Earth-Science Reviews, 12 (1976) 1—33

To each plutonic rock its proper name

A. Streckeisen*

ABSTRACT

Streckeisen, A., 1975. To each plutonic rock its proper name. Earth-Sci. Rev., 12: 1—33.

The paper comments on the recommendations on which the IUGS Subcommission on the Systematics of Igneous Rocks agreed at Montreal, August 1972.

Plutonic rocks are classified and named according to mineral contents. For nomenclature are considered: Q = quartz, A = alkali feldspar (incl. albite), P = plagioclase, F = feldspathoids, M = mafic and related minerals. Rocks with M less than 90 are named according to their positions in the QAPF diagram, the light-colored constituents being calculated to the sum 100. The following are treated: granitoids and related rocks, ultramafic and gabbroic rocks, charnockitic rocks, feldspathoidal rocks. A color index is used to distinguish the leuco- and mela-types of each rock group in comparison with normal types.

INTRODUCTION

Language is indeed the first step in scientific endeavor.
Nietzsche

Terminology is a matter of language and has no direct bearing on scientific research. Language, however, is requisite for communication and mutual understanding, both in the domain of science as well as in day-to-day conversation. If we do not speak a common language, no useful discussion will be possible. If the concepts of our knowledge are not clear and unambiguous, scientific communication will hardly be successful. As the development of an accepted formula, language has contributed decidedly to the progress of mathematical research and knowledge, so in other sciences the introduction of a common terminology has been a requisite for communication and discussion. Scientific terminology is based upon agreements and definitions. To a large extent, however, it is a matter of judgement and usefulness. In topics of nomenclature, tradition and long usage have often predominated over outstanding form and logical strictness.

---

* On behalf of the IUGS Subcommission on the Systematics of Igneous Rocks.

Many sciences have long ago arranged their terminology upon an international basis. It is not the case in petrology. This may be due to the fact that petrology is an old discipline and has developed, to some extent, independently in various areas of civilization. Long usage and venerable traditions have hindered unification. Thus, the same rock may be described by different names and the same term be used with different meanings, not only in different countries but also by different authors within the same country. Consequently, the nomenclature of petrology is a topic of low reputation because of the ambiguity of many of its terms. "It is especially unfortunate that the commonest igneous rocks are usually the most vaguely defined." (Howel Williams).

There is yet another reason. In biology, genera and species, which have a distinctive individuality, can be established and delimited. Igneous rocks, however, are transitional members of series, which, if ever, are delimited in an arbitrary manner. Moreover, there is no general agreement as to the principles on which delimitations should be based, whether on mineral content or on chemistry. This ambiguity as to the concept of a rock type makes petrological nomenclature still more difficult.

The need to agree upon a single rational and workable system for classifying and naming igneous rocks, which geoscientists throughout the world will use, is widely recognized. In order to establish the principles of a rational classification, the writer (1964) has put out an inquiry, which received larger attention than was expected. On the basis of the replies received, and taking into due consideration the systems proposed by the previous authors (see p. 5), in 1967 the writer published a "Classification and nomenclature of igneous rocks" that was termed a "final report of an inquiry". To discuss the proposals presented by this paper, a symposium was planned in connection with the 24th International Geological Congress of Prague, for August 21, 1968, but this, however, could not be realized. Subsequently, the International

Albert Streckeisen was born at Basel, Switzerland, in 1901 and received his Ph.D. at the University of Basel. He spent seven years as Professor of Mineralogy and Petrology at the Technical Institute of Bucharest, Rumania. He published various papers on crystalline terranes of the Swiss Alps and Rumanian Carpathians. In 1942 he became lecturer, and in 1954 professor at the University of Berne, now emeritus. Since 1964 he has been concerned with the systematics of igneous rocks. He is chairman of the IUGS Commission on Systematics in Petrology. The author's postal address: Mineralogisch-Petrographisches Institut der Universität Bern, Sahlistrasse 6, CH-3012 Bern, Switzerland.

Union of Geological Sciences (IUGS) created the Subcommission on the Systematics of Igneous Rocks under its Commission on Petrology. The purpose of this Subcommission is to deliberate on the various problems that attend igneous-rock nomenclature and to develop a workable system of classification. Although many igneous-rock classifications have been published by individuals or by small groups, this is the first attempt to develop a system through deliberation by a group of geoscientists from all parts of the world.

To begin with, the Subcommission was concerned with plutonic rocks. Future efforts of the Subcommission will be directed toward volcanic and hypabyssal rocks, carbonatites and melilite-bearing rocks. Deliberations carried on thus far have culminated in agreement on a system of classification and nomenclature for plutonic rocks. The system was approved by the Subcommission at its meeting in August 1972 in Montreal, and a summary of its recommendations has been published in various scientific reviews (IUGS Subcommission on the Systematics of Igneous Rocks, 1973). Fuller treatment, which gives the reasons for the decisions taken, is presented here and may be considered as a second, improved edition of the "Final Report".

The recommendations for plutonic rocks represent compromises between established usages in different parts of the world (see Streckeisen, 1967), and do not necessarily form the "best" system. Indeed, the inquiries and debates that preceded the agreement on the classification of plutonic rocks, suggest that although some systems are better than others, a "best" way to classify igneous rocks may not exist. However, the Subcommission considers its proposals as a practical compomise between the various classification systems now in use.

The proposals we submit are but recommendations. Practice will reveal whether they may be considered suitable and useful. However, considering the attention that was paid to the individual suggestions put forward by the writer in 1967, it may be presumed that the improved proposals, presented by an international body, will receive due attention.

The present writer thanks all those who contributed significantly to the achievment of the present proposals, above all the members of the Subcommission and its Working groups. Special thanks are due to the late Professor T.F.W. Barth who took a special interest in the classification work and gave precious advice. Thanks are also expressed to the IUGS Executive Committee and to the Chairman of its Advisory Board on Publication, Professor A. Martinsson, for the stimulating help they have given to the work of the Subcommission.

The IUGS Subcommission on the Systematics of Igneous Rocks at present consists of S. Aramaki (Japan), P.C. Bateman (U.S.A.), A. Dudek (C.S.S.R.), J. Ferguson (South Africa), A.M. Goodwin (Canada), K.R. Mehnert (F.R.G.), G. Pantó † (Hungary), D.L. Peck (U.S.A.), H. de la Roche (France), P.A. Sabine (U.K.), K. Smulikowski (Poland), H. Sørensen (Denmark), A. Streckeisen (Switzerland), N. Sukheswala (India), M.E. Teruggi (Argentine), G. Tischendorf (G.D.R.), A.C. Tobi (Netherlands), V. Trommsdorff (Swit-

zerland), O.A. Vorobieva † (U.S.S.R.), J.F.G. Wilkinson (Australia), and B. Zanettin (Italy).

Moreover, the following colleagues have contributed significantly to the work of the Subcommission: G.D. Afanass'yev (U.S.S.R.), A.M. Daminova † (U.S.S.R.), A. Davidson (Canada), S.V. Efremova (U.S.S.R.), R. Ivanov (Bulgaria), B.L. L'vov (U.S.S.R.) and W. Pälchen (G.D.R.) for granitoid and related rocks; S.E. Ellis (U.K.), E.D. Jackson (U.S.A.), N.P. Mikhailov (U.S.S.R.), A.J. Naldrett (Canada), and F. Rost (F.R.G.) for gabbroic and ultramafic rocks; D.S. Barker (U.S.A.), M.K. Bose (India), A.D. Edgar (Canada), and M.J. Le Bas (U.K.) for feldspathoidal rocks; P.G. Cooray (Zambia), E.H. Dahlberg (Suriname), J.G. Duchesne (Belgium), A.F. Laurin and K.N.M. Sharma (Canada), O.H. Leonardos, Jr. (Brazil), J. Martignole (Canada), J. Michot (Belgium), S.K. Sen (India), V.M. Shemyakin and K.A. Shurkin (U.S.S.R.), T. Torske (Norway), D. de Waard (U.S.A.), A. Watznauer (G.D.R.), A.P. Wilson (Australia), and H.G.F. Winkler (F.R.G.) for charnockitic rocks.

PRINCIPLES OF CLASSIFICATION

The Subcommission was guided by the following considerations:

(1) By igneous rocks we mean, as far as classification and nomenclature are concerned, "massige Gesteine" in the sense of Rosenbusch or "igneous and igneous-looking rocks" of Anglo-Saxon authors, irrespective of their genesis. They may have crystallized from magmas (including cumulates) or may have come into being by deuteric, metasomatic, or metamorphic processes. We should have learned from the granite controversy that phaneritic rocks can form by multiple processes, and it would be unwise to give the same rock different names according to the origin that is assumed by different authors.

(2) By plutonic rocks we mean rocks with phaneritic texture and presumed to have formed at considerable depth. Many phaneritic rocks that occur in orogenic belts have suffered some degree of metamorphic overprinting, and frequently it will be at the author's discretion whether they be described by igneous or metamorphic terms (e.g., gneissose granite vs. granitic gneiss).

(3) Plutonic rocks will be named according to their actual (modal) mineral content (expressed in volume percent). By this, historical tradition is followed, as plutonic rocks have generally been defined in this way.

A classification of plutonic rocks according to chemical composition (either by oxides or chemical parameters or normative minerals) is rarely supported nowadays. However, a system of rock chemistries ("magma-types" or "chemo-types") may, besides the mineralogical classification of rocks, have its advantages, especially for comparison. But, as a rule, magma-types are not rocks; chemical attributes should be added only by qualifiers to the rock names. Various systems of rock chemistries have been proposed; their discussion lies beyond the scope of this paper.

The extrusive rocks form a different case as their mineral content frequently cannot be exactly determined because of their microcrystalline or cryptocrystalline or even glassy matrix. In such cases, the chemical analysis has to be considered. The Subcommission has not yet decided upon which principles the classification of volcanic rocks should be based (whether on chemical characters such as oxides, chemical parameters, norm minerals, or on mineral assemblages, either actually recognized or calculated from the chemical analysis). Only a classification of plutonic rocks is presented here.

(4) A useful classification must satisfy the following requirements:
(a) it should correspond with natural relationships;
(b) be acceptable to most geoscientists and follow, as closely as possible, the historical tradition;
(c) be simple and easy to use.

With respect to natural relationships: Rocks are plotted, according to their mineral contents, into a diagram (QAPF diagram, Fig. 1a), which is subdivided into various fields. The limits between these fields are to be drawn considering natural relationships. Each rock type shows a certain variation of mineral content with a center of maximum distribution. Limits are to be drawn in such a way that the centers of maximum distribution fall in the interior of the respective fields and that boundaries pass through places of minor distribution. To establish the distribution centers, we plotted the modal analyses given by various compendia (Johannsen 1920, 1931—38, 1939, Tröger 1935, 1938, Shand 1927, 1943, 1947) into the QAPF diagram, and similarly those of a number of igneous complexes and associations (examples are shown in Streckeisen 1967, pp. 221—235, figs. 23—69). For granites we also refer to the valuable diagrams presented by Chayes (1952) and Fischer (1965).

With respect to historical tradition, we consulted the textbooks and relevant papers by previous authors of various countries (e.g. in the list of references: AGI Glossary, Barth, Cross et al., Daminova, Hatch et al., Harker, Heinrich, Holmes, Johanssen, Jung and Brousse, Lacroix, Loewinson-Lessing, Moorhouse, Muir, Niggli, Nockolds, Rittmann, Ronner, Rosenbusch, Shand, Teruggi, Tröger, USSR Petrographic Committee, Williams et al., Von Wolff, Zirkel). An attempt was made to find a suitable compromise between the systems presented by the various authors, compatible with natural relationships.

(5) For classification, the following minerals and mineral groups are used:
Q quartz, besides tridymite and cristobalite in volcanic rocks.
A alkali feldspars (orthoclase, microcline, perthite, anorthoclase, albite An 00—05, besides sanidine in volcanic rocks).
P plagioclase An 05—100, scapolite.
F feldspathoids or foids (leucite and pseudoleucite, nepheline, sodalite, nosean, hauyne, cancrinite, analcime, etc.).
M mafic and related minerals (micas, amphiboles, pyroxenes, olivines, opaque minerals, accessories (zircon, apatite, titanite, etc.), epidote, allanite, garnets, melilites, monticellite, primary carbonates, etc.).

With respect to feldspars: As agreed on by most petrologists, we assign albite to alkali feldspars, for petrological considerations. Even Johannsen (who assigned albite to plagioclase) attributed the albite contained in perthites to alkali feldspar, and it would not seem expedient to treat in a different way rocks in which perthitic feldspars have recrystallized into albite and potash feldspar.

But there arises the problem about the limit between albite and plagioclase. From 1908 until 1922 Johannsen used the name albite for An 00—05. Following the subdivisions proposed by Calkins (1917), Johannsen (1929) suggested the term sodaclase for An 00—10. For purposes of classification we consider a limit of An 05 as more appropriate and are supported, therein, by a number of colleagues. In this way, calc-alkali granites and syenites (which commonly contain albite-oligoclase An 05—30) are clearly distinguished from the alkali-feldspar granites and syenites (including peralkaline types) that contain pure albite. Moreover, the limit An 05 stands in conformity with the statement by Wenk (1967, pp. 241—242) that in the plagioclase series of plutonic rocks there exists a break at An 05, which separates pure albite An 00—05 from the members An 05—28.

With respect to melilites: It is controversial whether melilite be considered as a foid (undersaturated anorthite) or as a mafic mineral (undersaturated pyroxene). Most petrologists follow Johannsen (1939, p. 148) who assigned melilite to foids, whereas Tröger (1935, 1967, p. 130) and Rittmann (1952) enter a strong plea for attributing melilite to mafic minerals, and Williams et al. (1958) seem to share this position (on p. 82 they speak of turjaite and okaite as "melilite-rich ultramafites"). While gehlenite is related to anorthite, the melilites of igneous rocks show chemical characters that are more strongly related to pyroxenes, as follows from the chemical analyses recorded by Deer et al. (1962, vol. 1, pp. 242—243) and the respective norms calculated by Rittmann (1973, p. 208); see also Burri and Niggli (1945, p. 526, fig. 194). Therefore, we assign melilites of igneous rocks to the mafic minerals.

(6) Rosenbusch characterized the various rock types by outstanding qualitative descriptions. They may seem somehow complicated and not easy to survey, especially to the beginner; but the advanced student cannot but admire the adequacy of his definitions. On the other hand, Johannsen has given preference to quantitative definitions. He attempted to assemble the various rocks in a pigeon-holes system. His system is perfectly logical, but does not always correspond with natural relationships. With due respect for the outstanding work of Rosenbusch, preference is given to quantitative delimitations and definitions. Only a quantitative system is able to display a general survey of the multiple rocks that occur in nature.

However, we advocate that delimitations be managed in a flexible way. Maximum distribution centers should be more strongly considered than field boundaries that are always arbitrary to a certain extent. We fully agree with Barth (1974, pp. 85—86):

"We should keep in mind that a classification of rocks according to their mineral composition is a theoretical undertaking that not always will suit the demands of the geologist. The geological association, and the field relations may make it necessary to stretch the rules of the classification; where intermediate cases are encountered, or when the field relations indicate one thing, the mineral contents another, doubt will exist as to which class a rock properly should be referred to. Such exceptional cases do not invalidate the general usefulness of the proposed classification. As distinct from mathematics and theoretical physics, natural phenomena cannot be treated with schematic accuracy; all schematic classifications are to be regarded as idealized cases that approximately correspond to the physical facts."

(7) A first subdivision into 2 classes will be made according to the content of mafic and related minerals (M). One class contains rocks that consist almost entirely of mafic minerals. The other comprises the remaining rocks, by far the majority. As limit between the two classes, Ellis (1948) and Williams et al. (1958) proposed M = 70; Niggli (1931), Tröger (1938) and Rittmann (1952) M = 75; Wedepohl (1969) M = 85; Shand (1927), Tröger (1935), Jung and Brousse (1959) and Ronner (1963) M = 90; and Johannsen even M = 95. The differences are of minor importance, since the plutonic ultramafic rocks constitute a well-defined group. The large majority of them present color indices exceeding 90 (see examples in Tröger, 1935); the same applies to melilitites. On the other hand, theralites, shonkinites, melteigites, and missourites show color indices up to 90, and the same applies to basalts, nephelinites, and leucitites. For these reasons we retained M = 90 as limit.

It may be recorded that Johannsen (1939, vol. I, 2nd ed., p. 146 f.) and Niggli (1931, p. 304) suggested a double nomenclature for transitional rock types. As an example, a rock composed of 85% pyroxene and 15% labradorite could be described as gabbro-pyroxenite as well as mela-gabbro. This could apply to rocks with M between 75 and 90.

(8) Rocks with M less than 90 are classified primarily according to their light-colored constituents; rocks with M = 90—100 according to their mafic minerals.

(9) Rocks with M less than 90% are classified and named according to their positions in the QAPF double triangle (Fig. 1a), the light-colored constituents being calculated to the sum 100 (i.e., Q + A + P = 100, or A + P + F = 100). The limits of the various fields, on which agreement has been reached, are shown in Fig. 1a. The reasons for the delimitations are presented on pp. 9—11.

It is obvious that a plane representation, such as the QAPF diagram, cannot show all parameters, important for classification purposes. Neither the An content of plagioclase nor color index can be shown. It may be observed that the An content of plagioclase increases generally from the A corner to the P corner, and so does the color index, commonly. When it seems desirable, different designations may be provided for different An contents (e.g., diorite and gabbro, field 10). For the color index a separate representation will be proposed (pp. 22—23, Fig. 5).

For the graphical representation, a plane diagram has been chosen for reasons of simplicity. It has been discussed whether the relative amounts of the light-colored constituents should be calculated to the sum 100, which leads to a triangular diagram (Fig. 1a), or whether the actual amounts of

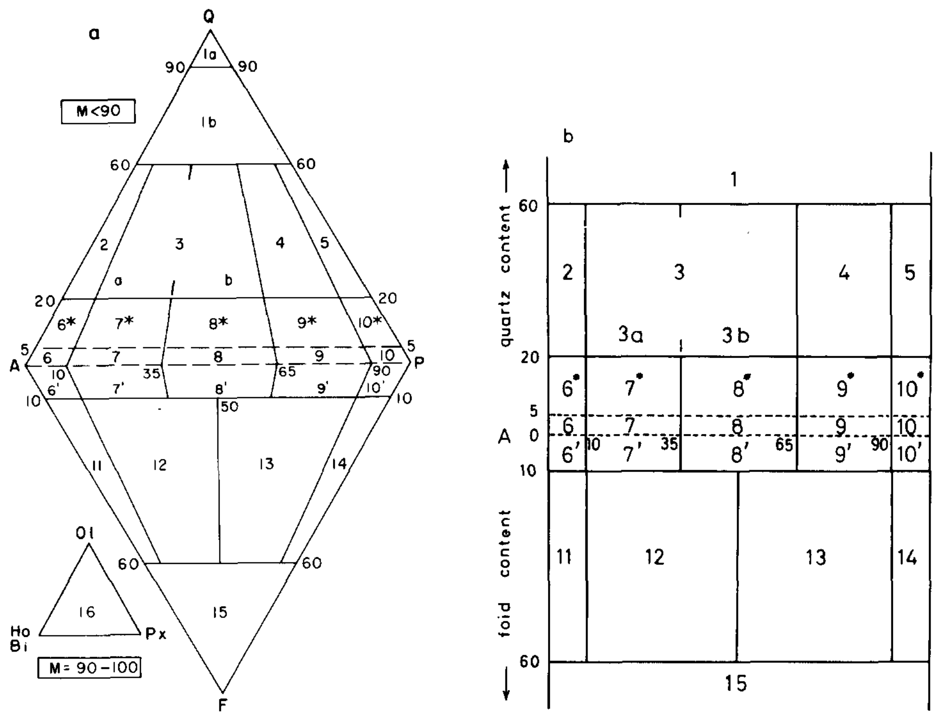


Fig. 1a. General classification and nomenclature of plutonic rocks according to mineral content (in vol. %).
Q + A + P = 100, or A + P + F = 100.
1a, quartzolite (silexite); 1b, quartz-rich granitoids; 2, alkali-feldspar granite; 3, granite; 4, granodiorite; 5, tonalite, 6*, quartz alkali-feldspar syenite; 7*, quartz syenite; 8*, quartz monzonite; 9*, quartz monzodiorite/quartz monzogabbro; 10*, quartz diorite/quartz gabbro/quartz anorthosite; 6, alkali-feldspar syenite; 7, syenite; 8, monzonite; 9, monzodiorite/monzogabbro; 10, diorite/gabbro/anorthosite; 6′, foid-bearing alkali-feldspar syenite; 7′, foid-bearing syenite; 8′, foid-bearing monzonite; 9′, foid-bearing monzodiorite/monzogabbro; 10′, foid-bearing diorite/gabbro; 11, foid syenite; 12, foid monzosyenite (syn. foid plagisyenite); 13, foid monzodiorite/foid monzogabbro (essexite = nepheline monzodiorite/monzogabbro); 14, foid diorite/foid gabbro (theralite = nepheline gabbro, teschenite = analcime gabbro); 15, foidolites; 16, ultramafic plutonic rocks (ultramafitolites).
b. Possible classification of plutonic rocks by using quartz and foid contents as actually present in the rocks. On the left margin: quartz and foid contents as given by the modes; from left to right: feldspar ratio f.r. = P/(A + P).

quartz and foids, as present in the rock, be directly plotted, which leads to a rectangular diagram (Fig. 1b). The first possibility, for which we decided, is advocated by Johannsen, Jung-Brousse, Lacroix, Niggli, Rittmann, Tröger and may be considered the more common. The second possibility is used in various English and American textbooks (Hatch et al., Heinrich, Muir, Nockolds, Williams et al.). In both representations, the A—P side is subdi-

TABLE 1

Comparison of plotting between triangular (Qtz, f.r.) and rectangular (Q,A,P) representation

Qtz	K-fsp	Plag	Mafics	Qtz	f.r.	Q	A	P
20	16	64	0	20	0.80	20	16	64
16	12.8	51.2	20	16	0.80	20	16	64
10	8	32	50	10	0.80	20	16	64
20	16	64	0	20	0.80	20	16	64
20	12	48	20	20	0.80	25	15	60
20	6	24	50	20	0.80	40	12	48

vided according to the feldspar ratio (f.r. = P/(A + P)), which facilitates plotting into the diagram.

For rocks with a low content of mafic minerals the differences between both representations are relatively small. It is different for rocks with higher color indices; for M = 40, a quartz content of 6% gives Q = 10, and a quartz content of 3% reaches the critical figure Q = 5. In such cases, the rectangular diagram could seem more appropriate. To compensate for this, the boundary at Q = 5 is reported as a dashed line, and we recommend in each case appropriate designations, because nomenclature, as a rule, should be managed in a flexible way. On the other hand, the rectangular diagram has the inconvenience that the same point may represent different Q/A/P ratios because of different M contents, and the same Q/A/P ratio may plot at different points. Examples are shown in Table I.

SUBDIVISION OF THE QAPF DIAGRAM

Let every student bear in mind: that all rocks are transitional members of series and that clear-cut boundaries are not to be expected.
Howel Williams

As a rule, delimitations have to correspond with natural relationships, which have been established by diagrams of modal analyses, as outlined above. A purely schematic subdivision has been excluded from the beginning. Moreover, classification diagrams of previous authors have been considered.

The upper triangle QAP

Considering common usage, boundary lines have been drawn, one set parallel to the A—P side, and the other set radiating from the Q corner.

We started at the granitoids. As shown by the diagrams presented by

Chayes (1952), Fischer (1965), Streckeisen (1967: Figs. 28—42), granites, granodiorites, and tonalites are commonly comprised within limits at Q = 20 and Q = 45; only a few show larger quartz contents. Nevertheless, the upper limit has been set at Q = 60, as such rocks have been recorded by various authors. To separate syenites etc. from quartz syenites etc., a dashed line has been drawn at Q = 5.

For the subdivision along the A—P side from the left to the right, it had first to be decided whether a major boundary should be set at feldspar ratio f.r. 50, as had been advocated by Johannsen and Niggli. Yet all the more recent classification schemes (from Tröger, 1935 up to Ronner, 1963) provide intermediate fields, partly broader partly narrower. Even Johannsen and Niggli presented alternative proposals. As most granites fall near the center of the QAP triangle (see Figs. 7—12, pp. 28—29), no major boundary line should be set at f.r. 50.

For the subdivision along the A—P side, Johannsen suggested the limits 5—50—95; this seems not very convenient, as the intervals 0—5 and 95—100 are too narrow, and those between 5—50 and 50—95 decidedly too broad. Niggli (1931) took over the 1/8ths subdivision of the CIPW classification and set major limits at 12.5 and 87.5, and optional limits at 37.5 and 62.5; he was followed by Rittmann (1952). Others set limits at 33.3 and 66.7, or at 40 and 60, or at 40 and 70, or at 35 and 65. The differences between the various proposals are rather small; the suggested limits lie between 33.3 and 40 on the one side, 60 and 70 on the other; 35 and 65 would be an acceptable compromise. It seems of minor importance at which figure the limit is set in each individual case, but it seems important that general agreement as to the limits be reached. As the 1/8ths classification is being more and more abandoned and preference is being given to a decimal subdivision, we decided for limits at 10—35—65—90. With respect to natural relationships, this subdivision is fully justified: at f.r. 10 alkali-feldspar granites and syenites are detached from the calc-alkaline ones; f.r. 90 separates, on the other hand, the widespread diorites and gabbros from the rather rare monzodiorites and monzogabbros; and between f.r. 35 and 65 monzonites are inserted. Thus, the upper triangle displays a symmetrical picture.

The lower triangle APF

The subdivision of the lower triangle has been more controversial, since Niggli and Tröger advocated that alkali feldspars and foids be more closely coupled because foids are to be considered as undersaturated alkali feldspars. Thus, Tröger (in Brinkmann, 1961, p. 217, fig. 182) suggested boundary lines radiating from the P corner. However, after careful consideration it was decided to conform to the more customary usage, i.e., to draw boundary lines similar with the upper triangle, the ones parallel to the A—P side, others radiating from the F corner.

With respect to foid content, boundary lines are drawn at F = 10 and F =

60, because they correspond with places of minor distribution (Fig. 14, p. 30).

Up to F = 10, limits along the A—P side have been set as in the upper triangle. For the area between the boundary lines at F = 10 and F = 60, a limit at f.r. 50 seems to be more appropriate, as Fig. 14 shows; from the left to the right, only four groups (11—14) are provided, two of which are of major importance.

Below F = 60 no subdivision seems to be necessary for plutonic rocks. For volcanic rocks, however, a further division will prove useful.

NOMENCLATURE OF PLUTONIC ROCKS

General rules

Considering the large, even too large, number of rock names that have come into use during the development of petrographic knowledge, certain rules should be observed in creating and using rock names.

(1) Names of plutonic rocks, when introduced, have been defined according to mineral content and texture. Names for rock chemistries are not rock names. Examples: engadinite, evisite, yosemitite.

(2) Rock names have to be applied in their hitherto usual sense. The original definition, which should be tested as to its usefulness, is not to be strictly observed if the common usage departs from it; examples: anorthosite, norite. Language changes with time, and so does terminology.

(3) Rock names with vague (ambiguous) meanings may be retained if precise definitions can be provided. Sometimes, they may be used as comprehensive terms covering several rock types. Example: syenodiorite.

(4) Rock names that are used with different meanings (e.g., in different countries or by different authors) should be given precise definitions by international agreement; example: quartz monzonite. If agreement cannot be reached, it is preferred to abandon the name to avoid confusion.

(5) Names that have been introduced without precise definition with respect to mineral content should be abandoned; example: kemahlite. The same applies to local names that can easily be characterized by mineral contents; example: deldoradoite = leucocratic cancrinite syenite. There are too many names in petrography, and it seems reasonable to eliminate those that are considered unnecessary.

(6) Names that have been introduced for genetic rock associations should not be used to describe a specific rock type. Example: banatite.

(7) Some terms have been introduced to cover varieties or rock groups of regional or local significance; examples: akerite, appinite. They may be retained if considered useful in their regional or local context.

(8) New names should be introduced only in cases where there exists convincing need. They should always be given precise definitions on the basis of mineral content and texture. Adding a chemical analysis would be useful.

(9) The Subcommission has agreed on terms in English. It is the task of competent national bodies to specify the terms which should be used in their languages. Example: quartz syenite (English), syénite quartzique (French), Quarzsyenit (German), quarzosienite (Italian), etc.

Granitoid and related rocks

(1) *Granite* is a term used with different meanings. English and American textbooks restrict granite to rocks of subfield 3a, whereas subfield 3b is covered by terms such as adamellite or quartz monzonite. On the other hand, granite is used in central Europe with a broad meaning, including, above all, rocks of subfield 3b. Thus, Mehnert (1968) defines granite as follows:

> "Phanerocrystalline, massive rock consisting of quartz, potash feldspar and sodic plagioclase (typically oligoclase) in nearly equal amounts, and a generally small amount (5—10%) of mafic minerals (biotite, hornblende, and others)."

Chayes (1957) suggests using granite with an even larger meaning, i.e., for massive or weakly oriented rocks with color index below 20 and with quartz contents between 20 and 40% (by volume), thus including granodiorite and tonalite.

The diagrams of modal analyses show clearly and consistently that the most widespread granites fall into subfield 3b, near the center of the QAP triangle (Figs. 7—12). It would not seem reasonable to assign to the most widespread granitic rocks an other name than that of granite, and to affirm that "granites" (in the sense of Anglo-Saxon authors) do not occur in such prominent orogenic belts as the Alps, or basement complexes as Black Forest and Bavarian Forest.

Considering these facts, the Subcommission decided to use the term granite with a large meaning, i.e., for the broad field 3. If subdivisions should seem desirable, special names may be applied to subfields 3a and 3b, which, however, should be related to the term granite; such as, e.g., granite A and granite B, alpha granite and beta granite, syenogranite and monzogranite, respectively. The terms syenogranite and monzogranite for subfields 3a and 3b, respectively, have been suggested in 1965 by W. Schreyer and E. Walger and have been used in this sense by G. Fischer (1965, p. 17, 29); monzogranite conforms with the term "granite monzonitique" of Lacroix (1933). Adamellite and quartz monzonite, however, are not recommended.

Adamellite has been introduced by Cathrein (1890, p. 74) for "orthoclase-bearing tonalites", obviously granodiorites, which occur in the Adamello massif besides the more predominant tonalites (Fig. 18); (see Tröger 1935, No. 779). The original definition has been changed by Brögger (1895) for normal granite; with this meaning, the term is used in most Anglo-Saxon textbooks, whereas this new definition was never accepted in central Europe. As the term is used with different meanings, Tröger recommended abandoning it; and so we do; all the more as "adamellites" do not occur in the Adamello massif.

Quartz monzonite has been introduced by Brögger (1895) in order to designate monzonites with a small quartz content (Rosenbusch, 1907, vol. II, p. 167; Rosenbusch and Osann, 1923, p. 145). With this meaning the term is still used by Soviet geologists. Lindgren (1900) changed the definition for andesine-bearing granite (see Tröger 1935, No. 86). Later, the meaning was extended to designate, generally, granites of subfield 3b; in this sense the term is used up to now by most American authors. The Subcommission discussed whether the term should be abandoned because of different meanings, but finally decided retaining the term with its original meaning, i.e., for rocks of field 8*, for reasons presented on p. 14.

(2) Granites of field 2 that contain alkali feldspar (orthoclase, microcline, perthite, albite) but no plagioclase have been described as alkali granites by many authors. However, the Subcommission decided that the term *alkali granite* should be restricted to granites that contain alkali amphiboles and/or pyroxenes ("soda granites" of various authors), and that *alkali-feldspar granite* be used as root name for field 2, specifying, in each special case, the nature of feldspars present (orthoclase granite, albite-microcline granite, albite granite, etc.). The same suggestion covers fields 6*, 6 and 6′, respectively. Most granites of field 2 are true alkali granites, to which belong, above all, the peralkaline one-feldspar granites. (Terms such as kaligranite or potash granite are not recommended, because, as a rule, nomenclature should be based on mineralogy not on chemistry; all the more as the large majority of "kaligranites" recorded by Johannsen (1932, vol. II, p. 55) contain more soda than potash if molecular figures are considered.)

The term *alaskite* may be used for light-colored alkali-feldspar granites (M = 00—10), according to its original definition given by Spurr (1900). He proposed the name alaskite for holocrystalline granular plutonic rocks characterized by essential alkali feldspar and quartz, and little or no dark component (Johannsen 1932, vol. II, p. 106).

Granites that contain albite and epidote in place of oligoclase (by late- or postmagmatic processes or slight epizonal alteration) should, however, be attributed to the normal granites of field 3. Such rocks are frequent, e.g., among the granites of the Alpine orogenic belt.

(3) Rocks of field 1b are rare and it is doubtful whether they should be considered as true igneous rocks. However, to incorporate them into the system, we suggest designating them as *quartz-rich granitoids* (quartz-rich granites and granodiorites).

For rocks composed almost entirely of quartz (field 1a), the term *quartzolite* (silexite) is suggested. Silexite is a term proposed by W.J. Miller (1919) for any body of pure or nearly pure silica of igneous or aqueo-igneous origin, which occurs as a dike, segregation mass, or cognate inclusion. We consider the term silexite less appropriate, because silex is the French term for flint and silexite the French term for chert (Cayeux, 1929, pp. 506—552).

(4) The most widespread rocks of field 4 are *granodiorites* (Fig. 13) that commonly contain oligoclase, more rarely andesine. It seems advisable to add the condition that the An content of the average plagioclase should be less than 50, in order to distinguish granodiorites from the rare group of *granogabbros*, which belong genetically to an entirely different branch (Bentor, 1974).

(5) For field 5 the term *tonalite* is recommended, whether hornblende is present or not, in agreement with Johannsen (1932, vol. II, p. 378); whereas quartz diorite, frequently used for this field, is restricted to field 10* (see p. 15). According to papers by Bianchi, Callegari, Malaroda, Zanettin and others, the typical tonalites of the Adamello massif (type area) contain nearly as much hornblende as biotite, and their plagioclases show corroded cores of labradorite-bytownite in zoned andesine (average An content about 50); see the comprehensive study by Bianchi et al. (1970) that presents ample information of the various rock types encountered in the Adamello massif. The same features have been recorded by Karl (1966) in tonalites from the Tauern (eastern Alps).

Trondhjemite (syn. *plagiogranite*, as used in the U.S.S.R.) may be applied for light-colored tonalites (M = 00—10) that contain oligoclase or andesine, according to its original definition (Goldschmidt, 1916).

(6) Rocks of fields 6 and 7 are *alkali-feldspar syenites* and common *syenites*. Many rocks described as syenites fall, however, into field 8* (e.g., the "syenites" of Plauen'scher Grund, Saxony, and Biella, Italy).

Rocks of fields 7* and 6* are intermediary between syenite and granite. They are disginated as *quartz syenites* and *quartz alkali-feldspar syenites*, according to common usage.

(7) As there is no major boundary drawn at feldspar ratio 50, field 8 is that of *monzonite*. Field 9 contains rocks intermediary between monzonite and diorite/gabbro, which are called *monzodiorite* and *monzogabbro*, according to the composition of plagioclase; names that have already entered into common use. Syenodiorite and syenogabbro, by definition intermediate between syenite and diorite/gabbro, may be used as comprehensive terms for monzonite and monzodiorite/monzogabbro.

In analogy to quartz syenite for rocks intermediary between syenites and granites of field 3a, we recommend *quartz monzonite* for field 8*, according to its original definition. This conflicts, however, with a widespread usage in USA and Canada. We tried a long time to find another name, appropriate for field 8*, but finally returned to quartz monzonite, because it is the most proper term. In addition, it is used with this meaning in Britain and the U.S.S.R. An inquiry made by P.C. Bateman among American geologists revealed that the term would be accepted with this meaning also in USA. Consequently, rocks of field 9* are *quartz monzodiorites* and *quartz monzogabbros*.

(8) *Diorite* and *gabbro* (including *norite*) are the common names for field 10, besides *anorthosite*. For the distinction between diorite and gabbro see p. 17—19.

For field 10* the names *quartz diorite*, *quartz gabbro* (incl. *quartz norite*) and *quartz anorthosite* apply, in analogy to quartz syenite and quartz monzonite. It has been mentioned above that for rocks rich in mafic minerals a relatively small quartz content will transgress the Q = 5 limit; this boundary has been reported as a dashed line, meaning that the nomenclature should be managed in a flexible way and that appropriate names be chosen in any specific case.

Gabbroic and ultramafic rocks, anorthosites

(1) *Ultramafic rocks* (ultramafitolites or, less correctly, ultramafites) are composed of olivine, orthopyroxene, clinopyroxene, hornblende, sometimes biotite, and various amounts of garnet, spinel, and opaque minerals. *Peri-*

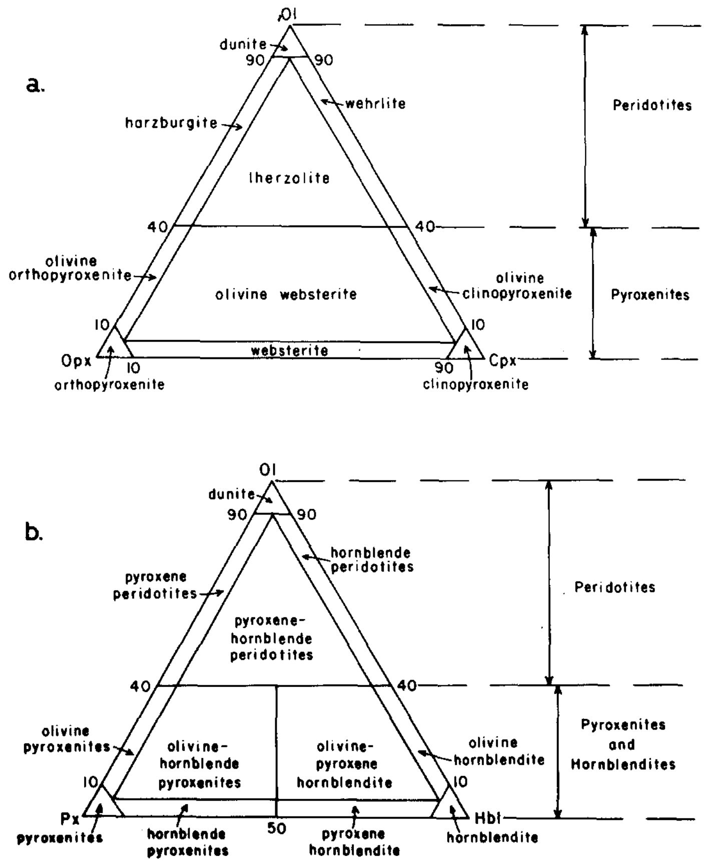


Fig. 2. Classification and nomenclature of ultramafic rocks.
Ol + Opx + Cpx + Hbl (+ Bi + Gar + Sp) $\geq$ 95; opaque minerals $\leq$ 5.
a. Ultramafic rocks composed of olivine, orthopyroxene, and clinopyroxene.
b. Ultramafic rocks that contain hornblende.

dotites are distinguished from *pyroxenites* by an olivine content more than 40%. This figure has been chosen with regard to lherzolites which may contain up to 60% pyroxene. Peridotites are subdivided into *dunite* (or olivinite, as used in the U.S.S.R., see Daminova, 1967 and Sørensen, 1974), *harzburgite*, *lherzolite*, and *wehrlite*; pyroxenites into *orthopyroxenite* (e.g., bronzitite), *websterite*, and *clinopyroxenite* (e.g., diallagite); see Fig. 2a. *Hornblendites* contain hornblende as shown in Fig. 2b.

Ultramafic rocks composed of olivine, orthopyroxene, and clinopyroxene are classified and named according to Fig. 2a. Hornblende is indicated as shown in Fig. 2b. Garnet is indicated as follows:

garnet ⩽ 5%: garnet-bearing peridotites, etc.

garnet > 5%: garnet peridotite, etc.

Spinel is treated in the same way. A content of opaque minerals up to 5% is not indicated. For larger contents, Johannsen (1939, vol. I, p. 150, 1938, vol. IV, p. 406) suggests designations such as follows:

5— 50% opaque minerals: chromite dunite, etc.

50— 95% opaque minerals: olivine chromitite, etc.

95—100% opaque minerals: chromitite, etc.

(2) *Gabbroic rocks* (gabbroids) are mainly composed of plagioclase (commonly labradorite or bytownite), clinopyroxene, orthopyroxene, olivine, hornblende, sometimes biotite. *Gabbro* consists essentially of plagioclase + clinopyroxene, *norite* of plagioclase + orthopyroxene, *troctolite* of plagioclase + olivine. *Gabbronorites* are gabbroic rocks that contain both clinopyroxene and orthopyroxene (both >5%): *orthopyroxene gabbro* (e.g., hypersthene gabbro) contains more clinopyroxene than orthopyroxene, whereas orthopyroxene exceeds over clinopyroxene in *clinopyroxene norite* (e.g., diallage norite) (Wilkinson 1967, p. 174). Additional olivine is indicated as shown in Figs. 3a and 4. *Hornblende gabbros* consist essentially of plagioclase and hornblende (pyroxene content <5%).

Gabbroic rocks composed of plagioclase, pyroxenes, and olivine are classified and named according to Figs. 3a and 3b. Hornblende is indicated as shown in Fig. 3c. Garnet, spinel, and opaque minerals are indicated in the same way as for ultramafic rocks.

For gabbroic rocks a color index of 35—65 is considered normal. Rocks with a higher color index are termed *melagabbros* (M = 65—90), those with a lower color index *leucogabbros* (M = 10—35). According to Buddington (1939), leucogabbros may be subdivided into anorthositic gabbros (M = 22.5—35) and gabbroic anorthosites (M = 10—22.5).

(3) The term *anorthosite* was formerly restricted to rocks that consist essentially of calcic plagioclase (Johannsen, 1937, vol. III, p. 196). Since that time the definition has been enlarged, and it has now become customary to call anorthosites all rocks that consist mainly of plagioclase (from anorthite down to andesine, and even oligoclase); (Turner and Verhoogen, 1960, p. 322, Wilkinson, 1967, p. 178, AGI Glossary, 1972). While anorthosites of layered intrusions (Bushveld, Stillwater, etc.) contain mainly basic labrador-

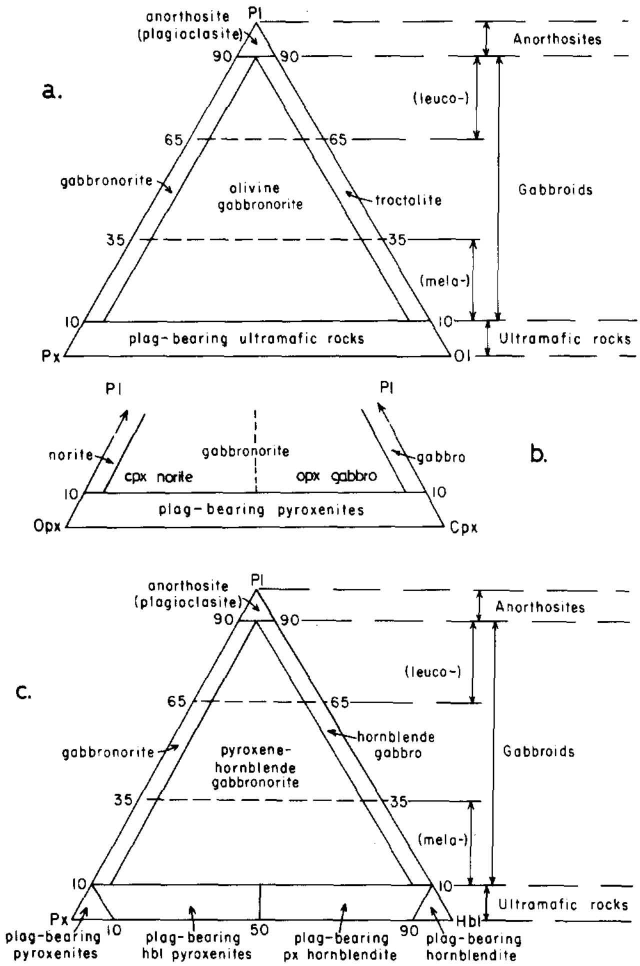


Fig. 3. Classification and nomenclature of gabbroic rocks.
Pl + Opx + Cpx + Ol + Hbl (+ Bi + Gar + Sp) ⩾ 95; opaque minerals ⩽ 5.

a. Gabbroic rocks composed of plagioclase, pyroxene, and olivine.
b. Subdivision of gabbroic rocks into gabbro, gabbronorite (opx gabbro and cpx norite), and norite.
c. Gabbroic rocks that contain hornblende.

ite and bytownite, those associated with charnockitic rocks (Norway, Adirondacks, Quebec, etc.) consist commonly of andesine and sodic labradorite; e.g., An 40—45 in the Egersund area, Norway.

(4) Figs. 4a—d show the classification and nomenclature of gabbroic and ultramafic rocks in the tetrahedron plagioclase—clinopyroxene—orthopyroxene—olivine.

(5) For the *distinction between diorite and gabbro (norite)*, various criteria may be considered: composition of plagioclase, nature of mafic constitu-

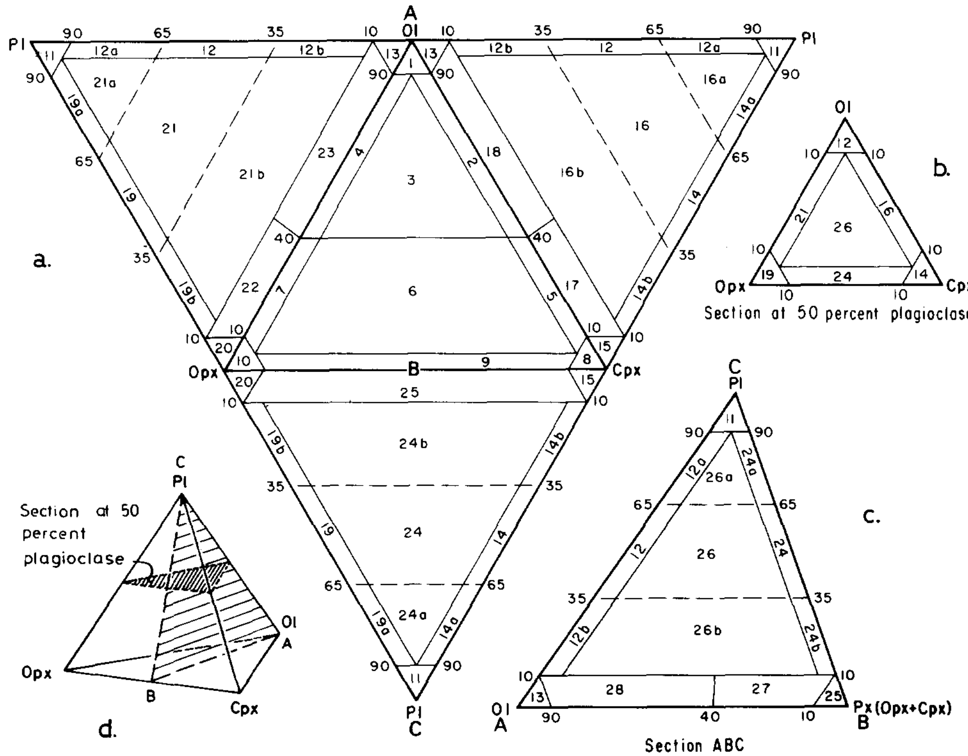


Fig. 4. Classification and nomenclature of ultramafic and gabbroic rocks (incl. anorthosites) in the tetrahedron olivine—plagioclase—orthopyroxene—clinopyroxene.

a. Faces of the tetrahedron.

b. Section parallel to the basis Ol—Opx—Cpx at 50% plagioclase content.

c. Section of the tetrahedron along the line A—B—C.

d. Tetrahedron showing the positions of Figs. 4b and c.

1, dunite (olivinite); 2, wehrlite; 3, lherzolite; 4, harzburgite; 5, olivine clinopyroxenite; 6, olivine websterite; 7, olivine orthopyroxenite; 8, clinopyroxenite (diopsidite, diallagite); 9, websterite; 10, orthopyroxenite (enstatitite, bronzitite, hypersthenite); 11, anorthosite (plagioclasite); 12, troctolite (a = leuco-, b = mela-); 13, plagioclase-bearing dunite; 14, gabbro (a = leuco-, b = mela-); 15, plagioclase-bearing clinopyroxenite; 16, olivine gabbro (a = leuco-, b = mela-); 17, plagioclase-bearing olivine clinopyroxenite; 18, plagioclase-bearing wehrlite; 19, norite (a = leuco-, b = mela-); 20, plagioclase-bearing orthopyroxenite; 21, olivine norite (a = leuco-, b = mela-); 22, plagioclase-bearing olivine orthopyroxenite; 23, plagioclase-bearing harzburgite; 24, gabbronorite (a = leuco-, b = mela-); 25, plagioclase-bearing websterite; 26, olivine gabbronorite (a = leuco-, b = mela-); 27, plagioclase-bearing olivine websterite; 28, plagioclase-bearing lherzolite.

ents, paragenetic relationships, possibly also chemical composition (Williams et al., 1958, p. 107). Color index should not be used, as it serves in distinguishing the leuco- and mela-types from the normal ones (see Fig. 5, p. 22). Although other criteria should be considered, composition of plagioclase (at the limit An 50) is commonly used as the distinctive criterion.

Typical diorites contain oligoclase or andesine; the chief mafic minerals are hornblende and/or biotite, in some cases also augite; olivine is uncommon. Diorites are usually associated with granodiorites, tonalites, and quartz diorites, or form smaller discrete masses.

Typical gabbros (norites) contain labradorite or bytownite; clinopyroxene, orthopyroxene, and olivine are the chief ferromagnesian constituents. Gabbroic rocks are commonly associated with anorthosites and pyroxenites in layered intrusions and in areas of charnockitic rocks. They also form discrete masses. Moreover, they are common in ophiolitic complexes in eugeosynclinal zones of orogenic belts.

Distinction by composition of plagioclase at An 50 is quite firmly entrenched in the literature, although Holmes (1917, p. 126) and Ellis (1948, p. 455) stated that a limit at An 47—48 would be more suitable. Tröger (1935, p. 146) proposed a transitional group of gabbrodiorites, but his suggestion has found little consideration.

There are, however, cases in which the nature of the mafic minerals and the paragenetic relationships carry more weight than the composition of plagioclase. Such is the case with norites and leuconorites associated with anorthosites in areas of charnockitic rocks, and which contain andesine, as recorded by many authors (J. Michot, P. Michot, Tobi, de Waard); see Streckeisen (1974). As an example, the anorthosites of the Egersund area, Norway, contain andesine An 40—45, and the same An content is shown in leuconorites and norites in which they are grading (J. Michot, 1961); the associated monzonorites contain plagioclase with An 40—25 (P. Michot, 1964). These rocks would be termed hypersthene diorites and hypersthene monzodiorites if plagioclase composition were considered; but since hypersthene is their prevailing mafic constituent and in view of their paragenetic relationships, they are better classed as norites and monzonorites, as they always have been described.

Charnockitic rocks

Charnockitic rocks constitute a genetic suite that is characterized by the presence of hypersthene (or fayalite + quartz), and by perthitic feldspars (perthite, mesoperthite, antiperthite) in many of its rocks. They are frequently associated with norites and anorthosites and seem to be restricted to Precambrian terranes. According to the mineral contents, they have originated in a "dry" environment of granulite facies. In many areas, they show widespread deformation and recrystallization phenomena, signs of metamorphic overprinting. The origin of charnockitic rocks, whether magmatic or metamorphic, is debated; it may be assumed that there are "charnockites and charnockites". Because of their phaneritic texture, they belong to "igneous and igneous-looking rocks" and are, thus, included in the nomenclature of plutonic rocks.

For rocks of the charnockitic suite, the same boundary lines in the QAP diagram are used as in the general system. The boundary line at Q = 5 is reported as a dashed line, in order to express that nomenclature be managed in a flexible way. For fields 6*—10* the names will be those of fields 6—10 preceded by the qualifier quartz.

For the classification and nomenclature, mesoperthite and antiperthite are to be distributed over A and P according to optical investigation or diffractometry. Perthites, as they occur, e.g., in alkali-feldspar granites and syenites, are attributed to A (see p. 5), as they commonly originated by unmixing of former homogeneous alkali feldspars.

The names of rocks that contain mesoperthite will be those of fields 2—10 preceded by the prefix m- (mesoperthite-).

Charnockitic rocks can be named by adding the qualifier hypersthene to the respective name of the general system. However, some special names are frequently used in papers on the charnockitic rock suite, which many authors like to retain. Therefore, we propose a nomenclature with alternative terms, which may be used in an optional manner. Note that mangerite is a rock of field 8; some authors are using it synonymously with hypersthene monzonite, others for rocks in which mesoperthite is the only feldspar.

A useful review of special names is presented by de Waard (1969). Moreover, nomenclature of charnockitic rocks is treated by Tobi (1971) and Streckeisen (1974).

Feldspathoidal rocks

Feldspathoidal rocks are shown in the APF triangle. The names for the various fields are "root names". Additional information, especially as to the

TABLE II

Nomenclature of charnockitic rocks

Field	General terms	Special terms
2	hypersthene alkali-feldspar granite	alkali-feldspar charnockite
3	hypersthene granite	charnockite (3b farsundite)
4	hypersthene granodiorite	opdalite or charno-enderbite
5	hypersthene tonalite	enderbite
6	hypersthene alkali-feldspar syenite	
7	hypersthene syenite	
8	hypersthene monzonite	mangerite (according to definition)
9	monzonorite (hypersthene monzodiorite)	jotunite
10	norite (hypersthene diorite) anorthosite ($M < 10$)	

nature of the foids present, nature and content of mafic minerals, color index, and even textural relationships, is needed to give a rock its proper name. A large number of names have been suggested for the various types of feldspathoidal rocks, some of which may seem unnecessary and could be abandoned without disadvantage. For the names the reader is referred to the useful glossary that has been compiled by Sørensen (1974).

Fields 6′—10′. Whereas a small content of quartz is commonly present in many igneous rocks without being expressed in the name of the rock, the appearance of foids, even in small amounts, is, however, petrologically significant and should be expressed in the rock name. Therefore, the names of fields 6′—10′ will be those of fields 6—10 by adding the qualifier "*foid-bearing*" (specified in every case such as nepheline-bearing, leucite-bearing, etc.).

For field 11, *foid syenite* is the root name; actual names should specify the feldspathoids present, as, e.g., nepheline syenite, sodalite syenite, cancrinite syenite, pseudoleucite syenite, etc. This remark also applies to fields 12—15. Field 11 contains the widespread nepheline syenites, many varieties of which have been given special names.

For field 12, *foid monzosyenite* or *foid plagisyenite*, synonymously, are proposed as root names. Rocks of this field are subordinate. Miaskite, that contains oligoclase, may be mentioned.

For field 13, *foid monzodiorite* and *foid monzogabbro* are used as root names. The term *essexite* may be applied for nepheline monzodiorite/monzogabbro; essexites commonly contain andesine or labradorite; rocks that contain labradorite are sometimes described as essexite gabbros. Again, rocks of this field are rather subordinate, as shown by Fig. 14.

For field 14, the root names are *foid diorite* and *foid gabbro.* Among the rocks of this field, which appear more frequently (see Fig. 14), we mention *theralites* which are nepheline gabbros, and *teschenites* which are analcime gabbros.

Field 15 contains rocks in which the light-colored constituents are almost entirely feldspathoids. As plutonic types of this field are rather rare, the Subcommission decided not to subdivide the field; which, however, will prove necessary for the respective volcanic rocks. To distinguish the plutonic rocks of this field from the volcanic ones, the plutonic rocks are termed *foidolites*, the volcanic ones *foidites.* To a certain extent, this corresponds with current usage. As recorded by Sørensen (1974), leucitite, nephelinite, noseanite, melilitite are extrusive rocks; while nephelinolite and melilitolite belong to the plutonic ones. This usage that we recommend, has been followed by Tröger (1935) and Ronner (1963). (However, it may be mentioned that Johannsen [1938, vol. IV, p. 336] used the terms nephelinolite, nephelinite, and nepheline basalt all for extrusive rocks and distinguished them by the nature of mafic minerals present, i.e., nephelinolite without mafics, nephelinite with mafics but no olivine, and nepheline basalt with mafics including olivine. This usage should not be followed, all the more so as olivine nephelinite and nepheline basalt are generally used as synonymous terms.)

Plutonic rocks of field 15 fall commonly near the F corner. Among those containing nepheline, we mention urtite, ijolite, and melteigite; while italite, fergusite, and missourite are rocks that contain leucite or pseudoleucite (see Fig. 14).

It should be emphasized that the boundary lines between the fields 12, 13, 14 and 15 are commonly not strictly observed and that nomenclature is managed in a flexible way (Fig. 14).

Succession of minerals in rock names

The Subcommission recommends that the minerals in composite rock names be arranged in order of increasing amounts, i.e., a more abundant mineral falls closer to the root name of a rock than a less abundant mineral. Example: hornblende-biotite granodiorite contains more biotite than hornblende.

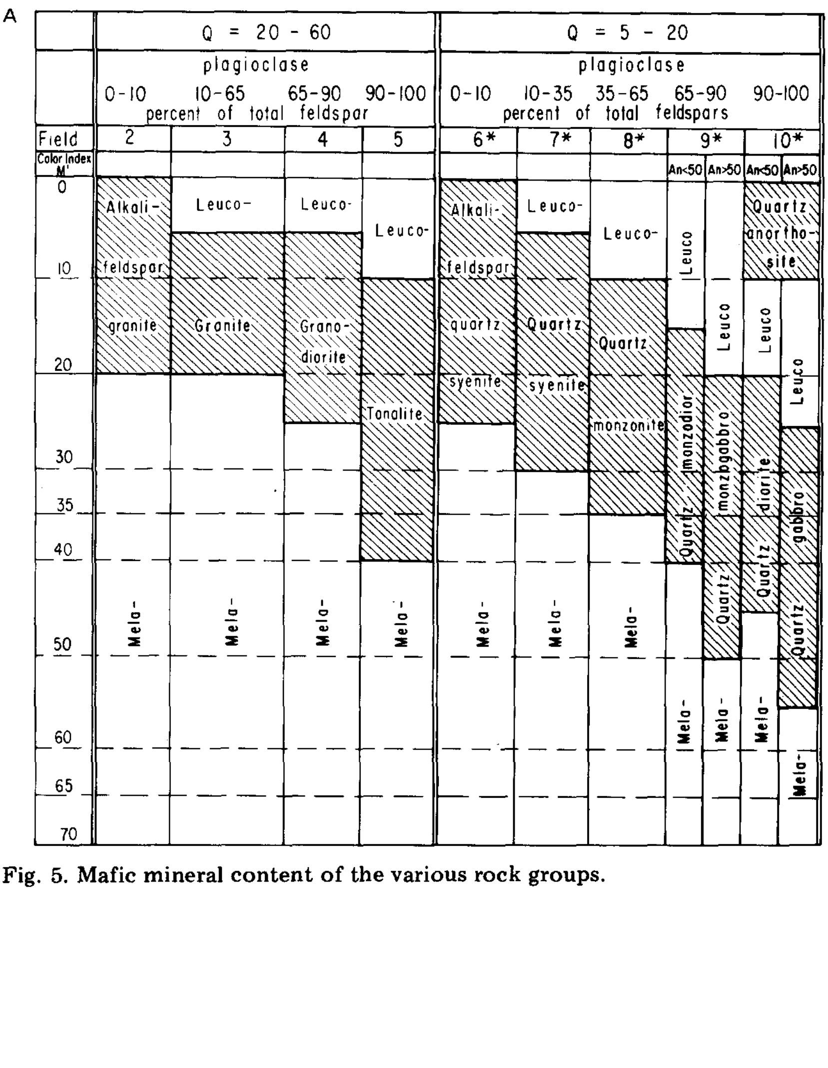
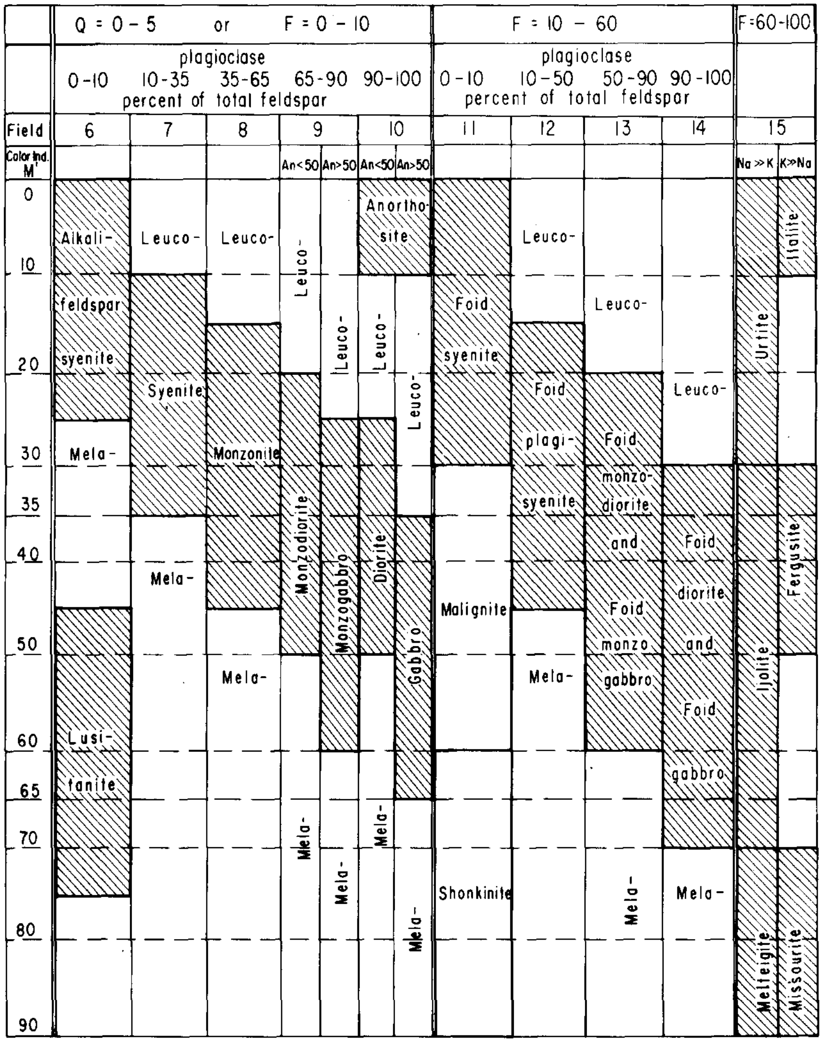


Fig. 5. Mafic mineral content of the various rock groups.

B



Color index

The content of dark-colored constituents of a rock should not be neglected in nomenclature. As muscovite, apatite, primary carbonates, etc., are commonly considered as felsic minerals (see Johannsen, 1939, vol. I, p. 149), color index M′ is defined as follows:

$M' = M -$ (muscovite, apatite, primary carbonates, etc.)

TABLE III

The meaning of color index terms according to various authors

This paper		Lacroix (1933)	Tröger (1935)	Shand (1927)	Ellis (1948)	Jung and Brousse (1939)
0—5	holo-leucocratic	0—5	0—10	0—30	0—10	0—10
5—35	leucocratic	5—35	$10—33^{1/3}$		10—40	10—40
35—65	mesocratic	35—65	$33^{1/3}—66^{2/3}$	30—60	40—70	40—60
65—90	melanocratic	65—95	$66^{2/3}—90$	60—90	70—100	60—90
90—100	ultramafic	95—100	90—100	90—100		90—100

The Subcommission suggests using the prefixes *leuco-* and *mela-* to designate the more felsic and mafic types of each rock group, in comparison with normal types. Fig. 5 shows tentatively the leuco- and mela-types of each rock group. The prefixes leuco- and mela- precede the root name: e.g., biotite leucogranite, biotite leuco-quartz diorite, mela-olivine gabbro, mela-nepheline diorite, nepheline-bearing melasyenite, etc.

Irrespective of these terms, rocks may also be grouped according to color index into *holo-leucocratic* (M' = 0—5), *leucocratic* (M' = 5—35), *mesocratic* (M' = 35—65), *melanocratic* (M' = 65—90), and *ultramafic* (holo-melanocratic) rocks (M' = 90—100). The intervals we suggest are shown in Table III in comparison with those proposed by Shand (1927), Lacroix (1933), Tröger (1935, p. 338), Ellis (1948), and Jung and Brousse (1959).

Terms according to Ellis (1948) are: holofelsic, felsic, mafelsic, mafic. Shand (1927) suggested mesotype for mesocratic, as he rightly considered mesocratic as a linguistic miscarriage; leucocratic means that light-colored minerals predominate; but the mean cannot predominate! However, the term mesocratic has become commonly accepted, and so we are using it.

It should be observed that the terms leucocratic mesocratic, melanocratic refer to rocks, not to minerals. Minerals are light- or dark-colored, but not leucocratic or melanocratic, and still less mesocratic!

THE SYSTEM OF IGNEOUS ROCKS

The system thus developed consists of 15 major fields (rock groups) within the QAPF diagram, to which field 16 (ultramafic rocks) is added. The system is merely of descriptive character, as it serves to order the rocks that occur in nature according to their mineral contents. It has no genetic significance. Therefore, we speak of groups, orders, classes; not of families, clans, stems. The same field may assemble rocks of quite different genetic characters; while genetically connected rocks of petrographic associations will commonly spread over various fields. The elaboration of a genetic system of

TABLE IV

System of plutonic rocks

Class	Order	Group (Field) Plutonic division*[2]	Section*[3]
	I Quartz-rich rocks	1a quartzolite (silexite) 1b quartz-rich granitoids	
	II Quartz-feldspar rocks	2 alkali-feldspar granite 3 granite 4 granodiorite 5 tonalite	I
M < 90	III Feldspar rocks*[1]	6 alkali-feldspar syenite 7 syenite 8 monzonite	II
		9 monzodiorite/monzogabbro 10 diorite/gabbro/anorthosite	III IV VIII
	IV Feldspar-foid rocks	11 foid syenite 12 foid plagisyenite (foid monzosyenite)	V
		13 foid monzodiorite/monzogabbro 14 foid diorite/gabbro	VI
	V Foid rocks	15 foidolites	VII
M = 90—100	VI Ultramafic rocks	16 peridotite	IX
		pyroxenite	X
		hornblendite	XI
		(melilitolite)	

[1] The subsidiary rock groups 6—10* and 6′—10′ that are strongly related to the main groups 6—10 are not distinctly listed.
*[2] As the present paper merely concerns plutonic rocks, those of volcanic and hypabyssal divisions are not listed.
*[3] Sections refer to Fig. 6.

igneous rocks, which shows relationships of consanguinity, is a worthwile task which, however, lies beyond the scope of the present paper.

As many rocks can be exactly determined only by microscopic study, it may be useful to have an even simpler system for field use. At the suggestion of the Central Geological Institute of the German Democratic Republic, the Subcommission presents, therefore, a *Preliminary System* that is composed of 11 sections (see Fig. 6a—c). Many names of these sections are characterized by the termination -oid. Thus, the term *granitoids*, already used in many countries, comprises alkali-feldspar granites, granites, granodiorites, and tonalites. *Gabbroids* is a comprehensive term for gabbros, gabbronorites, norites, and troctolites; etc.

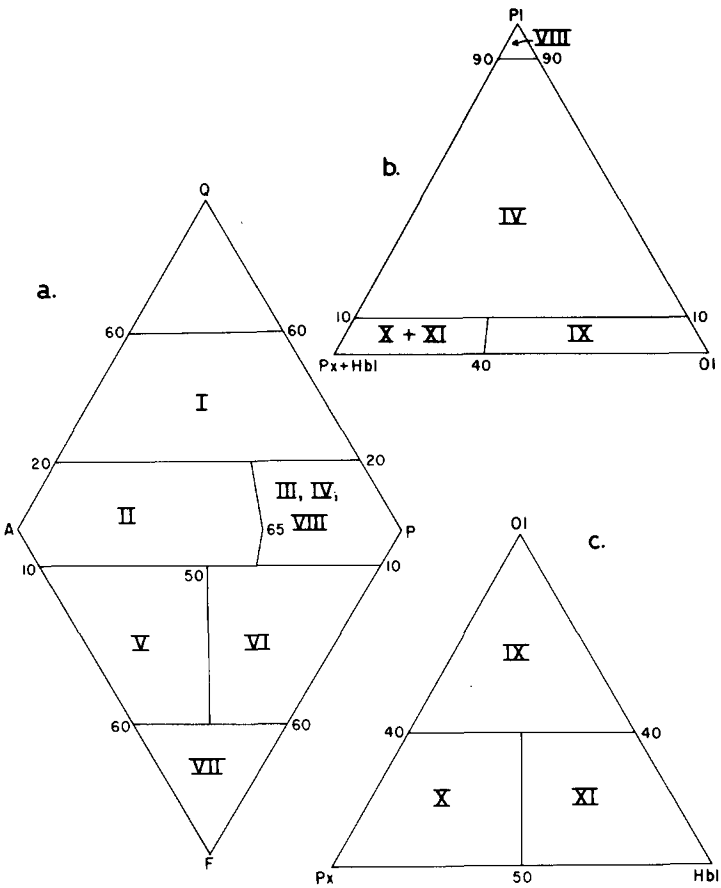


Fig. 6. Preliminary system (for field use).
a. General classification.
b. Ultramafic and gabbroic rocks, and anorthosites.
c. Ultramafic rocks.
I, granitoids; II, syenitoids; III, dioritoids; IV, gabbroids; V, foid syenitoids; VI, foid dioritoids and gabbroids; VII, foidolites; VIII, anorthosites; IX, peridotites; X, pyroxenites; XI, hornblendites; II—IV, qualifier "foid-bearing" if foids are present; IX—XI, ultramafic rocks.

GLOSSARY OF TERMS

The Subcommission is preparing a Glossary that will contain recommendations for terms to be abandoned and definitions of terms to be retained. In the meantime the reader is referred to the valuable glossary published by Sørensen (1974) and also to the useful glossary compiled by Muir (1973).

TABLE V

Determination key for plutonic rocks

M < 90			
I Q = 60—100% of light-colored minerals			
a Q = 90—100:		(1a) quartzolite (silexite)	
b Q = 60—90:		(1b) quartz-rich granitoids	
II Q = 20—60% of light-colored minerals			
a Plag 00—10% of total feldspar:		(2) alkali-feldspar granite	
b Plag 10—65% of total feldspar:		(3) granite	
c Plag 65—90% of total feldspar:		(4) granodiorite	
d Plag 90—100% of total feldspar:		(5) tonalite (trondhjemites are leucotonalites (M = 00—10) that contain oligoclase or andesine)	
III Q = 05—20% of light-colored minerals			
a Plag 00—10% of total feldspar:		(6*) quartz alkali-feldspar syenite	
b Plag 10—35% of total feldspar:		(7*) quartz syenite	
c Plag 35—65% of total feldspar:		(8*) quartz monzonite	
d Plag 65—90% of total feldspar:		(9*)	
	1 An < 50	quartz monzodiorite	
	2 An > 50	quartz monzogabbro	
e Plag 90—100% of total feldspar:		(10*)	
	1 An < 50	quartz diorite	quartz anorthosite
	2 An > 50	quartz gabbro	
IV Q = 00—05% of light-colored minerals			
a Plag 00—10% of total feldspar:		(6) alkali-feldspar syenite	
b Plag 10—35% of total feldspar:		(7) syenite	
c Plag 35—65% of total feldspar:		(8) monzonite	
d Plag 65—90% of total feldspar:		(9)	
	1 An < 50	monzodiorite	
	2 An > 50	monzogabbro	
e Plag 90—100% of total feldspar:		(10)	
	1 An < 50	diorite	anorthosite
	2 An > 50	gabbro	
V F = 00—10% of light-colored minerals			
a Plag 00—10% of total feldspar:		(6′) foid-bearing alk-fsp syenite	
b Plag 10—35% of total feldspar:		(7′) foid-bearing syenite	
c Plag 35—65% of total feldspar:		(8′) foid-bearing monzonite	
d Plag 65—90% of total feldspar:		(9′)	
	1 An < 50	foid-bearing monzodiorite	
	2 An > 50	foid-bearing monzogabbro	
e Plag 90—100% of total feldspar:		(10′)	
	1 An < 50	foid-bearing diorite	
	2 An > 50	foid-bearing gabbro	
VI F = 10—60% of light-colored minerals			
a Plag 00—10% of total feldspar:		(11) foid syenite	
b Plag 10—50% of total feldspar:		(12) foid monzosyenite	

TABLE V (continued)

M < 90			
c Plag 50—90% of total feldspar:	(13)		
1 An < 50		foid monzodiorite	essexite
2 An > 50		foid monzogabbro	
d Plag 90—100% of total feldspar:	(14)		
1 An < 50		foid diorite	
2 An > 50		foid gabbro (theralite)	
VII F = 60—100% of light-colored minerals	(15)	foidolites (see special tables)	
M = 90—100			
Ultramafic plutonic rocks (16) (see special tables)			

DIAGRAMS OF MODAL ANALYSES OF VARIOUS PLUTONIC ASSOCIATIONS

Figs. 7—14 show the variation of light-colored constituents in rocks of various plutonic associations, above all of granitoids.

Q + A + P = 100, or A + P + F = 100.

Moreover, Figs. 8 and 13 show also the contents of mafic minerals (on the left). Symbols (in brackets): (Q), quartz; (A + P), feldspars; (M), mafics, as actually present in the rocks.

A larger number of diagrams has been presented by Streckeisen (1967).

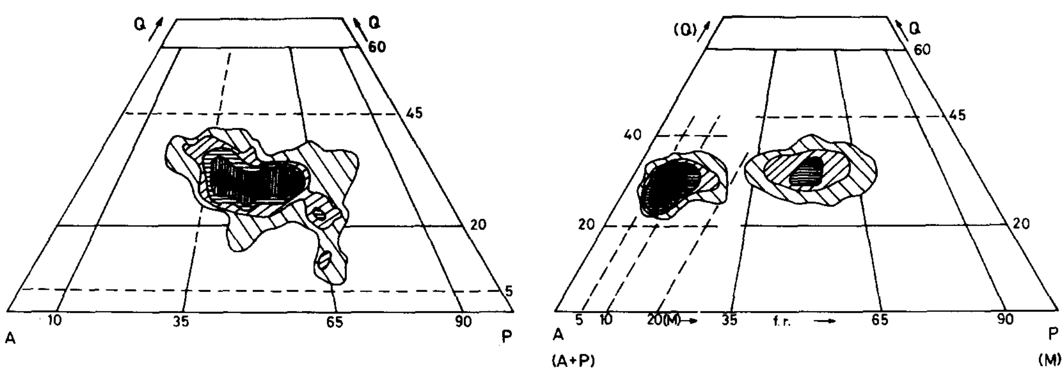
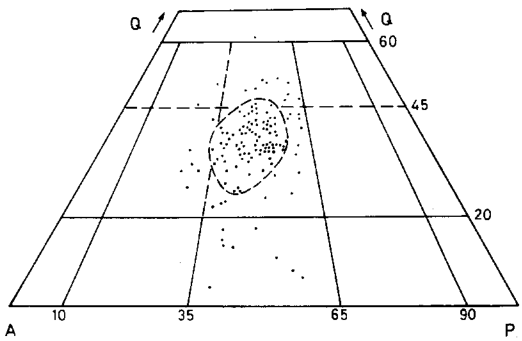


Fig. 7. Granitoids from North-Volhynia, according to K. Smulikowski (1947). An 05—30. 145 modes. Limits at 2.8, 4.1, 5.5, 6.8 and 10%.

Fig. 8. Finer-grained calc-alkaline granites of New England (U.S.A.), according to F. Chayes (1952). 145 modes. Limits at 10, 18, and 26%. On the left side color index is shown; symbols: (Q), quartz; (A + P), feldspars; (M), mafics, as actually present in the rocks; limits at 10, 18, 26 and 40%.



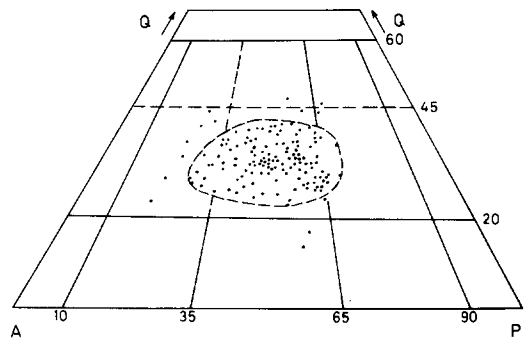
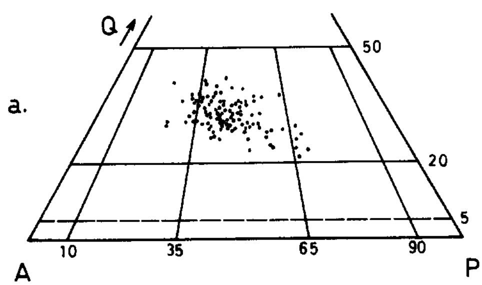
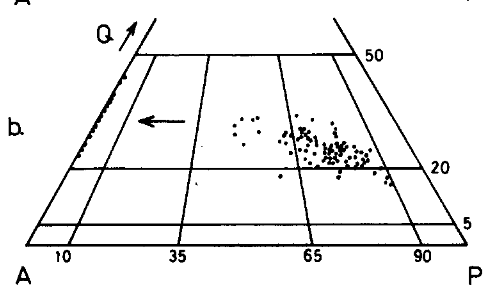


Fig. 9. Granites from the massifs of Tirschenreuth, Flossenbürg, and Oberviechtach, Northeastern Bavaria, according to G. Fischer (1965). 137 modes.

Fig. 10. Moldanubian granites from Northeastern Bavaria, according to G. Fischer (1965). 146 modes.





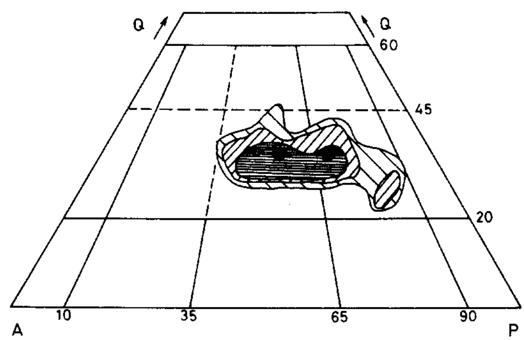
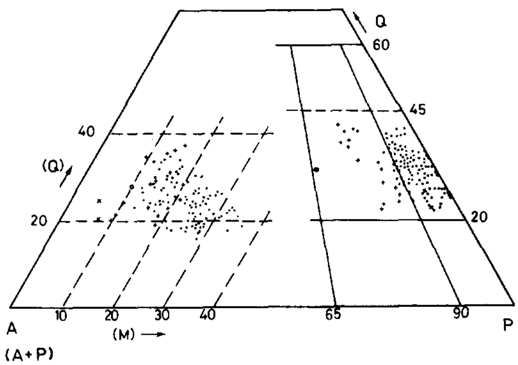


Fig. 11. Granitoids from Sierra Nevada, Calif., by kindness of P.C. Bateman (1974).
a. Scheelite sequence (Tungsten Hills and Casa Diablo Mountains).
b. Powell sequence (Lamarck granodiorite and leucogranite of Evolution Basin).

Fig. 12. Granitoids from the Swiss Alps. 57 modes. Limits at 5, 7, 9 and 12%.



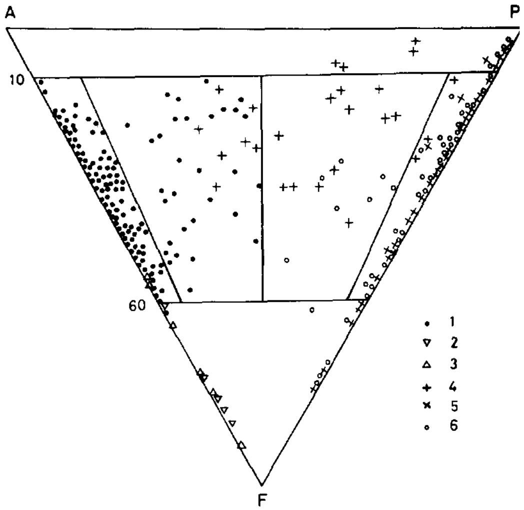


Fig. 13. Granitoids from the Adamello massif, Italy, according to A. Bianchi, E. Callegari and P.G. Jobstraibizer (1970).
Points: tonalites; crosses: granodiorite, x: trondhjemites, circle: granite. On the left side color index is shown: symbols: (Q), quartz; (A + P), feldspars; (M), mafics, as actually present in the rocks.

Fig. 14. Feldspathoidal rocks from the U.S.S.R., presented by O.A. Vorobieva (1972) on behalf of the Petrographical Committee of the U.S.S.R.
Symbols: 1, nepheline syenites; 2, juvites; 3, malignites; 4, essexites; 5, theralites; 6, teschenites. (Note that juvite and malignite, as used here, do not correspond with the original definitions.)

REFERENCES

American Geological Institute, 1972. Glossary of Geology.

Barth, T.F.W., 1944. Studies on the igneous rock complex of the Oslo region. II. Systematic petrography of the plutonic rocks. Sk. Utgitt Nor. Vidensk.-Akad. Oslo, I. Mat.-Naturv. Kl., 9.

Bentor, Y.K., 1974. Granodiorite. In: D.R. Bowes, (Editor), The Encyclopedia of Earth Sciences. V A, Igneous and Metamorphic Petrology (in press).

Bianchi, A., Callegari, E. and Jobstraibizer, P.G., 1970. I tipi petrografici fondamentali del plutone dell'Adamello. Mem. Ist. Geol. Min. Univ. Padova, 27.

Brinkmann, R., 1961. Kayser's Abriss der Geologie, I. G.A. Enke, Stuttgart.

Brögger, W.C., 1895. Die Eruptivgesteine des Kristiania-Gebietes. II. Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo im Südtyrol. Vid.-Selsk. Skr., I. Mat.-Naturv. Kl., 7.

Buddington, A.F., 1939. Adirondack igneous rocks and their metamorphism. Geol. Soc. Am., Mem., 7.

Burri, C. and Niggli, P., 1945. Die jungen Eruptivgesteine des mediterranen Orogens, I. Guggenbühl and Huber, Zürich.

Calkins, F.C., 1917. A decimal grouping of the plagioclases. J. Geol., 25: 157—159.

Callegari, E., 1963. La Cima Uzza II. Mem. Ist. Geol. Min. Univ. Padova, 24.

Cathrein, A., 1890. Die Dünnschliffsammlung der Tiroler Eruptivgesteine. N. Jahrb. Miner., 1890: 71—82.
Cayeux, L., 1929. Les roches sédimentaires de France. Mém. Carte Géol. France.
Chayes, F., 1952. The finer-grained calcalkaline granites of New England. J. Geol., 60: 207—254.
Chayes, F., 1957. A provisional reclassification of granite. Geol. Mag., 94: 58—68.
Committee on British Petrographic Nomenclature, 1921, 1936. Report. Miner. Mag., 19: 137—147; 73: 319—325.
Cross, W., Iddings, J.P., Pirsson, L.V. and Washington, H.S., 1902. The quantitative classification of igneous rocks. J. Geol., 10, 555—690.
Daminova, A.M., 1967. Petrografiya Magmaticeskich Gornich Porod. Nedra, Moskwa.
Deer, W.A., Howie, R.A. and Zussman, J., 1962. Rock-Forming Minerals, I—V. Longmans, London.
Ellis, S.E., 1948. On the delimitation of diorite and gabbro. Miner. Mag., 28: 447—469.
Fischer, G., 1965. Ueber die modale Zusammensetzung der Eruptiva im ostbayerischen Kristallin. Geol. Bavar., 55: 7—23.
Goldschmidt, V.M., 1916. Geologisch-petrographische Srudien im Hochgebirge des südlichen Norwegens, IV. Uebersicht der Eruptivgesteine im kaledonischen Gebirge. Vid.-Selsk. Skr., I. Mat.-Naturv. Kl., 2.
Harker, A., 1909. The Natural History of Igneous Rocks. Methuen, London.
Harker, A., 1923. Petrology for Students. University Press, Cambridge.
Hatch, F.H., Wells, A.K. and Wells, M.K., 1961. Petrology of the Igneous Rocks. Murby, London, 12th ed.
Heinrich, E.Wm., 1956. Microscopic Petrography. McGraw-Hill, New York, N.Y.
Holmes, A., 1917. A mineralogical classification of igneous rocks. Geol. Mag., 4 (6): 115—130.
Holmes, A., 1928. The Nomenclature of Petrology. Murby, London 2nd ed.; reprint 1971, Hafner, New York, N.Y.
Iddings, J.P., 1909, 1913. Igneous Rocks, I, II. Wiley, New York, N.Y.
IUGS Subcommission on the Systematics of Igneous Rocks, 1973. Classification and Nomenclature of Plutonic Rocks, Recommendations. — Geol. Newsletter, 1973, 2: 110—127 — N. Jahrb. Miner. Mh., 1973: 149—164 — Geotimes, Oct. 1973: 26—30 — Geol. Rundsch., 1974, 63: 773—785 — Vorobieva and Efremova (1973) — Sabine (1974) — Mikhailov (1975).
Johannsen, A., 1917. Suggestions for a quantitative mineralogical classification of igneous rocks. J. Geol., 25: 63—97.
Johannsen, A., 1920. A quantitative mineralogical classification of igneous rocks — revised. J. Geol., 28: 38—60, 159—177, 210—232.
Johannsen, A., 1922, 1929. Essentials for the microscopical determination of rock-forming minerals in thin sections. Univ. of Chicago Press, Chicago. 1st ed. 1922; 2nd ed. 1929.
Johannsen, A., 1931—1938, 1939. A descriptive petrography of the igneous rocks. I-IV, 1st ed., 1931—1938; I, 2nd ed., 1939. Univ. of Chicago Press, Chicago.
Jung, J. and Brousse, R., 1959. Classification Modale des Roches Éruptives. Masson, Paris.
Karl, F., 1966. Über die Zusammensetzung, Entstehung und gesteinssystematische Stellung tonalitisch-granitischer Gesteine. Tschermaks Miner. Petrogr. Mitt., 11: 413—438.
Lacroix, A., 1933. Contribution à la connaissance de la composition chimique et minéralogique des roches éruptives de l'Indochine. Bull. Serv. Géol. Indochine, 20 (3): 15—36, 183—206.
Lindgren, W., 1900. Granodiorite and other intermediate rocks. Am. J. Sci., 4 (9): 269.
Loewinson-Lessing, F., 1901. Lexique pétrographique. 8e Congr. Géol. Int., Paris, 2e fasc., 1003—1302.
Malaroda, R., 1948. Studi petrografici nell'Adamello nord-orientale.

Mehnert, K.R., 1968. Migmatites and the Origin of Granitic Rocks. Elsevier, Amsterdam, 393 pp.
Michel-Lévy, A., 1894. Structure et classification des roches éruptives. Bull. Carte Géol. France, 5.
Michot, J., 1961. Le massif complexe anorthosito-noritique de Haaland-Helleren et al palingenèse basique. Acad. Roy. Belg., Mém. Cl. Sci., 2 (15): 1—116.
Michot, P., 1964. Le magma plagioclasique. Geol. Rundsch., 54: 956—976.
Mikhailov, N.P., 1975. Klassifikatzija i nomenklatura plutoniceskich (intruzivnich) gornich porod. Akad. NAUK S.S.S.R., Petrograf. Komitet.
Milch, L., 1913, 1914. Die Systematik der Eruptivgesteine. Fortschr. Miner., 3: 189—227; 4: 175—250.
Miller, W.J., 1919. Silexite: a new rock name. Science, 44: 149.
Moorhouse, W.W., 1959. The Study of Rocks in Thin Sections. Harper, New York, N.Y.
Muir, I.D., 1973. A mineralogical classification of igneous rocks and glossary of terms. Dept. Miner. Pet., Cambridge.
Niggli, P., 1931. Die quantitative mineralogische Klassifikation der Eruptivgesteine. Schweiz. Min. Pet. Mitt. 11, 296—364.
Nockolds, S.R., 1954. Average chemical composition of some igneous rocks. Bull. Geol. Soc. Am., 65: 1007—1032.
Petrographical Committee of U.S.S.R. Sovremennoe sostojanie terminologii i nomenklaturi izverschennich porod. In: Magmatizm, Formatzii Kristalliceskich Porod i Glubini Zemli, IV (2). Nauka, Moskwa, pp. 87—100.
Rittmann, A., 1973. Stable Mineral Assemblages of Igneous Rocks. Springer, Heidelberg.
Ronner, F., 1963. Systematische Klassifikation der Massengesteine. Springer, Wien.
Rosenbusch, H., 1907—1908. Mikroskopische Physiographie der Massigen Gesteine. Schweizerbart, Stuttgart.
Rosenbusch, H. and Osann, A., 1923. Elemente der Gesteinslehre. Schweizerbart, Stuttgart, 4th ed.
Sabine, P.A., 1974. How should rocks be named? Geol. Mag., 111: 165—176.
Scheumann, K.H., 1925, 1929. Ausländische Systematik. Fortschr. Miner., 10: 187—310; 13: 235—311.
Shand, S.J., 1927, 1943, 1947. Eruptive Rocks. Murby, London.
Smulikowski, K., 1929. Les roches éruptives de la zone sub-beskidique en Silésie et Moravie. Kosmos, J. Soc. Pol. Nat., 54: 741—850.
Smulikowski, K., 1947. Petrological studies in the granitic areas of North-Wolhynia. Arch. Min. Soc. Sci. Lett. Varsovie, 16: 45—312.
Sørensen, H. (Editor), 1974. The Alkaline Rocks. Wiley, London.
Spurr, J.E., 1900. Classification of igneous rocks according to composition. Am. Geol., 25: 229—231.
Streckeisen, A., 1964. Zur Klassifikation der Eruptivgesteine. N. Jahrb. Miner. Mh., 195—222.
Streckeisen, A.L., 1967. Classification and nomenclature of igneous rocks. Final report of an inquiry. N. Jahrb. Miner. Abh., 107: 144—240 (out of print).
Streckeisen, A., 1974. How should charnockitic rocks be named? In: Géologie des Domaines Cristallins. Soc. Géol. Belg., Liège pp. 349—360.
Teruggi, M.E., 1950. Las Rocas Eruptivas al Microscopio. Coni, Buenos Aires.
Tobi, A.C., 1971. The nomenclature of the charnockitic rock suite. N. Jahrb. Miner. Mh., 1971: 193—205.
Tröger, W.E., 1935. Spezielle Petrographie der Eruptivgesteine. Verlag Dtsch. Miner. Ges.; reprint 1969, Schweizerbart, Stuttgart.
Tröger, W.E., 1938. Eruptivgesteinsnamen. (Nachtrag). Fortschr. Miner., 23: 41—53; reprint 1969, Schweizerbart, Stuttgart.
Tröger, W.E., 1967. Optische Bestimmung der gesteinsbildenden Minerale. 2. Schweizerbart, Stuttgart.

Turner, F.J. and Verhoogen, J., 1960. Igneous and Metamorphic Petrology. McGraw-Hill, New York, N.Y.
Vorobieva, O.A. and Efremova, S.V., 1973. O klassifikatzii izverschennich gornich porod. Izv. Akad. Nauk S.S.S.R., Ser. Geol., 8: 13—22.
de Waard, D., 1969. The anorthosite problem: The problem of the anorthosite-charnockite suite of rocks. In: Y.W. Isachsen (Editor), Origin of Anorthosite and Related Rocks. N.Y. State Mus. Sci. Serv., Mem., 18: 71—91.
Wedepohl, K.H., 1969. Composition and abundance of common igneous rocks. In: K.H. Wedepohl (Editor), Handbook of Geochemistry, I. Springer, Heidelberg, pp. 226—249.
Weinschenk, E., 1902, 1905. Grundzüge der Gesteinskunde, I, II. Herder, Freiburg i. Br.
Wenk, E., 1967. Die optischen Migrationskurven. In: C. Burri, R.L. Parker and E. Wenk (Editors), Die optische Orientierung der Plagioklase. Birkhäuser, Basel, pp. 179—242.
Wilkinson, J.F.G., 1967. The petrography of basaltic rocks. In: H.H. Hess, A. Poldervaart, (Editors), Basalts. Wiley, New York, N.Y. pp. 163—214.
Williams, H., Turner, F.J. and Gilbert, Ch.M., 1958. Petrography. Freeman, San Francisco.
von Wolff, F., 1951. Die Eruptivgesteine. Lang, Pössneck.
Wyllie, P.J. (Editor), 1967. Ultramafic and Related Rocks. Wiley, New York, N.Y., 464 pp.
Zanettin, B., 1956. Il gruppo del Marsèr. Mem. Ist. Geol. Min. Univ. Padova, 19.
Zirkel, F., 1893—1894. Lehrbuch der Petrographie, I—III. Engelmann, Leipzig, 2nd ed.

(Received March 11, 1975; revision accepted June 11, 1975)