the text should be noted on the caption sheet in the text, as "Text Editor: Please print on page facing figure X" or "To be printed on same page as figure X."

Figure numbers should appear on the illustrations themselves, not on attached slips. If copy for the illustration consists of more than one piece, such as a base map and an overlay sheet for geologic contacts or as three sections in three pieces, that fact should be shown on each piece, as "Figure 15, part 2 of 3 parts." Preferably, the base should be the first numbered, to show the order of layering.

## Review of Map Preparation Plans After Director's Approval

If your report contains colored plates or figures, you will receive a memorandum containing color and pattern choices and color chips for units on the map. Review the color choices carefully and discuss any questions or objections with your illustrator or map editor. Color changes are very expensive after map preparation begins and should be avoided.

## Review of Check Prints After Preparation for Publication

Routing procedures for prepared illustrations vary from office to office, but before your report goes to the printer, you will receive the original illustrations, mill copies, and check prints of the art. This material usually accompanies the edited text if the illustrations are part of a book report. Check prints, often called proofs, for your review are washcoat color prints or black-and-white copies of figures and photographs. (Technically, proofs are prints from the printing press and are rarely seen by the author.) Inasmuch as the check prints ordinarily provide your last chance to make corrections, you must check them carefully for placement of lines and type, symbols, explanation, spelling, color or patterns, and titles. Any changes or corrections should be clearly marked on the print: Draw a line from the item to be corrected to the margin, and note the correction in the margin so the illustrator will unmistakably understand it. Any corrections or queries placed on the check prints by the illustrator or editor should also be marked by you to show agreement, disagreement, or clarification. A small check mark or "OK" will indicate agreement.

At check-print stage, significant changes not on the approved mill copy must be justified. The mill copy and originals cannot be updated or otherwise altered at this time without editor approval. Some changes may be refused. The editor will accept essential and desirable changes that can be made quickly, easily, and inexpensively.

### Date and Initial

You must date and initial each check print in the box indicated so that all persons concerned will know you have seen it. If the final-drafted illustration is unacceptable, however, and a new, corrected check print is desired, you should so state on the unaccepted print. You must return all check prints, originals, and mill copies.

After approved changes are made in text and illustrations, the manuscript and illustrations are ready for the printer.

## Disposition of Original Illustrations, Photographs, and Reproducibles after Publication

After a book or map has been published, the original illustrations and mill copy, except photographs, are returned to you as author. Printer's negatives for books and MF maps are stored by the Branches of Technical Reports in Reston, Va., Denver, Colo., and Menlo Park, Calif. Printer's negatives for other map series are sent to the Washington National Records Center in Suitland, Md. Drafted material for all maps is returned to you as author after publication, but drafted material for books is returned only if requested.

All photographs used in Survey publications, both prints and negatives, are sent to the Survey's Photographic Library in Denver soon after a report is printed. (See following section.) They are not returned to the author.

# FIELD RECORDS AND PHOTOGRAPHS

## PERMANENT DISPOSITION

WHETHER OR NOT they have been used in the preparation of a report, all field notes, field maps, photographs, annotated aerial photographs, and other field documents acquired by Survey employees in connection with their official duties are Government property and are valuable parts of official records. When they are no longer being used for a project, these materials should be deposited in the Field Records Library or the Photographic Library, both of which are in Denver. The librarians will catalog and index them so they will be available to other Survey and non-Survey users.

## PHOTOGRAPHIC LIBRARY

The Survey Photographic Library is the official depository for ground-based and oblique aerial photographs. The collection contains about 250,000 photographs consisting of color and black-and-white prints and their corresponding negatives, color transparencies, and lantern slides, dating from the 1860's to the present. Many photographs from this collection have been published in textbooks or other outside publications. Materials are identified with the photographer's name and accession numbers and are indexed by subjects and geographic area. Prints by each photographer are mounted with captions in separate albums under the individual's name. Negatives are stored in acid-free or lignin-free jackets; color negatives and transparencies are placed in inert plastic containers. Negatives and transparencies are filed in a low-temperature/humidity environment.

Questions regarding proper handling and storage of photographic material for project use should be directed to the Photographic Library. Before photographic material is transmitted, the Photographic Library staff should be contacted for special instructions at USGS Photographic Library, MS 914, Box 25046, Denver Federal Center, Denver, CO 80225. General instructions for submitting photographic material to the Photographic Library are as follows:

1. Employees should submit color transparencies, negatives, and extra prints of photographs that are technically good and that clearly show the subject matter. Published photographs taken by Survey employees should be submitted, whether from Survey or non-Survey publications. Photographs should be filed as soon as the employee has no further use for them on the projects for which they were taken, normally not later than the completion of the report on the project. Survey employees may borrow negatives and slides or order prints at any time.

2. Manuscript processing units and visual-information-services groups should submit all color transparencies, negatives, and extra prints of photographs used in exhibits or publications after the material has been returned from the printer. An author who requests the return of the original material may obtain duplicate transparencies or copy negatives. These procedures will ensure that the Photographic Library is able to fill requests for copies of photographs that have been used in publications or exhibits.

3. Photographs should be accompanied by concise descriptions. Geologic and special features obvious to the researcher but not to an untrained viewer should be identified. Such information facilitates the selection of the best picture for a given purpose and helps ensure that pictures published outside the Survey are correctly captioned. Location and date should be specified; so should any reference to place of publication. A copy of the caption marked with the Photographic Library accession number assigned to the photograph will be returned to the photographer, if requested.

# FIELD RECORDS LIBRARY

The Field Records Library is the depository for the original recorded data of completed field projects. Survey regulations require that all field material be deposited in the library, including such items as field notes, field maps, and annotated aerial photographs. The Field Records collection consists of more than 15,000 notebooks or files, 2,400 map groups, 2,000 folders, and 60,000 aerial photographs. Records dating back to the Hayden Survey of 1871 are cataloged by project under senior author or field party chief and are additionally cross-referenced by geographic area, publication, subject, and project assistants or coauthors. Survey researchers may borrow any material or review it in Field Records. The public may examine the material after getting approval from the Assistant Chief Geologist, USGS Central Region, MS 911, Box 25046, Denver Federal Center, Denver, CO 80225.

Before depositing field material, employees must label all records and complete a form providing project information and the nature of any proprietary data in the records. This information is vital to cataloging the material and is essential to filling requests for the records. Before transmitting material, contact the USGS Field Records Library, MS 914, Box 25046, Denver Federal Center, Denver, CO 80225, to obtain forms and mailing instructions.

# TABLES

GOOD TABLES ARE ESSENTIAL to scientific reports simply because some information is presented best in tabular form. This section contains recommendations for designing tables and provides examples of tables (tables 8–13) that incorporate features likely to be used by authors preparing reports for the Geological Survey. These examples are modified from tables in published Survey books. They can only hint at the diversity of formats possible. The recommendations in this section are adapted from the U.S. GPO Style Manual (1984, p. 173–199), which is the principal guide and source of detailed instructions for Survey tables but which contains more information than most authors need to know. Stratigraphic tables and measured sections are discussed in the section on "Stratigraphic Nomenclature and Description." Table 7, from the U.S. GPO Style Manual (1984, p. 192–193), gives some terms and formats used in Survey publications; varied needs may cause minor differences.

**Simplicity.** Simple tables generally are more effective than complex ones. A table should deal with a single subject or should bring together related information for purposes of comparison. Several small tables generally are better than one big one. Editorial advice in the design of tables when your manuscript is still in draft may save time and effort.

**Numbers and titles.** Most tables are numbered and titled for ease of reference. The only tables that may be unnumbered and untitled are column-width tables that immediately follow their only citations. Such tables are not listed in the "Contents" of the report. A report may contain both numbered and unnumbered tables.

Every table, whether numbered or unnumbered, must be cited at least once in the text. Tables are numbered in the order cited, and Arabic numerals are used. The word "table" is lowercase in the text and is never abbreviated in Survey reports.

Titles of all numbered tables should be listed in the "Contents" almost exactly as they appear above the tables, but explanatory phrases in parentheses or set off by commas, such as "in weight percent," may be omitted from the "Contents."

Because a table should be able to stand alone, its title should be reasonably complete and should contain no unusual acronyms and abbreviations. At the same time, a title should be concise. Information that supplements a title belongs in a headnote; generally, a title should not take a footnote. Similar tables in the same report should have similarly worded titles, but each title should be unique. A title has no concluding punctuation.

The essence of a table is the logical arrangement of its information. The columns and rows (which are usually labeled by the entries in the first column) should be in some meaningful order. This order should be reflected in the order of items in the table title.

**Headnotes.** A headnote (if needed) is placed below the title to provide information pertaining to the title, to the table as a whole, or to the column headings. The headnote should explain acronyms, abbreviations, and symbols used, and it is a good place to mention methods used and to credit analysts. The headnote is enclosed in square brackets unless it is very long; no period precedes the closing bracket unless the headnote ends in an abbreviation followed by a period.

**Footnotes.** Explanations of individual entries in the table belong in footnotes. Footnotes usually are preceded by superscript Arabic numerals, but to avoid ambiguity, symbols or lowercase letters may be used. Footnote numbering in each table begins with the numeral 1. The footnote reference numbers increase from left to right in the column headings, then in the first line of the table body, and then across each succeeding line. The superscript numerals follow words and symbols and precede figures (tables 11, 12); if they stand alone, they are enclosed in parentheses (table 8).

**Column headings.** Every column in a table after the first column needs a centered heading, and in many tables the first column also has a centered heading. If two or more layers of headings (stacked headings) are appropriate, as in tables 9, 11, and 12, the highest heading (spanner head) is centered above a horizontal line that spans the headings of columns to which the heading pertains. For readability, column heads usually are horizontal, but to save space, they may be turned sideways (table 9). Down rules (vertical lines) are usually avoided, but some tables, such as table 9, may need them.

Columns may be numbered for ease of reference in the text or to avoid long column heads. If columns are numbered, the Arabic numerals may be explained below the table and its footnotes.

The units of measurement used must be provided within the table. They may be in the column headings, abbreviated if necessary to save space (table 11), or in

## Table 7. Definition and parts of a table

[To define and describe fully all of the many parts, terms, and details that enter into tabular presentation is difficult to explain in a few words or to understand readily without an accompanying visual example. The example shown is directed at people concerned with the construction and makeup of tables and with guidelines identifying tabular terms and details. Many of the terms can be applied to any form of tabular matter]

[Headnote or bracket line]

| | Stubhead | Column head | Spanner head [1] | | Subspanner head | | Standard date column head | Reading column head |
|---|---|---|---|---|---|---|---|---|
| | | | Coal | Coke | Car-loads more than other years | Wood | | |
| | CENTERHEAD | *Millions of dollars* | *Tons* | *Tons* | *Number* | *Thousands of pounds* | | |
| 1 | Lead or caption line [2]---- | [3] 900 | 150 | 191 | 246 | 1,987 | Feb. 12, 1958 [4] | Reading column. [5] |
| 2 | Wheat and other grains-- | 189 | 257 | 250 | 379 | 1,235 | May 9, 1957 | |
| 3 | Lumber and millwork--- | 326 | 382 | 177 | 584 | 1,742 | Dec. 31, 1957 | |
| 4 | -----do.[6]----------------- | 573 | 176 | 263 | 129 | 1,963 | -----do------- | Do. [7] |
| 5 | Total line--------- | 1,988 | 965 | 881 | 1,338 | 6,927 | -------------- | ([8]). |
| | CENTERHEAD | | | | | | | |
| 6 | Lead or caption line----- | 1,057 | ([9]) | 286 | 2,673 | 1,891 | July 19, 1958 | Same reading column with a runover. |
| 7 | Mining equipment------- | 321 | 156 | 112 | 1,114 | 3,821 | May 3, 1958 | Do. |
| 8 | -----do----------------- | 769 | -------- | -------- | -------- | -------- | -------- | |
| 9 | ([10])------------------- | 258 | 387 | 596 | 342 | 2,297 | June 15, 1958 | Reading column. |
| 10 | Total line-------- | 2,405 | 543 | 994 | 4,129 | 8,009 | -------------- | |

*The panel; Head rule—usually single; Boxhead; Boxhead cutoff rule—usually inferior dashes; Centerline in stub column; The line; Ditto or "do." line; Single dashline; Parallel dashline; Block or group; Total line; Quadline; Cutoff rule; Units of quantity over figure columns—italic; Clear; Field or body; Leader line*

*Stub column; Figures bear off; Figures against; Reading column*

*Cutoff rule*

| | 2 READING COLUMNS (Leader from top line) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Dairy products: | | | | | | | | | 1 |
| 2 | In ctns---pounds-- | 1,485,692 | 380 | 462 | -------- | 3,264 | Mar. 3, 1958 | Reading column. | Reading column------- | 2 |
| 3 | In cans------do--- | 263,491 | -------- | 198 | 3,762 | 5,783 | Dec. 17, 1957 | Do. | -----do----------------- | 3 |
| 4 | Clay products□boxes-- (other than pottery, refractories). | 325,000 | 621 | -------- | 4,111 | 1,926 | Nov. 26, 1957 | Do. | -----do----------------- | 4 |
| 5 | Ferrous alloys----tons- | 163,381 | 556 | 276 | 1,985 | 112,812 | -----do-------- | Same reading column. | Same reading column-- | 5 |

*Colon line; Subentry; Flush line; Runover indention*

*If tracer-figure (line number) column is used on right, preceding column will carry leaders to adjacent cast.*

| | 1 READING COLUMN (Leader from bottom line) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A short line-----boxes-- | 13,092 | 748 | 365 | 2,421 | 986 | Jan. 6, 1958 | 2,163 | 5,137 |
| 2 | A long, crowded line thousands of tons-- | 5,692 | 345 | 721 | 2,679 | 3,542 | Apr. 17, 1958 | 3,596 | 4,728 |
| 3 | A very long line that runs over-----crates-- | 386,591 | 475 | 582 | 13,563 | 12,297 | June 6, 1958 | 17,364,298 | 18,591,763 |
| 2 | 12.15 | 5 | 4 | 4 | 4 | 5 | 7½ | 6 | 6 |

*Foot or bottom rule; Cast*

*Tracer-figure (line number) column; Units of quantity in stub column—roman; Standard date column; Figure columns*

*Footnotes or reference lines*

[1] Reference number in boxheading.
[2] Reference number followed by leaders in stub or inside reading column.
[3] Reference number in figure column.
[4] Reference number in date column.
[5] Reference number in last or outside reading column.
[6] Reference number following "do." in inside reading column.
[7] Reference number following "Do." in last or outside reading column.
[8] Reference number standing alone in last or outside reading column, enclosed in parentheses followed by period "([8]).," and quadded out to end of line.
[9] Reference number standing alone in figure column, enclosed in parentheses ([9]), and centered in column.
[10] Reference number standing alone in inside reading column, enclosed in parentheses ([10]), and leadered out to cast on right.

NOTE.—If no tracer-figure column is used on left of table and the stub or reading column is set flush, "Do." will be capitalized and leadered out to cast on right.

the title, headnote (table 12), footnotes, or subheads between table-width cross rules (table 10).

**Blank spaces and leaders.** Spaces may not be left blank within the body of a table except in first or last columns containing words (reading columns). If no data are available, the space should be occupied by symbols such as leaders or suitable abbreviations such as "n.d." These symbols and abbreviations should be explained in the headnote.

Besides occupying spaces for which data are not available, leaders follow words in reading columns to guide the eye across the table; the final word of each entry in a last (far right) reading column is followed by a period or a question mark. Either dot leaders or dash leaders are acceptable, but only one style is generally used within a table and report. On word processors, dots generally are easier to type than dashes. If any entry in a reading column runs onto a second line, the overrun is indented. In tables containing a single reading column as the first column, leaders follow the bottom line of the entry consisting of words (table 12). In tables having more than one reading column, other entries align with the top lines of multiline entries in the reading columns, and the top lines are not followed by leaders (tables 11, 13). Multiline entries end with periods or question marks. Single-line entries in reading columns are followed by leaders as usual if space permits. The period is omitted immediately before the leaders (tables 9, 13).

Like leaders, double spaces at regular intervals may enhance a table's readability. A long table consisting mostly of single-line entries may have double spaces after every five lines of type. The interval should be chosen to provide a good appearance or to group similar entries, but it should not vary within a table except to keep single lines from following a double space at the end of a table section.

**Subheads between table-width cross rules.** Under the column headings, tables may be divided horizontally by subheads between pairs of lines that span columns (table 10). Each subheading pertains to all items between it and the next subhead beneath it. A table containing such subheads can be used to compare several kinds of information for the same sample, time, or area, because each column heading applies to every entry in its column, no matter which spanner head the entry is under.

**General information.** Manuscript tables should be submitted double spaced, and margins on all sides should be at least an inch wide to leave room for editorial marks and instructions for the typesetter. Each table should be on a separate page or group of pages. Oversize sheets are fine. If a table must continue onto a second page, the title followed by "—Continued" should appear at the top of the second page, and all column headings should be repeated. The headnote should also be repeated, if it is not too long.

Camera-ready tables are used in many Survey reports. Persons preparing camera-ready tables should seek editorial advice. The following tables illustrate most formats likely to be presented in Survey reports.

**Table 8.** Mineral assemblages in samples of rocks from within and around the Taconic allochthon, southwestern Massachusetts and adjacent parts of Connecticut and New York

**[Sample localities are given in table 2. Sample numbers in parentheses mean that the assemblage data are based only on X-ray powder diffraction; all other data are, in addition, based on petrographic observations. Abbreviation of mineral names: Bt, biotite; Ch, chlorite; Cd, chloritoid; St., staurolite; Ga, garnet (always almandine rich); Ep, epidote; Pg, plagioclase; Ksp, potassic feldspar (microcline where the structural nature has been established); Mu, muscovite; Pa, paragonite; Q, quartz; Cc, calcite; Dol, dolomite; Ilm, ilmenite; Mt, magnetite; Tour, tourmaline; Stp, stilpnomelane. ×, mineral present; query (?), identification uncertain; leaders (--), mineral not detected]**

| Sample number | Bt | Ch | Cd | St | Ga | Ep | Pg | Ksp | Mu | Pa | Q | Cc | Dol | Ilm | Mt | Tour | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-1 ---------- | ? | × | × | -- | -- | -- | -- | -- | × | × | × | -- | -- | × | -- | -- | |
| 3-2 ---------- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | × | -- | -- | -- | × | -- | |
| 3-3 ---------- | -- | × | -- | -- | -- | -- | × | -- | × | × | × | -- | -- | -- | -- | -- | |
| 3-5 ---------- | -- | × | -- | -- | -- | -- | × | -- | × | -- | × | -- | -- | -- | -- | -- | |
| (3-6) ---------- | -- | × | -- | -- | -- | -- | -- | -- | × | -- | × | -- | -- | -- | -- | -- | |
| 4-1 ---------- | × | × | -- | -- | -- | -- | -- | -- | × | -- | × | × | -- | -- | -- | -- | |
| 14-1 ---------- | × | × | ([1]) | × | × | -- | × | -- | × | -- | × | -- | -- | × | -- | × | |
| 15-1 ---------- | -- | × | -- | × | × | -- | × | -- | × | -- | × | -- | -- | × | × | -- | |
| 16-1 ---------- | -- | × | × | -- | × | -- | × | -- | × | -- | × | -- | -- | -- | × | -- | |
| (16-2) ---------- | -- | × | -- | -- | -- | -- | -- | -- | × | -- | × | -- | -- | -- | × | -- | |
| (17-1) ---------- | -- | × | × | -- | -- | -- | -- | -- | × | -- | × | -- | -- | -- | -- | -- | |
| 18-1 ---------- | × | -- | -- | -- | -- | -- | × | -- | × | -- | × | -- | -- | × | -- | -- | |
| 19-1 ---------- | ? | × | -- | -- | -- | -- | × | -- | × | -- | × | × | -- | -- | -- | -- | Stp? |
| 25-1 ----------- | -- | -- | -- | -- | -- | -- | × | × | -- | -- | × | × | -- | -- | -- | -- | |
| 36-1 ----------- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | × | × | -- | -- | -- | Palygorskite. |

[1] Chloritoid in cores of garnet only.

Table 8 shows:

- ► Cross reference to another table instead of all information being given in one long table.
- ► Explanation in long bracketed headnote of (1) parentheses in first column, (2) abbreviated column headings, and (3) other abbreviations and symbols.
- ► No period before closing bracket of headnote.
- ► "Number" written out, where possible.
- ► Blank spaces acceptable in final reading column.
- ► Period or question mark at end of final reading column.
- ► Footnote reference number standing alone; it is superscript and is enclosed in parentheses.
- ► Use of blank lines for readability.

**Table 9.** Geographic distribution of Early Jurassic ammonites from outcrops in northern and east-central Alaska

[Quadrangle occurrences are listed in table 7. Numbers 5-15 are keyed to area numbers in figure 1. Higher numbers are U.S. Geological Survey Mesozoic locality numbers. ×, taxon present; leaders (--), taxon not found]

| Genus and species | Northwestern Alaska Delong Mountains | | | | | | | North-central Alaska | | | | Northeastern Alaska | | | | East-central Alaska Old Rampart area | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Clay shale | | | | | | | Claystone | | | | Kingak Shale | | | | Glenn Shale (in part) | | | | | | |
| | 5 | | | | | 6 | | 7 | 8 | 9 | | 10 | 11 | 12 | 13 | 14 | | | | | | 15 |
| | 29159 | 29160 | 29161 | 29163 | 29776 | M2241 | 29164 | 29775 | 29774 | 29281 | 29282 | 23772 | 22081 | 29165 | 30074 | 29737 | 29738 | 29739 | 29740 | 29742 | 29743 | 29340 |
| *Psiloceras* sp | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- |
| *P.*? *sp* | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | × | -- |
| *P.* (*Franziceras*) sp | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | -- |
| *P.* (*F.*) cf. *P.* (*F.*) *ruidum* (Buckman) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | × | × | -- | × | -- | -- |
| *Uptonia* cf. *U. jamesoni* (J. de C. Sowerby) | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | | | | | | | | | | | |
| *Uptonia*? sp | -- | -- | -- | -- | -- | -- | -- | × | -- | × | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| *Amaltheus margaritatus* (Montfort) | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| *A. stokesi* (J. Sowerby) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | × |
| *A.* cf. *A. stokesi* (J. Sowerby) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- |
| *A.* sp | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | | | | | | | | | | | |
| *Dactylioceras* (*Orthodactylites*) cf. *D.* (*O.*) *directum* Buckman | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| *Harpoceras* cf. *H. exaratum* (Young and Bird) | × | × | × | -- | × | -- | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| *Eleganticeras* sp. juv | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| *Pseudolioceras* cf. *P. compactile* (Simpson) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| *P.* cf. *P. lythense* (Young and Bird) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | × | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

Table 9 shows:

- ► Cross references to table and figure.
- ► Stacked column headings.
- ► Vertical and horizontal column headings.
- ► Down rules in column headings only; in some tables, down rules need to extend into the body.
- ► A heading centered over the first column.
- ► Use of double spaces at regular intervals for readability; blank lines are not vital in this short table but are added to serve as a model for a longer table.
- ► No period after "sp" and "juv" before leaders. Dot leaders would cause each abbreviation to appear to be followed by a period as usual, but because dash leaders are used in tables 8 and 10-13, table 9 must also use dash leaders for consistency.

**Table 10.** Major-oxide and normative mineral composition, in weight percent, of the Chopawamsic Formation, Virginia

| Suite | A | | | | | | | | | | | B | | C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample number | 1 | 3 | 13 | 10 | 8 | 4 | 5 | 14 | 6 | 7 | 2 | 11 | 9 | 17 | 16 | 15 | 12 |
| Field number | P-71-9 | P-70-73 | P-76-142A | P-73-13 | P-72-150 | P-70-67 | P-70-64 | P-76-124 | P-70-63 | P-70-61 | P-71-7 | P-77-37 | P-70-128 | P-76-117 | P-76-139 | P-76-141 | P-76-145 |
| **Major-oxide composition**[1, 2] | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 50.8 | 51.5 | 51.69 | 53.4 | 55.0 | 56.5 | 59.0 | 64.40 | 64.5 | 76.0 | 78.3 | 72.2 | 73.6 | 61.72 | 73.54 | 73.86 | 76.75 |
| $Al_2O_3$ | 19.2 | 17.0 | 15.20 | 15.6 | 15.3 | 14.6 | 13.8 | 14.72 | 11.4 | 12.7 | 11.6 | 13.17 | 12.7 | 15.90 | 13.38 | 13.56 | 12.40 |
| $Fe_2O_3$ | 1.4 | .50 | 8.2 | 2.8 | 5.5 | 3.6 | 5.2 | 3.2 | 3.5 | 2.4 | .61 | 1.3 | 1.1 | 2.3 | 1.6 | 1.5 | 1.8 |
| FeO | 8.3 | 10.2 | 6.1 | 10.7 | 7.5 | 7.6 | 6.7 | 4.2 | 6.4 | .38 | 1.9 | 2.0 | 2.3 | 5.8 | .16 | 1.1 | 1.0 |
| MgO | 7.1 | 7.0 | 3.18 | 5.4 | 3.9 | 3.5 | 3.0 | 2.11 | 2.6 | .16 | .43 | .61 | 1.4 | 2.15 | .00 | .01 | .00 |
| CaO | 4.1 | 4.7 | 7.25 | 3.8 | 6.8 | 6.2 | 2.5 | 2.85 | 3.8 | 1.2 | .27 | .19 | .50 | 2.32 | .17 | .67 | .34 |
| $Na_2O$ | 4.9 | 5.0 | 3.40 | 4.8 | 4.1 | 4.4 | 5.7 | 3.26 | 4.6 | 5.6 | 5.2 | 1.43 | 5.7 | 2.41 | .04 | 3.07 | 4.20 |
| $K_2O$ | .12 | .25 | .23 | .08 | .19 | .15 | .15 | .64 | .15 | .80 | .13 | 6.68 | .85 | 2.31 | 8.91 | 3.88 | 1.22 |
| $H_2O^+$ | 3.4 | 2.5 | 1.3 | 2.1 | .86 | 1.0 | 1.6 | 1.7 | .80 | .34 | 1.2 | .87 | 1.0 | 1.6 | .74 | .58 | .56 |
| $H_2O^-$ | .07 | .14 | .39 | .16 | .11 | .07 | .22 | .22 | .03 | .03 | .14 | .30 | .05 | .37 | .07 | .10 | .09 |
| $TiO_2$ | .36 | .87 | 2.06 | 1.6 | 1.5 | 1.5 | 1.6 | 1.30 | 1.5 | .21 | .14 | .55 | .59 | .87 | .24 | .29 | .20 |
| $P_2O_5$ | .06 | .10 | .12 | .25 | .22 | .26 | .23 | .18 | .24 | .07 | .04 | .07 | .19 | .18 | .04 | .06 | .01 |
| MnO | .25 | .25 | .19 | .24 | .11 | .22 | .30 | .14 | .22 | .03 | .03 | .06 | .04 | .22 | .02 | .05 | .06 |
| $CO_2$ | .05 | .08 | .01 | .04 | .02 | .05 | .05 | .01 | .05 | .02 | .05 | .01 | .02 | .01 | .00 | .01 | .02 |
| Total | 100.11 | 100.09 | 99.32 | 100.97 | 101.11 | 99.75 | 100.0 | 98.93 | 99.79 | 99.94 | 100.04 | 99.44 | 100.04 | 98.16 | 98.91 | 98.74 | 98.65 |
| **Normative mineral composition** [Based on analyses recalculated to 100 percent water-free oxides] | | | | | | | | | | | | | | | | | |
| Q | ---- | ---- | 12.9 | 2.9 | 9.6 | 10.7 | 13.6 | 33.8 | 24.6 | 37.9 | 45.8 | 37.0 | 33.9 | 28.8 | 39.1 | 40.5 | 47.9 |
| C | 3.8 | 0.4 | ---- | 1.4 | ---- | ---- | .3 | 4.1 | ---- | .7 | 2.5 | 3.5 | 2.0 | 5.9 | 3.3 | 3.3 | 3.7 |
| or | .7 | 1.5 | 1.4 | .5 | 1.1 | .9 | .9 | 3.9 | .9 | 4.7 | .8 | 40.2 | 5.1 | 14.2 | 53.6 | 23.4 | 7.3 |
| ab | 42.9 | 43.4 | 29.4 | 41.2 | 34.6 | 37.8 | 49.1 | 28.4 | 39.3 | 47.6 | 44.6 | 12.3 | 48.7 | 21.2 | 1.2 | 26.5 | 36.2 |
| an | 20.7 | 22.7 | 26.1 | 17.2 | 22.7 | 19.9 | 11.1 | 13.3 | 10.1 | 5.4 | 1.1 | .4 | 1.1 | 10.7 | .6 | 2.9 | 1.5 |
| wo | ---- | ---- | 4.1 | ---- | 3.9 | 4.0 | ---- | ---- | 3.1 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| en | 10.3 | 5.3 | 8.1 | 13.6 | 9.7 | 8.8 | 7.6 | 5.4 | 6.5 | .4 | 1.1 | 1.5 | 3.5 | 5.5 | ---- | .1 | ---- |
| fs | 8.1 | 5.3 | 1.4 | 15.3 | 7.0 | 9.1 | 6.0 | 3.3 | 6.9 | ---- | 2.8 | 1.8 | 2.4 | 8.0 | ---- | .4 | .1 |
| fo | 5.6 | 8.9 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| fa | 4.9 | 9.7 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| mt | 2.1 | .7 | 12.2 | 4.1 | 8.0 | 5.3 | 7.7 | 4.8 | 5.1 | .7 | .9 | 1.9 | 1.6 | 3.5 | ---- | 2.2 | 2.7 |
| hm | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 1.9 | ---- | ---- | ---- | ---- | 1.6 | ---- | ---- |
| il | .7 | 1.7 | 4.0 | 3.1 | 2.8 | 2.9 | 3.1 | 2.5 | 2.9 | .4 | .3 | 1.1 | 1.1 | 1.7 | .4 | .5 | .4 |
| ru | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | .1 | ---- | ---- |
| ap | .2 | .2 | .3 | .6 | .5 | .6 | .6 | .4 | .6 | .2 | .1 | .2 | .5 | .4 | .1 | .1 | .1 |
| cc | ---- | .2 | .1 | .1 | .1 | ---- | ---- | .1 | ---- | .1 | ---- | .1 | .1 | .1 | ---- | .1 | .1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| **Differentiation index (DI) and normative mineral composition in terms of diopside, hypersthene, and olivine** | | | | | | | | | | | | | | | | | |
| DI | 43.7 | 44.9 | 43.7 | 44.6 | 45.3 | 49.4 | 63.7 | 66.2 | 64.8 | 90.3 | 91.2 | 89.5 | 87.7 | 64.2 | 93.9 | 90.4 | 91.5 |
| di | ---- | ---- | 7.8 | ---- | 7.7 | 7.9 | ---- | ---- | 6.1 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| di-wo | ---- | ---- | 4.1 | ---- | 3.9 | 4.0 | ---- | ---- | 3.1 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| di-en | ---- | ---- | 3.1 | ---- | 2.2 | 1.9 | ---- | ---- | 1.5 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| di-fs | ---- | ---- | .6 | ---- | 1.6 | 2.0 | ---- | ---- | 1.5 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| hy | 18.4 | 10.6 | 5.9 | 29.0 | 12.9 | 14.0 | 13.6 | 8.7 | 10.4 | .4 | 3.9 | 3.4 | 6.0 | 13.6 | ---- | .5 | .1 |
| hy-en | 10.3 | 5.3 | 5.0 | 13.6 | 7.5 | 6.9 | 7.6 | 5.4 | 5.1 | .4 | 1.1 | 1.6 | 3.5 | 5.6 | ---- | .1 | ---- |
| hy-fs | 8.1 | 5.3 | .9 | 15.4 | 5.4 | 7.1 | 6.0 | 3.3 | 5.3 | ---- | 2.8 | 1.8 | 2.5 | 8.0 | ---- | .4 | .1 |
| ol | 10.5 | 18.5 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| ol-fo | 5.6 | 8.8 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| ol-fa | 4.9 | 9.7 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

[1]Major elements determined by—
1. X-ray spectroscopy: P-77-37, P-76-124, P-76-142A, P-76-145, P-76-117, P-76-139, P-76-141; P. Hearn and S. Wargo, analysts.
2. Rapid rock analysis:
   a. P-70-64, P-70-67, P-70-63, P-71-7, and P-71-9; P. Elmore, H. Smith, and J. Kelsey, analysts;
   b. P-70-61, P-70-128, P-70-73, P-72-150, and P-73-13; Lowell Artis, analyst.

[2]$H_2O^+$, $H_2O^-$, and $CO_2$; N. Skinner, analyst.

DESCRIPTION OF SAMPLES

1. Metabasalt: quartz-chlorite-amphibole gneiss: Stafford quadrangle at lat 38°25′57″ N. and long 77°27′45″ W.
2. Metaquartz keratophyre: quartz-albite-chlorite-amphibole gneiss: Stafford quadrangle at lat 38°25′58″ N. and long 77°28′02″ W.
3. Metabasalt: quartz-albite-chlorite-amphibole gneiss: Storck quadrangle at lat 38°25′27″ N. and long 77°30′02″ W.
4. Meta-andesite: quartz-albite-amphibole gneiss: Stafford quadrangle at lat 38°25′06″ N and long 77°29′51″ W.
5. Metafelsite: quartz-albite-amphibole gneiss: Stafford quadrangle at lat 38°24′58″ N. and long 77°29′48″ W.
6. Interior of metamorphosed pillow: Stafford quadrangle at lat 38°24′57″ N. and long 77°29′48″ W.
7. Metafelsite: quartz-albite gneiss: Storck quadrangle at lat 38°24′52″ N. and long 77°29′44″ W.
8. Meta-andesite: quartz-epidote-plagioclase-amphibole gneiss: Storck quadrangle at lat 38°23′03″ N. and long 77°36′22″ W.
9. Metafelsite: quartz-albite-chlorite-mica porphyritic gneiss: Storck quadrangle at lat 38°22′16″ N. and long 77°37′13″ W.
10. Meta-andesite: quartz-albite-amphibole gneiss: Salem Church quadrangle at lat 38°21′57″ N. and long 77°36′24″ W.
11. Metafelsite: muscovite-biotite-plagioclase-quartz porphyritic gneiss: Brokenburg quadrangle at lat 38°14′28″ N. and long 77°44′55″ W.
12. Metafelsite: muscovite-plagioclase-quartz gneiss: Belmont quadrangle at lat 38°08′36″ N. and long 77°51′18″ W.
13. Metafelsite: amphibole-biotite-chlorite-quartz gneiss: Belmont quadrangle at lat 38°07′49″ N. and long 77°51′12″ W.
14. Metabasalt: quartz-albite-amphibole gneiss: Belmont quadrangle at lat 38°08′34″ N. and long 77°50′00″ W.
15. Metafelsite: muscovite-biotite-potassic feldspar-quartz gneiss: Lake Anna West quadrangle at lat 38°05′47″ N. and long 77°50′11″ W.
16. Metafelsite: muscovite-potassic feldspar-quartz gneiss: Lake Anna West quadrangle at lat 38°05′49″ N. and long 77°51′28″ W.
17. Meta-epivolcaniclastic rock: garnet-biotite-feldspar-quartz gneiss: Lake Anna West quadrangle at lat 38°03′45″ N. and long 77°50′46″ W.

Table 10 shows:

- ► Subheads between table-width cross rules.
- ► No zero before the decimal point; zeros preceding the decimal point would be used only in the first line of each section.
- ► The word "Total" indented and followed by leaders.
- ► The line separating the actual totals from the entries above.
- ► The basis for calculating the norms, the names of the analysts (this example shows only one initial, but the analysts' initials or full given name should be shown), the methods used, and the description of samples. Inclusion of the oxides calculated on a water-free basis would be a service to other petrologists.

**Table 11.** Production from medium and large oil and gas fields of Utah

[Production data from Smith and Brown (1981). MB, thousands of barrels; MMCF, millions of cubic feet; MMB, millions of barrels; BCF, billions of cubic feet; do, ditto; NA, data not available]

| Number in figures 1, 2 | Field | Basin or province | Year discovered | Primary reservoir age | 1980 production | | Cumulative production through 1980 | | Estimated ultimate production | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Oil (MB) | Gas (MMCF) | Oil (MMB) | Gas (BCF) | Oil (MMB) | Gas (BCF) |
| 1 | Aneth (Greater) | Paradox | 1956 | Pennsylvanian | 6,741 | 7,315 | 306 | 294 | [1]378 | NA |
| 2 | Lisbon | do | 1960 | Mississippian | 718 | 17,078 | 43 | 358 | NA | NA |
| 3 | Ismay | do | 1956 | Pennsylvanian | 79 | 91 | 10 | 17 | [1]12 | 21.5 |
| 4 | Altamont-Bluebell. | Uinta | 1955–72 | Eocene | 8,446 | 12,351 | 132 | 168 | [2]250+ | NA |
| 5 | Red Wash | do | 1951 | do | 2,935 | 4,368 | 115 | 316 | [3]135 | NA |
| 6 | Natural Buttes | do | 1951 | do | 140 | 13,093 | .3 | 59 | NA | NA |
| 7 | Ashley Valley | do | 1948 | Permian and Pennsylvanian. | 296 | 0 | 19 | 0 | [4]22 | 0 |
| 8 | San Arroyo | do | 1955 | Cretaceous and Jurassic. | 3 | 1,851 | 125 | 74 | NA | NA |
| 9 | Clay Basin | Green River | 1927 | Cretaceous | 5 | 1,836 | 318 | 139 | NA | NA |
| 10 | Bridger Lake | do | 1966 | do | 160 | 2,988 | 10 | 31 | NA | NA |
| 11 | Pineview | Thrust Belt | 1975 | Jurassic | 2,948 | 3,436 | 16 | 17 | NA | NA |
| 12 | Anschutz Ranch | do | 1978 | do | 147 | 7,129 | .1 | 1 | NA | NA |
| 13 | Anschutz Ranch E. | do | 1979 | do | 278 | 1,245 | .3 | 7 | NA | NA |
| 14 | Clear Creek | Wasatch Plateau. | 1951 | Cretaceous | 0 | 103 | 0 | 135 | 0 | [4]168 |
| 15 | Upper Valley | Kaiparowits | 1964 | Permian | 674 | 0 | 19 | 0 | [1]21 | 0 |

[1]From Fassett (1978). [2]From Lucas and Drexler (1976). [3]From Oil and Gas Journal (1970). [4]From Preston (1961).

Table 11 shows:

- ► Explanation in headnote of abbreviations and acronyms.
- ► Stacked column headings.
- ► Alignment of a table containing two reading columns that have overruns.
- ► Use of leaders after all one-line entries in reading columns.
- ► Use of a period after the last word in a multiline entry in a reading column.
- ► Use of "NA" to mean "data not available" (used for example purposes only; leaders would probably look better here.)
- ► Use of "do" for "ditto."
- ► Superscript footnote reference numbers to left of figures.
- ► Placement of short footnotes in a single line to save vertical space.

**Table 12.** Thickness of the three parts of the Yale Member, Ironwood Iron-Formation, Wisconsin and Michigan

[In meters]

| Yale Member | Drill core from west of Upson, Wis. | North Palms drill hole 81, Bessemer, Mich. (see p. 42 for location) | Eureka Mine, Ramsay, Mich. | |
|---|---|---|---|---|
| | | | "Eureka Mine stratigraphic diagram" (unpub. data, 1918) | Old trenches and a railroad cut |
| Upper part | 13.1 | 53.0 | 70.1 | 63.4 |
| Tuffaceous layer | 0 | 5.5 | 13.4 | [1].9 |
| Lower part | 0 | 4.3 | 15.2 | 12.2 |
| Total | 13.1 | 62.8 | 98.7 | 76.5 |

[1]Tuffaceous layer thickness is roughly estimated from relative abundance of dump material.

Table 12 shows:

- ► Explanation in the headnote of measurements in the body of the table.
- ► Stacked column headings.
- ► Alignment of a table containing only one reading column.
- ► The word "Total" indented and followed by leaders.
- ► The line separating the actual totals from the entries above.
- ► Superscript footnote reference number to left of decimal figure.
- ► Position of a long footnote and indention of its first line.

**Table 13.** Location, stratigraphic position, and age of phytoclase samples from early Mesozoic basins in the Eastern United States

[do and Do., ditto]

| Basin name and sample designation | Location and stratigraphic position | Age |
|---|---|---|
| Taylorsville basin: ASH-1. | 146 m in core taken 1.6 km south of Taylorsville, Va.; Falling Creek Member of Doswell Formation. | Middle Carnian. |
| Culpeper basin: | | |
| CB785-13 | Licking Creek locale, Midland, Va.; Midland Formation fish bed. | Hettangian. |
| Culpeper log | Millbrook quarry, Thoroughfare Gap, Va.; Waterfall Formation. | Sinemurian-Pliensbachian. |
| Newark basin: | | |
| NB584-14 | H and K quarry near Chalfont, Pa.; Skunk Hollow member of Olsen (1984) of the Lockatong Formation. | Late Carnian. |
| 16 | do | Do. |
| 24 | Pompton Lakes, N.J.; middle carbon-rich laminated zone of the Towaco Formation. | Hettangian. |
| Newark basin—Continued | | |
| NB584-25 | Pompton Lakes, N.J.; tufa-encrusted phytoclast from the lower laminated zone of the Towaco Formation. | Hettangian. |
| 26 | Gill quarry, off Potshot Road near Fairview Village, Pa.; Weehawken member of Olsen (1984) of the Lockatong Formation. | Late Carnian. |
| SP1 | State Park quarry near Eagleville, Pa.; Gwynedd 1 member of Olsen (1984) of the Lockatong Formation. | Do. |
| SP3 | do | Do. |
| Hartford basin: | | |
| Portland, Conn | Longbrook, Conn.; near the base of the Portland Formation. | Pliensbachian. |
| Portland, Mass | Suffield, Mass.; middle to lower part of the Portland Formation. | Do. |

Table 13 shows:

- ► How to double up a table under one title.
- ► Alignment of a table containing several reading columns that have overruns.
- ► Use of headings in first column followed by colons; a single entry after a colon is run in (Taylorsville basin: ASH–1), whereas several entries after a colon are placed on separate lines.
- ► Clearing (avoiding repetition of) the first part of a sample number containing a dash but not clearing a number that has no dash (NB584–14 as opposed to SP1).
- ► Use of "Continued."
- ► Use of "do" and "Do."
- ► Use of figures even at the beginning of a reading-column entry; "146" is not written out the way it would be at the beginning of a text sentence.
- ► No period after "Conn," "Mass," and "do" before leaders.
- ► A logical arrangement of data; basins are listed from south to north.

# PHOTOGRAMMETRY APPLIED TO EARTH SCIENCE IN THE U.S. GEOLOGICAL SURVEY

GEOLOGISTS AND HYDROGEOLOGISTS have traditionally prepared their maps by field-surveying techniques, either by sketching pertinent information directly on topographic or planimetric base maps or by annotating data directly on aerial photographs or on transparent overlays. Geologic mapping with only a topographic map as a base is still common, but when aerial photographs became widely available in the 1940's their use superseded much direct plotting on base maps. Nowadays in the Geological Survey, photogrammetric techniques are commonly used both for geologic mapping and for compiling data from aerial photographs.

Geologists who map on aerial photographs take advantage of the three-dimensional quality of the stereoscopic model and the wealth of its inherent image detail for interpreting and accurately delineating geologic features. Details that can be seen and mapped on the photographs, however, must be transferred to a base map for compilation and publication, and much of the accuracy gained by careful annotation can be lost by inaccurate transfer. Excessive radial displacements caused by high topographic relief, and distortions caused by tip or tilt of the aerial camera, must be corrected in the transfer process. These corrections can be made visually by careful and skillful terrain interpretation and freehand sketching, or instrumentally by the use of photogrammetric techniques. For areas of low relief, where radial distortions are small, details mapped on aerial photographs can be adequately transferred to a base map by tracing or by using a simple optical projector to make adjustments for scale differences; if tip or tilt cause distortions, a tilt-correcting device, such as a sketchmaster, can be used to correct them. Many mapping projects, however, are in rugged areas of high relief where radial distortions must be corrected photogrammetrically for accurate compilation.

## HISTORY AND DEVELOPMENT

During the 1940's and early 1950's, the use of aerial photographs for geologic interpretation and mapping increased rapidly, and new instruments and techniques were devised. Though limited in capability, radial planimetric plotters were used for constructing planimetric base maps and transferring geologic annotations from the paper prints onto the base map. Higher order projection-type photogrammetric plotters such as the ER-55 and Kelsh were used routinely for topographic contouring and base-map control. These plotters were first used in 1954 by Survey geologists who soon afterward began teaching other geologists to set up and orient the stereomodels. The Survey's Kelsh and ER-55 plotters were widely used for geologic mapping during the 1960's and the early 1970's.

The PG-2 plotter replaced the projection plotters, because it combines high plotting accuracy with an excellent viewing system for stereoscopic inspection. It also is the only instrument that (1) with equal ease uses black-and-white or colored paper prints and film or glass transparencies, (2) has a high-quality viewing system incorporating a readily changed, variable magnification, (3) has an illuminated floating mark that can be easily seen in dark parts of the image, and (4) has an ease of operation that enables geologists with little use experience to operate the machine as soon as the stereomodel has been oriented. Though designed for topographic mapping, the PG-2 plotter is particularly well suited for geologic studies because the paper prints used by the geologist in the field can be placed directly in the plotter so that field annotations, together with additional data observed in the stereoscopic model, can be plotted directly and accurately onto a topographic base map. This plotter also enables the operator to sit comfortably in a well-lit room while viewing the model and at the same time referring back to field notes and photographs. The projection-type plotters required subdued room lighting and, therefore, were inconvenient for studying map annotations and field notes simultaneously.

Once the photographs are properly placed in the machine and parallax is cleared from the stereoscopic model, the PG-2 plotter is simple to operate. However, certain procedures must be followed to clear the parallax and level and scale the model to a base map. At the Geologic Division Plotter Laboratory in Denver, a photogrammetric technician orients the model for geologists who prefer not to do so themselves. Features seen in the model can then be plotted by tracing their images, just as with other stereoplotters. Many geologists use the machines only to trace lines already mapped on the photographs, simply compiling previously mapped geology (thus the needed capacity of the plotter to accommodate paper prints). Other geologists, using field stations or measurements mainly as guides to mapping, prefer to map directly from the stereomodel, followed by field checking—a combined procedure that is highly effective for mapping areas of good exposure and little vegetation, such as deserts, high mountains, and polar regions.

## The Computer-Assisted Geologic Mapping System

In the 1980's the Survey devised a computer-assisted geologic mapping system that uses the PG-2 plotter to (1) enhance the capabilities of the plotter for geologic mapping, (2) provide a means for geologists to make geologic maps more efficiently, and (3) develop new ways to apply computer technology to geologic studies. The system is capable of producing geologic maps and geologic-map products such as structure-contour and isopach maps, overburden and interburden maps, and surface profiles for geologic cross sections—all from stored digital information generated by the plotter, supplemented by subsurface data entered from a two-axis digitizing table. In some projects, it will be possible to go directly from stored data from photographs to published maps without the necessity for drafting or scribing. In addition, a set of computer routines designed specifically to aid in geologic studies has been developed jointly by the U.S. Geological Survey and the Geological Survey of Greenland in Copenhagen, Denmark. This routine, called Geoprogram, allows the geologist to integrate the visual stereoscopic model with the three-dimensional mathematical model of the geology. A rapid interchange of information between the computer and the operator is one of the most useful aspects of the system. As the tracing carriage is moved about the stereomodel, the Geoprogram provides the kinds of information the operator needs for making structural interpretations by the near-instant generation of mathematical planes representing geologic attributes. For example, dips and strikes of any planar surface can be computed automatically by simply tracing the floating mark along the outcrop of the surface or by occupying three or more points on the surface. Once a plane has been computed, the floating dot can be guided by the computer so that it remains on the plane throughout the model and thus allows comparisons of geologic surfaces, mapping of covered contacts, and precise measurements of inclined strata. The dot can also be controlled by a surface-model grid, which allows projection of curved geologic surfaces, rather than flat planes, throughout the model.

Analytical plotters, which are fully computer controlled, are not restricted by the limitations of the mechanical analog plotters. Computer-controlled systems offer the additional advantages of working with a wide array of photographic materials ranging from hand-held, 35-mm stereophotographs of any orientation to satellite imagery. All that is required to utilize the stereoimagery is control in the form of $x$-$y$-$z$ coordinates for at least three points that appear on both images of the stereopair. Mappers should be familiar with these new instruments and techniques.

## How to Get Aerial Photographs

The great increase in use of aerial photography in the United States in the past few decades has resulted in millions of photographs. These range from low-altitude photographs of small areas with great detail to high-altitude photographs that cover more than 100 square miles in one exposure and to photographs from space that cover vast regions of the planet.

The U.S. Geological Survey's Earth Science Information Center (ESIC) maintains records of aerial photographic coverage of the United States and its Territories, based on records from other Federal agencies, State governmental agencies, and commercial companies. From these records, called the Aerial Photography Summary Record System, ESIC can assist you in finding the photography to meet your needs. (Address is at the end of this section.) Records go back as early as the late 1930's for certain areas. Most early photographs were taken on black-and-white film. Color and color-infrared films were introduced later. Contact paper prints, film positives, or enlargements of these photographs can be ordered.

Contact paper prints 9 × 9 inches presently cost about two-thirds as much as film positives; film positives, however, produce the highest quality images for photointerpretation and mapping on the PG-2 plotters. For official use, the Geologic Division Plotter Laboratory in Denver can borrow available compilation photography or "quad-centered" high-altitude (1:80,000-scale) film positives and paper prints from National Mapping Division's photographic libraries. Quad-centered photographs are those taken at the centers and north-south borders of 7½′-quadrangles—each photograph portrays the area of more than one 7½′-quadrangle.

Before ordering aerial photographs, you must identify the area of needed coverage. Send ESIC the geographic coordinates (longitude and latitude) of your area of interest, and ESIC will promptly research your request. If the geographic coordinates are unknown, ESIC strongly recommends circling, pinpointing, or outlining the area on a USGS topographic map or a State or local highway map to indicate the desired area—the more specific, the better. Also state if stereoscopic coverage is required.

ESIC cooperates with the Earth Resources Observation System's (EROS) Data Center in Sioux Falls, South Dakota. Both ESIC and the EROS Data Center take orders for aerial and space photographs and space images. If the exact roll and frame numbers are known, ESIC and the EROS Data Center can provide addresses, prices, and order forms for ordering from many other Federal and State agencies and commercial companies. For information write or contact:

Earth Science Information Center
U.S. Geological Survey
507 National Center
Reston, VA 22092

or

User Services Section
EROS Data Center
U.S. Geological Survey
Sioux Falls, SD 57198

All ESIC and EROS photograph and image orders must include project accounting or prepayment by check or money order. Each print of a photograph is custom made, so all orders must contain the correct information.

# GUIDELINES FOR REVIEWING TECHNICAL REPORTS

COUNTLESS BOOKS AND PAMPHLETS have been published in recent years to alert aspiring authors to the need for clarity and precision in technical writing. Far fewer books address the responsibilities of reviewers, even though such responsibilities are second only to those of authors in ensuring accurate communication of ideas. If the prime objective of technical writing is precise communication, what could be more pathetic than a failure to communicate? An author may miss logical flaws and ambiguities that a skilled reviewer will catch before they are committed to print. The Survey, therefore, sees a thorough review as a good review, a light one as a disservice to the Survey, the author, and the reader. Judging the content of a manuscript is the reviewer's greatest responsibility, but the reviewer must naturally consider the presentation of the content as well. A good review is hard but not hostile. The following guidelines are mostly from Malde (1986), but details of Malde's report covered elsewhere in STA are omitted here.

This section concisely addresses the responsibilities of the reviewer, but it also contains helpful suggestions for authors. These suggestions are couched in dry, direct terms, but they should not be construed as dogma. They simply call attention to circumstances that commonly confront reviewers and that may need attention.

## REVIEW PRACTICES

### TREAT MANUSCRIPTS AS PRIVILEGED DOCUMENTS

Manuscripts must not be exploited; they are sent to reviewers only to solicit advice. Unless agreed to by the author, it is unethical to copy, discuss, or cite an unpublished manuscript, or to use the work described for one's own research. Some editors of scientific journals, moreover, caution reviewers not to contact the author, even if the author is a colleague in the reviewer's organization, because such contact can mislead the author into thinking that problems about the manuscript can be resolved with the reviewer, not the editor. However, constraints are less rigidly applied on interactions between critics and authors of internal manuscripts that are written for scientific laboratories or government agencies, or that are being prepared within such organizations for outside journals. Within the Survey, reviewers commonly discuss troublesome points with the author of an internal report or with the author's supervisor and if necessary with colleagues in the Survey.

### HAVE A POSITIVE ATTITUDE

Act as an impartial, tactful ally of the author, looking for ways to improve the content and presentation of the manuscript. Acknowledge the good points and suggest new insights. Make no personal attacks or statements that impugn the integrity or competence of the author, and avoid acrimony and sarcasm.

### BE PROMPT

Reviewing is most effective when the reviewer stays with the manuscript until the review is completed. Reviews of internal Survey manuscripts take precedence over personal research. Editors of most technical journals expect reviewers to meet deadlines of 2 to 3 weeks, but more time can be requested if needed.

### DOCUMENT THE REVIEW

In fairness to the author, reviewers should substantiate their statements about a manuscript. The following steps are recommended: (1) Read the title and the abstract, (2) test whether the illustrations and tables are intelligible on their own by considering them just after the abstract, (3) read the text critically for content and presentation, making appropriate marginal notes and numbered comments keyed to places in the text, and suggesting possible improvements in the organization and writing, (4) point out any specialized topics that need expert review, (5) do whatever library research may be needed on uncertain points, (6) judge whether all essential points have been covered by rereading the manuscript, editing the comments, and deciding which ones are most important, (7) finally, write a summary explaining what the manuscript contributes to science—or, if it falls short, why it fails.

## Elements That Affect the Significance of the Report

### Prior Publication

Scientific results are sometimes anticipated by previous workers. Authors whose work is not new are sometimes unaware of the fact; as a reviewer, you should point out the duplication and call attention to any references that may have been missed. If a new finding is described, consider whether the background information is sufficient without repeating already published work. Formal reports may repeat, in perhaps more polished form, information from theses, abstracts, technical comments, and conference reports that have not been formally published. Publishing information that is not wholly new may be worthwhile if so doing is important to the times, if republishing it confirms or refines known results, or if it calls attention to obscure or forgotten findings.

Sending a manuscript to more than one publisher at a time is unethical, and reviewers who learn of it should caution the author or inform the appropriate editors.

### New Facts; Useful Reviews

Reviewers should judge whether the author's discovery has been adequately verified. The usual test is whether arguments in favor of the discovery are convincing.

Review papers generally summarize results and comment on areas of agreement, contradictions, and controversies. The most useful review papers also take stock, pare down reported results, put the useful pieces into perspective, define what has been achieved, and suggest starting points for future research.

## Intended Readership

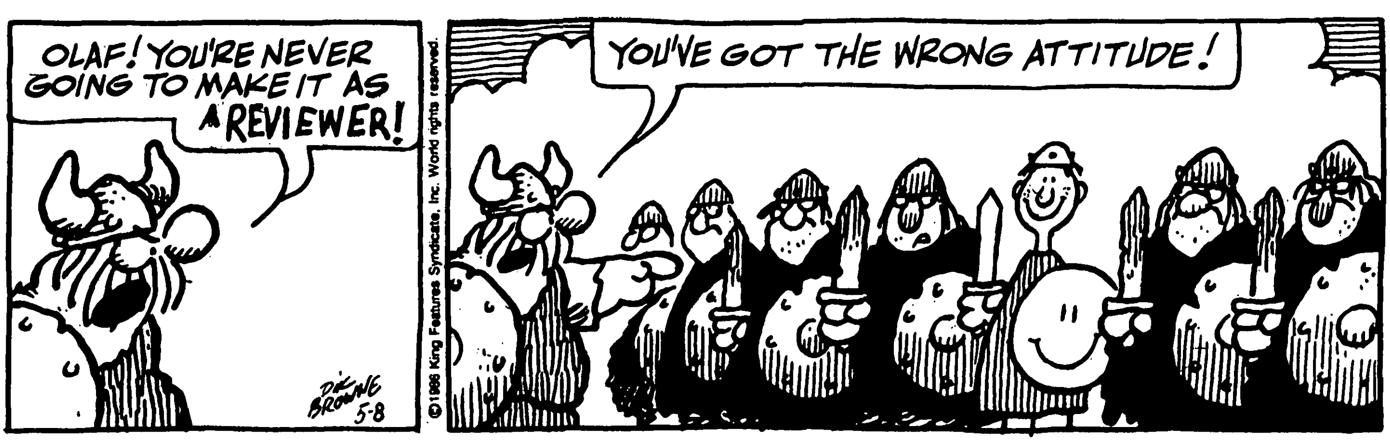
Consider whether the manuscipt is appropriate for the intended readership, and if it is, consider its suitability in terms of relevance to ongoing studies, stimulus given for new ideas, and the probable size of the readership. The manuscript may have greater interest if the author's objective is to develop a new principle, solve a nagging scientific problem, or establish criteria to cope with an unsolved problem—not just to describe field relationships or laboratory results. Timeliness also enhances interest.

## Timeliness

Editors of journals that try to publish new results quickly, such as "Science," tell reviewers that "a paper should have news value for the scientific community." Such a manuscript might pertain to a current topic, raise a new subject, question an established theory, or respond to a point of controversy.

## Adequacy of Detail

Scientists judge the worth of new facts or concepts by considering how such information adds to previous knowledge. For the facts or concepts to be potentially useful, a contribution to an established field should be either fairly detailed or based on a closely reasoned argument. In contrast, when little is previously known in a field of study, any relevant finding or idea may be worthwhile. All data needed to understand a paper should be published, but a reviewer should judge whether or not voluminous supporting data such as modal analyses, chemical data, stratigraphic descriptions, and repetitive measurements might be better placed in an appendix or in a data depository.



## Adequacy of Approach

Consider whether or not the author has used all the tools that are available and whether or not the research approach is adequately explained. Stratigraphic evaluations may need supplemental measured sections, petrographic studies may need supporting chemical analyses, geomorphologic analyses may need terrain measurements, and so on. Point out any oversights to the author. The manuscript should explain what was studied and the procedures used—not just the results. Data for an age determination, for example, should describe the sample: its precise locality, a brief description of its distinguishing features, its relations to other rock units, and pertinent factors about the analytical method. The methods used should be properly explained. Familiar, published techniques can simply be cited, but possible differences from previous methods should be clarified. Judge whether the methods are reliable and adequate, citing other methods when appropriate.

## Results and Their Relative Importance

Geological results are commonly given as tables, maps, cross sections, well logs, photographs, graphs, and diagrams. Such results should reinforce ideas presented in the text, but should not duplicate each other. A concise text, moreover, is not littered with undigested results or with unrelated facts or ideas. If the lack of a certain result under the described conditions could be important, point it out.

## Soundness and Relevance of Conclusions

The conclusions should discuss the relationships between the observed facts, should interpret their significance, and should tie evidence to inference. A mere summation of the results is superfluous. The author should explain gaps and limits in the results, if any, and show how the results support or contradict the findings of others. Speculation should be limited to reasonable, testable hypotheses. Be sure that the author does not make too much from too little and does not ignore obvious alternative hypotheses. Some authors fail to see a useful principle in clouds of detail. Some digress on irrelevant matters or reach illogical conclusions. The most significant conclusions should also be mentioned in the abstract and the introduction.

## Presentation

### Title

After reviewing the content of the report, reaffirm that the title is appropriate. If it is not, suggest possible alternatives. Key words make a title more precise. Some authors even forget to include an identifying geographic name. Delete needless words ("Investigations on"). The use of nouns as adjectives should be discouraged ("Ocean Disposal Symposium"). Abbreviations, jargon, and unusual terms should not be used either. Cleverly worded titles are unsuitable for scientific papers but may be provocative for essays and other expressions of individual views. Titles in the form of a question or a statement can be forceful ("Is the Suffolk Scarp a Shoreline?" and "Densities of Brines Should be Measured at 4°C").

### Abstract

A plainly written abstract invites the reader to study the paper that follows. It should not be treated as an introduction. It gives the essence of the paper but stands on its own; it outlines the purpose of the work, methods used, and important results, and it gives only the information that is in the paper. Authors sometimes forget to include needed facts, such as important localities, but they more commonly give extraneous details. The reviewer should point out unneeded words and ideas. Abbreviations, symbols, or acronyms are rarely needed, but if they must be used for brevity, the author should define them. References are best left to the body of the report; if an abstract must cite a reference, sufficient information must be given in parentheses for the reader to find the reference because the abstract must stand alone. The order of topics in an abstract must be logical but need not be the same as in the body of the paper. Giving the conclusions first and then the background and supporting facts can be effective.

### Introduction

A good introduction can be organized in many ways but should include the following elements: (1) A description of the research objective and the purpose of the paper, (2) a summary of previous work, (3) a description of the methods used and the responsibilities of the coauthors, (4) a mention of the principal results and their importance, and (5) an outline of how the rest of the report is organized. The reviewer should check that the rest of the report is consistent with the introduction. The introduction should be written as if it appeared without the title and abstract.

### Illustrations and Tables

Check to be sure that illustrations and tables (1) are consistent with interpretations in the text, (2) show what the author intends to show, (3) do not unnecessarily repeat information given in the text, (4) are readily understandable on their own, and (5) are in proper form. Be sure that the report contains neither too many nor too few illustrations or tables. Also ask yourself if details in the text could be expressed more clearly or concisely as illustrations or tables.

### References

Inform the author if relevant work has been missed or, conversely, if irrelevant work has been cited. References not directly related to the work are superfluous, although published work of historical interest can be pertinent. Reviewers are expected to check citations in the text against the list of references, noting omissions or discrepancies in names, dates, or pagination.

### Acknowledgments

Acknowledgments are the author's prerogative but preferably should be given for noteworthy contributions and financial support (p. 12). In Government reports, cooperation with another agency is noted on the title page. Credits for supporting information should be placed in the text where the information is used. Contributors who share importantly in the work may be listed as coauthors. Some editors require that acknowledgments be approved by those whose help is acknowledged, on the grounds that an acknowledgment may mistakenly imply endorsement of the author's work.

### Organization

Thoughtful suggestions on organization and clear writing may help the author better express important results and concepts. Scientific papers are easier to understand when the findings and their significance are clearly explained, when extraneous matters are left out, and when elements of the work can be quickly found. Understandable reports proceed from the statement of a problem to its solution. A classic sequence is: "Introduction, Materials and Methods, Results, and Discussion," but no prescribed form can be universally recommended. The results derive from the approach taken and the methods used. Interpretations are best placed in the closing discussion, where the meaning and significance of the results are explained and evaluated. Carelessly organized papers fail to state the purpose of the work, explain the approach taken, or clearly derive an explanation of the results.

### Clarity

Clarity and conciseness are improved by following simple rules: Favor the active voice and the first person; do not use nouns as verbs; delete needless words; use concrete words, not vague or abstract terms; substitute short words for long ones; say what things are, not what they are not; express parallel thoughts in parallel form; avoid jargon.

### Accuracy and Consistency

Reviewers are expected to catch technical errors that might otherwise be missed. Look especially for numerical errors and for mistakes in technical terms and proper names that may be unfamiliar to the editor. If an error is found in a calculated value, ask the author to check all the values. A common error is a misplaced decimal point. Even when the calculated values are correct, check the method of calculation. If in doubt about the mathematics, statistics, chemical formulas, or other technical usage, explain to the editor or supervisor that review by an appropriate expert is needed. If many technical terms are used, the report may need a glossary. Try to check definitions and quotations. Verify that abbreviations or acronyms are defined when first used; would they be better spelled out? Check scales on maps and photographs. Geographic names in the text must agree with those on the maps and preferably with names on published topographic maps. All names used in the text should be shown on a map in the report or be otherwise adequately located.

# REVIEWING MAPS AND CROSS SECTIONS

REVIEWING GEOLOGIC MAPS AND CROSS SECTIONS is much like making them: The reviewer and the author are concerned about the same things. A first concern is that maps and sections have all their needed parts—the simple matter of completeness that can be verified with a checklist. A second, more important concern deals with accuracy and logic—why lines are where they are, what they show and if they show it correctly, and what interpretations these lines suggest. Maps and sections must be geometrically consistent and logical.

## RESPONSIBILITIES

Reviewing maps from time to time is expected of all Survey geologists, just as each of us expects others to review maps that we have prepared ourselves. The principal responsibility of the technical reviewer is to help the author and, so, ultimately to help the Survey and the users of Survey products. With different eyes and different insights, you as reviewer can ferret out failures of logic or consistency in mapping or interpretation and other problems the author might fail to see. If an interpretation is flawed, tactfully suggest reasonable alternatives.

The author is obliged to consider each review comment and to make any necessary changes. If suggested changes are unacceptable, the author must explain why in a marginal note or memorandum. The responsibility of the author to respond to every comment should be kept in mind by the reviewer in deciding whether or not to comment on minor points of contention.

## STARTING THE REVIEW

As a first step, you as reviewer should scan the map, sections, and explanation to get familiar with the map units and their sequence, general lithologies, and thicknesses. Find out why the map was made; learn its intended purpose.

Get a general overview of the structure, both from the map and from the sections as interpreted by the author.

Look for obvious problems, such as dangling contact lines, questionably placed lines, erratic or unexplained changes in formation thickness, and doubtful fits of contacts and faults to topography and bedding attitudes.

Make some notes to yourself in soft pencil on the review copy—reminders to look more closely. (Do not mark on the colored copy.)

The first step serves two importants purposes:

1. It gives you a general feeling for the map area—a feeling to be expanded as you review the map and sections more closely.
2. It helps you gain some level of confidence in the map and sections. For example, you gain an impression that

    The map has few problems, or
    It is a good map but needs some attention, or
    It is a fair map but has many problems, or
    It is seriously flawed.

Maps and sections submitted for review should be able to stand by themselves without reference to others, published or unpublished. They must be legible, neatly drafted on a clearly legible base, and printed on a clearly legible review copy.

## WHAT TO CHECK NEXT

**Marginal data**

Most but not all of the following apply to all maps:

Spelling and punctuation are correct.
Latitude and longitude, townships and ranges are correctly placed and numbered.
Scale is appropriately given:
- Ratio scale.
- Rake or bar scale.
- Vertical scale on sections; if exaggerated, must say so.
- Contour interval.

Magnetic declination and year, if needed, are correct.
Source of base map is credited, and projection of base map is provided with the credit.

Mapping credit is given:

Authors, assistants, time(s) of mapping, acknowledgment of work by others are included.

Location or index map is included.

A sketch map showing published maps of conterminous areas is included if appropriate.

A sketch map showing the reliability of data if appropriate. Such a map would show the area for which data were assembled from photogeologic interpretation, areas of reconnaissance mapping, areas originally mapped at different scales, and areas mapped by different contributing authors.

Title is appropriate and definitive. Includes quadrangle or area name, county (if needed), and State or country.

Authorship line and year of publication are correct and positioned below title.

### Correlation of map units

Unit boxes are complete and accurate in relation to adjacent units and time boundaries.

Age brackets are clearly and carefully drawn.

### Description of map units

All units shown in boxes are actually on the map.

All units shown on the map and sections are listed and described.

Map, sections, and explanation all use the same unit symbols.

### Map symbols

All conventional and special structural symbols shown on the map and sections are included in the explanation and are adequately explained.

Any dashed or dotted lines on the map are explained.

Faults shown on the map are adequately explained as to kind and attitude.

Symbols for fault displacements are explained.

Traces of axial surfaces of folds (or symbols for crests and troughs) are accurately plotted and explained.

### References

References are complete and in Survey style.

### Other

All enclosed areas on the map and sections are labeled by symbol or are distinctively colored.

Line weights on the map and sections are distinctive enough to be clearly identified by the illustrator for final drafting.

## Reviewing the Map Units

As you go over the map you will be working back and forth constantly from the map and sections to the explanation. You should carefully consider the "Description of Map Units" and "Correlation of Map Units," therefore, early in the review. In this way, you will quickly learn the sequence of units, their ages, thicknesses and variations, lithologies, sequence of events, and other characteristics that you must know to adequately evaluate the map and sections.

## What to Look For in the Explanation

Units and symbols for rock units on the map and cross sections are in the explanation and are clearly and consistently labeled on map and cross sections, in the correlation of map units, and in descriptions of map units. Symbols are kept to four letters or less.

Descriptions of map units are clear and concise and follow a consistent format, including distinguishing characteristics such as rock type(s), color, grain size, bedding, and thickness. Also given are any other distinctive characteristics that the map user should know about, such as mineralogy and fossils.

Descriptions are complete enough to enable a map user to identify the rock unit in the field and to permit a reader to compare each unit with the same unit elsewhere.

If a map unit is present only in a small part of the map area, its description might usefully say where.

If a description includes several units or members within a formation, they are described in sequence from youngest to oldest, from the top down.

## Reviewing the Map and Cross Sections

### General Guidelines

Maps and cross sections must be completely and clearly drafted. Poorly prepared copy reflects on the author, and the reviewer should not be asked to do what the author has not done in terms of compilation, thoughtful interpretation, and cross-checking.

Maps and cross sections must be internally consistent. Interpretations shown on maps or on cross sections must be logical, reasonable, and compatible with mapped data. Maps and cross sections should fit with adjacent, recently prepared maps and cross sections; structural interpretations, new concepts, or serious misfits should be explained.

### What to Look For on the Map and Sections

After reviewing the guidelines that follow, look at every line on the map and sections. Ask yourself the following questions:

Are all lines properly located? Are they topographically compatible?
Are they compatible with other stratigraphic and structural data?
Are they logical?

Every line on the map is related to other lines and to other data; taken together, all must make sense.

You cannot review a map well or consistently by random spot checking. You must work your way systematically over the map area bit by bit, checking back and forth from map to sections to explanation to make sure that everything fits. Only then, will you have answered the critical questions: Is this a disciplined, thoughtful, consistent geologic map; are the sections properly constructed and are the interpretations they show logically supported by the map; is this map a credit to the author and to the Geological Survey; and is it an appropriate addition to a long line of quality geologic maps made by Survey field geologists?

# Checklists for Reviewing Maps and Sections

## Map Logic

| Feature | Check against |
|---|---|
| 1. Sequence of stratigraphic units and tongues. | Correlation of map units.<br>Description of map unit.<br>Text. |
| 2. Thicknesses of stratigraphic units. | Thickness as measured from the map.<br>Thickness given in text and explanation. |
| 3. Contacts. | Strike and dip on topography for consistency with bedding attitudes.<br>Offsets on faults (map units move up dip on downthrown side). |
| 4. Normal, reverse, and strike-slip faults. | Justification by offset, structural deflections, or sheared rock symbol.<br>Offset shown by symbols.<br>Amount of throw along trace for consistency or merge into fold. |
| 4. Normal, reverse, and strike-slip faults—Continued | Direction and amount of dip (three-point method).<br>Direction of throw versus drag.<br>Agreement of throw symbols and unit offsets.<br>Offset of intersecting faults. |
| 5. Thrust faults. | Same as 4, plus:<br>Variation of foot-wall and hanging-wall units versus attitude of beds.<br>Vertical sequence of plates versus joints.<br>Ramps versus ramp folds or faults.<br>Direction of apparent transport versus erosional trace of thrust. |
| 6. Folds. | Justification of trace of axial surface, crest, or trough as deduced from bedding attitudes.<br>Plunge of fold from bedding attitudes and map patterns.<br>Dip of axial surface.<br>Offset on faults. |
| 7. Does the geology of the map area make regional sense? | External consistency or explanation for variation. |

## Cross Sections

___ Is topographic profile plotted correctly?
___ Are the lines of section selected to best show the structure?
___ Do map lines correctly intersect the profile?
___ Are apparent dips correctly plotted?
___ Are all structural features in the line of section shown on cross sections?
___ Are data near the line of section correctly projected into the cross section?
___ Are unit thicknesses compatible with surface geology?
___ Are folds correctly shown?
___ Do kinds of structural features in section match kinds of structural features on map?
___ Do structural features that intersect on the map near a section also properly intersect on section and at correct along-strike or along-plunge depths?

___ If two or more sections accompany the map, are thicknesses of units, dips and throws on faults, and depths to geologic intersections compatible from section to section? (At this point, a complex section might be cut apart and taped back together to restore the section as it was before faulting.)

___ Do hanging wall and foot wall match across faults and is direction of throw the same as indicated by map symbol? By pattern of units offset on map?

___ In restored (cut apart) sections, can holes or overlaps be explained reasonably? (Area or volume balance.)

___ Do bed lengths in highly folded areas or between major thrust faults match from top to bottom in the sequence? Do they match properly between restored structural features?

___ If two sections intersect, are all lines correctly plotted on both sections at the vertical line of intersection?

___ Does the map support the interpretation shown on the sections? Are the sections consistent with what is known regionally?

___ If the vertical scale is exaggerated, is the exaggeration warranted?

## Other Considerations

Maps occasionally are submitted for publication at scales larger than needed to adequately portray the geologic detail. Unless a particular scale is required to match some local map series, such as the uniform 1:24,000-scale series for Kentucky, the reviewer should recommend whatever scale best fills the need.

Appropriate map scales and data density are generally determined by the kind of geologic map needed to solve anticipated problems and by the available topographic base. Some mappers will doggedly plot every bit of available data, will carefully preserve every attitude, and will clutter the map in the belief that the more profuse the data the more accurate the map, no matter how repetitious. A sufficiently detailed geologic map is one that adequately (1) portrays the geology of a region at the selected map scale, (2) provides the factual basis for interpretations shown in accompanying sections, and (3) reflects disciplined, thoughtful fieldwork. If more detail is required in an especially complex area, an inset map may be prepared at an appropriate larger scale.

The accuracy and logic of a map reflect the care, thought, and discipline of the mapper. Carefully restored but erroneous cross sections can be drawn from a map that is wrong.

Even the simplest geologic map shows rock relations that have resulted from complex sequences of events. Such sequences must agree on the map and on all accompanying cross sections. A fault that moved only in Proterozoic time cannot be shown cutting Paleozoic rocks. A fault that is buried beneath alluvium should be shown by a dotted line if the alluvium appears on the map.

Some suggestions for reviewing large-scale maps of small areas do not apply to small-scale maps of large areas because both rocks and structures can and do change significantly across large areas, but the foregoing suggestions for map mechanics apply equally. Beyond that, the map and any accompanying cross sections must be logical, and interpretations in cross sections must be supported by mapped data. A second map may be appropriate for showing structural data.

# PREPARING REFERENCES FOR SURVEY REPORTS

NEARLY ALL SCIENTIFIC REPORTS refer to the work of other researchers. The usual practice in Geological Survey reports is to cite author, date, and page in the text and to list complete references at the end of the text. In some multichaptered reports, references are listed at the end of each chapter. Authors should doublecheck that each reference cited in the text is included in the reference list and that each reference is complete and accurate. Inaccurate or misquoted references reflect on the scholarship of the report and may mislead the reader. Survey reference style may differ from that of outside journals. Check to be sure, if you plan to publish outside.

In general, brackets, not parentheses, are used for any material added to a direct quotation in the text of a report, or to the formal information cited in a reference from the report cited, particularly from the title or copyrighted pages.

## TYPES OF MATERIAL CITED

All reports listed as references must be reasonably available to the public. Unavailable reports should not be cited. Listed reports mostly are books, periodicals and other serials, symposium and conference or congress volumes, and maps, but certain unpublished material may also be cited—such things as dissertations and master's theses, some guidebooks, and reports open filed by the Survey or by other Federal, State, foreign, or private agencies.

Unpublished dissertations, guidebooks, and Survey Open-File Reports should be referred to the same way as published reports, both in the text and in the list of references. (See examples 16, 20–22, 43, and 44 in the sample list of cited publications at the end of this section.) Open-file reports of non-Survey organizations may be cited as published reports if complete bibliographic information is available; the reader will be helped if you state where such reports may be inspected.

Oral and written communications are unpublished data of another category that includes oral data and opinions, written correspondence, memorandums, field notes, and manuscripts and maps in all stages of preparation. (See discussion about manuscripts in preparation under "In press" below.) All such material is cited only in the text and does not appear in the reference list at the end of the report.

## REFERENCES CITED WITHIN THE TEXT

Text references include the author's last name (and initials if needed to prevent confusion), the year of publication, and, optionally, specific page(s), plate(s), or figure numbers. For example, "Production of lithium was begun at Searles Lake, Calif., in 1938 (Mumford, 1949, p. 513)." The exact page or pages must be given if a reference is to quoted matter; paging should be given in a reference to a report large enough for the reader to need help in locating the information. Pages are unneeded if the article cited is only a few pages long and if no content is quoted. Full paging for the entire book or article—not given in the text reference—should appear in the reference list at the end of the report.

**Author's name.** If an author's name forms part of a sentence, only the date and the page reference appear in parentheses, as in "Schaller (1911, p. 49)." If the cited author's name is in the possessive case, the citation immediately follows the word modified: "Carrara's study (1979, p. 307) suggests that," or "well shown on Dyni's map (1968)." If reference is made to several articles published by an author in one calendar year, indicate them by letters a, b, c after the year, as in "(Reeside, 1927a, p. 5–7)." Use the same letters in the reference list at the end of the paper. (See examples 39 and 40 in sample list of references.)

**Multiple authors.** If a paper has two authors, both authors' names should be cited, as in "(Schaller and Carron, 1952, p. 301)." If a paper has three authors, the reference may be either to the first-named author "and others" (if there is no possibility of confusion) or to all the authors. You may treat each group of authors individually—for example, "(Palache and others, 1951)," "(Palache, Berman, and Frondel, 1951)," or "according to Rowley and others (1985)." Whether or not the reference is within parentheses has no bearing on the use or nonuse of "and others." Whichever method is chosen should be followed consistently throughout the paper. To save text space and prevent long lists of names that tend to break the reader's train of thought, papers having four authors or more are customarily cited as the first author "and others." For clarity, however, the text references for "Ruth, May, Aaron, and Henry, 1980," and "Ruth, Henry, May, and Aaron, 1980," would be "Ruth, May, and others, 1980," and "Ruth, Henry, and others, 1980," respectively. The Survey doesn't use "et al."

In the list of references, all authors' names should be given.

**Multiple references.** Multiple references may be listed alphabetically by author—for example, "(Ashley, 1910, 1918, 1940; Drake, 1965; Drake and others, 1967; Lesley, 1880; Swartz, 1922, 1929)"—or they may be listed chronologically. In fairness to the authors cited, a chronological listing better emphasizes the relative priority of each author's contribution to the literature. All works by one author in a chronological listing should follow the first listing of that author's name, to prevent needless repetition and to ease the reader's task in looking up the references. For example, "(Lesley, 1880; Ashley, 1910, 1918, 1940; Swartz, 1922, 1929; Drake, 1965; Drake and others, 1967)."

**Book titles.** Titles of books, articles, and other reports mentioned in the text are enclosed in quotation marks. Capitalize all important words: "Bibliography of North American Geology, 1970"; "Dictionary of Alaska Place Names." Follow this practice if the complete formal title is used. If such a reference is cited many times in the text, give the formal title the first time, followed by a shortened informal title in parentheses. Thereafter, use the short title: "United States Government Printing Office Style Manual, 1984" (U.S. GPO Style Manual); "Suggestions to Authors of the Reports of the United States Geological Survey" (STA). If repeated citations are separated by many pages of text, a repeat of the full title is a service to the reader.

**Unpublished information.** Oral or written communications and unpublished data in the text are referred to in parentheses in the text but do not appear in the reference list at the end of the report. Give the name(s) of the author(s), including initials or first name, abbreviated "oral commun(s).," "written commun(s).," or "unpub. data," followed by the date(s), as follows: "(A.B. Smith, oral commun., 1985)," "(Charles Brown, written commun., 1983)," "(D.E. Jones, and W.D. Johnson, Jr., unpub. data, 1984)," or "according to I.J. Witkind (oral commun., 1985)." The Survey avoids the expression "personal communication." References to unpublished information may include the author's affiliation after the name as a courtesy to the author and a convenience to the reader. See also page 237 regarding manuscripts in preparation.

## REFERENCE LIST (REFERENCES CITED) OR BIBLIOGRAPHY

Correct referencing is the responsibility of the author, not the reviewer or the editor. The reference style discussed here is used for most Survey books and map reports. In some special-purpose bibliographies and reports, the style may vary. In the following discussion, example numbers refer to sample references in "Examples of Cited Publications," beginning on page 239. Do not number your own references.

The headings "References Cited" or "References" are used by the Survey if all the publications listed are referred to in the text; the heading "Selected References" is used if the list is more extensive; "Bibliography" is used if it is exhaustive. The heading "Selected References" should not be used to avoid citing in the text one or two papers in the reference list.

### HOW TO LIST REFERENCES

References are listed alphabetically by names of authors. All reports by an author alone are listed in chronological order. Next are reports written by that person as senior author with coauthors; each identical grouping of authors is treated as a unit, and each unit is listed alphabetically by the names of its coauthors. Under each unit, references are also listed chronologically. For example—(1) papers by Smith alone, listed chronologically; (2) papers by Smith and Brown, also chronologically; (3) papers by Smith, Brown, and Jones; (4) papers by Smith and Jones; (5) papers by Smith, Jones, and Brown. If two or more papers within a chronological listing have the same publication year, they are listed alphabetically by title, and the dates are followed by letters such as a, b, and c (examples 39, 40).

After the first listing of an author or group of authors, a 3-em dash is traditionally substituted for the name or names to avoid repetition. One dash substitutes for all the names in the previous citation. The dash is not followed by a comma, and no space is left between the dash and the year (examples 2, 3, 39, 40). When the dash substitutes for a group of names, the authors represented by the dash must be exactly the same as those in the preceding reference and must be in the same order. For example, no dash is used if a paper by Ashley, Baker, and Carter is followed by a paper by Ashley, Carter, and Baker.

The use of the dash, however, may cause problems with computer-generated bibliographies. Many scientists maintain bibliographic lists on disks for recurrent use and selective retrieval, but the computer cannot alphabetically sort and retrieve references beginning with a dash. The best solution is to repeat the author's name in each entry on the disk and in the bibliography. STA endorses this procedure, but cautions that use or nonuse of the dash must be consistent in any given report.

## Elements of a Bibliographic Citation

Use the following order for the various elements in a citation:

1. Name(s) of individual author(s), surname first and initials or one given name; *or* name of corporate author; *or*, if no author can be found, name of the periodical in which the article is published; followed by a comma.
2. Year of publication, followed by a comma.
3. Title, followed by a colon.
4. Information following the colon:
   a. For books and book-type publications not in a series: Give the place of publication, followed by a comma; name of publisher, followed by a comma; full paging (exclusive of preliminary pages in Roman numerals) for the book or for that section or chapter cited in the title part of the reference, followed by a period if end of citation, or by a comma if not; plates and figures (in that order), if important or significant. Tables generally are not listed.
   b. For serial publications: Give the name of periodical or other serial publication, followed by a comma; volume and number in Arabic numerals (if a serial has no designation of volume or number other than the year of publication, that year should be used in place of the volume or number), followed by a comma; full paging for the article or report, or for that part cited in the title of the reference, followed by a comma; number of plates and figures, if important or significant. Tables generally are not listed. For maps in series, give number of sheets (if more than one), followed by a comma; ratio scale.
   c. For maps not in a series: Give the place of publication, followed by a comma; publisher, followed by a comma; number of sheets (if more than one), followed by a comma; ratio scale.
   d. For publications of congresses, conferences, and similar meetings, and some guidebooks, when such publications cannot be cited like books: Name of congress or conference, followed by a comma; its number (1st, 4th, etc.), followed by a comma; place of meeting, followed by a comma; year of meeting, followed by a comma; and series, volume, part, if any, followed by a comma; full paging of article cited, or of the entire volume if it is cited as a whole. Some guidebooks can be treated like conference publications, some like serials, and others like books; no general rule can apply.

## Details of the Citation

**Name of author.** If the author of the work cited uses only one given name, the name should be written out in full, as "Butts, Charles." If the author uses more than one given name, initials are preferred unless the name in that form does not uniquely identify the author. If authors have initials or names that might cause confusion, the given names should be written out. Initials and periods should be set without spaces. If applicable, the abbreviation "ed(s)." for editor(s) or "comp(s)." for compiler(s) follows the initials or given name (examples 4, 7, 11, 15, 26, 30, 33, 52).

Selection of the last name under which to list a citation may be difficult when citing a foreign name. The author's own usage, if ascertainable, or the custom of the author's country should be followed. Otherwise, a prefix that is a definite article (La, Le, L') or a preposition and an article forming one word (Dall', Du, Della, Lo) are generally considered to be part of the surname (examples 17, 24, 25). If a prefix is a preposition standing alone in a nonanglicized name (de, van, da), it is not considered to be part of the surname (examples 6, 24, 60). In anglicized names, however, the prefix *is* considered to be part of the surname, even if it stands alone (example 59). In foreign Chinese names, no comma follows the surname (example 12), but in Chinese-American names, the comma should be used. Compound names are common in some countries. These names should ordinarily be cited under the first of the compound names (examples 13, 14). Diacritical marks, if any, should follow the author's usage. Authors' names in a multiple-author reference are usually separated by commas, but semicolons may be used if needed for clarity.

If no one is named as the principal author, editor, or compiler of a report, the publishing organization—U.S. Government, State, or municipal agency; foreign government, provincial, or municipal agency; university; corporation; scientific society; publishing house—may be listed as corporate author (examples 53–57). The name of the publishing periodical may be used as author if no individual or organization can be named (see example 42). "Anonymous" is not used by the Survey. In citing a corporate author, the general rule is to use the name of the specific organization or agency responsible for the publication, not the larger body to which the agency may belong. For example, for Survey publications, use "U.S. Geological Survey" not "U.S. Department of the Interior, Geological Survey."

**Year of publication.** Use the date (year) shown on the title page of the publication. If no date appears on the title page, use the copyright date, if there is one.

If the year of release differs from the year of publication, both dates may be given, but need not be. The release date may be important to questions of priority, as in paleontological reports, but it generally is unnecessary. If both dates are given, the actual publication (imprint) date must follow the author's name; the release date follows the imprint date in brackets, as "1987 [1988]," (example 32).

If the date of publication is not on the title or copyright page but is discovered elsewhere in the report—or is otherwise known—it is placed in the reference in brackets in the usual place after the author's name (example 55). If the date cannot be found but can be estimated, or guessed at, it is followed by a question mark and is enclosed in brackets "[1983?]." If no estimate can be made, use "[n.d.]."

**In press.** Manuscripts by Survey authors cannot be listed in the references as "in press" until publication is approved either within the Survey or in an outside publication. Manuscripts by non-Survey authors must have been accepted by a publisher or journal. When an "in press" report is listed in the references, the words "in press" should substitute for the publication date, after the author's name (example 47). Text references to several "in press" reports by the same author may appear as "(Smith, in press a, b)."

"In press" references to a book or to a nonseries map must cite the place of publication and publisher; such references to an article in a periodical or other serial publication must give the name of the publication in which the article will appear. If that information is not available, the report is not in press.

Manuscripts in preparation cannot be cited in the text or included in the references. After all, such a manuscript may never be completed. If a report by a Survey author has not received Director's approval or if a report by a non-Survey author has not been accepted for publication by a publisher or journal, the manuscript may be cited in the text only as "unpub. data" or "written commun."

**Title.** The title of the work cited should be taken from the title page (or from the face of a map), not from a cover page or jacket, which may have a somewhat different title. Titles should be cited completely and without changes, except to correct typographical errors. Any other word considered to be in error should be reproduced exactly as it appears on the title page, followed by "[sic]." Words may be deleted from an overly long title, any deletion being shown by asterisks * * * (examples 7, 60). Occasionally, words may be added in brackets for clarification (examples 18, 19). If the typographical style of a title page omits needed punctuation, such as a comma or semicolon, such punctuation should be supplied. A colon within a title is usually shown in the list of references by a dash, so that it does not become confused with the colon that, in Survey reference style, marks the end of the title.

For titles in English, only the first word, proper nouns, and proper adjectives should be capitalized, but in other languages, the national practice should be followed. Any diacritical marks should be reproduced. Titles in foreign languages may be (but do not have to be) followed by an English translation enclosed in brackets. Translations are particularly helpful for languages other than French, German, and Spanish (examples 50, 51).

Titles in Asian languages are usually given in English translation only, enclosed in brackets. A parenthetical statement at the end of the citation should tell the reader the language from which the translation was made and indicate whether the article or book includes a summary in English or in another language (example 12).

**Edition.** If a work has more than one edition, the edition cited in the text must be shown in parentheses immediately after the title and before the colon (examples 4, 5, 7).

**Abstracts.** If the work cited is an abstract, the abbreviation "[abs.]," in brackets, immediately follows the title, just before the colon (example 1).

**Citing parts of chapters.** When the reference cited is a part of a larger report, care should be taken to distinguish the part from the whole. Generally, the title of the part is cited first, followed by "*in*," or by "chap. 2 *of*" or "pt. 3 *of*" if the part has a formal designation in the book or report (see examples 10, 20, 46). When citing the paging for such a reference, give paging of the part or chapter only, not of the whole book or report.

**Information following the colon for books.** If the work cited is a book, the place of publication immediately follows the colon at the end of the title. Usually, the place of publication is printed on the title page of the book. If it is not there but is known, put it in brackets (examples 15, 21); if the place is guessed at, add a question mark "[New York?]." Well-known large American cities, such as New York, Chicago, San Francisco, New Orleans, and others, need not be identified by State; large foreign cities, such as London, Paris, Rome, and Moscow, can also stand alone. When a State name follows a smaller or less well known U.S. city or town, the customary abbreviation (p. 105) is used (examples 4, 5), not the U.S. Postal Service code.

When well-known commercial publishers are cited, the full corporate name is not required. For example, "Merriam" is sufficient for "G. & C. Merriam Co.," 'Macmillan," for "The Macmillan Company," and "Wiley," for "John Wiley and Sons, Inc." If the publisher is not well known or the publication is difficult to identify, more information should be given. The U.S. Government Printing Office is given as the publisher of reports issued by special or temporary Government bodies, but ordinarily it is not listed as the publisher of reports issued by permanent Federal agencies.

If a book or report includes more than one volume and if the entire work is cited, the number of volumes should be given rather than the total pages (examples 26, 58). Total paging may also be provided but is not required—for example, "3 v., 2,818 p."

**Information following the colon for serials.** If the work cited is in a serial publication, the spelled-out name of that publication immediately follows the colon. Use the name as it appears on the title page of the volume containing the article cited, not the serial name currently in use if it has changed. Serial publications include periodicals released at regular intervals, such as "Journal of Paleontology", and numbered books and map series that are released irregularly, such as U.S. Geological Survey Bulletins and Geologic Quadrangle Maps.

When publications of governmental organizations are cited, the name of the country, State, province, or city should be given first—for example, "Canada Geological Survey," not "Geological Survey of Canada." The abbreviations "U.S." and "U.S.S.R." or "SSSR" are used, but other names are spelled out.

When publications of nongovernmental organizations are cited, the name of the organization is placed first, but the word order of the organization name itself is not changed; thus, "Geological Society of America Bulletin." Names of periodicals that do not include the name of the organization issuing them are not changed, except for the omission of any initial article—for example, "Engineering Geologist," not "The Engineering Geologist"; "Erde," not "Die Erde."

If a serial title lacks information that might identify it—for example, if (1) a government publication lacks the name of the country that issued it, or if (2) two periodicals from different sources have the same name, or if (3) a periodical from a non-English-speaking country has a title in English—the name of the city, State, or country in which the serial is published should be given in brackets: "[France] Bureau de Recherches Géologiques et Minières"; "Explorer [Ohio]" and "Explorer [India]"; "Science Record [China]" (example 13).

Publications issued in sections or series should include the identifying number or letter of the section or series if the same volume number appears in more than one section or series—for example, "American Journal of Science, 4th ser., v. 1"; "New Zealand Journal of Science and Technology, sec. B, v. 35."

**Information following the colon for conferences and congresses.** In citing the proceedings of conferences, congresses, and such, the date of the meeting should be given in addition to the date of publication (see discussion under "Elements of a Bibliographic Citation"; examples 10, 14). Normally, the year is sufficient, but if more than one meeting took place in a calendar year, the exact dates of the meeting should be given.

**Information following the colon for guidebooks.** Guidebooks present particular problems. Each guidebook is different, and some of them may be correctly cited in several ways. Some guidebooks are issued as parts of regular geological society series or State geological survey series (example 20). These are treated like any other serial publication. Other guidebooks are issued by various conferences or congresses and can be cited the same way as other publications of those meetings. Still others can be treated like books (examples 21, 22) if sufficient bibliographic information is available.

The title pages of many guidebooks, however, lack such information as place of publication and publisher, some lack a publication date, and some are unpaged or variously paged. Such information may perhaps be found in a preface or accompanying letter or may be learned from someone who attended the meeting. Sometimes it may only be guessed at. If the guidebook is cataloged in the Survey Library or in another large library, needed information may be on the library card or in the computer system, but many guidebooks are never cataloged anywhere.

When referencing a guidebook, or any other book for which bibliographic information is sparse, use the facts that are available on the title (not cover) page. Then, any information from other parts of the book or from the author's own knowledge should be enclosed in brackets, with a question mark if necessary. If each trip in a guidebook or if each chapter or section in any report has its own paging, the words "variously paged" may be used in place of the full paging (example 56). For an unpaged book, the total number of pages may be counted and supplied in brackets "[50] p." or approximated "[about 300] p." (example 57).

**Miscellany.** Arabic numerals are generally substituted for Roman numerals unless the Roman numerals appear in a title or in a cited page reference, as "Baker (1958, p. iii)."

In citations of foreign publications, use "v.," "pt.," "no.," and "p." rather than the equivalent foreign terms, unless such terms appear in the title of an article or report. Table 14 shows the English terms and some of their foreign equivalents:

**Table 14.** Some English terms and their foreign equivalents

| | *Volume* | *Part* | *Number* | *Page* |
|---|---|---|---|---|
| Bohemian (Czech) | svazek<br>kniha | část | čislo | strana |
| Danish | bind<br>aargang | del | nummer<br>hefte | side |
| Dutch | boekdeel<br>jaargang | aflevering<br>deel | nummer | bladzijde<br>pagina |
| French | volume<br>tome<br>année | part<br>fascicule | numéro | page |
| German | Band<br>Jahrgang | Teil | Nummer<br>Heft | Seite |
| Greek | τόμος | μέρος | αριθμός | σελις |
| Hungarian | kötet | rész | szám | lap |
| Italian | volume<br>anno | parte | numero | pagina |
| Norwegian | bind | del | nummer<br>hefte | side |
| Polish | rok<br>książka<br>tom | część | numer | stronca |
| Portuguese | volume<br>tomo<br>anno | parte | número | página |
| Russian | том | часть | выпуск<br>номер | страница |
| Spanish | volumen<br>tomo<br>año | parte | número | página |
| Swedish | volym<br>band | del | häfte<br>nummer<br>numro | sida<br>page |
| Turkish | cilt | cüz | sayi | sahife |

# EXAMPLES OF CITED PUBLICATIONS

The following numbered list includes many varieties of citations arranged as they would appear in a list of references. The numbers preceding these examples are only for reference use in this volume; citations are not numbered in Survey reports. An alphabetical key is given here to help the reader find examples quickly. Thus, to find an example of an abstract or an annual report, look under names of authors beginning with "A"; for examples of a book or Bulletin, look under names beginning with "B"; for a Circular, conference publication, or compound name, look under "C"; for a guidebook, look under "G"; for a map or for multiple authors, look under "M," and so on. A Chinese reference is under "C," and two Russian references are under "R." This system was first used in STA 5. It can be used to find most examples listed, but a helpful quick index to some commonly used examples is also given here for further assistance.

| *Item* | *Reference number(s)* |
|---|---|
| Abstract | 1 |
| Annual report | 2, 3 |
| Books | 4–7 |
| Brackets, use of | 1, 12–15, 18–21, 32, 41, 50, 51, 55, 57, 61 |
| Bulletin (USGS) | 8, 9 |
| Circular (USGS) | 11 |
| Conference report | 10 |
| Congress, International | 14 |
| Date of publication different from delivery date | 32 |
| Dissertation, Ph.D | 16 |
| Edition (No.) | 4, 5, 7 |
| Foreign | 6, 12–14, 22–25, 27, 38, 39, 50, 51, 60 |
| Guidebook | 20–22 |
| *in* | 7, 10, 21, 52, 60 |
| Maps: | |
| Geologic Quadrangle (USGS) | 34 |
| Geophysical Investigations (USGS) | 31 |
| Hydrologic Investigations (USGS) | 32 |
| ~~Miscellaneous Field Studies (USGS)~~ | 35 |
| State | 30, 33 |
| National Technical Information Service (NTIS) | 41 |
| *of* | 46 |
| Open-File Report (USGS) | 43, 44 |
| Professional Paper (USGS) | 45–47 |
| Chapter in | 46 |
| Water reports (USGS): | |
| State Water-Data Report | 49 |
| Techniques of Water-Resources Investigations | 48 |
| Water-Resources Investigations Report | 41, 61 |
| Water-Supply Paper | 62 |
| *with a section on* | 8 |

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8. Brown, R.D., Jr.; Leinz, Reinhard; Federspiel, F.E.; and Leszcykowski, A.M., 1981, Mineral resources of the Snow Mountain Wilderness Study Area, California, *with a section on* Interpretation of aeromagnetic data, by Andrew Griscom and R.D. Brown, Jr.: U.S. Geological Survey Bulletin 1495, 48 p., 2 pls. in pocket.

9. Bryant, Bruce, 1962, Geology of the Linville quadrangle, North Carolina-Tennessee—A preliminary report: U.S. Geological Survey Bulletin 1121-D, 30 p.
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21. Gerrard, T.A., 1969, Stratigraphy of the Fort Apache Member, Supai Formation (Permian), east-central Arizona, *in* Geology and natural history of the Grand Canyon region—Four Corners Geological Society, 5th field conference, Powell Centennial River Expedition, 1969: [Durango, Colo.], Four Corners Geological Society, p. 174-180. [Example of a guidebook that is not part of a series. Place of publication is not shown on title page but is known and is therefore supplied in brackets.]
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35. Mullineaux, D.R., 1976, Preliminary overview map of volcanic hazards in the 48 conterminous United States: U.S. Geological Survey Miscellaneous Field Studies Map MF-786, scale 1:7,500,000. (Reprinted 1979.)
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37. Munk, W.H., Ewing, G.C., and Revelle, R.R.D., 1949, Diffusion in Bikini Lagoon: American Geophysical Union Transactions, v. 30, no. 1, p. 59-66.
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# POSTERS FOR SCIENTIFIC MEETINGS

POSTER SESSIONS have gained increasing acceptance and popularity at scientific meetings. Although most topics are presentable either as talks or as posters, some topics lend themselves best to graphic presentation. Many authors, moreover, prefer person-to-person discussions, with their illustrative material at hand, rather than speaking to a large audience in a formal setting. Authors and attendees alike find the opportunity rewarding to exchange ideas freely and at some length. Many attendees appreciate being able to walk quickly past several presentations, scanning each for its general content, before returning at leisure to the displays they find most interesting.

Most scientific meetings now allow abstracts to be submitted for either an oral presentation or a poster presentation. Abstracts for poster presentations are published in the proceedings of meetings along with those for oral presentations, and they carry the same prestige. At the larger 3- and 4-day meetings, poster sessions commonly run for half a day each, and authors are expected to be present while their posters are on display during a specified period, generally 2 hours. During each of these half-day sessions as many as 30 to 60 posters may be displayed, so competition for attention is keen. At smaller gatherings, a single group of posters may be shown during the whole meeting.

## PLANNING THE POSTER

Good science coupled with uncluttered and colorful design, brief and legible text, and concise organization equals a good poster. As a participant, you should learn specifically where the display area is (by map or number designation) as early as possible and the size and orientation of the display boards. Individual display areas commonly have tack boards mounted long-side horizontally at eye level and measuring about 4 by 8 feet. Three boards of this size commonly are joined to form a booth. Vertically placed display boards should be discouraged. They crowd the available space and cause design problems because much of the display area is well above or below eye level. You need to know the dimensions of your display boards, and whether the long side will be horizontal or vertical, before you begin to design your poster; a call to the sponsoring society is necessary if this information is not given with notification of acceptance of the abstract. Also knowing in advance the color of the display board may prevent a clash with the colors of the poster. As a rule of thumb, allow 6 weeks of discontinuous work to prepare an attractive exhibit, to allow time to print photographic enlargements, to gather all needed materials, and to actually execute the poster.

New and exciting ideas based on sound research can draw deserved recognition through a well-written abstract and an eye-catching poster design. However important your work, you must recognize that attendees at a scientific meeting most likely have not read your abstract before they walk into the display area. Their attention will invariably be drawn to crisp, clean posters and snappy titles. The title, composed months before, must be directed toward this strolling audience. Think of the title as a newspaper headline vying for attention. Once the viewer's attention has been caught by a display that looks interesting, all aspects of the design and the science will work together to keep or lose that attention.

### SCIENTIFIC CONTENT

The story you tell must be interesting and your research must be sound, but neither need be uncontroversial. Work that encompasses other disciplines and has broad applications or implications is most likely to be accepted for poster presentation and most likely to receive feedback.

Authors commonly try to tell too much. Use restraint and present only enough data to support your conclusions. Modesty here, however, is not a virtue—the significance and originality of your work should be made clear to viewers who may be unaware of the extent of your contribution.

### DESIGN

The subject of design is complex, and rules can be broken creatively and pleasingly if you have an artistic flair. A few guidelines, however, will help you make a poster more accessible, attractive, and interesting.

- From 10 to 15 feet away the viewer should glimpse an easy-to-read title and a neat uncluttered arrangement of illustrations and text. Your name should not be hard to find. Where to start looking and where to go from there should be obvious—generally left to right, top to bottom, like a comic strip. The component parts may be numbered to facilitate reading, or arrows can graphically lead the viewer through the display (fig. 55).
- Leave some open space in the design. When you have finished the design, as when you have packed a suitcase, take out half. Tightly packed space tires the eye and the mind.
- Use elements of different size and proportion. Same-size, same-proportion components make for a boring design. For areas of particular emphasis, try different shapes. Curved shapes or lines attract the eye if most other lines are straight. Straight lines draw attention if others are curved (fig. 56).
- A large or bright center of interest—a bold cross section, a colorful paleogeographic map, a blownup photograph of a new species or of an outcrop—will draw the eye to the most important point of the poster. For a modest price, poster-size color prints can be made from 35-mm slides or negatives at most photographic shops. Computer graphics can be enlarged, reduced, and manipulated in various ways.
- Emphasize simplicity. Make all illustrations bold and simple. Leave out unnecessary detail.
- Convert tabular material to graphics. Try scatter plots, bar graphs, triangular diagrams.
- Actual rock specimens or fossils add a nice touch of authenticity. They can be fastened to poster board with silicone glue or wires. Display large specimens on a table.
- Make a scale drawing of your tentative layout and have a few colleagues criticize its overall design.

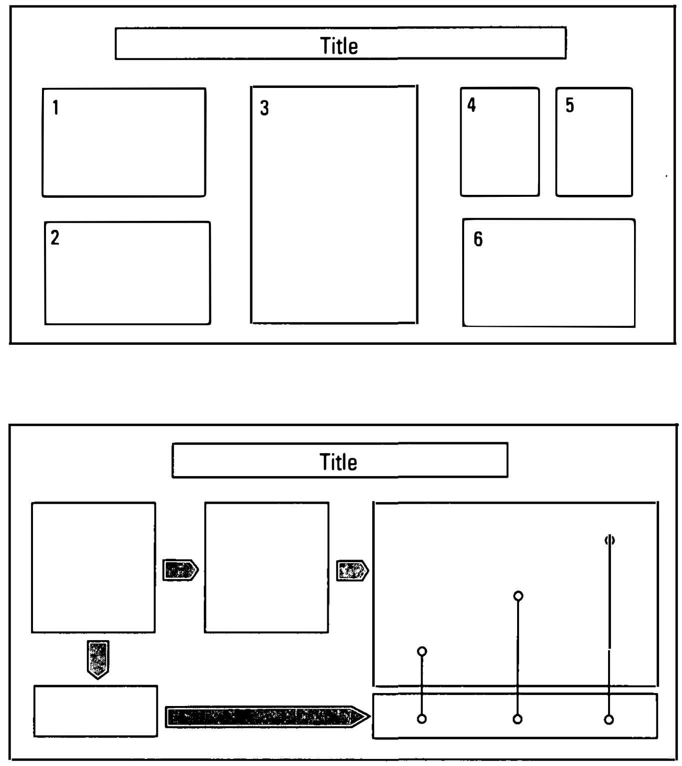


**Figure 55.** Two methods of leading viewers through poster: numbers and arrows.

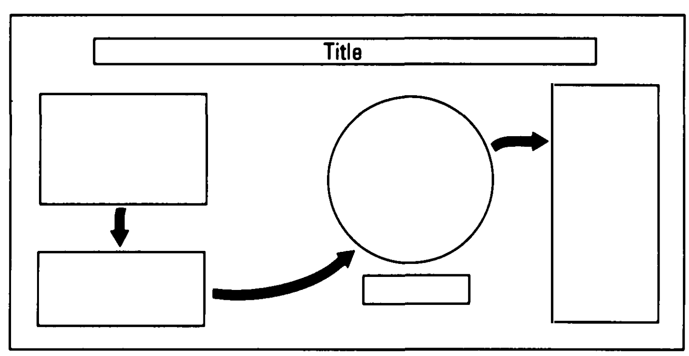


**Figure 56.** Attention-getting combination of curved and straight shapes and lines.

### Lettering, Line Weights, and Color

Lettering should be legible 5 feet away; senior scientists should not need a reading glass. Minimum type size should be no less than 18 point and the style should be bold or semibold in clean and simple letters. Title lettering should be about 2 to 3 inches high, subheadings ½ to 1 inch. Office- and art-supply stores have a wide variety of stick-on and rub-on letters in various colors and sizes that are ideal for titles and subheadings. The sponsoring organization may choose to prepare the title, for uniformity, but take along your own in case theirs is too small. For lettering other than titles and subheadings, use uppercase and lowercase letters in combination.

Uppercase type—all in capital letters—is harder to read than lowercase type. If you don't believe it, contrast this paragraph with the one below, which is printed in capital letters only. Words cast in uppercase have less diversity and character than those in lowercase and, therefore, are less quickly caught and recognized by the eye and mind. Slow recognition slows comprehension. All-cap type is fine for short titles but not for sentence content, either in the body of a report or in the brief captions for a poster session. Do your reader a favor by using lowercase type.

UPPERCASE TYPE—ALL IN CAPITAL LETTERS—IS HARDER TO READ THAN LOWERCASE TYPE. IF YOU DON'T BELIEVE IT, CONTRAST THIS PARAGRAPH WITH THE ONE ABOVE, WHICH USES CAPITALS JUST TO FLAG THE FIRST WORD OF EACH SENTENCE. WORDS CAST IN LOWERCASE HAVE MORE DIVERSITY AND CHARACTER THAN THOSE IN UPPERCASE AND, THEREFORE, ARE MORE QUICKLY CAUGHT AND RECOGNIZED BY THE EYE AND MIND. QUICK RECOGNITION ENHANCES COMPREHENSION. ALL-CAP TYPE IS FINE FOR SHORT TITLES BUT NOT FOR SENTENCE CONTENT, EITHER IN THE BODY OF A REPORT OR IN THE BRIEF CAPTIONS FOR A POSTER SESSION. DO YOUR READER A FAVOR BY USING LOWERCASE TYPE.

Serif typefaces are easier to read than sans serifs. The serifs (feet) add character to the letters and enhance reader recognition, which in turn increase reading speed and comprehension. Sans serif typefaces are appropriate in brief headings or titles, where they can be eyecatching, but they should be used elsewhere with discretion. Contrast this paragraph with the one below:

Sans serifs typefaces are harder to read than serif typefaces, because the serifs add character to the letters and enhance reader recognition, which in turn increase reading speed and comprehension. Sans serif typefaces tend to be dull and tedious. They are appropriate in brief headings or titles, where they can be eyecatching, but they should be used elsewhere with discretion. Contrast this paragraph with the one above.

Text material can be typed (about 12-point size) and then enlarged on a copying machine to as large as 24 point without serious loss of clarity, if a carbon ribbon and a clean type element are used. This method is the least expensive way to produce neat-looking text material (fig. 57). Text may also be enlarged photographically. For a professional appearance, use a lettering machine that produces strips of stick-on text. Apply these lines of text in final size to plain white paper, then photograph them so the glossy tape will not show.

Both the typed lettering and the stick-on lettering can be combined with black-and-white line drawings before the final copy (copy-machine enlargement or photograph) is made. All drawings of maps, diagrams, fossils, cross sections, and other figures should use a line weight that will be no thinner than 0.70 mm (No. 2 pen) in the final product. Bolder lines are preferable. Keep the drawing simple by omitting extraneous details.

Color is as complex a subject as design and in fact is an element of it, but there are no set rules for its use. Some authors prefer muted colors; others like deep or bright ones. Any color can be attractive, within some constraints. The temptation is to use color everywhere. Don't. The viewer's eye will jump erratically around the poster instead of tracking through it to the crucial points. The less important parts of the poster—the necessary background information and supporting data—will seem to recede into the background, as they should, if done in cool blues, greens, and grays. The featured parts can then be highlighted in warm reds and yellows, black if the background colors are soft, or white if the background colors are bright or deep. In choosing colors, be aware that lighting in the display area may not be optimal.

Color should be applied to the black-and-white drawings after they are photocopied unless the cost of color printing is no object. Transparent or opaque sheets of stick-on color provide the most even shading, preferably with a nonglare matte finish. Colored stick-on tape comes in widths of $\frac{1}{32}$ to 2 inches. Flexible tape can be used for linework. Tape is perfect for bar graphs and histograms, for borders, and for leaders from one element of the poster to another. Colored stick-on dots, squares, and triangles are available in various sizes. Large colored arrows can be cut from stick-on tape or from stick-on color sheets.

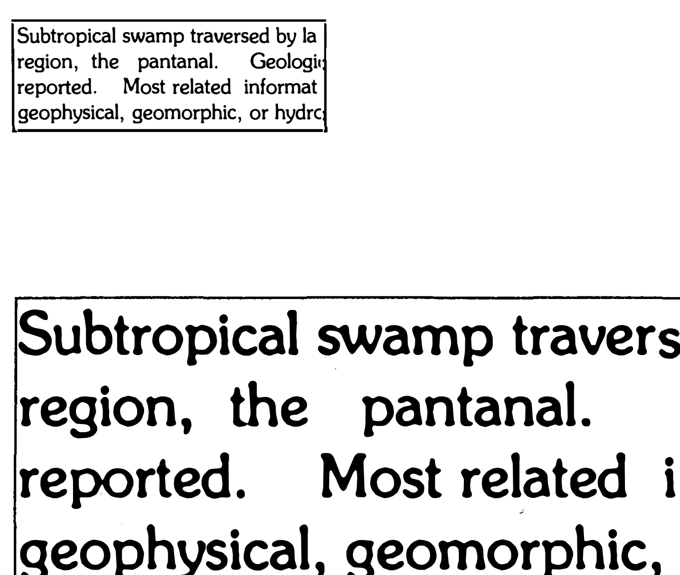


**Figure 57.** Typed text enlarged on a copying machine to about 24 points.

### Computer Printouts

Computer printouts are poor copy for posters. The standard type size is too small and the line weight is too thin. Computer programs are available, however, to enlarge (or reduce) maps on printers or on digital plotters. If printouts are used, enlarge the tabular material to improve legibility; add color with stick-on tape to enhance lines and enliven graphics.

### Text

The text should be extremely brief, or most of the viewers will walk away without reading it. Some authors like to include their full abstract as part of the poster, but few viewers will read it. Expect more success from a succinct statement of major conclusions at the head of the poster—perhaps as an expanded subtitle. Present the supporting text in brief segments along with the appropriate illustrations, and make the significance of the findings forcefully clear at the end. Aim for "Wow!" from the viewers as they walk away. Handouts of the abstract may be made available for those viewers who are really smitten.

## Mounting, Packaging, and Displaying

All poster elements should be mounted with an adhesive on poster board or on ⅛-inch foam-core board so they will lie flat. For a cleaner look, mount the caption on the same board as the illustration. A half inch or so of the colored poster board extending beyond the edge of the illustration makes an attractive frame. Select the mounting color carefully to avoid overpowering the picture. Illustrations mounted on white foam-core board can be edged with colored stick-on tape.

Your poster may have to be taken to a distant convention. To avoid the panic of lost luggage if you are traveling by air, make the poster elements small enough to package within the carry-on dimensions, generally 17×22 inches, but call the airline to be sure.

You may have only a short time to set up your display, so prepare for it in advance, and have the following items in an emergency kit:

- tape measure
- 9-foot length of string
- box of clear push-pins (longer than standard if mounted illustrations are thicker than one-eighth inch)
- box of thumbtacks
- box of dressmakers' round-headed pins
- roll of double-stick tape
- scissors
- glue
- package of tissue paper.

Have a sketch of the poster layout, showing measured positions of a few key components, so you will know where to place them. Set up a level line, if needed, by tying the string between push-pins set a measured distance above the bottom of the display board. The poster elements can be fastened to the board without visible attachments, as shown in figure 58, or can be attached with the push-pins (or dressmaker's pins) or with lots of double-stick tape. When you remove the display, if you've used double-stick tape, you'll need to put sheets of tissue paper between the components when stacking them to keep them from sticking together.

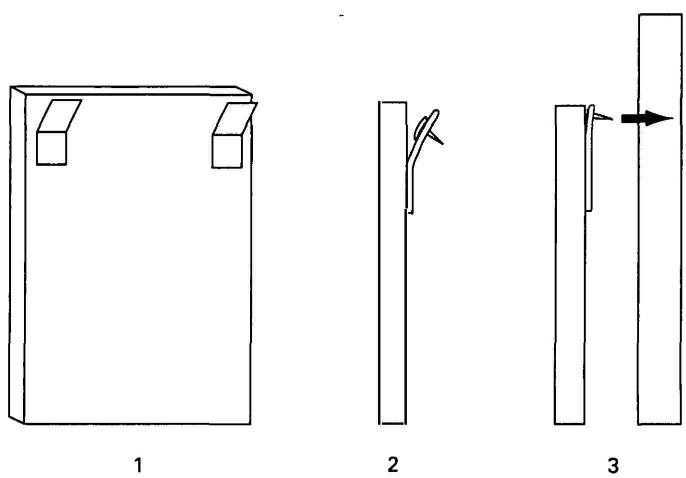


**Figure 58.** A method of using concealed thumbtacks to attach poster elements to the display board. You can also use Velcro.

(1) Attach tabs to back of mounted illustration. Leave upper half of tabs free.
(2) Push thumb tacks through upper half of tabs.
(3) Push illustration against bulletin board.

## The Alternative Poster

The professional-looking poster just discussed has an attractive counterpart. If artistically inclined, you can sketch a poster entirely by hand. Follow the same science and design guidelines as above, but execute with colored felt-tip markers on poster board of pleasing complementary or neutral color. Text material equivalent to a minimum of 18-point type is easy to do by hand with felt markers over lightly penciled guidelines. The less formal result is fast and inexpensive, and if neatly and imaginatively done can have a very special charm.

# NEWS RELEASES

NEWS RELEASES translate knowledge from technical reports into language that lay people can understand. They also announce anything newsworthy for which the Survey is the logical outlet. They are directed toward a broader readership than most Survey reports, and the style of writing is far less formal. To reach that readership, you as author must adapt your writing style to different ground rules. Formal publication makes the results of your research available to your scientific colleagues, but what about the general public? Interest in your subject may extend beyond the scientific community. Would your results be useful to people who normally do not read scientific reports and journal articles? After months or years of effort in putting your research into words, should you spend a few more hours preparing a news release?

You, as the author, are in a good position to know if your work ought to reach a wider readership of community leaders, government officials, planners, managers, business people, students, teachers, and homeowners. You can help decide if your report is one that deserves telling to the rest of the world through a news release.

The Survey issues news releases through Division representatives and public affairs specialists at headquarters and regional offices. These releases help fulfill our mandate to publish and disseminate information about the Nation's natural resources and natural hazards. About half the releases issued each year concern current earth-science events, the start of major new projects, speeches and talks, and major appointments and awards. In addition to written news releases, more than 100 stories are telephoned in each year to the news wire services to describe such current events as earthquakes, volcanic eruptions, and floods. For timeliness, increasing numbers of releases are sent to the news media by electronic mail. Each year, information in Survey news releases reaches millions of citizens through newspapers, magazines, radio, and television. For many citizens, news releases are the only link to the research activities of the Survey, and they can go a long way toward explaining the wide range of our good work.

Writing the first draft of a news release is not easy. The sample news release that follows contains

(your Survey address here)
(your name here)

PHONE: (your office phone number here)

For release: (Put a date at least 3 to 5 days after mailing)

or

For release: UPON RECEIPT (Prepared: Put here date of mailing)

SHORT, NEWSY HEADLINE

Again, short and newsy--catch and hold the editors' attention with the first paragraph. Give the editors the gist of the story: why this news release will interest their readers, listeners, or viewers and why the information is timely. Use facts, not adjectives. Catch editors with the first 10 to 15 words of the first sentence, and then finish the paragraph by giving credit to the U.S. Geological Survey, Department of the Interior.

Now that you have the editors' attention, expand on the news given in the first paragraph. Start filling in the who, why, what, when, where, or how that will show why the readers, listeners, or viewers will want to and need to know the hard news.

The second or third paragraph is a good place to acknowledge your cooperators, but don't lose an editor with a lot of backscratching.

According to most news-release writers, by the fourth paragraph, the editor is looking for some single identified authority to quote. Someone who can give the facts in a short, pithy way as if talking directly to the reader. Someone who can add a human element to the release. Someone who can give the editor quotable--and believable--quotes.

(more)

2

The release should be understandable to a teenager or the nonscientist next door. Read the release aloud to yourself or to a nonscientist to see if it's understandable. Write in short paragraphs. Write in short sentences. Use familiar words. Write to be read.

By now you have given the editors the heart of the story. Expand on the hard news in the remaining paragraphs, but don't save any vital facts until last. From here on the paragraphs are more and more expendable and may be sacrificed to fit the space available.

To help prevent errors in rekeyboarding, complete your paragraphs on a page and don't split words at the end of a line. Double space the first paragraphs to allow the editor room to edit and rewrite.

If appropriate at this point, you should list the title, authors, series, number, price, and availability of any covering report: Copies of the _____ page report, "Title of the Report," by (Author's Name) and published as U.S. Geological Survey (report series and no.), are available from the USGS (office that distributes the report).

If you have a collection of interesting facts to cram into the release, run them as separate filler items at the end:

- o Be professional. Avoid technical jargon, but don't insult the intelligence of your readers. Include illustrations. Photographs of scientists at work and simplified maps showing key localities are possibilities.
- o A release needs to reach the right editors or desks. Do not send it just to your favorite reporter; you will lose more news media friends than you will make. Work with the USGS Public Affairs Office to develop a good mailing list.
- o You need not announce at the beginning that this is a NEWS RELEASE. The release date and the format will convey that to the editor. Similarly, you don't need a covering memorandum announcing that you are attaching a news release.
- o If a page is to be followed by another page, type "(more)" at the bottom of the page. And finally, end the release with a mark that lets the editor know that you are done:

3

* * * USGS * * *

(Note to editors: Sometimes, in this space between parentheses, a "Note to Editors" might advise of the availability of a photograph or a special contact for additional information. For more information, call the Public Affairs Office.)

detailed information on how to proceed. Your first draft should lay out the most interesting and important scientific facts. Reviewers in the Public Affairs Office (Reston) will help add polish, ensure necessary clearance, and provide wide distribution to news media.

Clearing a news release can be difficult and frustrating. Why? One explanation is that people in high places read more news releases than scientific reports, especially releases picked up by a wire service, a large newspaper, or the TV evening news. News releases are also sent directly to members of Congress and other key officials, and because of such high-level distribution, they often receive detailed high-level review and clearance, particularly any news release that deals with sensitive or national issues. Each Survey Division has a liaison officer who works with the USGS Public Affairs Office in clearing news releases. Some regional offices also have special liaisons. Check with your supervisor or the Public Affairs Office in the Office of the Director for further information.

Some news releases are issued by field offices—usually releases dealing with basic data reports or new reports or maps of local interest. Procedural guidelines are spelled out in the Survey Manual and the Department of the Interior Manual. When in doubt, call the Public Affairs Office. That office can help you with official clearance and can also provide practical advice on mailing lists, release dates, and other details that could make or break a story no matter how good the words or subject.

When the USGS celebrated its 100th anniversary, it adopted the slogan "Earth Science in the Public Service." That slogan reflects the justifiable pride of the Survey in the quality of the earth science we have provided since 1879 and also our rededication to continue to serve the public.

## Writing a News Release

Before you begin to write, scan some past news releases to see what has worked before. Much of what you have done to produce a technical report or a scientific talk will not work. You are writing now for the news media and for a different readership.

The release date at the top of the front page is part of the recognized news-release format. Most news editors appreciate a set date of release and will honor it. The set date lets reporters know how much time they have to expand on your story before the news will break. There may be a reason to set a release date in the future. If the story is too hot to allow lead time, or there is no reason to set a release date in the future, give the date of preparation so that editors know how old the story is. If the story is even hotter, you probably should telephone it in.

The preceding example in news-release format outlines some of the needs, mechanics, and reasons for writing news releases.

## Talking to the News Media

An advantage of a news release is that facts as you see them are set down on paper. Chances of mistakes and misinterpretations between you and the reporter are minimized.

Interviews with reporters and broadcasters also provide opportunities to communicate with the public, but the risks of error and misunderstanding are heightened. A suggestion: Bosses don't like surprises; let them know you have been interviewed before they read it in the morning paper or before their own boss calls. Handle questions discreetly, and check with your boss before the interview if possible. Additional guidelines: (1) stick to your own field of expertise; (2) avoid discussions of programs and budgets; (3) if you are uncomfortable with the way a question has been asked, have the interviewer restate the question, and then answer it.

## Letters to Editors

Letters to editors, including letters to forums in scholarly journals, can be useful and sometimes entertaining, and they help relieve stress. They also can backfire or produce stories we would rather not read about. As private citizens, we have the right to write, but as employees of the Survey, we have a responsibility not to involve the Bureau in our private fights. The higher one rises in the organization, the harder it is to separate the public role from the private and the harder it is to disclaim the mantle of writing as an official spokesman. The Survey has a proprietary interest in any such communication involving information and views gathered directly or indirectly as a result of your employment with the USGS. These communications, therefore, require formal Division and Bureau approval through the "Director's approval" process. It is then appropriate for your communication to show affiliation with the USGS. Given these conditions, it is *not* appropriate to use your home address or to use your home address to circumvent formal approval.

Letters and similar communications to journals, magazines, newspapers, and other media do not require technical review, Branch approval, or Survey editorial scrutiny, but for Division and Bureau approval, submit your draft directly to the Associate Chief, Office of Scientific Publications, at the National Center, Reston, VA 22092.

# HAZARD WARNINGS

THE HAZARD WARNING and Preparedness Program is the Survey's mechanism for assuring that the public and its officials get hazard information quickly and in a suitable form. Begun in 1976 in response to congressional legislation, this program coordinates, evaluates, and disseminates information and warnings of geologic-related hazards.

Survey guidelines require that you document a geologic hazard upon discovering it and, if the danger is not imminent, contact your Branch or District Chief, who will forward the assessment through your Division to the Assistant Director for Engineering Geology. The Division Chief is generally responsible for getting expert review of the data and conclusions. The Assistant Director for Engineering Geology is generally responsible for getting approval from the Director to issue a formal Geologic Hazard Warning and to forward the notification to appropriate Federal, State, and local agencies and to the public through news media.

As stated in the Federal Register of January 31, 1984, a Geologic Hazard Warning by the Director of the Geological Survey is a formal statement about a specific geologic condition that poses a significant threat to the public and for which some timely response would be expected. The criteria for a Geologic Hazard Warning are as follows:

- A degree of risk is greater than normal for the area or a hazardous condition has recently developed or has only recently been recognized.
- A threat warrants consideration of a near-term public response.

Information that fails to meet these criteria may also be sent by the Director to public officials, but such information would not constitute a Hazard Warning.

## IF YOU DETECT A GEOLOGIC HAZARD

If you identify a hazardous condition, you should document the hazard as precisely and completely as possible. A Geologic Hazard Warning contains the following elements:

- A description of the geologic or other pertinent conditions that cause the concern.
- Factors that indicate such conditions are hazardous.
- Location or area that may be affected.
- Estimated severity and time of occurrence, if available information justifies such estimates.
- A probabilistic statement, if possible, on the likelihood that a given event or events will occur within a specific time period.
- A description of continued Survey involvement and an estimate of what and when additional information might be available.

If the hazard is a clear risk to life and property and there appears to be insufficient time to contact a responsible Survey official for scientific evaluation and policy review, you should make every reasonable effort to contact the affected parties and appropriate local public officials as soon and as directly as possible.

Direct notification to public officials in such emergencies should be limited to a statement of the conditions observed; it should not be expressed as an official Geologic Hazard Warning. As soon as possible after communicating the information to local public officials, you should notify both your supervisor and the Assistant Director for Engineering Geology of (1) the hazard observations, (2) the actions you took, (3) the current status of the hazardous condition, and (4) the actions taken by public officials. Information concerning hazardous situations will be submitted, upon receipt of such information, to a scientific evaluation panel for review and appropriate action.

For further information about the Hazard Warning and Preparedness Program, contact the Office of the Assistant Director for Engineering Geology, National Center, Reston, VA, 22092.

# FORMATTING SURVEY MANUSCRIPTS FOR REVIEW AND EDITING

THIS SECTION TELLS HOW to format a Survey manuscript for technical review, editing, and Director's approval, whether formatted by a typist or by you yourself. General guidelines that apply to the entire manuscript are listed first, followed by details specific to particular parts. Few manuscripts are likely to have every part listed here. Most of the information applies to any technical manuscript; information that is specific to formal USGS series books or maps is so indicated.

## WHERE TO BEGIN

Before you begin work on your manuscript, gather all needed materials. You will need a recent sample of the publication, publisher's instructions, pertinent style manuals (such as this book), published examples of particular items (such as measured sections), and any specialized dictionaries or reference books. Of course for checking spelling and word usage you will have access to a dictionary (USGS and GPO recommend "Webster's Third New International Dictionary" for spelling), and "The Glossary of Geology, third edition" (Bates and Jackson, 1987). If your manuscript is to be published by the USGS, your local manuscript processing office will have guidelines for you. Take a few minutes to look through what is appropriate in those instructions and books so that your keyboarding session will be efficient and fruitful.

## GENERAL GUIDELINES FOR THE ENTIRE MANUSCRIPT

1. Use 8½- by 11-inch white paper; continuous-feed computer paper is acceptable, but you should set the page length so that copy does not print on or close to the bottom or side perforations.
2. Leave a margin of at least 1 inch all around each page.
3. Number pages consecutively; if there is a break, indicate in the following manner which page follows:

   18 (p. 34 follows)

   This kind of notation assures a reader that no pages are missing. Letters can be added to page numbers (when material is inserted, for example), but the page following the last lettered number should be indicated in the same way:

   18d (p. 34 follows)

4. Double space all text, tables, and figure captions.
5. Avoid dividing words at the end of a line; use the wraparound feature on word processor or computer (so there are no carriage returns at the ends of sentences within a paragraph).
6. Complete paragraphs on a page, for easier review and editing, even if the page runs short.
7. Rank of heading is indicated by number of spaces the heading is indented in the table of "Contents."

   **Professional Papers.**

   CENTER AND CAPITALIZE
   ALL HEADINGS

   **Bulletins, Circulars, and Water-Supply Papers.** Type headings flush left for first three ranks and center headings of lower rank; capitalize or lowercase letters as follows:

   FIRST-RANK HEADING ALL CAPS, flush left

   Second-Rank Heading Cap and Lowercase, flush left

   Third-Rank Heading Cap and Lowercase, flush left

   Fourth-Rank Heading Cap and Lowercase, center

8. Leave right margins ragged (not right-justified)—copy is easier to read.
9. Underline letters or words that are to be typeset in italic if your word processor does not have an italic typeface.
10. Capitalize and abbreviate according to guides in this book and in the GPO Style Manual for reports to be published by the USGS. Follow publisher's guide for reports to be published outside the USGS.

## NOTE FOR "NEW PUBLICATIONS OF THE U.S. GEOLOGICAL SURVEY"

All USGS books and all maps that are accompanied by text must have a brief note for the monthly list "New Publications of the U.S. Geological Survey." This note, written by the author and generally limited to about 75 words, may be titled "Note for Monthly List of Survey Publications" or perhaps just "Note for Monthly List." In the sample below, note format, spacing, and punctuation. Price is not entered for USGS Circulars because they are free. Make copy double spaced, with 1-inch margins.

Observe that the note for the monthly list is neither an abstract nor a synopsis. It describes the general content of the report but states no technical conclusions.

NOTE FOR MONTHLY LIST

Professional Paper

Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio, by M.R. Winslow. 19 . p. $ .

About 80 species of microfossils have been described and illustrated from beds usually regarded as sparsely fossiliferous. About 130 horizons from 10 localities in northern and central Ohio were sampled from outcrops, cores, and well cuttings to establish the basic pattern of distribution for land plant spores and sporelike marine microfossils in Upper Devonian and Lower Mississippian Formations. Thirty-five of the most abundant and characteristic species have been named; four new genera are represented.

## FRONT MATTER

Front matter includes a title page and a table of contents that generally includes lists of illustrations and tables. Front matter also may include a frontispiece, false title page, foreword, and preface. If there is to be an art cover, you should provide a brief description of it; this description is printed on one of the first inside pages of the book. You may be asked to provide copy for the cover and backstrip of a USGS book. Any cooperative statement is placed on the cover, as well as on the title page. Double space all text in front matter.

## TITLE PAGE

Use the title page of a recent version of the series in which your report will be published as a guide to style, capitalization, and spacing. If words on the printed page are in italic (such as the word "By"), underline similar words on the copy you are preparing to indicate to the typesetter that those words should be set in italic. Follow the style of any descriptive note or cooperative statement for the particular series. Double space everything.

## CONTENTS

Use a recent version of the publication as a guide to formatting the contents, including lists of tables and illustrations. Align figure and table numbers on the period. Pay particular attention to indention of headings, as this indention indicates rank. Five spaces is the general rule for indentions; overruns are indented five spaces also, but may be indented more to avoid conflict. On a typewriter, word processor, or computer, use tab settings for these indentions rather than spaces. If headings are continued on a succeeding page, write each continued heading as follows so that the rank is preserved:

First-rank heading--Continued

Second-rank heading (indented five spaces)--Continued

New third-rank heading (indented five spaces) ----------------

Either dot or dash leaders are acceptable. Run the leader from the last line of the entry (see sample "Illustrations" page). Some publications, such as the 8½- by 11-inch USGS Bulletin, have no leaders at all. Type page numbers at the end of the leaders to indicate to the reviewer or editor the page in the manuscript on which the item (such as a figure) appears or the page on which it is first mentioned. Double space all entries, and leave 1-inch margins.

## LIST OF ILLUSTRATIONS

The list of illustrations, which follows the "Contents," consists of short titles (not necessarily the entire caption), in which the illustrations are identified as to kind, such as map, diagram, or photograph. Four or more similar kinds of illustrations listed consecutively may be grouped and indented under one descriptor (see 3–6 in sample on facing page). Plates are listed before figures, regardless of where plates appear in the manuscript. Numbers are aligned on the period. Overruns are indented five spaces. A copy of the publication is your best guide to capitalization of "figure" and "plate." Double space all entries. Leave 1-inch margins.

[Sample of contents page]

CONTENTS

Page


Abstract -------------------------------------------------------------------------------- 1

Introduction ---------------------------------------------------------------------------- 1

Analytical methods ---------------------------------------------------------------------- 2

' Sample selection and preparation ------------------------------------------------- 3

Chemical methods ------------------------------------------------------------------- 4

Computer techniques ---------------------------------------------------------------- 6

Petrography ----------------------------------------------------------------------------- 7

References cited ------------------------------------------------------------------------ 11


[End sample contents page]

## LIST OF TABLES

Type the list of tables the same way as the list of illustrations. Tables also can have short titles and be grouped according to kind. Overruns are indented five spaces, numbers are aligned on the decimal, and all entries are double spaced.

## FIRST PAGE

Title, authorship, and abstract generally go on the first page, but a recent copy of the publication will be your best guide. A long abstract may continue for several pages.[1] Page numbering begins with Arabic 1 on the first page and continues to the end of the report. (See also item 3 under "General Guidelines for the Entire Manuscript.") Leave at least 1-inch margin on all sides.

[1]A footnote before the end of the abstract (such as for an author's affiliation) is double spaced at the end of the abstract under a line about 16 spaces long. The footnote number is a superscript, the first line of the footnote is indented five spaces (use a tab), and any overruns are flush left. Footnotes are numbered consecutively throughout the text. Footnotes in tables are independent of those in text.

[Sample list of illustrations page]

ILLUSTRATIONS


| | | Page |
|---|---|---|
| Plate 1. | Fossils found in the Santa Rita quadrangle | 45 |
| | [If plate were an oversize map, it would be shown as follows:] | |
| 2. | Geologic map of the Santa Rita quadrangle | In pocket |
| Figure 1. | Index map of New Mexico [this entry is being extended to show that overrun is indented five spaces and that entries are leadered from the last line] | 6 |
| 2. | Columnar section of layered rocks | 10 |
| 3-6. | Photographs: | |
| | 3. Percha Shale-Lake Valley Limestone contact | 15 |
| | 4. Box Member of Percha Shale | 23 |
| | 5. Oswaldo Formation | 25 |
| | 6. Syrena Formation | 31 |
| 7. | Diagram showing Larsen plot of volcanic rocks | 34 |
| 8. | Map showing internal structure of rhyolite plug | 36 |


iii

[End sample list of illustrations page]

## BODY OF TEXT

Double space all text. Allow at least 1-inch margins all around each page. Indent paragraphs five spaces (use a tab). Try to complete each paragraph on a page.

Paragraph heading.--Type the paragraph heading as shown here--indent as for a paragraph, underscore, period, hyphen, hyphen (in print the hyphens will be replaced by a long solid line called a one-em dash). This heading is used for topics that require only a paragraph or two, such as the description of a series of minerals found in a certain rock unit. Paragraph headings may be a subheading under any order of heading and usually are omitted from "Contents."

# FIGURE AND TABLE REFERENCES IN TEXT

After the paragraph that has the principal reference to a figure or table, insert a note indicating where the figure or table is to be placed in the printed text as shown in the following sample:

[blank line]

**FIGURE X.--NEAR HERE**

[blank line]

[blank line]

**TABLE X.--NEAR HERE**

[blank line]

Leave a blank line above and below the insert, as shown. Note that the insert is typed in boldface (but plain capitals are acceptable if your machine won't accommodate bold). No such insert is needed for a plate reference, because plates are either at the end of the book or in a pocket. In a USGS series publication, figure and table references in the text are not capitalized, and "table" is never abbreviated. "Figure" and "plate" are abbreviated (fig. and pl.) only where they appear inside parentheses or in tables.

[Sample text pages]

HISTORY OF THE VOLCANO

Mount St. Helens is a symmetrical volcanic cone in southwestern Washington about 75 km northeast of Portland, Oreg. (fig. 1). Most of the visible part of the cone has been formed within the last thousand years, but it overlies an older volcanic center that evidently came into existence before 36,000 years ago (Hyde, 1975, p. B10). Mount St. Helens has had a long history of spasmodic explosive activity, and we believe it to be an especially dangerous volcano because of its past behavior and the relatively high frequency of its eruptions during the last 4,500 years (table 1).

**FIGURE 1.--NEAR HERE**

**TABLE 1.--NEAR HERE**

In the future, Mount St. Helens probably will erupt violently and intermittently just as it has in the recent geologic past,[1] and these future eruptions will affect human life and health, property, agriculture, and general economic welfare over a broad area.

[1]Place a footnote under a rule about 16 spaces long at the end of the paragraph in which the footnote is first used. The footnote number is a superscript, the first line of the footnote is indented (tabbed) five spaces, any overruns are flush left, and copy is double spaced.

[End sample text pages]

## FORMATTING ILLUSTRATIONS AND THEIR TITLES (CAPTIONS)

Each illustration (figure, plate, map) has a title or caption. An illustration can also have text, such as an explanation or description of map units. All captions and any text that is part of a figure or plate should be typed double spaced for reviewing and editing.

Each illustration must be referred to in the text.

Number illustrations consecutively in the order of their principal reference. If illustrations are added, combined, or deleted during review or editing, do not renumber at this stage (which might introduce errors). Use the following scheme and indicate changes in the short list of illustrations in "Contents."

1. Illustration added—Add letter to number of previous figure. Thus, an illustration added after figure 2 would be numbered figure 2A.
2. Illustrations combined—Use lowest figure number of illustrations combined. Thus, combined figures 3, 5, and 6 would be numbered figure 3.
3. Illustration deleted—Show deletion in "Contents" list.

Show these transactions in the "Contents" short list of illustrations as follows:


Figure 1------------------------------------------

Figure 2------------------------------------------

Figure 2A (added)---------------------------------

Figure 3------------------------------------------

Figure 4 (deleted)

Figure 5 (combined with figure 3)

Figure 6 (combined with figure 3)

Figure 7------------------------------------------


Illustrations are renumbered before Director's approval.

A duplicate of the illustrations list is a useful inventory item to accompany the illustrations themselves in the mill copy of your report during further processing.

The mode of publication determines placement of figure and caption in the draft copy of the manuscript, as follows:

**USGS book and map series only.** Each figure caption is on a page by itself. Attach figure caption page to the mill copy of the figure; also attach a completed "Author's Check List" to the mill copy of the figure or map. The "Author's Check List" is the yellow sheet—Form 9-1517 (revised March 1987). Do not interleave the illustrations themselves in the manuscript; place them at the end of the mill copy of the report (with the figure caption and the "Author's Check List").

**USGS Open-File Reports only.** Place caption below illustration on the same page.

**Reports for outside publication.** Follow instructions from journal or publisher.

### Sample Figure Captions

Use the following styles for figure captions in USGS book reports. Note capitalization, punctuation, and spacing. Underline letters that represent parts of the figure (A,B) to indicate italic. The caption for fossil photographs that will be plates in a USGS book has a different style. A good general rule is to follow the style of a recent publication.

#### USGS Professional Paper and Techniques of Water-Resources Investigations

FIGURE 13.--Fort Union Formation, east side of Crooks Gap, Wyo., in NW1/4NW1/4 sec. 17, T. 28 N., R. 92 W. A, Localities from which pollen samples were collected (open circles); B, Uranium prospects (solid circles).

If more than two lines, the first line of caption is flush left and overruns are indented five spaces.

#### USGS Bulletin, Circular, and Water-Supply Paper

Figure 1. Fort Union Formation, east side of Crooks Gap, Wyo., in NW1/4NW1/4 sec. 17, T. 28 N., R. 92 W. A, Localities from which pollen samples were collected (open circles); B, Uranium prospects (solid circles).

Note that this format differs slightly in that "Figure" is cap and lowercase, no dash follows period, and first line and overruns are flush left; all other elements remain the same.

#### Short Title

The following example shows how to condense the long caption to a short title for the "Contents" list of illustrations (indention depends on style of publication).

Maps showing localities of pollen samples and uranium prospects in the Fort Union Formation near Crooks Gap, Wyo.

## Formatting and Typing Tables

Tables for review or editing should be typed double spaced, except for column heads, which may be single spaced. If tables are long and time is of the essence, legible handwritten copy is acceptable. Keep in mind, however, that the tables will have to be keyboarded and proofed at some stage, so you must plan time for that. Follow the style and format of the book or map in which the table will be published. (See also section on tables, p. 216.)

Margins on the table must be adequate—at least 1 inch, and preferably as much as 1½ inches—on all four sides. Fold oversize tables to page size if possible using accordian-type folds so that the table number and at least part of the title appear at the top and the page number appears at the bottom. Make folds between columns to avoid damage to the typed matter. (Extremely large tables may need to be rolled instead of folded, and camera-copy originals should not be folded.)

At the end of the paragraph that contains the first principal reference to a table, insert a note indicating where the table is to be printed (see preceding section on figure and table references). The table itself is the next page of text (except for tables so large that they must be rolled instead of folded), and each sheet of the table is given a sequential text page number. (If you are preparing camera-ready tables, talk first to an editor.)

### Parts of a Table

#### Title

All tables, like figures, should stand alone—that is, a reader should be able to get the gist of a table without having to refer to any other part of the report. The title, therefore, should include as much information as is necessary for comprehension, including the geographic location. No ending period follows the title in USGS publications (unless the last word is abbreviated). Some titles should be underlined for italic. If a table is continued from one sheet to another, repeat (1) the title followed by "—Continued," (2) any explanatory material, either inside or outside brackets, between the title and the body of the table, and (3) any column headings. Follow the style of the book or map series in which you plan to publish the table. Use sample figure captions as guides for typing titles of various lengths.

### Bracketed Headnote

Include qualifying or explanatory information relevant to the table in a bracketed headnote. Brackets are the preferred punctuation mark for indicating such supplied information.

[A bracketed headnote follows the title and is typed double spaced. Use sample figure captions as guide to placement of lines and indentions. Headnote can be written in telegraphic style (as is a figure caption). Headnote contains such items as the definition of any abbreviations or acronyms used in the table: ppm, parts per million; Tr., trace; m, meters. Analysts: Dorothy Covel and Benton Curtis. Internal punctuation can be used, but no period at the end (unless the last word is abbreviated)]

### Leaders

Leaders in a table serve (1) to carry the eye from a reading column to the next column and (2) to indicate something within a column. Use dot or dash leaders for the first type and three hyphens, ---, for the second. Define the second type in the bracketed headnote.

| Material present | Amount, in ppm |
|---|---|
| Green stuff ---------------------------------------- | 6.9 |
| Orange and red stuff ------------------------- | --- |
| Orange and blue stuff------------------------ | 7.8 |

### Horizontal and Vertical Rules

Place a rule the width of the table at the beginning and end of the table; if the table is 10 pages long, the end rule goes only at the end of the table on page 10, not at the end of each page of the table. The GPO style manual describes use of rules within the table. Use vertical rules sparingly.

## CAMERA-READY TEXT AND TABLES

Because of the cost savings involved, camera-ready text and tables (those that can be photographed onto a printing plate for reproduction) are becoming increasingly popular. They are used in many Survey reports and maps (for example, USGS Professional Papers 852 and 1052, and Circular 827). Many outside publishers require camera-ready copy, particularly for abstracts. Camera-ready text and tables must be typed perfectly because the copy is the final one required for reproduction.

Print text or tables on a letter-quality printer after final corrections and formatting. Use good-quality bond paper; continuous form paper is not recommended but is acceptable if nothing else is available (do not print on perforations).

Text or tables stored in a computer can be transmitted electronically to another system and printed out on any good quality printer linked to the system. Printing terminals allow different print fonts, line spacing, 10 or 12 characters per inch (pitch), and even fine touches such as justification with incremental word/letter spacing and line measures (number of picas). Copy from a line printer or from dot matrix printers generally does not make good camera-ready copy.

### GUIDELINES

The following guidelines are useful for typing camera-ready tables:

1. Width is the most important dimension of the table. For best results, type tables at least 10 percent larger than publication size, but not larger than 50 percent. Use all the horizontal space. To arrange the data neatly within the allotted space, try this method: Select the longest line from each column and type all the words on one line. Check to see if the line will reduce to column width, page width, or broad measure. Then divide the space remaining between the end of this line and the right-hand margin for the required width into equal parts and apportion this space between the columns. Be sure to separate columns by at least two spaces.

2. Type all material in camera-ready tables single spaced, with the following exceptions:

   2.1 Use half-spaces above and below all horizontal rules (except above the top horizontal rule).

2.2 To make tables easier to read, insert a blank line after every four or five lines of data. To decide when to skip a line, add up the number of lines, and then determine what number the total is most easily divided by—four, five, or six—and place blank lines accordingly.

2.3 If subscripts or superscripts overlap adjacent lines, allow more space between lines. The method for doing this varies with the machine.

3. If titles and bracketed headnotes of tables in USGS books will be set by the typesetter, type the title on a separate page. At the top of camera-ready copy of the table, type the table number and title, and the name and typeface of the element (or the name of the print wheel or program) you used, so that corrections can be made if necessary.

4. Center column headings horizontally above the columns and vertically between the cross rules or as close to vertical as is possible.

5. Type horizontal rules if your printer makes a smooth, neat line. If not, mark the rules in blue pencil and have them drafted. If vertical rules are necessary (they seldom are) have them drafted.

6. Type footnote numbers within and at the bottom of the table as superscript numbers. The shelf (_/), which sometimes is marked on manuscript copy to indicate footnote numbers, should not be typed on camera-ready copy. If a Greek-math typing element, print wheel, or program is available, the small numerals on it should be used instead of full-size superscripts.

7. Avoid underlining (to indicate italic) in tabular matter. If italic type is required in a table, use an italic print wheel or typing element that makes a crisp, dark imprint. Paleontologic names may be underlined, however, if italic is unavailable.

### Maximum, Minimum, and Ideal Widths for Camera-Ready Tables Prepared for USGS Publications

Widths are herein listed in inches. Widths are based on readable reductions of standard 12-pitch type (12 characters per inch). Tables typed in 10-pitch type (10 characters per inch) can be about 20 percent wider (table 15).

## Equations

Equations can be typed or handwritten legibly for review and editorial purposes. Most letter symbols in equations are set in italic; logarithmic and trigonometric functions, chemical symbols, and units of measure are not italic. Indicate italic to the typesetter by underlining each letter. Underlining can be done by hand on typed copy, if it is too difficult or time consuming to do on a machine. Center equation on the manuscript page and place the equation number in parentheses at the right margin.

In text, reference is to equation 1 (no parentheses around number). The equations on the facing page show format, spacing, and usage (U.S. GPO Style Manual, p. 155–156). If you need to prepare camera copy of equations, your local editor may have current advice.

**Table 15.** Widths, in inches, for camera-ready tables

| Type of publication and form of presentation | Publication width | Typed camera-copy widths | | |
|---|---|---|---|---|
| | | Maximum[1] | Minimum | Ideal |
| Professional Paper: | | | | |
| Column width | 3.5 | 5.3 | 3.9 | 4.4 |
| Page width | 7.2 | 10.8 | 8.0 | 9.0 |
| Side title | 9.0 | 13.5 | 10.0 | 11.3 |
| Bulletin, Circular, Water-Supply Paper: | | | | |
| Column width | 3.3 | 5.0 | 3.7 | 4.2 |
| Page width | 6.9 | 10.4 | 7.7 | 8.6 |
| Side title | 9.2 | 13.8 | 10.2 | 11.5 |
| Techniques of Water-Resources Investigations | | | | |
| Column width | 3.2 | 4.8 | 3.5 | 4.0 |
| Page width | 6.5 | 9.8 | 7.2 | 8.1 |
| Side title | 8.7 | 13.0 | 9.6 | 10.8 |
| MF map: Column width[2] | 4.0–4.5 | 6.0 | 4.0 | 5.0 |
| Other maps: Column width[2] | 4.2–4.6 | 6.0 | 4.2 | 5.0 |

[1]Tables wider than the suggested maximums may be unavoidable, but be aware that every extra fraction of an inch over the maximum decreases the legibility and quality of reproduction of the table.

[2]Tables may be designed to span any number of text columns. To find recommended size for typed copy, multiply the column-width figure by the number of text columns to be spanned, and then add 0.5 in. for each column more than one.

$$\sqrt{\Phi} = \sum_{h=0}^{m} k(A_k \cos k_\psi + B_k \sin k_\psi)) \qquad (1)$$

$$\frac{e}{e_0} = \frac{1}{\sqrt{\left[1-(f/f_M^2)+\frac{C_M}{c}\right]^2+\left[\frac{r}{X_{c_M}}\right]^2}} \qquad (2)$$

$$\begin{aligned} O &= \left(\frac{p_2}{p_2}\right)^{\frac{1}{\gamma}} \left\{2gp_1 v_1\left(\frac{\gamma}{\gamma-1}\right)\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{1}{2}}\right\} \\ &= A_2 \frac{p_1}{v_1}\left(\frac{\gamma}{\gamma-1}\right)\left[\left(\frac{p_2}{p_1}\right)^{\frac{2}{\gamma}}-\left(\frac{p_2}{p_1}\right)^{\frac{\gamma+1}{\gamma}}\right]^{\frac{1}{2}} \end{aligned} \qquad (3)$$

$$\begin{aligned} \omega_n(x,\theta_x) = & \frac{1}{\sqrt{r_1 r_2}} \int_0^x dx_2 \int_0^{x_2} dx_1 \cos n\psi_x(x_1,x_2) \\ & \left[\frac{r_1 r_2}{p_1 p_2}(\phi_{n-1}(k_1)+\phi_{n+1}(k_1))+2\phi_n(k_1)\right] \end{aligned} \qquad (4)$$

$$\begin{aligned} m_{s_1 s_2} = & \int_{x_{i_1}}^{x_{i_1}} dx_1 \int_{x_{i_n}}^{x_{i_n}} dx_s \int_0^{2\pi} \frac{d\theta_1}{2\pi} \\ & \int_0^{2\pi} \frac{d\theta_2}{2\pi} \frac{\frac{r_1 r_2}{p_1 p_2}\cos(\theta_2-\theta_1)+1}{\sqrt{(x_2-x_1)^2+R^2(\theta_2-\theta_1)}} \\ = & \int_{x_{i_1}}^{x_{i_1}} dx_1 \int_{x_{i_n}}^{x_{i_n}} dx_2 \int_0^{2\pi} \frac{d\psi}{2\pi} \frac{\frac{r_1 r_2}{p_1 p_2}\cos\psi+1}{\sqrt{(x_2-x_1)^2+R^2(\mathrm{c})}} \end{aligned} \qquad (5)$$

$$\begin{aligned} \sum_2(\psi_n,c_n) = & \; 2_{c_2}\frac{\tan(2_{\psi_2}-_{\psi_1}) \quad \tan(2_{\psi_3}-_{\psi_2})}{\cos(2_{\psi_3}-_{\psi_2})+6c_3\cos(2_{\psi_4}-_{\psi_3})} \\ & +14c_4\frac{\tan(2_{\psi_4}-_{\psi_3})}{\cos(2_{\psi_5}-_{\psi_4})}+\ldots \\ & +2(2^{1+n}-1)c_{n+2}\frac{\tan(2\psi_{n\pm 2}-\psi_{n+1})}{\cos(2\psi_{n+3}-\psi_{n+2})}\ldots \end{aligned} \qquad (6)$$

## MEASURED SECTIONS

General directions for preparing measured sections are given on page 54. Instructions for keyboarding follow:

Measured sections are similar in format to tables in many ways. For example, the title of a section is underlined for italic, and the final period in the title is omitted (unless the last word is abbreviated). Abbreviate units of measurement, such as m and cm, when used with a value. Double space all entries in manuscript.

Repeat the title of a measured section (followed by "—Continued") and the column headings on continued pages. This repetition helps the typesetter and reader maintain correct stratigraphic ordering. To avoid excessive repetition, especially if the title is long, use paper longer than regular manuscript paper. Do not repeat the bracketed headnote.

Do not break the description of individual stratigraphic units at the bottom of a page. However, the section may be broken between units, with the proper headings repeated on the next page followed by "—Continued" as shown on the sample measured section.

If description requires more than one line, indent overruns at least two spaces. Indent total lines about three or four spaces more than the spaces allowed for overruns so as to emphasize the total. In deciding whether to put rules above or below the total values, much depends on what is being totaled throughout the section. Look at published sections, use judgment, and perhaps seek the advice of an editor. The annotated section that follows may be useful.

Some reports contain many measured sections, which may be scattered through the text or grouped at the end of the report. If many sections are grouped together, you may number the sections ("Section 1," "Section 2," and so on) to facilitate cross reference (see sample).

[Sample measured section]

```
        Section 1.--Three Forks, Jefferson, and Maywood Formations, and
         Devils Glen Dolomite along ridge on west side of George Gulch
        [SW1/4 sec. 31, T. 22 N., R. 9 W.; measured by M. R. Mudge,
        August 1974]

                                                              Thickness
                                                               (meters)
fl  Allan Mountain Limestone.
align  Three Forks Formation:
points
    4  12. Limestone, very fine grained, grayish-brown,
             very thick bedded; weathers gray; brachiopod
             fragments--------------------------------------- 25.9
       11. Evaporite-solution breccia containing fragments
             of limestone and magnesium limestone, light-
             yellowish-brown, massive; forms prominent ledge- 18.5
              2 Total Three Forks Formation----------------- 44.4
    Jefferson Formation:
    2 Birdbear Member:
    4  10. Limestone, dolomitic, very pale orange, thick
             bedded; forms ledge----------------------------- 12.2
       #9. Dolomite, calcitic, light-brownish gray; very thin
             bedded; weathers platy-------------------------- 6.1
              2 Total Birdbear Member----------------------- 18.3
    2 Lower member:
    5  #8. Dolomite, finely crystalline, dark-yellowish-brown;
             weathers yellowish gray; calcite-line pits------ 8.2

                                 33
```

## Disclaimers

The Geological Survey has a longstanding policy of avoiding the use of trade, product, industry, or firm names in its reports. The purpose of this policy is to maintain the Survey's unbiased objectivity in the eyes of its readers. At times, however, the Survey must use trade or product names to identify particular things that have unique properties. Industry or firm names rarely must be used to aid in identifying sampling or study sites, especially if these sites have been publicly identified. The use of industry or firm names in connection with statements about sources of pollutants or factors causing changes in natural or artificial systems has never been permitted. Since 1988, Survey policy has been to put the trade and company (product) names disclaimer on the back of the title page of all Survey book reports, regardless of whether or not any such names are used in a given report. Use the wording given in the footnotes at right (but without the footnote number and end period). In Survey map series reports, place the same disclaimer in the lower right corner of the map, above the for-sale note. Survey authors publishing outside the Survey should footnote the first usage of such a name and place the disclaimer at the end of that paragraph as you would any footnote, as follows:

---

[1]Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

The following disclaimer may occasionally be appropriate, and the same guidelines apply:

Section 1. Three Forks, Jefferson, and Maywood Formations, and Devels Glen Dolomite along ridge on west side of Big George Gulch--Continued

| | Thickness (meters) |
|---|---|
| (f1) Jefferson Formation--Continued | |
| 2 Lower member--Continued | |
| 4 #7. Dolomite, porous; dark-brown; weathers blocky, fetid odor | 14.6 |
| 2 Total lower member | 22.8 |
| Total Jefferson Formation | 41.1 |
| Unconformity. | |
| Maywood Formation: | |
| 2 Upper member: | |
| 4 #6. Limestone, magnesium, brownish-gray, thin-bedded | 18.3 |
| #5. Dolomite, pale-yellow, thin-bedded; weathers blocky | 15.2 |
| 2 Total upper member | 33.5 |
| 2 Lower member: | |
| 4 #4. Mudstone, gray, iron-stained; weathers olive green | 6.1 |
| #3. Limestone, dolomitic, grayish-brown; fine laminated in upper part | 9.1 |
| #2. Mudstone, like unit 4 | 7.6 |
| 2 Total lower member | 22.8 |
| Total Maywood Formation | 56.3 |

align points

34

[End of sample measured section]

[1]The use of trade, product, industry, or firm names in this report is for descriptive or location purposes only and does not constitute endorsement of products by the U.S. Government nor impute responsibility for any present or potential effects on the natural resources.

Two other types of disclaimers also are used by the Survey. The first generally is used on Open-File Reports, but either may be appropriate for other types of reports as well. Use only those parts of the disclaimer that actually apply to the report.

1. For reports generated within the Survey:

    This report (map) is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code.

2. For reports prepared by contractors or grantees:

    This report (map) was prepared under (contract to) (a grant from) the U.S. Geological Survey and has not been reviewed for conformity with USGS editorial standards or with the North American Stratigraphic Code. Opinions and conclusions expressed herein do not necessarily represent those of the USGS.

If you plan to publish a computer program, you may want to include a disclaimer either on the title page or in the introduction. There is no formal wording for such a disclaimer, but what you want to tell readers is that the program runs on your machine but might not run on theirs.

# REFERENCES CITED

## REFERENCE LIST

The reference list in Survey publications generally is called "References Cited." Basic guidelines for formatting references are summarized here. Detailed instructions for preparing references in USGS style are given in the section "Preparing References for Survey Reports," page 234.

- All entries are double spaced.
- Overruns in a reference are indented five spaces.
- References are arranged alphabetically by author and chronologically under each author's name, the earliest publication first.
- A dash about six typewritten spaces long (use underline) can take the place of exactly the same name(s) in the previous citation.
- If there is more than one reference by the same author (or exactly the same group of authors) in the same year, letters are added to the year to make the distinction.

- Authors' initials have periods, but no spaces, between them.
- All journal names are spelled out.
- Only first words and proper names are capitalized.
- Generally, only one colon per reference is used—after the title.
- Brackets indicate supplied information [translation of a title, for example].

The following generalized format is used for each citation in the reference list, depending on type of publication:

Author, Initial,Initial, year, Title:
City, State, publisher, pagination (for book);
Journal name, volume, pagination;
Series name and number, pagination.

### Unpublished Information

Unless approved for publication, a report "in preparation" is not listed under "References Cited"—to do so would mislead your reader. Such material is cited in text as unpublished data or unpublished mapping. Information acquired from other workers is also cited only in text and as a written or oral communication.

If the name is a logical part of the sentence, cite in text as follows:

The cave was explored by P.C. Noble (unpub. data, 1978), or

P.C. Noble (unpub. mapping, 1979), or

P.C. Noble (oral commun., 1980), or

P.C. Noble (written commun., 1981)

If the name is not a logical part of the sentence, put the citation at the end, as in the following example:

The cave walls are mainly limestone (P.C. Noble, unpub. mapping, 1979).

Add an affiliation and an address after the name, if such information would be useful to the reader.

### Reference Citation in Text

References in text of Survey publications are cited as follows: If a paper has one or two authors, both authors' names should be used—in and out of parentheses. If the paper has three or more authors and if only one reference can be cited in that way, the reference should be to the first author "and others."

#### Samples of References Cited in Typed Text

Some of the pyrite with the uranium minerals is framboidal, according to Daniels and Gilbert (1966). According to Wilson and others (1973), however, the pyrite * * *. This report was prepared on the basis of earlier work in the area (Turner and Verhoogen, 1960; Wilson and others, 1973; Sohl, 1978; J.E. Hogan, written commun., 1973).

Two papers by exactly the same author (or exactly the same group of authors) in the same year are cited in text as "* * * according to Smith (1979a, b)."

Note punctuation (semicolons, commas, ellipses) and spacing. See section "Preparing References for Survey Reports" for more detailed instructions (p. 234).

## Halftitle Page

A halftitle page is used in a USGS book report before a group of items (tables or fossil plates, for example) at the end of a report to designate what follows. Double space this material and center it vertically on the page with a double rule before and after the typed material. (See facing page.)

## Appendixes

Appendixes are placed at the end of a USGS report and generally are preceded by a halftitle page. For more than one appendix, number (not letter) them consecutively. Type them in the same manner as text or tables and follow the same general rules for format, style, and spacing. List them in "Contents" after "References Cited."

## Formatting Abstracts for Scientific Meetings

Prepare double-spaced copy for review and editing as you would any manuscript. Send all technical review copies with the mill copy. You can print the abstract on a copy of the society's form to check the fit and ensure that you've made the best possible use of the space, but wait until Director's approval to print out the final copy.

The USGS asks authors to list their government mail address (as well as affiliation) so that readers know where to direct inquiries.

You'll need to be aware of how the society will process your abstract. Will the abstract be reduced from your camera-ready copy? If so, resist squeezing too much into too little space. Leave the right margin ragged because it's easier to read than right-justified text. Avoid ornate typefaces. Past programs are a source of both good and bad ideas. Copy from a proportional-space printer looks more typeset than that from other printers. An impact printer produces sharper copy than a thermal or dot-matrix printer. A reducing copier will help you see how your abstract looks when reduced.

[Sample halftitle page]

PLATES 2-7

Contact photographs of the plates [here, photographs of fossils] in this report are available, at cost, from the U.S. Geological Survey Photographic Library, Denver Federal Center, Denver, CO 80225.

[The number of lines in the title determines placement; follow guides in preceding section "Sample Figure Captions." The statement about contact photographs should accompany any fossil plates.]

[End of sample halftitle page]

If your abstract is past deadline, please write a note to reviewers and editors explaining the circumstances. If they don't know it's late, they probably will assume you have already submitted it and will see little point in spending their time in offering suggestions.

See section "Abstracts for Talks at Scientific Meetings" (p. 23) for information about writing the abstract.

# CHECKLISTS

## CHECKLIST FOR COMPLETED MANUSCRIPT

### General Guidelines

____Copy is on 8½- by 11-inch white paper.
____Cover and title page are in style of publication.
____Cooperative note is on both cover and title page.
____Author affiliation and address are given, if appropriate.
____Top of first page of text has 1½-inch margin.
____Each succeeding page has 1-inch margin all around.
____Pages are numbered consecutively.
____All textual material, including tables and figure captions, is double spaced. Wrap-around feature on word processor is used.
____Words are not divided at the end of a line.
____Paragraphs are indented five spaces using a tab.
____Paragraphs are complete on a page if possible.
____All headings in a USGS Professional Paper are centered and all words are capitalized.
____Headings in a USGS Bulletin, Circular, or Water-Supply Paper are flush left for first three ranks and centered for lower ranks. Capitalization follows scheme shown on page 250 in section "General Guidelines for the Entire Manuscript."
____Right margin is ragged (not right justified).
____Abbreviation and capitalization follow publisher's style.
____Words to be set in italic are underlined.
____Note for USGS monthly list is in correct format.

### Contents, Lists of Illustrations, and Tables

____Overruns in "Contents," "Illustrations," and "Tables" are indented five spaces.
____Rank of heading is identified by indention.
____Illustrations list (in "Contents") identifies figures as to kind.
____Short titles of figures are used in list of illustrations.
____Figure and table numbers are aligned on period in "Contents."

### Footnotes

___Footnotes are placed under a rule about 16 typewritten spaces long at the end of the paragraph in which they first appear. The first line of a footnote is indented five spaces and overruns are flush left.
___Footnotes are numbered consecutively throughout text.
___Footnote numbers are superscripts.

### Figure and Table Citations in Text

___The following notation is made at the end of the first paragraph that contains the principal citation to the figure or table, and a blank line precedes and follows each such notation.

**FIGURE X.--NEAR HERE**

**TABLE X.--NEAR HERE**

___Figure and table citations in text are capitalized and abbreviated according to publisher's style. USGS style is figure 1 and table 1 outside parentheses (and fig. 1 and table 1 inside parentheses).

### Illustrations and Their Captions

___Illustrations are numbered consecutively.
___Figure caption is in proper place in manuscript.

### Tables

___Tables are numbered consecutively and are interleaved in text.
___Tables have margins of at least 1 inch all around.
___Bracketed headnote in table or measured section has no period at the end.
___Tables have one top (head) and one bottom (end) rule.
___Entries in table are centered under column head.
___Entries in table are aligned on decimal point or hyphen (denoting range).

### Equations

___Equation number is in parentheses at right margin.
___Reference to equation in text is not parenthesized.
___Letters are properly underlined for italic.

### Measured Sections

___Measured sections are in format and style of publisher.
___Each stratigraphic unit in a measured section is complete on a page.
___Ordering is maintained in measured sections by repeating headings and "—Continued" at the top of the following page.
___Overruns are consistently spaced in measured sections.

### Disclaimers

___Appropriate disclaimers are used, if needed.

### References

___Reference citations are in correct format in both text and list.

### Appendixes

___Appendixes are numbered consecutively and are at the end of the report.

## Checklist for Abstracts for Scientific Meetings

___Copy is double spaced.
___Survey author's affiliation and address are given.
___Right margin is ragged.
___Technical review copies are with mill copy.

# PROOFREADING

## RATIONALE AND TYPES

Your reward for proofreading—however tedious the task may seem—is the satisfaction of an error-free publication. Although when to read proof varies with the publisher and frequency of revision, at least two different types of proofreading are essential. One type (A) is a comprehensive proofreading of text, tables, and illustrations for scientific integrity as well as for presentation (correct style, usage, and grammar) and internal consistency. The second type (B) is a conventional proofreading for such items as spelling, typographical errors, or incorrect word breaks. Both types can be done simultaneously, although the techniques for each differ.

Comprehensive proofreading (A) is a rigorous exercise that requires (1) a cool, objective appraisal of the science, (2) validation of any mathematics, and (3) checking for factual agreement among text, references, tables, and illustrations and their captions. Think of comprehensive proofreading as a technical review of your own work—difficult, but vital.

Conventional proofreading (B) is perhaps more difficult than comprehensive proofreading because it requires scanning textual and graphic material with little regard for meaning. At least one conventional proofreading session should be done with another person (see techniques for two-person proofreading).

The more frequently the report is revised, the greater the need for proofreading. Errors seem to multiply insidiously with each new printout, despite your best efforts to proof them away. Still, that one last try may catch the very error that might prove embarrassing to you or to the Survey. At best, your thoroughly proofed copy inspires a publisher's confidence in the care with which you prepared the report.

## WHEN TO PROOFREAD

Your Branch or Office may advise you when to proofread your report, and your local editor undoubtedly will ask you to proofread your USGS book or map at least once in the publication process. You may have to proofread on your own initiative more frequently as the manuscript progresses. If you know you won't be available for proofreading, designate someone who will do it as meticulously as you would. Changes are feasible before the manuscript is typeset, but changes to galley proofs and check prints are discouraged, except to correct typographical errors, serious factual errors, or deviations from the mill copy used as a guide by the typesetter or drafter. Extensive changes at galley-proof or page-proof stage are time consuming and costly.

Comprehensive proofreading (A) usually is done while the science and documentation are fresh in mind—for example (1) just before a report to be published by the USGS is sent for technical review or (2) just before a report to be published outside the USGS is sent to the journal. If technical review necessitates considerable rewriting and reorganization, however, another comprehensive proofreading of the revised report is advisable.

Conventional proofreading (B) generally is required (1) right after the report is first typed, (2) just before the final mill copy is submitted for Director's approval, and (3) when you receive galley proofs or page proofs and check prints. (See section "Preparing Maps and Other Illustrations," p. 210–213, for advice on proofreading check prints of illustrations). This is your last chance to make corrections, although they should be rare at galley-proof stage.

Conventional proofreading at (1) and (2) is most effective if you can let a little time elapse (several days perhaps) before you begin to proofread. Errors are more apt to leap from the page after the manuscript has cooled a bit and the wording of the text is no longer quite so fresh in your mind.

## GENERAL TECHNIQUES OF PROOFREADING

Accurate proofreading is exacting work and demands concentration. Choose a time when you are wide awake and alert, and take a short break when you begin to tire.

If you are proofreading alone, try to avoid proofing something that you have just finished typing. You are much more likely to see errors if you leave the report for a while. You may want to read aloud to yourself. For example, words with multisyllables and vowels are commonly misspelled; you can check them carefully by consciously pronouncing each syllable. You can read backward (from right to left), which will force you to focus on individual words. A spelling program on a word processor is useful, but it won't flag words correctly spelled but incorrectly used ("now" for "not").

Proofreading tabular data requires extra diligence and a ruler to ensure that you are reading across just one horizontal line at a time. Check the vertical alignment in each column to be sure that all numbers are aligned on the decimal point (or whatever symbol has been chosen, such as a hyphen denoting range).

A list of commonly used proofreader's marks and an example of their usage are at the end of this section. Although typeset copy is shown, the same principles and marks apply to typewritten text as well. See also the U.S. GPO Style Manual (1984, p. 5, 6).

### Two-Person Proofreading

When proofreading with another person, first agree how to proceed. For example, you won't say a capital letter at the beginning of a sentence and you'll tap a pencil to indicate a period at the end of the sentence. You should, however, say aloud all nonobvious punctuation and spell out uncommon words. The session will be less tiring if you take turns; one reads aloud from the original document while the other silently checks the new copy.

The author, if proofing, should follow the original while the other person (a typist, perhaps) reads aloud from the redone copy. This way, any errors or omissions in the new copy will automatically be read out.

Typographical errors, however, may still escape detection. At some point in the proofreading, every single word of the new copy must be read individually and deliberately if all typographical errors are to be eliminated.

## How and Where to Make Corrections

Instructions and marks should be legible, intelligible, and close to the change desired. Avoid marginal notes that dogleg around the page and "skyrockets" that zoom a change from text to a distant part of the page.

### Before Typesetting

Instructions, changes, additions, or deletions to a manuscript before typesetting can be made in the body of the text, in the margins, on a copy of the illustration, or on a separate piece of paper—just as long as they are intelligible to the person who must read or type from them. Separate pieces should be clearly marked: for example, "Insert A" or "Part 1 of 3." Make a small check in the right margin next to the line containing a minor change that might be overlooked; you may want to make a check for every change in the line.

### After Typesetting

When you receive galley proofs or page proofs and check prints, the typesetter or editor may have marked them already. Some of the marks may be queries to the author, which you should answer. Make corrections clearly and legibly in the margin of the proof as close to and as much in line with the error as possible; the typesetter is not obliged to search the body of the text for changes. Use common proofreader's marks. Indicate by AA (Author Alteration) or AC (Author Correction) any changes that differ from the copy used as a printer's guide. Do not mark the guide.

### Common Changes

Six changes are most common: insertion, deletion, substitution, transposition, punctuation, and capitalization (or lowercasing). The following examples show conventional marks for indicating these changes:

#### Insertion

To indicate that something should be inserted, place a caret (^) at the point on the line in the text where the insertion should be made, and write in the margin what is to be inserted:

o Pr^fread carefully

#### Deletion

To indicate that something should be taken out and not replaced by anything else, draw a line through it and place the "dele mark" ( ), a form of "d" meaning "delete," in the margin.

Proofread~~read~~ carefully

#### Substitution

To indicate that something is to be substituted for the matter deleted, mark through the matter to be replaced and write the substitute matter in the margin.

Proofread ~~erratically~~. carefully

### Transposition

Transposition is more common in early drafts of a report than in galley or page proofs. To indicate that something should be in a different place (transposed), draw lines to indicate the switch and write "tr" in the margin.

tr. carefully Proofread

If more than a few words are to be transposed and the change involves several lines, write the revised version on a separate piece of paper, cross out all the obsolete lines, and write "Insert A" (or whatever you have labeled the piece). This procedure allows for far less error than does drawing lines in text.

### Punctuation

Place punctuation or other marks that might be obscure to the left of a diagonal stroke, thus: ,/ ;/ -/.

The diagonal stroke is also used (1) to separate one correction from the next where they are crowded in the margin and (2) to indicate the end of the corrections.

Cheer, cheer for the fourth of July its ;/ '
our Nation's birthday

### Capital or Lowercase Letters

To indicate capitalization, draw a slash through the letter that is to be capitalized and write the letter with three lines under it in the margin.

P proofread carefully

To indicate lowercase, draw a slash through the letter that is to be lowercased and write l.c. in the margin.

Proofread Carefully l.c.

## Commonly Used Proofreader's Marks

USE WORDS IN MARGIN and lines in text. Mark clearly and distinctly. Write out instructions that might be ambiguous. For more marks, see the GPO Style Manual (1984, p. 5).

| | | |
|---|---|---|
| Boldface b.f. (in margin), (in text) | Print CONTENTS in boldface. | b.f. |
| Brackets [/] | [Brackets indicate supplied information. | ] |
| Capitalization: | | |
| Caps and small caps C + SC | For authorship: By DIANE CURTIS. | C + SC |
| Small caps SC | Use SMALL CAPS for headings. | SC |
| Uppercase caps | That map shows Ogden and Salt lake City. | L |
| Lowercase / | Where have the Animals and Birds gone? | l.c./l.c. |
| Caret ^ | General indicator used to mark exact posion of error. | i |
| Close up | can not | |
| Delete | You might want to write ~~the word~~ "delete" in the margin also. | |
| Indention ⌐ 3 | A box with a number indicating how many spaces. | ⌐ 3 |

Insert:

| | |
|---|---|
| Apostrophe | Water was ponded at the glaciers edge. |
| Colon | in the following sequence |
| Comma | garnet, wollastonite and tremolite |
| Exclamation point ! | Please be careful |
| Hyphen = | olive green schist = |
| Parentheses ( / ) | as noted by Page 1964) |
| Period | Water, then, was ponded |
| Question mark ? | Why did the river turn south |
| Quotation marks | "These beds, said Powell, are Green River." |
| Semicolon ; | Many volunteered few were chosen. |
| Space # | Rocks littered theroad. # |
| 1-em dash $\frac{1}{M}$ | two different types granite and syenite $\frac{1}{M}$ |
| 1-en dash $\frac{1}{N}$ | only 10 12 years old. $\frac{1}{N}$ |

(em and en are printer's terms for the size of a space; an en is half the width of an em. The 1-em dash is represented by two hyphens in typewritten copy and the en dash by one hyphen.)

| | |
|---|---|
| Italic *ital* (in margin) ___ (in text) | Spiriferina pulchra *ital* |
| Paragraph ¶ | Regional uplift then ensued. ¶ |
| No paragraph No ¶ | Ash, however, continued to fall. No ¶ |

Position:

| | |
|---|---|
| Move right | Move left |
| Move up | Move down |
| Center horizontally | Center vertically |

| | |
|---|---|
| Spell out Sp O | The sample contained only Fe. Sp O iron |
| stet (let it stand) – – – | Use dashes in text and ~~word~~ in margin. stet |
| Subscript [inferior] | $H_2O$ 2 |
| Superscript [superior] | Fe ++ |
| Transpose tr. | Use loop in text (tr./and) in margin. tr. |

## Geochemisty

n/b.f. caps

A geochemical survey to evaluate the mineral potential of the Flat Tops Wilderness included samples from streams which drain the Hack Lake Wilderness Study Area (Mallory and others, 1966). The analyses of these samples revealed no anomalous concentrations of any elements that might indicate outcropping mineralized rocks. H/O is prevalant in seams.

## MINERAL AND ENERGY RESOURCES

No mineralized areas were identified in the wilderness study area; however, gypsum and anhydrite may be present in the Eagle Valley Evaporite. In the vicinity of Eagle, about 20 mi southeast of the Study area, the Eagle Valley Evaporite is about 9,000 ft thick and contains isolated pods and lenses of gypsum and anhydrite (500/1,000 ft thick Mallory ~~and other,~~ 1971). It may be present beneath a thick cover of basalt (base approximately 3,000 ft beneath the area). The Eagle Valley Evaporite thins northeast of Eagle and is not exposed in the study area.

The Belden Formation, approximately 4,000 ft beneath the wilderness study area, may contain beds of coaly shale. Bass and Northrop (1963 noted that coal in the Belden is discontinuous near the wilderness study area.

The wilderness study area lacks favorable host rocks and ~~structural~~ traps ~~for oil and gas~~. The potential for uranium is low because the wilderness study area lacks host rocks favorable for uranium.

The low mineral resource potential in the wilderness study area is assigned a certainty level of B (fig. 3B) for all commoditiesbecausethe distribution of occurrences in rocks beneath the area cannot be observed and has not been well defined near the wilderness study area.

tr. t l.c. tr. stet. ital. #/# run-in; no ¶ eq. #

## REFERENCES CITED


Mallory, W.W., 1971, The Garcia Valley Evaporite, northwest Colorado—a regional synthesis: U.S. Geological Survey Bulletin 0000–A, 37 p., 3 pl.

Nadeau, J.G., 1977, Mineral investigation of the Melone Lake Wilderness Study Area, Cayer County, Colorado: U.S. Bureau of Mines Open-File Report MLA 00–00, 7p.


Table 1.//Conversion factors for SI metric and U.S. customary units of measurement ~~/.Continued~~

l.f./□ 9/10 Optima Med.


Bass, N.W. and Northrop, S.A., 1963, Geology of the Field Springs quadrangle and vicinity, northwestern Colorado: U.S. Geological Survey Bulletin 0000—A, 74 p.


Reset in 19picas.

# EXCEPTIONS TO THE GPO STYLE MANUAL

AUTHORS OF SURVEY reports should comply explicitly with the rules and directions of the U.S. GPO Style Manual except for a few deviations that better fill the Survey's particular needs. Some exceptions of greater concern to editors than to authors are not given here. The exceptions below are keyed to chapters and paragraph or page numbers of the U.S. GPO Style Manual (1984).

**Chapter 5. Spelling**

5.2. Gauge: The traditional Survey spelling is "gage," not "gauge."

**Chapter 6. Compound Words**

6.11. Words ending in "-field," or "-bed": The terms "coal field," "coal bed," "oil field," and the like are to be shown as two words. "Saw teeth" is written as two words in Survey reports. "Caprock" is written as one word; so is "wallrock."

6.51. X-ray: Use capital "X" followed by a hyphen.

**Chapter 7. Guide to Compounding**

Compounding geologic terms: Use the third edition of the American Geological Institute's "Glossary of Geology" (Bates and Jackson, 1987) as a guide for compounding geologic terms.

**Chapter 8. Punctuation**

8.51. In Survey reports a comma is put between superior figures or letters in footnote references:

Numerous instances may be cited.[1,2]
Data are based on October production.[a,b]

**Chapter 9. Abbreviations**

9.7. "Abbreviations and initials of a personal name with points [periods] are set without spaces. However, abbreviations composed of contractions and initials or numbers will retain space." The Survey generally will follow the GPO Style Manual, but particular design requirements such as large displays and titles may require deviation.

9.13. The Postal Service style of two-letter State and Province abbreviations will be used only in postal addresses. The standard abbreviations of States and Provinces will be used in texts. These abbreviations are listed in the section on "Abbreviations, Signs, and Symbols" (p. 105).

9.38. For parts of publications mentioned in parentheses, brackets, footnotes, sidenotes, list of references, synonymies, tables, and leaderwork, and followed by figures, letters, or Roman numerals, the following abbreviations are used:

no., nos. (number, numbers). Lowercase "n" is used in Survey reports except in column heads.

9.51. "The words 'latitude' and 'longitude,' followed by figures, are abbreviated in parentheses, brackets, footnotes, sidenotes, tables, and leaderwork, and the figures are always closed up." No periods are used after "lat" and "long" in illustrations, tables, or text.

9.53. Temperature is expressed in figures. Following the practice of the American Society for Testing and Materials "Standard for Metric Practice," STA recommends no space before or after the degree sign (100°C, 212°F).

### Chapter 13. Tabular Work

13.3. "Tables shall be set without down (vertical) rules when there is at least an em space between columns, except where: (1) In the judgment of the Government Printing Office down rules are required for clarity; (2) the agency has indicated on the copy they are to be used." The Survey will use vertical down rules where clarity demands them, especially between vertical headings.

13.36. Where column consists of single decimal, the Survey will not add ciphers to the right of decimal numerals without the author's approval.

13.46. The abbreviation "Do." for ditto: The Survey prefers not to use "Do." If "Do." must be used, follow the rules of the Style Manual and define the abbreviation in a headnote. Use "Do." in first and last columns; "do." elsewhere.

### Physiographic Terms (p. 227, 228)

The terms "province" and "section" used with other proper terms are parts of names for specific physiographic entities and are therefore capitalized (Robert C. McArtor, Chairman, GPO Style Board, oral commun., 1990).

### U.S. GPO Style Manual (1973). 13.58–13.68. Date Columns

The 1984 GPO Style Manual has no rules on date columns. Follow the 1973 Style Manual for guidance.

13.88. "If the footnotes to both table and text fall together at the bottom of a page, the footnotes to the table are placed above the footnotes to the text, and the two groups are separated by a 50-point rule flush left; if there are footnotes to the text and none to the table, the 50-point rule is still used (50 points equals about 0.7 inch)."

Follow the GPO Style Manual. It is better, however, to design the page with tables or illustrations at the top, above the text, to avoid confusion between text and table footnotes. Do not bury text footnotes above a table or any place inside a page. Readers naturally look to the foot of the page to find footnotes.

13.97. "All fractions are set flush right to the bearoff." The Survey aligns number columns on the unit or the decimal. Do not set fractions or mixed decimal fractions flush right.

# REFERENCES


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