Saskatchewan Geological Survey
Style Guide for Geoscience Publications, First Edition (September 2, 2016)

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R.F. Davie
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In collaboration with G. Heather Brown and the
Saskatchewan Geological Survey

To reflect changing language usage and spelling, this report will be reviewed regularly and updated as needed. Feedback from users of this guide is welcome. If you have comments or suggestions for revisions, please contact the Saskatchewan Geological Survey's production editor.

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Introduction

Editing Philosophy

The primary purpose of all editing is to ensure adherence to recognized rules of grammar, spelling and punctuation, and to ensure that what an author has written is clear, concise and can be understood by the target audience. Geoscience editing involves all of the above, but it also involves ensuring adherence to scientific and geoscientific standards, and accuracy of statements made in a publication.

It is an editor's job to review a manuscript for correct spelling and grammar, unclear phrasing or disjointed order of paragraphs; it is not an editor's—or a peer reviewer's—job to rewrite anything. If a word is spelled wrong, correct it; if some phrasing is unclear, question it and suggest alternate woding. If an author's style of writing produces confusing or convoluted sentences, or if the text contains too much jargon or too many clichés, an editor or reviewer may point this out to the author and suggest they rewrite the text. But an editor or reviewer does not change the text just because it isn't written the way they would write it.

Sources for Standards

The goals of any in-house style guide are to

- assist authors in preparing publications by establishing the organization's expectations in terms of format and content, and by answering the many questions that arise during the writing process; and
- provide a consistent, comprehensive set of standards that can be followed when a manuscript is edited, either by an editor within the organization or by a contract editor.

After careful consideration of several options, the Saskatchewan Geological Survey adopted *Geoscience Reporting Guidelines* by Brian Grant (Grant, 2003) as the basis for its in-house style.

Other sources for the guidelines and standards in this style guide are

Canadian Oxford Dictionary, Second Edition (2004), by K. Barber.

EUB Style Guide (December 1999), by the Alberta Energy and Utilities Board.

Glossary of Geology, Fifth Edition (2005), by K.K.E. Neuendorf, J.P. Mehl, Jr. and J.A. Jackson of the American Geological Institute.

Guide to Authors (1998), by the Geological Survey of Canada.

OGS Editorial Guide, Fourth Edition (1996), by A.J. Weatherston of the Ontario Geological Survey.

The Canadian Style: A Guide to Writing and Editing (1997), by Dundurn Press Ltd. and Public Works and Government Services Canada Translation Bureau.

The Chicago Manual of Style, Sixteenth Edition (2010), by The University of Chicago Press.

Although many topics discussed in Grant (2003) are also included in this style guide, for the main part the guidelines presented here comprise clarifications, exceptions or additions to the standards in that publication. Some of the guidelines in Grant (2003) are repeated here, for emphasis.

Visual Identity and Disclaimer

The Saskatchewan Geological Survey (SGS) is a branch of the Minerals, Lands and Resource Policy Division of Saskatchewan's Ministry of the Economy. Authors of SGS publications should ensure they use the full names of both the ministry and the survey in all addresses and example references. Within the text of a publication, only the survey name need be used.

The unofficial abbreviation for Saskatchewan Geological Survey is ‘SGS’. It’s acceptable to use this abbreviation in publications when the name appears frequently, but it should be defined on first use. The official abbreviation for Saskatchewan Ministry of the Economy is ‘ECON’. As with ‘SGS’, it may be used in publications if defined on first use.

An approved ‘visual identity’ logo must be displayed on all Saskatchewan government publications. These are added to all Saskatchewan Geological Survey publications by the production editor or the data manager.

In addition to the approved logo, all Saskatchewan Geological Survey publications must include the following disclaimer:

> Although the Saskatchewan Ministry of the Economy has exercised all reasonable care in the compilation, interpretation and production of this product, it is not possible to ensure total accuracy, and all persons who rely on the information contained herein do so at their own risk. The Saskatchewan Ministry of the Economy and the Government of Saskatchewan do not accept liability for any errors, omissions or inaccuracies that may be included in, or derived from, this product.

It is also useful to include the following statement on all SGS publications:

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substituting the digits for the correct year for ‘xx’.

There are no restrictions on the use or duplication of SGS publications for personal or educational purposes, but appropriate credit should be given. Adding the following statement to a publication ensures that credit is given in the proper format:

> Information from this publication may be used if credit is given. It is recommended that reference to this publication be made in the following form:

This statement is followed by an example of how to write the reference for the publication. For example, a reference for a paper in *Summary of Investigations* would be written:

> Schuurmans, E.D., Dale, J. and Salad Hersi, O. (2015): Preliminary study of paleosols in the Lower Cretaceous McLaren and Waseca members of the Mannville Group in Saskactchewan; *in* Summary of Investigations 2015, Volume 1, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Paper A-3, 11p.

Part 1 – Writing a Report: Grammar, Language and the Geosciences

Some may argue that the main focus of geoscience writing is the science, not accuracy in the application of arcane rules of grammar. But if a reader cannot easily grasp a point an author is trying to make, or has to read a sentence or paragraph three or four times to understand it, then the dissemination of that geoscience knowledge suffers.

To write as clearly and concisely as possible, keep the following points in mind:

- Titles and headings should clearly identify content.
- Use simple, well-structured, concise sentences. Shorter sentences are easier to read; a sentence length of 22 words or less is optimal.
- Keep in mind that the emphasis in a sentence can be changed simply by changing the order of the words. For example, “The discovery of uranium in the Athabasca Basin area was made in the early 1950s.” puts the emphasis of the sentence on ‘discovery’, but “Uranium was discovered in the Athabasca Basin area in the early 1950s.” puts the emphasis on ‘uranium’.
- Avoid ambiguity and colloquialisms; use concrete terms rather than abstractions (see ‘Word Usage’).
- Terminology must be consistent; new terms should be defined when they are introduced, each term should have only one meaning, and the same term should be used to mean the same thing throughout the text.
- Information should be easy to read and assimilate, organized in logical chunks, with similar topics presented in a similar manner.
- Paragraphs should be complete, organized units of information with smooth transitions between paragraphs.
- The text should reflect an appropriate level of detail for the intended audience.
- Figures should enhance and clarify information in the text; tables should succinctly present results or summarize details that, because of their length, would disrupt the flow of the narrative if written out in the text.

Word Usage

Grant (2003, p.221-246) has an excellent discussion on the misuse and overuse of certain words, and the trend toward use of jargon and cluttered language. Here are further points of clarification on the topic.

About and **approximately:** In most instances, these words can be used interchangeably, although approximately suggests a more careful calculation.

Abstract *versus* **concrete:** Try to avoid using abstract words when describing concrete things. Terms implying geological processes such as mineralization, chloritization, shearing, faulting, *etc.*, are abstract. 'Faulting' cannot 'strike northeasterly', though the fault or fault zone may.

Affect/effect: 'Affect', meaning to "produce an effect on; influence" (Barber, 2004), is used almost exclusively as a verb. 'Effect' can be used as a noun meaning "the result or consequence of an action" (Barber, 2004) and also as a verb meaning to "bring about or accomplish" (Barber, 2004).

Altitude/elevation: Although both terms denote 'height above sea level', 'altitude' is generally used to refer to the height of an object above the Earth's surface, whereas 'elevation' is generally used to refer to the height of the ground, or a feature fixed to the ground, relative to mean sea level.

Around means on every side, enveloping, and should not be used to mean 'about'.

An **assay** is a determination of the concentration of valuable metals in an ore and, as such, is a type of geochemical analysis. It should not be used as a synonym for 'geochemical analysis'.

Border/boundary: Although there are no rules governing the proper use of these two terms, it makes sense to use the former for political dividing lines or the surround of a map so the latter can be reserved for geological dividing lines, especially since the two uses can occur in the same sentence:

> The western boundary of the Wollaston Domain is defined by a pronounced geophysical lineament that is traceable from the Manitoba–Saskatchewan border northeasterly to the Nunavut border.

Both: Don't follow 'both' by 'as well as'; 'and' is sufficient.

Characteristic, distinctive, typical: The 'characteristic' quality of something is the one that distinguishes and identifies that thing. 'Distinctive' denotes an individual trait that sets something apart from its type or group. 'Typical' implies that the thing or person shows the characters peculiar to the type, class, species or group to which it belongs.

Contiguous/continuous/continually: The dictionary (Barber, 2004) defines the first as "touching, adjoining, in contact", the second as "unbroken, uninterrupted", and the third as "constantly or frequently recurring; always happening". Don't use them interchangeably.

Defective/deficient: 'Defective' is used when referring to what is lacking in quality; 'deficient' refers to what is lacking in quantity.

Disinterested and uninterested: A report on a mining property should be 'disinterested' (unbiased by personal interest) but should not suggest the author is 'uninterested' (not interested) in the subject.

Due to: The word 'due' is an adjective and must refer to some particular substantive in the sentence, not to the general notion expressed in the main sentence. "Due to the icy roadway, the car skidded." is incorrect, but "The skidding of the car was due to the icy roadway." is correct. If the reference is to the verb, 'because of' or 'owing to' should be used (*e.g.*, "Because of the icy roadway, the car skidded.").

Earlier/later and **older/younger:** 'Earlier' and 'later' are time terms, as in 'Upper Cretaceous or earlier'; 'older' and 'younger' refer to stratigraphic position, as in 'Gravelbourg Formation or older.'

Entail is often used where 'need', 'cause', 'impose' or 'necessitate' should be substituted.

Facilitate: Work may be ‘facilitated’ but people are not. So “The field geologist was facilitated in his work by three assistants.” is incorrect and should be written “The mapping carried out by the field geologist was facilitated by three assistants.”

Few, fewer, less: ‘Few’ and ‘fewer’ are used when referring to numbers; ‘less’ refers to degree, quantity or extent. ‘Less’ takes a singular noun (less choice), ‘fewer’ a plural noun (fewer choices).

Generally speaking: Avoid the expression ‘generally speaking’ in such sentences as, “Generally speaking, the outcrops were easy to see.” No one is speaking, not even the outcrops.

Hanging participle: Take care to avoid phrases where the subject is missing (called a hanging particle). The sentence “Having eaten our lunch, the boat sailed for the mainland.” is just as serious an error as “On crossing the ridge, the quartz veins appeared at closer intervals.”

However: Avoid using ‘however’ (which implies a comparison between things) when you really mean ‘nonetheless’ or ‘nevertheless’ (‘in spite of’), or ‘notwithstanding’ (‘all the same’).

***i.e.* and *e.g.*:** The first stands for *id est* (that is) and introduces a statement; the second stands for *exempli gratia* (for the sake of example) and introduces an example. Do not use one when you mean the other.

If and **when:** One of these words is usually sufficient.

Impact: Avoid using unless something actually hits something. Instead, use ‘effect/influence’ for the noun and ‘affect/influence’ for the verb.

Include/comprise: The verb ‘include’ implies only part of a whole; the verb ‘comprise’ implies all. So a section may ‘include’ fossiliferous limestone, but it ‘comprises’ this limestone as well as other rocks.

Intense, intensive: The former means existing in a high degree, the latter means directed to a single point, area or subject.

Last, latest: The former means final, the latter means most recent.

Least: It’s incorrect to use ‘least’ when referring to only two persons or things, use ‘less’ instead.

Major: Do not use as a substitute for ‘main’, ‘important’, ‘chief’, ‘principal’.

May/might: ‘Might’ is used as the past tense or the subjunctive of ‘may’. Therefore, ‘may’ should be used when the possibility remains open, either because the situation is unresolved or because its outcome is unknown:

> He may have killed himself. [suicide is suspected but not certain]
>
> He might have killed himself. [he’s lucky to be alive]

More or less: More or less is an overworked expression. “The beds are more or less vertical.” and “The situation is more or less unique.” are poor sentences. Nothing can be more than vertical or more than unique. ‘Almost’, ‘approximately’ and ‘virtually’ are more appropriate.

Multiple is often being used when what is really meant is ‘many’ or ‘numerous’.

Non: Avoid creating new words by prefixing ‘non’ to them when a suitable opposite already exists, *e.g.*, non-audible for inaudible; nonurban for rural; non-essential for unessential; non-concurrence for dissent.

Not to exceed: Except in technical specifications and similar work, ‘not more than’ should be used.

Over: The preposition ‘over’, whose primary meaning is “above, in or to a position higher than” (Barber, 2004), is too often used in place of ‘during’, ‘more than’ and ‘throughout’. Avoid the use of ‘over’ to mean ‘more than’ when referring to numbers.

Owing to: 'Owing to' is commonly followed by 'the fact that', a wordy phrase for which the conjunctions 'because', 'for' or 'as' might better be substituted.

Partly, partially: The first means 'in part, in some degree'; the second means 'incompletely'.

Preferable: Preferable should not be compared; 'more preferable' is incorrect.

Proportion: Use only to refer to statistics. For 'a proportion of', use 'some'; for 'a large proportion of' use 'many'.

'Provided that' introduces a stipulation (on the condition that) and is preferable to 'providing'.

Quantity: Avoid such expressions as 'the majority of', 'a good deal of', 'a lot of' and 'a number of' where the words 'most' or 'much' will serve for the first three expressions, and one or other of 'a few', 'several', 'many' or 'numerous' will convey a more definite meaning for the last.

Substitute/replace: 'Substitute' is to put a person or thing in place of another; 'replace' is to take the place of another. 'Substituted by' is incorrect, the correct term is 'replaced by'.

Such as/so forth: A series list that includes 'either' or 'so forth' should not be introduced by 'such as'. The phrases 'such as' and 'so forth', used together, are redundant.

Thick and thickness: The expression 'the beds are 2 to 3 m thick' is preferable to 'the beds are 2 to 3 m in thickness', but no choice is allowed in the expression 'the beds vary in thickness from 2 to 3 m'.

Time: Although not incorrect, the expression 'occurred closer to the end of Mannville time' would be more accurate if reworded as 'occurred closer to the end of deposition of the Mannville Group'.

Time terms: 'While', 'when', 'since', 'never' and 'often' are essentially time terms, and should be replaced by 'although', 'where', 'because', 'as', 'nowhere', 'commonly', *etc.*, in such sentences as "While others may disagree..." (should be rewritten as "Although others may disagree...."); "When the fault swings to the west ..." (should be rewritten as "Where the fault swings to the west..."); "Since the shaft is flooded..." (should be rewritten as "Because the shaft is flooded..."). The words are correctly used in "While I am away, you...", "When the first assays were run...", "Since the First World War, prices ...".

Under way/underway: 'Under way' is used when the meaning is that something is happening, is going ahead, as in "The project is now under way." 'Underway' is an adjective that means 'occurring while in motion', as in "We are going to try underway refuelling."

Value is an attribute, not a substance. An ore does not 'carry high gold values', though it may contain much of that valuable metal. Nor does an explorationist 'encounter good values' in a sample, but may encounter valuable minerals, or minerals that carry valuable metals.

Verbal: Do not use 'verbal' (which means 'in words') when 'oral' (which means 'in spoken words') is meant.

Voice: A change of voice, from active to passive or *vice versa*, should not occur in a sentence, and preferably not in a paragraph. For example, the sentence "The writer spent last season in the area, and it is expected that he will return next year." should read "The writer spent last season in the area, and expects to return next year."

While: Use 'whereas' when the meaning is 'in contrast or comparison with' and 'while' when the meaning is 'during the time that'.

Anthropomorphism

Reports cannot discuss, suggest or recognize; only humans are capable of such actions. Therefore, the following:

> the project aims to...

should be reworded to

> the aim of this project is to…

Pluralization of Rock and Mineral Names

Authors should use ‘rocks’, ‘deposits’, ‘sedimentary rocks’ (lithified) or ‘sediments’ (unlithified), as appropriate (*e.g.*, ‘granite’ or ‘granitic rocks’ rather than ‘granites’, ‘metavolcanic rocks’ rather than ‘metavolcanics’, ‘sand’ or ‘sand deposits’ rather than ‘sands’, ‘clastic sediments’ rather than ‘clastics’).

Use ‘accessory minerals’ rather than ‘accessories’.

Use of the plural form of a rock name is acceptable when two different types of the rock are being referred to, as in the following example:

> This correlates with the G_4 cataclastic and augen gneisses within the RAGC.

or when the term ‘basalt’ is being used to refer to each flow of a flood basalt unit such as the Chilcotin Group in British Columbia, so the set of flows would be referred to collectively as ‘basalts’. The same exception would apply to such sedimentary terms as ‘turbidites’ and ‘olistostromes’, and such textural terms as ‘tuffs’, ‘breccias’ and ‘pegmatites’, all of which are more likely to be used in the singular to refer to individual units or beds.

The following example shows the proper use of both the singular and plural forms of a rock name:

> They comprise gneisses of metasedimentary origin, including biotite, hornblende-biotite-garnet, cordierite-sillimanite-biotite-garnet and quartz-rich types, interpreted to have formed from arenite to arkosic wacke to pelitic greywacke.

Avoiding Grammatical Faults

Restrictive and Nonrestrictive Clauses

The following succinct explanation, reproduced verbatim from the *EUB Style Guide* (Alberta Energy and Utilities Board, 1999, p.6), expands on the brief explanation in Grant (2003):

> A restrictive clause is an adjectival clause or phrase that follows a noun and restricts or limits the meaning of the noun in a way that is essential to the meaning of the sentence; it usually begins with *that* (or *who* in references to persons); and it is not set off by commas.
>
> > The metavolcanic rocks that lie west of the fault are the only ones with copper mineralization.
>
> A nonrestrictive clause is an adjectival clause or phrase that is purely descriptive and could be dropped without changing the meaning of the sentence; it usually begins with *which* (or *who* in reference to persons); and it must be set off by commas.
>
> > The metavolcanic rocks, which have not yet been thoroughly sampled, will be the subject of next year's fieldwork.
>
> Traditionally, *that* introduces a restrictive clause, while *which* introduces a nonrestrictive clause, as above.

The following example illustrates the confusion that can be caused by incorrect use of punctuation with a nonrestictive clause.

> The pillows which are adjacent to a shear zone have a flattening ratio of approximately 10:1.

Does the author mean that only those pillows adjacent to a shear zone have the flattening ratio of 10:1 (in which case, 'which' should be replaced by 'that'), or that all the pillows are adjacent to a shear zone and all have the same flattening ratio (in which case, there should be commas around 'which are adjacent to a shear zone')?

Singular and Compound Subjects and Objects

Notwithstanding the statement in Grant (2003) that a compound subject (two nouns connected by 'and') always takes a plural verb, a singular verb can be used when the compound subject refers to a single entity or concept, as in the following example:

> Sand and gravel is important to the construction industry.

A singular verb is necessary when the subject is singular and the complement is plural.

> Our only guide was the Regulations. **but** The Regulations were our only guide.

The word *what* takes a singular verb even if its complement is plural.

> What we need is more samples.

Words joined to the subject by *with*, *together with*, *including*, *as well as*, and similar connectives do not affect the number of the verb.

> The foreman, as well as the men, was leaving.

If the word *number* is used collectively, the verb is singular.

> The number of samples taken is more this year than last.

If individual units are referred to, the word *number* takes the plural verb.

> A number of the samples are from the same rock unit.

Company and organization names are treated as a single entity, as in the following example:

> Actlabs allows its clients to choose from among numerous analytical methods.

Although one would say “the concentrator was designed to handle 5000 tonnes/day”, common practice is to use the singular, as in “the 5000 tonne/day concentrator”.

A construction such as “…Methy and Waterways formations outcrops…” should be changed to “…outcrops of the Methy and Waterways formations….”. However, “shale overlies the Prairie Formation halite” is acceptable.

Unless unavoidable, try not to use (s) to indicate a plural, as in “The event(s) that caused the deposition to be interrupted...”. Instead write “The event or events that caused the deposition to be interrupted...”

The following sentence reads best if both singular and plural versions of the verb are included:

> In summary, the parental magma(s) of the Mayville intrusion was/were subalkaline and tholeiitic, and may have been contaminated by crustal material during emplacement into a magmatic-arc environment.

Pronouns Taking Singular Verbs

The word *none* takes a singular verb when its meaning is strictly confined to *not one*:

> None was injured.

However, when the intended meaning of *none* is *not any*, use a plural verb:

> None of the enquiries were answered.

Words such as *either* (or *any* if referring to one), *neither* (or *none* when referring to one), *each,* and *everyone* also take a singular verb when used as pronouns:

> Neither of the clerks is eligible.
>
> Everyone complains that their pay is inadequate.

Prepositions and Idiomatic Expressions

A common problem in writing of any kind is selecting the best preposition to use in a given situation. Appendix 1 is a list of appropriate prepositions to use with certain nouns, verbs, adjectives and adverbs.

Contrary to what we think is a rule set in stone, there <u>are</u> instances when a sentence can end in a preposition:

a) when the spontaneity of a sentence would be lost by inverting the preposition.

> That depends on with what you write.
>
> sounds much better when written:
>
> That depends on what you write with.

b) when the preposition is part of a contrived verb, like *put off*, *put forward* or *put up with*.

Do not omit a preposition in expression of time (*on* October 4) or when a different preposition is required in a series.

> She had a knowledge **of** and a keen interest **in** Archean tectonics.

Parallelism

Nonparallelism is a situation in which the structure of an item in a list is not consistent with that of the remaining items. Some examples of rewriting to avoid nonparallelism:

> The quartz crystals range in length from 6 to 9 mm and in width from 2 to 3 mm.
>
> **not** The quartz crystals range in length from 6 to 9 mm and from 2 to 3 mm in width.
>
> The boundary between the belts is fairly distinct in some places and indefinite in others.
>
> **not** The boundary between the belts is fairly distinct in places and in places indefinite.

In the following example, the structure of the last item in the list is not parallel with that of the others because it doesn't complete the sentence begun by the introduction to the list:

> The aim of the 2014 field investigation was to 1) map the Bassett Lake intrusion in detail; 2) re-evaluate the contact relationships between the intrusion and mafic to felsic volcanic rocks to the north and south; and 3) hand samples would be collected for whole-rock geochemical analysis.

The sentence should be written:

> The aim of the 2014 field investigation was to 1) map the Bassett Lake intrusion in detail; 2) re-evaluate the contact relationships between the intrusion and mafic to felsic volcanic rocks to the north and south; and 3) collect samples for whole-rock geochemical analysis.

Problems with Modifiers

The proper placement of a modifier (a word that 'modifies' a word or term it precedes) is important to the clarity of a sentence.

In the following sentence, the reader can't be certain whether the conductivity of the overburden and limestone is highly variable or variably high:

> The airborne electromagnetic survey showed that the overburden and limestone is variably highly conductive.

The revised sentence, below, assumes that the latter alternative is the correct one:

> The airborne electromagnetic survey showed that the overburden and limestone have highly variable conductivity.

The following table illustrates several more examples of how proper placement of modifiers can improve the clarity of a sentence.

In the following examples, the complexity of one of the modifiers makes the sentence difficult to read	They are much clearer when rewritten as
Drillcore from two holes that intersected an at least three hundred metres long, several metres thick, massive to disseminated, stratabound and stratiform sulphide layer was examined.	Drillcore was examined from two holes that intersected a massive to disseminated, stratabound and stratiform sulphide layer that was at least 300 m long and several metres thick.
The Eden Lake carbonatite complex is a syenite-monzonite-alkali granite dominated, upper-mantle/lower-crust derived alkaline complex that is exposed over an area greater than 30 km^2.	The Eden Lake carbonatite complex is an alkaline complex, exposed over an area greater than 30 km^2, that is derived from the upper mantle–lower crust and dominated by syenite, monzonite and alkali granite.
a several kilometre thick unit	a unit several kilometres thick
a variably silica altered, chlorite amygdule bearing feldspar phyric basaltic flow	a variably silica-altered, chlorite-amygdule–bearing, feldspar-phyric basaltic flow
Here, fine to medium grained massive pyrrhotite plus chalcopyrite boulders up to 50 cm size occur as float beneath a large, gossanous outcrop of highly silica altered, feldspar plus clinopyroxene phyric andesite porphyry.	Here, boulders of fine- to medium-grained massive pyrrhotite plus chalcopyrite, up to 50 cm in size, occur as float beneath a large gossanous outcrop of highly silica-altered, feldspar+clinopyroxene–phyric, andesite porphyry.
This is a north-trending, steeply east-dipping and fault-hosted quartz-pyrite-galena-tetrahedrite--bearing banded shear vein.	This is a north-trending, steeply east-dipping, banded shear vein that is fault hosted and contains quartz, pyrite, galena and tetrahedrite.
Samples were crushed between 20 to 30 mesh sieve sizes.	Samples were crushed to a sieve size of 20 to 30 mesh.
250 m line-spaced airborne magnetic survey	airborne magnetic survey flown at 250 m line spacing
Project objectives include generating deposit type and surficial environment specific geochemical exploration models.	Project objectives include generating geochemical exploration models for specific deposit types and surficial environments.

Italicization and Non-English Characters

The majority of words that should be italicized in the text of a report comprise paleontological terms (which are based on the *Code of Stratigraphic Nomenclature* and should be followed closely), and foreign words and phrases such as *et al.*, *etc.*, *lit-par-lit*, *versus*, *circa* and their abbreviations (*vs.*, *ca.*).

Modifiers to paleontological terms, such as cf. and sp. are not italicized.

Other instances where italicization is used in the text of a publication are

- when giving titles of books, journals, newspapers, *etc.*;
- for the titles of acts and laws, *etc.* (*e.g.*, '*The Mining Act*'); and
- for figure and table captions in SGS publications.

Although in the past file extensions (*e.g.*, *.pdf*, *.txt*) were usually italicized, that is no longer common practice.

If at all possible, retain accents and other embellishments for characters that are from languages other than English (*e.g.*, á, ě, ï, õ, ŗ). The majority of letters that take various types of accents in foreign languages can be found in the submenus of Word's extensive Symbols list. If you can't find a certain character, make sure to bring it to the attention of the editor when you submit your publication so that it can be dealt with properly.

Quebec (the province) is a name of 'pan-Canadian' significance and therefore doesn't have an accent in English text. Québec (the city) doesn't have pan-Canadian significance and therefore does have an accent. In French text, both city and province would have an accent.

Capitalization

Grant (2003, p.265-272) includes an extensive set of guidelines for capitalization of many types of words commonly used in geoscience writing, including various types of geoscience terms. The following points expand on, clarify or add to those guidelines.

Titles and Headings, Footnotes and Captions

Use title case in all titles of SGS publications, and all levels of heading. For example:

> Geology, Geochemistry and Geochronology of Basement Rocks in the Area of the Discovery Camp **[title]**
>
> Study Area and Methods **[heading]**

Footnotes, and figure and table captions are sentence case (*i.e.*, only the first word and proper nouns are capitalized). For example:

> *Table 1 – Results of platinum group element and gold analyses for selected samples of mafic rocks from the Bassett Lake intrusion. (Sample locations are shown in Figure 2.)*

Column headings in tables are in title case; text within the rows is in sentence case.

Proper Adjectives and Nouns

Names of institutions are capitalized, as are official titles of persons when used without their personal name.

> Saskatchewan Research Council
>
> University of Saskatchewan
>
> the Premier
>
> the Solicitor General
>
> the Minister
>
> Canadian Pacific Railway

Words like 'government', 'department' and 'ministry' are only capitalized when used in a specific sense (*e.g.*, 'the Saskatchewan Government', 'the Department of Internal Affairs', 'the Ministry of the Economy').

Capitalize NI 43-101 official categories, *e.g.*, 'Measured and Indicated Resources'.

The common names of species are generally not capitalized unless part of the name is a proper noun (*e.g.*, mountain pine beetle, sockeye salmon **but** Douglas fir, Kirtland's warbler, Carolina wren). When in doubt, a quick search of Wikipedia should give you correct capitalization rules according to the academic practice in each group of organisms.

Terminology Related to Aboriginal Peoples and Communities

The following guidelines for capitalization of terminology related to Aboriginal Peoples are taken verbatim from *The Canadian Style* (http://www.btb.termiumplus.gc.ca/tpv2guides/guides/tcdnstyl/index-eng.html?lang=eng&lettr=&page=../introduction):

> Capitalize the singular and plural forms of the nouns *Status Indian, Registered Indian, Non-Status Indian* and *Treaty Indian,* as well as the terms *Aboriginal, Native* and *Indigenous* when they refer to Aboriginal people in Canada.
>
> The terms *Aboriginals* and *Natives* are **not** used as proper nouns. When *Aboriginal, Indigenous* and *Native* are used as adjectives, note the following noun forms:
>
> > Aboriginal person (one individual)
> >
> > Aboriginal persons, Aboriginal people (more than one person)
> >
> > Aboriginal peoples (two or more Aboriginal groups)
> >
> > Representatives from three Aboriginal peoples were present.

Any Native person in Alberta is eligible under this program.

The conference could not have succeeded without the help of almost a thousand Indigenous people from all over Saskatchewan.

The official names for First Nation communities vary in format from community to community; they are listed on the Aboriginal Affairs and Northern Development Canada website at http://pse5-esd5.ainc-inac.gc.ca/fnp/Main/Index.aspx?lang=eng.

When referring to several communities by location, use “from the Cree communities (or First Nations) at Norway House, God’s Lake Narrows and Oxford House”; when referring to the First Nation names, use “from the Cree First Nations of Norway House, God’s Lake and Bunibonibee”. Entities traditionally known as ‘reserves’ should be identified as First Nation Reserve Lands and should be identified by their names on a map (*e.g.*, Dog Lake Reserve Lands or Red Cloud Reserve Lands). Communities that self-identify with Cree or Dene rather than First Nation will call themselves Dog Lake Dene Nation 206, so the map polygon would be termed Dog Lake Dene Reserve Land.

Biozones

“All words in every formally named stratigraphic unit begin with capital letters, except for the specific name in a biozone.” (Owen, 2009; see also Murphy and Salvador, 1999). Therefore, everything but the species name is capitalized. For example

Early *varcus* Conodont Zone

Spiriferide Brachiopod *Emanuella meristoides* Zone

Political and Geographic Divisions

Grant (2003) lists a few examples of correct capitalization of geographic terms and the reasoning behind it, but here are a few more examples:

Carleton County

the Prairie provinces, Atlantic provinces (contrary to Grant, 2003)

the Eastern Townships

the West

the Continental Divide

the International Boundary

the Northern Hemisphere

Coast Mountains (*but* eastern Coast Mountains)

Pacific coast (not a specific geographic division)

Great Divide

Great Plains

Red River valley

Fraser River valley

Geographic Names

If appropriate to the text, use the word ‘the’ in front of ‘Northwest Territories’ but not in front of ‘Yukon.’

Use ‘United States’, not ‘United States of America’.

When two or more features of the same type are listed, the generic should be lower case regardless of whether it precedes or follows the specific, *e.g.*,

Athabasca and Sturgeon rivers

lakes Erie and Ontario

When an unofficial place name is used as a modifier for a noun, the generic of the place name should be lower case to avoid giving the impression that the place name is official (*e.g.*, Crenulation bay pegmatite dykes). If a named camp is used as a geographic location, it is permissible to capitalize the specific part of the name (*e.g.*, "... the geochemistry of the basement rocks around the Discovery camp ......").

In an area with few named geographic features, it is permissible to assign an alphanumeric character to a feature that is frequently used as a reference point for the locations of geological features of interest. The generic must be in lower case and the alphanumeric character must be in single quotation marks (*e.g.*, lake 'A').

If you are uncertain whether a geographic name is official or unofficial, check the *Canadian Geographical Names Data Base* (CGNDB) at Natural Resources Canada (http://www4.rncan.gc.ca/search-place-names/search?lang=en). Any names not appearing in this database are considered unofficial.

Geological Time

The SGS uses the *International Chronostratigraphic Chart*, published by the International Commission on Stratigraphy, as its standard for chronostratigraphic stages (go to 'http://www.stratigraphy.org', then click on the link for 'Chart/Time Scale' to access the most recent chronostratigraphic chart).

Notwithstanding the usage in the abovementioned chart and in agreement with Grant (2003, p.234), modifiers used to denote part of a unit of geological time (*e.g.*, eon, era, period, epoch) should be early, middle and late. They can only be capitalized if the subdivision in question has been formally divided in this manner. A well-known exception is the Cretaceous, which has been subdivided only into Early and Late; therefore, Middle Cretaceous does not exist, but it is acceptable to use mid-Cretaceous if the author is referring to a time period that straddles the boundary between Early and Late Cretaceous.

Note that the terms 'early', 'middle' and 'late' are used when referring to age; 'lower', 'middle' and 'upper' are used when referring to stratigraphic position.

If an author wishes to use proposed—but not necessarily widely known—terminology for geological subdivisions, it is suggested that these subdivisions be defined, and their source indicated. For example, at the first use of the term 'Rhyacian', a geologist should add the following footnote:

> This paper uses the following proposed subdivisions of the Paleoproterozoic era (*after* Gradstein *et al.*, 2004), from oldest to youngest: Siderian (2.50 to 2.30 Ga), Rhyacian (2.30 to 2.05 Ga), Orosirian (2.05 to 1.80 Ga) and Statherian (1.80 to 1.60 Ga).

Stratigraphic Nomenclature

The SGS follows the rules of the North American Commission on Stratigraphic Nomenclature (NACSN) for capitalization of formally and informally recognized stratigraphic units. The Petroleum Geology Unit produces a *Stratigraphic Correlation Chart* that shows the accepted stratigraphic nomenclature for units in Saskatchewan, neighbouring provinces and states. This chart is used for confirmation of correct spelling of all stratigraphic units in the areas covered by the chart.

For capitalization of stratigraphic units outside the geographic area covered by the Petroleum Geology Unit's *Stratigraphic Correlation Chart*, use the recognized standards for that area. The *Geological Atlas of the Western Canada Sedimentary Basin* (Mossop and Shetsen, 1994) is a good source for capitalization of stratigraphic units in Canada's western provinces.

Names of Geological and Other Features

The rules for capitalization of geological features—both formal and informal—vary from province to province, state to state and country to country: always retain the capitalization given by the original author and give a reference for the origin of the term. A general rule to follow is: if a unit is formally recognized, it should be capitalized.

When two or more formally recognized names of the same type are listed, the feature type should always be lower case (*e.g.*, Shaunavon Formation, Gravelbourg Formation **but** Shaunavon and Gravelbourg formations; Wollaston Domain, Glennie Domain **but** Wollaston and Glennie domains; Upper Bakken Member, Lower Bakken Member **but** Upper and Lower Bakken members).

If in doubt about whether a unit is formal, a good place to begin your research is the *Lexicon of Canadian Geological Names* (http://weblex.nrcan.gc.ca/weblex_e.pl).

Authors may request a change in the name, status or description of a Phanerozoic lithostructural feature by submitting supporting documentation (*i.e.*, the publication(s) in which the feature is formally named and described) to their manager, who will review the request. If approved, the author must cite the supporting document(s) following the first use of the feature in their report.

To avoid ambiguity, authors intending to convey the original definition of a Precambrian geological feature (*e.g.*, Pikoo kimberlite belt) should provide the accepted original reference for that term immediately following its first use in their report.

When used in conjunction with a named feature, lithostructural terms that are not formally recognized should only be capitalized as shown below.

allochthon (*e.g.*, Snow Lake allochthon)

anticline (*e.g.*, Beresford Lake anticline)

arc (*e.g.*, Yavapai arc)

arch, Arch (*e.g.*, Severn arch **but** Sweetgrass Arch)

assemblage (*e.g.*, Four-Mile Island assemblage, Flin Flon arc assemblage)

axis (*e.g.*, Birdtail-Waskada axis)

basin (*e.g.*, Kisseynew basin, Jackfish basin; except for widely accepted features such as, Athabasca Basin, Western Canada Sedimentary Basin, Hudson Bay Basin)

batholith, Batholith (*e.g.*, Wathaman Batholith (Sask.) **but** Chipewyan batholith (Man.), Chipewyan/Wathaman batholith (general))

beach (*e.g.*, Campbell beach)

belt (*e.g.*, Rice Lake greenstone belt, Birch Rapids straight belt, Kisseynew gneiss belt, Kisseynew metasedimentary gneiss belt)

block (*e.g.*, Split Lake block)

boundary (*e.g.*, Wollaston Domain boundary)

cave (*e.g.*, Sunset cave)

collage (*e.g.*, Amisk collage)

complex (*e.g.*, Jackpine Lake complex, Flin Flon–Glennie complex, Taltson basement complex, Jan Lake granitic complex, Garner Lake intrusive complex, Wanipigow River plutonic complex)

craton (*e.g*., Sask craton, Hearne craton)

delta (*e.g.*, Assiniboine delta)

diatreme (*e.g.*, Ospika diatreme)

diversion (*e.g.*, Churchill River diversion)

Domain (*e.g.*, Kisseynew Domain, Beaverlodge Domain)

dome (*e.g.*, Herblet Lake dome)

escarpment, Escarpment (*e.g.*, Meadow Lake escarpment, Manitoba escarpment **but** Niagara Escarpment)

fault, Fault (*e.g.*, Black Bay fault, Railway thrust fault, Ross Lake–Mandy Road fault block **but** Tabbernor Fault)

formation, Formation (*e.g.*, Gillies Channel formation, Mission Canyon Formation); only capitalized for a formally defined stratigraphic unit, as recognized by NACSN

glacial Lake Agassiz, global Last Glacial Maximum, Last Glacial cycle, Lateglacial period

glacial terrain zone (*e.g.*, Quinn Lake glacial terrain zone) gorge (*e.g.*, Souris gorge)

granite, Granite (*e.g.*, Jan Lake granite but Lodge Bay Granite)

group, Group (*e.g.*, Thluicho Lake group, Athabasca Group, Colorado Group, Madison Group); only capitalized for a formally defined stratigraphic unit, as recognized by NACSN

ice divide, ice extent, ice field, ice sheet (but Keewatin Ice Divide, the Maximum Ice Extent, Columbia Icefield, Laurentide Ice Sheet)

inlier (*e.g.*, Black Bay Island Lake inlier)

intrusion

island arc (*e.g.*, Bonanza island arc)

layer (*e.g.*, lower chromitite layer)

level, Level (*e.g.*, 200 m level of the mine, Second Prairie Level)

lobe (*e.g.*, Red River lobe)

marsh (exceptions: Delta Marsh, Netley Marsh)

member, Member (*e.g.*, Dunlop member, Raibl member, Upper Shaunavon Member); only capitalized for a formally defined stratigraphic unit, as recognized by NACSN

metallotect

moraine (*e.g.*, Darlingford moraine)

occurrence

oil field trend, oil sands (*e.g.*, Upper Shaunavon oil field trend, Athabasca oil sands)

Orogen (*e.g.*, Trans-Hudson Orogen)

orogeny (*e.g.*, Trans-Hudson orogeny, Grenville orogeny)

plate (*e.g.*, Juan de Fuca plate)

pluton (*e.g*., Hanson Lake pluton, Rachkewich Lake pluton)

pool (*e.g.*, Dollard pool, Rapdan pool)

property

prospect

Province (*e.g.*, Hearne Province, Superior Province)

redbed (when used generically)

Red Beds (*e.g*., First Red Beds, Lower Red Beds)

reservoir, reservoirs (*e.g.*, Middle Jurassic reservoirs); unless used to distinguish a specific reservoir identified in a study (*e.g.*, "In the study area, the extent of Reservoir A has been defined as ....")

ridge (*e.g.*, Blackfoot ridge)

sea, Sea (*e.g.*, Bearpaw sea but Mediterranean Sea)

sequence (*e.g.*, Grey Point sequence)

series (*e.g.*, ultramafic series of the Bird River sill)

shale (except when the rock type is part of the formal name of a formation, in which case, 'Shale'; *e.g.*, Pierre Shale, Second White Speckled Shale)

shear zone (*e.g.*, Johnson shear zone)

showing

sill (*e.g.*, Bird River sill)

spillway (*e.g.*, Pembina spillway)

structure (*e.g.*, Carswell structure)

subdomain (*e.g.*, Northern Lights subdomain, Suggi subdomain)

subgroup, Subgroup; capitalize only if recognized by NACSN

subprovince

subunit

suite (*e.g.*, Jan Lake suite, Nemeiben Lake intrusive suite, Footprint Lake plutonic suite) supergroup, Supergroup; capitalize only if recognized by NACSN (*e.g.*, Wollaston Supergroup)

superterrane (*e.g.*, North Caribou superterrane)

syncline, synform (*e.g.*, Hidden syncline, Haugen Lake synform)

terrane (*e.g.*, Oxford Lake–Stull Lake terrane)

thrust (*e.g.*, McLeod Road thrust)

till (*e.g.*, Kormano till)

unit (*e.g.*, unit 8, Boyne Member–chalky unit)

uplands (*e.g.*, Grand Rapid uplands)

uplift (*e.g.*, Black Hills uplift)

valley (*e.g.*, Berry Creek valley)

window; not capitalized unless part of a formally recognized term (*e.g.*, Hunter Bay tectonic window, Pelican tectonic window **but** Pelican Window)

zone; not capitalized unless part of a formally recognized term or for formal biostratigraphic zones (*e.g.*, Superior boundary zone, Cadillac–Larder Lake fault zone, Howard Lake mylonite zone, Paull River shear zone, Lawrence Point suprasubduction zone, Snowbird tectonic zone **but** Reindeer Zone, Churchill–Superior Boundary Zone, Birdtail-Waskada Zone, Fish Scales Zone, Lower Tournaisian *sulcata* Zone)

Punctuation

Comma

Grant (2003) outlines thoroughly the correct use of commas, including the ‘serial comma’ or ‘Oxford comma’ (the Oxford comma is so called because it was traditionally used by editors and printers at Oxford University Press; it is placed before the final ‘and’ or ‘or’ in a list of elements within a single sentence). Whether to include the serial comma has sparked many arguments over the years. Many style guides are in favour of inclusion because omitting the final comma may cause ambiguities, whereas including it seldom will.

The SGS follows the lead of the majority of style guides in **not** using the serial comma. So the following sentence

> These include sediment transport processes, short- and long-term sedimentation rate, oceanic productivity, and clay mineral microfacies.

should be written

> These include sediment transport processes, short- and long-term sedimentation rate, oceanic productivity and clay mineral microfacies.

Nevertheless, there is at least one instance where the serial comma is necessary. When the last or second to last element in a series consists of a pair joined by ‘and’ or ‘or’, the pair and the ‘and’ (or ‘or’) before the last series element should be preceded by a comma:

> The meal consisted of soup, salad**, and** macaroni and cheese.
>
> John was working, Jean was resting**, and** Alan was running errands and furnishing food.
>
> The Sickle Group comprises a diverse stratigraphy of quartzofeldspathic sandstone, pebbly sandstone, hornblende-bearing sandstone and pelite, and heterolithic conglomerate.
>
> The Snow Lake primitive arc, which is composed of low-Ti refractory basalt lavas (Welch formation), boninite lavas, and isotopically juvenile felsic flows and tonalite plutons, has been interpreted by Bailes and Galley (1999) to be the result of high-temperature hydrous melting of refractory mantle sources in an extensional and/or proto-arc environment.

Colons and Semicolons

In addition to the uses listed in Grant (2003) for colons and semicolons, the following guidelines will help geoscience writers.

Colons are used to introduce a word, a phrase, a clause, a list or a complete sentence **only if they do not separate a preposition from its object, or a verb from its object or object complement**.

For example, the sentence

> The middle Carlile member contains mainly specimens of *Saccammina alexanderi*, *Ammobaculites* sp., *Ammobaculites whitneyi*, *Haplophragmoides* sp., *H. Howardense*, *H. gigas*, *Trochammina* sp., *T. rutherfordi* and *T. boehmi (?)*.

is correct because to place a colon after ‘of’ would separate the preposition from its objects.

Similarly, having a colon after the word ‘are’ in the following sentence

> The main fossil species of this unit are: *Globigerinelloides prairiehillensis?*, *Heterohelix globulosa*, *Hedbergella planispira* and *Heterohelix reussi?*.

is incorrect, because the colon is separating the verb from its objects.

Colons also should not be used after an introductory clause, unless that clause is an independent one. The sentence below does not take a colon after ‘such as’ because that introductory clause is not an independent one.

> The lower part of the Milk River Formation logged in this study is comprised exclusively of agglutinated benthic taxa, such as *Trochammina ribstonensis*, *Pseudobolivina rollaensis*, *Haplophragmoides* sp., *Ammobaculites* sp. and *Dorothia smokyensis*.

If rephrased as

> The lower part of the Milk River Formation logged in this study is comprised exclusively of agglutinated benthic taxa, such as the following: *Trochammina ribstonensis*, *Pseudobolivina rollaensis*, *Haplophragmoides* sp., *Ammobaculites* sp. and *Dorothia smokyensis*.

the use of a colon after ‘the following’ is correct.

A colon is also used to identify a ratio of chemical elements where there is no specific value given, *e.g.*, “Au:Ag ratios are consistent throughout the outcrop.”, but use a solidus if there are values given, *e.g.*, “The deposit was said to have Au/Ag ratios of 2:1.”

Semicolons introduce a pause or a degree of separation of ideas in a sentence that is less than a colon but more than a comma. Proper use of semicolons can be essential for understanding, particularly in the case of lists:

> [Before] The exposed Precambrian crystalline basement in northeastern Alberta hosts over 200 occurrences of stratiform and disseminated sulphide, intrusion-related, magmatic-hydrothermal iron oxide breccia or vein, and shear-hosted quartz vein precious and base metal occurrences, some with significant exploration potential.
>
> [After] The exposed Precambrian crystalline basement in northeastern Alberta hosts more than 200 occurrences, some with significant exploration potential, of stratiform and intrusion-related, disseminated sulphides; magmatic-hydrothermal iron-oxide breccias/veins; and shear-hosted quartz-vein precious and base metals.

Lists and Bulleted Items

The main use for colons and semicolons in geoscience writing is in lists, either serial lists (where the items are listed in one continuous sentence) or vertical lists (where each item in the list is placed on a separate line with the individual items marked by bullets or numbers).

The section on bulleted and numbered lists in Grant (2003, p.162-163) provides good advice on this important component of scientific reports. Note, however, that for vertical lists it is not always necessary to indent the entire list for visual effect, since the hanging indent associated with the bullet or number is usually sufficient to set the list apart from the text.

The *EUB Style Guide* (Alberta Energy and Utilities Board, 1999, p.10-11) has an excellent set of guidelines for vertical lists, which is reproduced here verbatim:

> Items in vertical lists may be single words or phrases, sentence fragments, complete sentences, or complete paragraphs. How lists are punctuated (or not) depends on their content and context. This guide itself contains all kinds of lists. Scan it for examples.
>
> Use a colon to introduce a list only when the introductory sentence is a complete sentence [or when it ends with ‘the following’]. Do not use any punctuation when the list items are single words or phrases not adding up to a complete sentence — i.e., do not put commas or semicolons at the end of each item or a period after the last item.
>
> > The subprojects include four large-scale studies:
> >
> > - delineation of oxygen-isotope patterns for regional-scale VMS-related hydrothermal systems
> > - trace-element research of all known VMS deposits and major sulphide occurrences
> > - a regional alteration study of the ‘Bear Lake volcano’
> > - a 1:10 000 scale cross-border geological compilation of the Flin Flon area
>
> If the sentence is completed by the sentence fragments in the list that follows, do not use a colon. When the list items are sentence fragments, end each item with a comma (if they are short) or a semicolon (if they are longer and contain commas within them). Put a period after the final list item. [In some situations, such as when each list item consists of

an incomplete sentence followed by one or more complete sentences, it's more appropriate to end each bullet item with a period.]

The objectives of the Flin Flon TGI are to

- increase understanding of the volcanic and hydrothermal history of the central Paleoproterozoic Flin Flon volcanic belt;
- determine how these factors influenced the formation of contained VMS deposits; and
- assist the development of exploration strategies to support the discovery of new VMS deposits.

Only capitalize the first word of each list item if it is a proper noun or if the items are complete sentences. Otherwise, do not capitalize the first words.

Write lists using parallel structure. List items must all be sentence fragments or all be complete sentences.

Bulleted Lists

Use bullets for most lists.

If you have another bulleted list under a bulleted item, use a different bullet style.

Numbered Lists

Use numbered lists when it is important to indicate a sequence of events or the specific order that steps in a procedure must follow, as well as to make it easier to refer back to specific items, such as when completing a form. Number each item, with the number followed by a single parenthesis, as below. If a numbered subset is included, use lowercase letters, each followed by a single parenthesis.

1) Enter the company name.

2) Enter the name of the contact person.

3) Enter the full address.

If in later text you refer to an item by number or letter only, enclose the numeral or letter in full parentheses:

From (1), (2), and (3) it is apparent that….

If a category name is used, do not use parentheses:

Methods 1, 2 and 3 all require….

The following sentence illustrates the case of not needing a colon preceding a serial list because to do so would be to separate the verb from its objects:

There is nothing wrong with using abbreviations if 1) uncommon ones are defined the first time they appear (with the abbreviation afterward in parentheses) and occasionally thereafter if it is a long report, and 2) the editor and author agree that repeating the full form might be necessary (*e.g.*, in the 'Conclusions').

Below are examples of when to introduce a vertical list with a colon, and when not to.

Process the return by performing the following steps:

1) Enter the return.
2) Perform the shipment feedback.
3) Print the credit memo.

Process the return by

1) entering the return;
2) performing the shipment feedback; and
3) printing the credit memo.

Hyphens, En and Em Dashes

A hyphen is a punctuation mark used to join words and separate syllables of a single word; en and em dashes are so called because they are the width of an 'n' and 'm', respectively. The hyphen is used to clarify meaning in a sentence; en and em dashes are used in more specific cases and to add emphasis in a sentence.

Hyphens: There is no better or more concise set of guidelines to hyphenation than those given in Grant (2003). If there is one of those guidelines worth remembering at all times it is this: the justification for a hyphen is clarification.

Note that

- most words with prefixes or suffixes are not hyphenated unless the addition forms a double vowel or consonant.
- hyphens join prefixes to proper nouns such as pre-Paleozoic, sub-Phanerozoic.
- a hyphen is used between a digit and a character, *e.g.*, '4-digit key block', '2-character field', '24-hour turnaround time'.
- hyphens may be used in terms like 'pebble-cobble gravel' when the intent is to imply that both components are present, and both components have the same importance.

Contrary to Grant (2003), the SGS follows these hypenation standards:

- Compound colour adjectives in which the first word ends in 'ish' are hyphenated (*e.g.*, pale brownish-grey dolostone).
- Hyphens should not be used in measurements that appear in an adjectival context when the unit of measure is abbreviated (*e.g.*, '1500 ft. level', '1 km wide zone' not '1500-ft. level' or '1-km wide zone') but they should be used when the unit of measure is written out (*e.g.*, 15-foot-long trench', '12-metre-thick bed'). However, it's always best to reword such sentences (*e.g.*, 'the bed was 12 m thick').
- A hyphen should be used after the first part of a suspended compound (*e.g.*, pre- and post-Triassic events; fine-, medium- and coarse-grained granite; super- and subscripts); however, in a complex case such as 'grey-brown– to red-brown–weathered, pyroxene-plagioclase–phyric basalt', it's probably clearer if the dash is omitted from both parts of the suspended compound (the second one being replaced with a space; *e.g.*, 'grey-brown to red-brown weathered, pyroxene-plagioclase–phyric basalt').

The following table illustrates examples of how to rewrite compound expressions to clarify meaning.

Original	Rewrite
Fe-Ti oxide bearing cumulate gabbronorite	cumulate gabbronorite containing Fe and Ti oxides
basinward-thickening, southwestern-sloping wedge	wedge that slopes southwest and thickens toward the basin
345º to 350º-trending foliation	foliation trending 345 to 350º
upper amphibolite to granulite facies grade rocks	upper-amphibolite– to granulite–facies grade rocks
pre 1.8 Ga	pre–1.8 Ga
pre Trans-Hudson aged zircon	zircon of pre–Trans-Hudson age
garnet-staurolite (+ vein kyanite)-bearing pelite	pelite containing garnet-staurolite (+ vein kyanite)
older ocean floor backarc basin basalts	older ocean-floor backarc-basin basalts [or ask the author to rewrite the sentence]
post high grade metamorphism cooling	post-high-grade-metamorphism cooling [or rewrite as 'cooling that postdates high-grade metamorphism']
A single lithofacies of well-bedded, matrix-supported, heterolithic mafic volcaniclastic rocks with subrounded to rounded clasts and a crystal-rich pyroxene- and plagioclase-phyric matrix comprises unit 8.	Unit 8 comprises a single lithofacies of well-bedded, matrix-supported, heterolithic mafic volcaniclastic rocks with subrounded to rounded clasts and a crystal-rich pyroxene- and plagioclase-phyric matrix.

If you are uncertain about the optimal hyphenation for certain geoscience terms, or when dealing with prefixes and suffixes, consult the tables in Appendix 2.

En Dash: The Chicago Manual of Style, Sixteenth Edition (The University of Chicago Press, 2010, Section 6.80, p.332) states that "The en dash can be used in place of a hyphen in a compound adjective when one of its elements consists of an open compound or when both elements consist of hyphenated compounds." (*e.g.*, quasi-public–quasi-judicial bodies). The en dash (generated in Microsoft® Word® by choosing Insert > Symbol > More Symbols > Special Characters and selecting En Dash) is therefore correctly used in the following sentence:

> The geometry of the D_4 structures is interpreted to result from east-southeast–west-northwest shortening.

In the next example, the en dash joins a prefix to a two-word noun and joins 2 two-word nouns:

> The post–Late Cretaceous rocks are best exposed in the Turtle Mountain–Whitewater Lake area.

In the last example, the names of minerals in a complex mineral assemblage are joined by en dashes because two of the mineral names are themselves hyphenated:

> The composition of these generally Fe-rich metasediments ranges from psammitic to pelitic, as well as being mafic (mudstone) in some localities (biotite–quartz–plagioclase±K-feldspar±garnet±staurolite±Fe-amphibole±graphite±sulphides).

En dashes are also used to

- join the names of two or more places (*e.g.*, the Birch–Uchi greenstone belt, the Destor–Porcupine fault);
- join two proper names (*e.g.*, Kidd–Munro mine, Northgate–Marshal Resources Ltd.).

Do not use a hyphen or an en dash to join a range of numbers (except when giving a range of page numbers, in which case a hyphen is used). For example, write '10 to 15%' not '10-15%'.

Do not use a hyphen or an en dash to join a range of rock types. 'Mafic-felsic' leaves open the questions: Does the outcrop contain only mafic and felsic volcanic rocks, no intermediate volcanic rocks? Is the chemistry of the volcanic rocks somewhere between mafic and felsic but the author is uncertain? There's no such ambiguity when you write 'mafic to felsic volcanic rocks'.

Because geoscience reports are full of 'compounds of compounds', such as 'fault fill type quartz veins', there is always a problem with how to hyphenate them. It's potentially confusing and grammatically incorrect to have 'fault fill-type' because the type is 'fault fill', not just 'fill'. Without rewriting the sentence, the best solution is to use a hyphen and an en dash, as indicated in the following example:

> The central portions of D_3 shear zones commonly contain fault-fill–type quartz veins that are less than 30 cm thick and have associated copper-gold-porphyry–style mineralization.

Other examples of proper use of the en dash are shown below:

> pH 7–controlled leach
>
> inductively coupled plasma–mass spectrometry (ICP-MS)
>
> upper-amphibolite–facies conditions
>
> hand-sample–scale slabs of core
>
> ice-advance–phase glaciolacustrine sediments
>
> non NI 43-101–compliant

Note that, contrary to what is stated in Grant (2003), there should be no space on either side of the en dash (cf. *Chicago Manual of Style, Sixteenth Edition* (The University of Chicago Press, 2010, Section 6.80, p.332).

Em Dash: The em dash (generated in Microsoft® Word® by choosing Insert > Symbol > More Symbols > Special Characters and selecting Em Dash) is mainly used as a substitute for a colon, semicolon, comma or parentheses, but it indicates a more emphatic break in a sentence.

> These hypothetical gradients could reveal the direction of fluid flow during dolomitization—the flow direction being recorded by increasing δ^{26}Mg values in the dolomite.
>
> Some beds, however, have sedimentary structures—including tabular and cross-laminations, and horizontal laminations—and may be sparsely to moderately bioturbated.

The following example, taken from Robert Ludlum's novel *The Paris Option*, shows the proper use of the em dash, en dash and hyphen:

> Sir Arnold fervently hoped so, because the other justification could be the first salvo in a dangerous vision of Europe as a second—and rival—superpower to the Americans in this new, post–Cold War, terrorist-filled world.

As with the en dash, there should be no space on either side of the em dash.

Parentheses and Brackets

Parentheses are used to

- set off an auxiliary or explanatory part of a sentence (*e.g.*, "Because of the long residence time of strontium in the modern ocean (~2.5 million years), the $^{87}Sr/^{86}Sr$ ratio of seawater is effectively constant on million-year time scales.");
- to enclose reference citations in the text (*e.g.*, "The rocks in the area are similar to those mapped by previous workers (Claus, 2003; Anderson, 2006)."); and
- to enclose references to figures and tables within a publication (*e.g.*, "The wireline log for well 41/03-08-001-11W2M (Figure 3) shows .....").

Beware of overuse of parentheses, though. The following is an example of when a sentence should be rewritten because the numbers of parentheses affect its readability:

> [Original] The most economically important deposit types associated with these intrusions are epithermal and polymetallic veins (intrusions outcropping on Grouse and Dome mountains), porphyry Cu±Mo±Au deposits (Bell past producer (MINFILE 093M 001; MINFILE 2008; Carter, 1981; MacIntyre, 2006), Granisle past producer (MINFILE 093L 146; Carter, 1981; MacIntyre, 2006) and Big Onion developed prospect (MINFILE 093L 124; Carter, 1981; MacIntyre, 2006), all shown on Figure 2) and porphyry Mo deposits (low F-type; Davidson developed prospect (MINFILE 093L 110; Carter, 1981; MacIntyre, 2006; Figure 2)).
>
> [Rewritten (note the placement of assessment files at the end of the list of citations)] The most economically important deposit types associated with these intrusions are the following:
>
> - epithermal and polymetallic veins—intrusions outcropping on Grouse and Dome mountains;
> - porphyry Cu±Mo±Au deposits—Bell past producer (Carter, 1981; MacIntyre, 2006; MINFILE 093M 001; MINFILE 2008), Granisle past producer (Carter, 1981; MacIntyre, 2006; MINFILE 093L 146) and Big Onion developed prospect (Carter, 1981; MacIntyre, 2006; MINFILE 093L 124), all shown on Figure 2;
> - low F-type porphyry Mo deposits—Davidson developed prospect (Carter, 1981; MacIntyre, 2006; MINFILE 093L 110; Figure 2).

Use square brackets to enclose text added to a quote (*e.g.*, "A company's registered name is its legal identification and should always be written in full [at least] the first time it is used in a manuscript.") and to enclose equations and chemical formulas (*e.g.*, leucite [$KAlSi_2O_6$]).

Question Mark

Further to the discussion in Grant (2003) regarding the use of the question mark to express doubt about the correctness of a word or expression, it's not necessary to put parentheses around the question mark if that word or expression is already in parentheses, as in the following examples:

> diamicton (till?)
>
> …caused by a later generation of folds (F_3?)
>
> Footwall rocks comprise Middle Jurassic Nelson intrusive rocks and a younger (Cretaceous?) granitic suite.

But there should be parentheses if the question mark stands alone, for example:

> glaciofluvial(?) deposit

> A number of small isolated granitic stocks and bodies included in the Cretaceous(?) suite intrude Nelson plutonic rocks west of the main granitic body on TRIM map sheet 082E/049.

Quotation Marks

Use single rather than double quotation marks to introduce terms (*e.g.*, “The ‘Bafflegab gneiss belt’ of Thorne (1987).....”); for citing other chapters or sections in the same report (*e.g.*, “As discussed above (see ‘Fossil Diversity’)..”; or when introducing unofficial place names (*e.g*., “Outcrops on ‘Fish Lake’ (unofficial name) were examined as well.”).

Use double quotation marks when quoting text.

Solidus

Grant (2003) covers all of the accepted uses for the solidus (also known as the slash, slant, diagonal or virgule).

Do not use the solidus in

- 8/10/00 as an abbreviation for a date, since this could mean either October 8, 2000 or August 10, 2000; a better method of abbreviating dates is 8-Oct-00;
- Cretaceous/Tertiary boundary (should be Cretaceous–Tertiary boundary, using the en dash because two formal names are involved); and
- structural geology expressions such as D_0-D_1 (a solidus here would imply D_0 <u>or</u> D_1).

Grant (2003, p.282) also differentiates the use of a colon *versus* the solidus when discussing ratios of chemical elements. A solidus is used when a numeric value is given (*e.g.*, “The Au/Ag ratio in the deposit is 0.147.”), but a colon is used when no specific values are given (*e.g.*, “The Au:Ag ratio is inconsistent across the strike of the deposit.”).

Note that there should be no space on either side of the solidus.

Spelling

The SGS authority for spelling of nontechnical words is the *Canadian Oxford Dictionary* (Barber, 2004). Because ‘Canadian’ spelling is a mixture of British and American usage, every Canadian style guide specifies its preferences using generalizations and/or a list of spellings. *The Canadian Style* (Dundurn Press Ltd. and Public Works and Government Services Canada Translation Bureau, 1997) gives the following useful generalizations, which are endorsed by the SGS:

- *ou* in words such as honour, colour and favour
- *re* in words such as centre, metre, litre, fibre and theatre, **but** spectrometer
- *z* in words such as analyze, criticize, synthesize and mineralize
- *s* in words such as focused
- *ll* in the past tense of words such as totalled, cancelled, travelled, fulfilled, instilled and enrolled
- **but** *l* in such derivatives as fulfilment and enrolment
- double the consonant in the past tense of words such as benefit[1]
- *e* for the digraphs *ae* and *oe* in words from Latin and Greek such as Archean, archeology, encyclopedia, eolian, fecal, fetid, hematite, paleontology, syneresis; the exceptions to this are aesthetic and anaerobic

The SGS authority for spelling of geoscientific terminology is the American Geological Institute’s (AGI) *Glossary of Geology* (Neuendorf *et al.*, 2005). However, in instances where the AGI *Glossary of Geology* differs from accepted Canadian spellings, or where its rules for hyphenation or word breaks differ from ours, use the spelling in Grant (2003) and Appendix 3 in this style guide.

Please remember that a spell checker is no replacement for a careful proofread of a document. Note that Word’s spelling utility is unable to identify hyphenated words (*e.g.*, wide-spread) as being misspelled.

The SGS has acquired a subscription to the online AGI *Glossary of Geology*: check with your manager to be added to the list of users under this subscription.

The SGS agrees with all spellings in Grant (2003) except for the following:

- ‘preempt’, ‘reentrant’, ‘reestablish’ and ‘reevaluate’ should all be hyphenated (*i.e.*, ‘pre-empt’, ‘re-entrant’, ‘re-establish’, ‘re-evaluate) because the word being prefixed begins with an ‘e’
- ‘post-paleozoic’ should be ‘post-Paleozoic’ and ‘precambrian’ should be ‘Precambrian’ (cf. Neuendorf *et al.* (2005); both of these are, in fact, errors in Grant (2003))
- ‘symmetrical’ should be ‘symmetric’ (for consistency with ‘asymmetric’)

The list of preferred spelling in Appendix 3 includes

- words that are not recognized by Word’s main dictionary;
- the spelling list from Grant (2003);
- other words that frequently cause problems; and
- some word strings that show proper compounding of adjectives.

If you encounter words that are not covered by any of these sources, please submit them to your manager for discussion and possible inclusion in this style guide.

[1] “The final consonant is doubled in words of more than one syllable ending in one consonant preceded by one vowel, if the accent is on the last syllable and the suffix begins with a vowel” (Dundurn Press Ltd. and Public Works and Government Services Canada Translation Bureau, 1997).

Abbreviations, Symbols and Equations

An **abbreviation** is a shortened form of a word or phrase. A period is generally (but not always) placed at the end of the shortened form. An **acronym** is a pronounceable word formed from the first letters of a series of words (*e.g.*, NAFTA, SHRIMP). An **initialism** is also formed from the first letters of a series of words but is generally not pronounceable (*e.g.*, SGS, IBM, NRCan, GSC). Periods and spaces are omitted between the letters of acronyms, whereas periods may or may not be omitted between the letters of initialisms (*e.g.*, U.S., USGS). A **symbol** is a non-alphanumeric character used to represent a word (*e.g.*, $, &, @, %, ™, γ). All of these are often collectively referred to as 'abbreviations', as will be done here.

The more complex our science becomes, the more abbreviations, acronyms, initialisms and symbols we see in the literature. The list of abbreviations in Appendix 4 has been compiled from several sources, mainly Weatherston (1996), Geological Survey of Canada (1998), Alberta Energy and Utilities Board (1999) and Grant (2003). The original list has been supplemented over the years with legitimate abbreviations encountered during the course of editing projects. Those entries with an asterisk in the second column are standard abbreviations that do not have to be defined at first use because they are well known and, in some cases, occur as dictionary entries.

The abbreviations in Appendix 4 and the following points are intended only as a guide. If not specifically dealt with in this style guide, the issue of when to define a new abbreviation will be considered on a case-by-case basis.

Abbreviations

There is nothing wrong with using abbreviations if 1) uncommon ones are defined the first time they appear (with the abbreviation afterward in parentheses) and occasionally thereafter if it is a long report, and 2) the editor and author agree that repeating the full form might be necessary (*e.g.*, in the 'Conclusions').

Abbreviations should be avoided in the abstract of reports. If, however, a given term is used numerous times in an abstract or executive summary, the abbreviation can be introduced at the first appearance of the term and used subsequently. Reintroduce the abbreviation the first time it is used in the text.

Although a sentence should not begin with an abbreviation, it's acceptable to begin a heading with one (*e.g.*, 'D_2 Deformation', 'PGE Analytical Results'). Titles can begin with abbreviations but the practice should be avoided if at all possible.

If abbreviations are used in a table or a figure, the abbreviations must be explained in the caption, or in a legend in the figure or footnotes at the bottom of the table.

Directions are always written out in full in the text (*e.g.*, north, northwest, north-northwest); their abbreviations may be used in figures and tables.

Townships and ranges in the Dominion Land Survey system are written out in the text but may be abbreviated in tables and figures as 'Tp.' / 'Rge.' or 'T' / 'R' as long as the abbreviations are explained in a footnote or legend, or in the caption.

All place names should be written out in full in the text. Exceptions are places like British Columbia and Northwest Territories: if used frequently in a report, write them out once and then use the abbreviation (Table 1).

Country, province and state names may be abbreviated in addresses.

Abbreviation of the names of countries, provinces and states is not a requirement in figures and tables but, if used, there must be consistency in the style used.

Table 1 – Abbreviations of place names (Canadian in particular).

Name	Abbreviation in Text	Abbreviation in Addresses
Alberta	Alta.	AB
British Columbia	B.C.	BC
Manitoba	Man.	MB
New Brunswick	N.B.	NB
Newfoundland and Labrador	N.L.	NL
Northwest Territories	N.W.T.	NT
Nova Scotia	N.S.	NS
Ontario	Ont.	ON
Prince Edward Island	P.E.I.	PE
Quebec	Que.	QC
Saskatchewan	Sask.	SK
Yukon	Y.T.	YT
Nunavut	Nvt.*	NU
United States	U.S.	USA

* There is no official abbreviation for Nunavut at this time; this abbreviation is provisional.

Abbreviations such as % (percent), t (tonne(s)), Mt (million tonnes; note the lack of a space between the 'M' and 't'), g/t (gram(s) per tonne) and ppm (part(s) per million) should only be used in conjunction with numbers. When an author is being deliberately vague, the units should be written out, as in 'several percent' or 'several hundred million tonnes'.

Note that, contrary to Grant (2003), the abbreviation 'T' is used for ton or tons; 't' is the abbreviation used for tonne.

The ampersand (&) must not be used anywhere in titles, headings, the main body of the text or in captions of a report or paper, unless it is an official part of the name of a company or organization, or if it's part of the publication title for a reference in the reference list.

Use '*ca.*' rather than 'approximately', 'approx.' or '~' with radiometric dates (*e.g.*, '*ca.* 3.8 Ga'). The abbreviation is preferred in the main body of the text, but may be written out for titles and headings. 'Approximately', 'approx.' or '~' (with no space between the symbol and the measurement it modifies) may be used for all other measurements.

The plural of an initialism or acronym is formed by adding a lower case 's' (*e.g.*, KIMs, PGEs, REEs).

The full names of minerals should be used throughout the text; abbreviations can be used in tables and figures to save space, and are capitalized when used. The abbreviations used must be explained in the table or figure caption, or in a footnote to the table or legend in the figure.

If you commonly use any abbreviations that are not included in Appendix 4, please submit them to your manager for consideration for inclusion in this style guide.

Units of Measure

Abbreviations for most units of measure use lower case letters, except when the unit is defined with an upper case letter (*e.g.*, L for litre to distinguish it from the numeral 1, or temperature abbreviations (Celsius - C; Fahrenheit - F; Kelvin - K) because they are derived from proper nouns).

Unless they occur at the end of a sentence, abbreviations for metric units do not end in periods; abbreviations for Imperial units of measure do end in periods, unless used in an expression with 'per' (*e.g.*, 'miles per hour' is abbreviated as 'mph').

Abbreviations for units of measure are never pluralized (*i.e.*, never write '45 kgs' or '3 lbs.').

Always put a space between a number and its unit of measure (*e.g.*, 40 m, not 40m; 10 mm, not 10mm).

If you spell out a number—for instance, if the number occurs at the beginning of a sentence—spell out its unit of measure as well (*e.g.*, "Fifty-five kilometres west of the study area, the rocks are more mafic.").

Analytical Methods

There has been enough inconsistency regarding the meanings of abbreviations for spectrometric analytical methods, especially ICP-ES, ICP-MS and TIMS, to warrant a brief explanation. 'Inductively coupled plasma' (ICP) is a means of ionizing the elements in the sample, after digestion, into a form in which they can be detected and quantified. Therefore, ICP cannot stand on its own, but is only the front half of the analytical method. The back half—the detection and quantification of the target elements—is accomplished by 1) emission spectrometry (ES), also known as optical emission spectroscopy (OES) or atomic emission spectroscopy (AES); or 2) mass spectrometry (MS).

Inductively coupled plasma–emission spectrometry (ICP-ES) measures the light emitted at element-specific wavelengths from thermally excited analyte (element of interest) ions in the plasma. Multi-element analysis is then done at the parts per million (ppm) to low percent (%) level. In preparing a sample for ICP-ES analysis, one can do either fire assay (FA) or a chemical digestion. Some people and some labs use ICP to mean ICP-ES, but this should be avoided to prevent confusion with ICP-MS.

Inductively coupled plasma–mass spectrometry (ICP-MS) measures the masses of the ions generated by the plasma. Multi-element analysis is then done at the parts per trillion (ppt) or parts per billion (ppb) to low ppm level. The detection limit of ICP-MS is therefore considerably lower than that of ICP-ES.

Elements that cannot be measured by ICP methods include H, C, N, O, Ar and the halogens. Because of its higher detection limit, ICP-ES is used for elements that are present in higher concentrations, such as Fe, Ca and Cu. The lower detection limit of ICP-MS makes it better suited for low-abundance elements, such as the rare earth elements (REEs), U and Cr. Whereas peridotite might require ICP-OES for Ni, a granite would require ICP-MS because of the lower concentration of Ni in this rock type. Analytical labs will run certain elements in some samples by both ICP-ES and -MS, and then report the results from the method with the best quality-control statistics.

Thermal ionization mass spectrometry (TIMS) is particularly useful for the analysis of the isotopes used in radiometric dating: initially Rb and Sr, and then, because of advances in instrumentation, Nd, Sm, Pb, U and Th. There are two types of thermal ionization mass spectrometry: isotope dilution (ID-TIMS) and thermal extraction (TE-TIMS).

Analytical Units

With few exceptions (*e.g.*, Au, Ag, Cu), elements are not present on Earth as native metals (*i.e.*, in their pure elemental form). Rather, they occur as oxides, carbonates, sulphides, *etc*. However, analytical instrumentation measures the elemental state (*i.e.*, Ca, not $CaCO_3$). To address this and to facilitate comparison, geoscience has adopted a convention of portraying elemental compositions of the common rock-forming elements (*e.g.*, Si, Ti, Al, Ca), also known as the 'major elements', as oxides (*e.g.*, SiO_2, TiO_2, Al_2O_3, CaO).

The instrument results in parts per million (ppm) or percent (%) are recalculated as weight percent oxide (wt. %) to address the presence of oxygen in the mineral crystal lattice. Thus, what is measured as ppm Ca by XRF or ICP-OES/MS is converted to wt. % CaO by multiplying by 1.399. For this reason, ppm Ca does not equal wt. % CaO. Therefore, the unit 'wt. %' can only be used with an oxide, whereas 'ppm' or '%' can only be used with an element. They cannot be used interchangeably.

Chemical Elements

In general, element names should be written out in the text of reports and papers rather than using symbols, unless the elements in question are in an equation or are used in an analytical context.

In addition to the guidelines provided in Grant (2003), the following may be helpful:

- symbols are used in ore grades and analytical concentrations (*e.g.*, 3.5 g/t Au, 65 ppm Cu)
- element names are written out when the elements are being mentioned in a mineralogical rather than a geochemical context (*e.g.*, finely disseminated gold, native copper, iron sulphides)
- element names are written out when the elements are used as adjectives (*e.g.*, 'nickel-copper-platinum-palladium deposit', 'gold values were in the range...')
- element names are used whenever possible in titles and headings
- be consistent; the following is an example of what not to do:

    > A scatter diagram of F/chlorite and MgO/chlorite ratios (Figure 5) demonstrates a strong relationship between fluorine and Mg concentrations in chlorite and, more importantly, shows that the highest concentrations of these elements occur in contact mudstones close to fluid upflow zones.

- in the expression "sediment samples were analyzed for Au by lead-collection fire assay", 'gold' could be used in place of 'Au' if the rest of the paper isn't peppered with other elemental symbols, but 'lead' should not be replaced with 'Pb' because it's part of a compound adjective

Use FeO^t to represent total iron expressed as FeO.

Isotopic compositions should be formatted as $\delta^{34}S$ (the Greek letter 'delta' is in the Symbol font).

The expression 'epsilon Nd', defined as "the relative deviation in parts per 10,000 from the $^{143}Nd/^{144}Nd$ composition of the 'Chondritic Uniform Reservoir' (CHUR) at a given time T" (Dickin, 2005), is best abbreviated as ε_{Nd} (the Greek letter 'epsilon' is in the Symbol font and 'Nd' is subscripted), with the following footnote at the first occurrence of the abbreviation in the text:

> All epsilon Nd values were calculated at the known or inferred age of crystallization.

Symbols

The symbols for degree, percentage and dollar do not have a space between the number and the symbol (*e.g.*, 10% not 10 %; 12° not 12 °; $10.00 not $ 10.00).

In text where monetary values are given in more than one currency, the dollar symbol ($) is placed after the abbreviation for Canadian or U.S. dollars (*e.g.*, C$100.00, US$89.00). Abbreviations for other countries' currencies may be found at http://www.njc-cnm.gc.ca/directive/app_d.php?lang=eng&let=C.

The degree symbol, when used to express temperature, is placed immediately after the number and before the abbreviation for the unit of measure, with no space between the number and the degree symbol (*e.g.*, 12°C, 52°F).

The American Petroleum Institute measure of density of a petroleum liquid is expressed as 'API gravity' and is measured in degrees API. When expressing API gravity, leave a space between the degree symbol and the abbreviation for the unit of measure (*e.g.*, 31° API, 31° API gravity oil).

Mathematical operators (*e.g.*, >, <, ≥, ≤, ≈, ~, ±) may be used in connection with measurements of all types in text, tables, figures and maps. There should be no space between the operator and the number that it precedes, although spaces would be used on either side of the operators in an equation. The following is an example of when mathematical operators and element symbols should be used (the abbreviation HREE was introduced earlier in the text):

> These characteristics include enrichment in Sr, Na and Eu; depletion in Y and HREE; SiO_2 >56 wt. %; Al_2O_3 >3.5 wt. %; Sr >400 ppm; Y <18 ppm; Yb >1.9 ppm; La/Yb ~20; and Sr/Y ~40 (Drummond and Denfant, 1990).

The '+' symbol should not be used in an expression such as '100+ years'. Use instead 'more than 100 years'.

The '±' symbol is used to indicate uncertainty in radiometric dates and to indicate local presence of particular minerals in mineral assemblages. When used with radiometric dates, leave a space before the symbol but none after (*e.g.*, 2150 ±20 Ma). When used in mineral assemblages, there is no space before or after the symbol:

> The composition of the metasedimentary rocks ranges from psammitic to pelitic, as well as being mafic (mudstone) in some localities (biotite–quartz–plagioclase±K-feldspar±garnet±staurolite±graphite).

Minerals in an alteration or mineralization assemblage are normally given in order of decreasing abundance. At the very least, the order of the minerals in a particular assemblage should be consistent throughout the text of a publication.

Because readers whose first language isn't English may not know that 'x' can be used in place of the preposition 'by' in expressions such as '20 x 12 m', it's better to use '20 by 12 m'.

Equations

Spaces are required on either side of a mathetical operator in equations.

$$3CaMg(CO_3)_2 + 4SiO_2(aq) + H_2O \longrightarrow Si_4O_{10}Mg_3(OH)_2 + 3CaCO_3 + 3CO_2(g)$$

If an equation will not all fit on one line, *The Chicago Manual of Style, Sixteenth Edition* (The University of Chicago Press, 2010, Section 12.23, p. 593) recommends that it be broken before an operation (*e.g.*, +, –, x, ÷, ±) or relation (*e.g.*, =, ≠, ≅, >, <, ≥, ≤, →) sign.

Word's Equation Editor is useful for creating extended mathematical expressions. The variety of mathematical symbols and templates in Equation Editor simplifies the process of constructing even the most complex formulas; however, please be aware that equations created using the Equation Editor tool do not always convert well when opened in different software, or even in earlier or later versions of Word. Equation Editor should be used judiciously.

Trademarks

The following definitions have been taken from Grant (2003):

A **trademark** (™) is a word, phrase, symbol or design, or a combination of words, phrases, symbols or designs, that identifies and distinguishes the source of the goods of one party from those of others.

A **service mark** (℠) is the same as a trademark, except that it identifies and distinguishes the source of a service rather than a product.

A **registered mark** (®) can only be used once the mark is actually registered in the country's patent and trademark office.

The appropriate symbol should be added to the first instance of the trademarked or registered name in the abstract (if it appears), and the text (if it appears).

Numbers and Measures

Use numerals for numbers greater than nine, but spell out numbers from zero to nine (*e.g.*, "There were three field assistants this summer.") except when referring to numbered tables and figures (*e.g.*, "See Figure 1."), and except when used as

- units of measure (*e.g.*, 4 km)
- time (*e.g.*, 7 a.m.)
- dates (*e.g.*, 4 January 2016)
- page numbers (*e.g.*, "See pages 2 to 7.")
- percentages (*e.g.*, "At least 6% of the core is weakly oil stained.")
- money (*e.g.*, "The cost for each claim tag is $5.00.")
- proportions (*e.g.*, 4 of 50)

If single- and multi-digit numbers occur in the same sentence, write out all numbers for consistency:

> Of the 64 samples analyzed, 23 had Th/U ratios greater than 0.34, 15 had Th/U ratios between 0.11 and 0.34, and 5 had Th/U ratios less than 0.11.

Write out the first or smaller number to distinguish between two numbers that are adjacent to each other:

> "... 85 two-gram samples."

In the latter instance, it would be better to rewrite the sentence, particularly when the sample weight isn't a whole number (*e.g.*, "...85 samples, each weighing 1.5 g.").

Numbers are normally written with no commas for four or more digits (*e.g.*, 1200 m; 10 000 claim units; 100 000 man-hours), except if the number is a measure in Imperial units (*e.g.*, 1,000 feet; 10,000 ounces).

Do not superscript ordinal numbers (*e.g.*, 1st, 3rd not 1^{st}, 3^{rd}).

Do not hyphenate between the number and the abbreviated unit in compound adjectival expressions (*e.g.*, the 200 m level, a 25 kg sample, a 5.4 m wide band)

Never mix spelled out and abbreviated terms of measure, *e.g.*, write 'ppm' or 'parts per million' **not** 'parts per 10^6'.

Dates

The simplest and clearest methods of expressing dates are

> January 28, 2016
>
> 28-Jan-16

Due to the potential for confusion between different standards for writing dates (*e.g.*, does 5-6-2016 mean May 6, 2016 or June 5, 2016?), it's best to avoid all-number formats.

When discussing decades in generals terms, they are written as, for example, 1980s or '80s.

Decimal Fractions

Grant (2003) states that "decimal fractions should be presented as whole numbers whenever possible, *e.g.*, 0.0673 metres is preferred as 67.3 millimetres." Context is important in such situations, however, because 50 cm can imply a higher degree of accuracy for a measurement than the author intended when he/she originally used 0.5 m. Units should be changed only 1) to match other similar measurements in a paragraph, or 2) in the case of a numerical range that has mixed units.

Other guidelines:

- use µg/g rather than $\mu g \cdot g^{-1}$;
- ensure that the number of digits after a decimal point are the same for all values given in the same table (*i.e.*, 10.23, 9.61, 8.00 not 10.23, 9.6, 8), unless they've come from the lab that way.

Numerical Ranges

Grant (2003) includes a comprehensive section on numerical ranges. Some additional guidelines follow.

Use 'to' in all numerical ranges where a hyphen is normally used (*e.g.*, 10 to 20% not 10-20%). A hyphen is acceptable for a range of calendar years in expressions such as, "During the 2015-2016 field season ....".

Delete unit designators such as '%' and '°' from the first part of a range, unless doing so introduces uncertainty.

> The maximum temperature of formation ranges from 340 to 590°.
>
> The quartz content of the rock (10 to 20%) ....

However, the symbol should follow each item in a list, as in the following examples:

> …general trends of 200° and 316°
>
> The main trends are 100°, 140°, and from 180 to 190°.

Time Conventions

Contrary to Grant (2003), you may use millions of years (Ma) and billions of years (Ga) as measures of absolute time, especially in Sm-Nd model ages.

As stated in Grant (2003), the abbreviations CE ('Common Era') and BCE ('Before Common Era') should be used instead of AD ('*Anno Domini*' or 'in the year of our Lord') and BC ('before Christ'). Both terms follow the year (*e.g.*, '276 BCE'). The old abbreviations can follow the new ones in parentheses if you feel that some readers might not be familiar with the new ones.

Note, however, that the term 'BP' (before present) is still used for radiocarbon dates.

Geological Time

Radiometric dates are expressed as '1856 ±2 Ma', '1881 +3/-2 Ma', '2.9 Ga'.

When a date has enough significant figures (usually four) to allow it to be expressed as a whole number without decimals, then that should be done. For example, if a date is provided by the lab as 2.983 or 2.980 Ga, it should be written as 2983 or 2980 Ma. If it is provided as 2.98 Ga, it should remain as is.

When expressing dates BCE, the convention is to present the 'youngest' date first (*i.e.*, the larger number), as in "So-and-so lived between 476 and 432 BCE." The same logic applies to geological dates.

When speaking in more general terms about the various geological periods, one always presents the oldest period then the youngest period (*i.e.*, Jurassic to Cretaceous, never Cretaceous to Jurassic). Use 'Devonian to Carboniferous' rather than 'Devono-Carboniferous'.

The convention when using stratigraphic modifiers is to use 'early', 'middle' and 'late' when referring to subdivisions of the geological time scale (*e.g.*, Early Jurassic), but 'lower', 'middle' and 'upper' when referring to position within the stratigraphic column (*e.g.*, Lower Deadwood Formation).

Ka/Ma/Ga should be used if indicating 'xxx years before present'. If indicating a time range (*e.g.*, deformation went on for 50 million years), then the 'm.y.' abbreviation should be used. For example:

> The granite intruded in several stages over a period of 4 m.y.

Radiometric Dating Methods

Use hyphens to join the element names and symbols in radiometric dating methods, except in instances where the method involves isotopic ratios, in which case the solidus is used, as in the first method listed below. A radiometric method may be referred to either by the element names (especially in the title or at the beginning of a sentence) or by the element symbols.

> $^{40}Ar/^{39}Ar$ method
> lutetium-hafnium (Lu-Hf) method
> potassium-argon (K-Ar) method
> rhenium-osmium (Re-Os) method
> rubidium-strontium (Rb-Sr) method
> samarium-neodymium (Sm-Nd) method
> thorium-lead (Th-Pb) method
> uranium-lead (U-Pb) method

When giving uncalibrated (^{14}C) and calibrated (cal.) radiocarbon dates, the terms ‘years’, ‘yr.’ and ‘ka’ are placed before the symbol for uncalibrated or calibrated. For example:

> *Uncalibrated:*
> 18 000 ±600 years/yr. ^{14}C
> 18 ka ^{14}C
>
> *Calibrated:*
> 18 000 ±600 years/yr. cal.
> 18 ka cal.

Azimuth and Bearing

The three variants of each compass direction (*e.g.*, north, northward, northerly) can cause problems when combined with ‘striking’, ‘trending’ or ‘directed’ to form a compound adjective because they have different hyphenation requirements when that compound adjective precedes the noun it modifies. Specifically, the first two variants are hyphenated and the last is not:

> north-striking, northward-striking, northerly striking

Strike and Dip, Trend and Plunge

The Right Hand Rule states that the strike of a planar feature that has a measurable dip (between 1 and 89 degrees from horizontal) shall be the orientation in which the person taking the measurement faces while their right arm points down dip. For vertically dipping features, or planes that waver around 90 degrees dip, the right-hand rule cannot be accurately applied, and therefore two compass directions are given to eliminate the assumption that the feature dips one way or the other.

However, the Right Hand Rule is defined differently in different parts of the world; therefore, it’s best to follow conventions that are recognized worldwide and use the universally recognized strike-and-dip system:

- 085°/37°N indicates a planar feature striking 085° and dipping 37° to the north;
- 142°/90° indicates a planar feature striking 142° and dipping vertically;
- 031°/62° indicates a linear feature striking 031° and plunging 62°.

Express a range in strike as “…foliation strikes 050 to 070°…”, not as “…foliation strikes between Az. 50 and 70°….”

International System of Units (SI)

Although all measurements in SGS publications should be given in SI (metric) units, an original Imperial value can be retained in the text, with the SI value included afterward in parentheses. Examples include references to stratigraphic and exploration core intervals for cores originally logged in Imperial units, the locations of samples in diamond-drill core that have been assayed, and the assay results. In this way, if an error was made in the conversion from Imperial to SI, the reader will have the original values to do their own conversions:

> Visibly altered footwall rocks that occur between approximately 3,200 and 3,400 ft. (975 and 1035 m) in the drillcore have assay values ranging from 0.05 to 0.20 oz./ton Au (1.7 to 6.9 g/t).

Some mixing of units is acceptable, as in the following example:

> Ridgeway, New South Wales: 53 Mt grading 2.5 g/t Au and 0.77% Cu, total Au content of 132.50 million g (4.26 million oz.).

Aboriginal Affairs and Northern Development Canada (AANDC) considers it an industry standard to leave the U_3O_8 content of a uranium deposit in Imperial without a metric equivalent.

By convention, parts per million (ppm) is used for concentrations between 0.01 and 0.0001%, and parts per billion (ppb) is used for concentrations between 1 and 0.001 ppm.

Referring to Geographic Locations

Although Grant (2003) now includes a comprehensive section on geographic locations, the following notes are still warranted.

- Always write out compass directions (*e.g.*, north, south, northeast, north-northeast) in the text rather than abbreviate, unless the compass direction is used in the context of a coordinate system. For example, "The sample was taken at UTM 123456E, 1234567N." Abbreviations may be used in figures and tables.
- Geographic locations in the northern part of Saskatchewan are primarily referred to using latitude and longitude (see 'Spherical Coordinate System'), National Topographic System designations (see 'Canada's National Topographic System') or eastings and northings (see 'Universal Transverse Mercator'). Locations in the southern part of the province—basically, below the southern limit of the Precambrian Shield—are referred to using Township and Range designations (see 'Dominion Land Survey System').

Spherical Coordinate System

Write latitude and longitude values as 'latitude 53°31'04"N, longitude 113°09'56"W' in text or as 'lat. 53°31'04"N, long. 113°09'56"W' in parenthetical text or in tables and figures. Note that

- notwithstanding the statement to the contrary in Grant (2003), the compass direction (N for latitude and W for longitude) should always be included in text;
- in databases, a negative sign is often used before longitudes instead of the 'W': do not use both;
- latitude and longitude are not capitalized but, contrary to what is stated in Grant (2003), the abbreviations of these terms should be followed by periods;
- '0' should be included before single-digit minute or second values;
- the degree symbol should be used rather than the superscripted lowercase letter 'o';
- a range of latitudes and/or longitudes would be expressed as 'latitudes 49 to 52°N and longitudes 95 to 98°W'; and
- the 'prime' and 'double prime' symbols should be used for minutes and seconds, respectively, rather than single and double quotation marks.

In the digital world, a minus sign is traditionally used for west longitude or south latitude. Therefore, although the cardinal points of the compass are used in text, if the minus sign is present in tables generated from digital files, leave the latitudes and longitudes as they are and include a footnote regarding the use of the minus sign.

Canada's National Topographic System

The official way of writing a National Topographic System (NTS) map area is:

- 74 P (1:250 000-scale map area),
- 74 P/12 (1:50 000-scale map area) and
- 74 P/2, 3, 4 (several 1:50 000-scale map areas).

Although many organizations have adopted a style of writing NTS areas without the space between the number and letter and without the solidus (*e.g.*, 63H; 63G, H; 63H12; 62J13, 14), the SGS has decided to exert its individuality by choosing to write NTS area <u>without</u> the space between the number and letter but <u>with</u> the solidus between the letter and the numbers following it (if present), and with a '0' before single-digit numbers.

The following formats should be used in SGS publications when referring to NTS areas:

NTS 74P/05 and /06

NTS 73O/13, /14, /15, 74P/02, /03

parts of NTS 53M/04, /05 and 63P/01, /08

NTS 62F, parts of 62G and K

parts of NTS 63J/15, /16, 63O/01, /02, /08, /09, /16, 63P/12, /13 and 64A/04

parts of NTS 63K/13 to /16 and 63N/01 to /04

Universal Transverse Mercator

The datum and Universal Transverse Mercator (UTM) zone must be specified whenever UTM locations are given, but only the first time such a location appears in the text or a caption. The word 'zone' should be lower case when used in the generic sense (*e.g.*, "You need to include the UTM zone with the first set of coordinates.") and upper case when used in the specific sense (*e.g.*, "All coordinates are in North American Datum 83 (NAD83), UTM Zone 17.").

When stating UTM coordinates for a specific sample, outcrop, photo location, *etc.*, write the coordinates as 'UTM 123456E, 1234567N'.

Dominion Land Survey System

The Township and Range designations of the Dominion Land Survey (DLS) system are used in Manitoba, Saskatchewan and Alberta, and in parts of British Columbia. The basic layout of the DLS system is a series of north-south and east-west survey lines. Townships are numbered sequentially from '1' northward from the Canada–U.S. border; ranges are numbered eastward or westward relative to the seven meridians established by DLS surveyors. In Saskatchewan, ranges are numbered westward from the First (also known as the 'Prime' or 'Principal' Meridian, located west of Winnipeg, Manitoba), Second and Third meridians (Figure 1). The southeast part of the province is covered by Ranges 30 to 34 west of the First Meridian; in the remainder of the province, the meridians are divided into 30 ranges.

Originally, the DLS township grid in Saskatchewan ended at the northern limit of arable land, or at Township 65 along the west border of the province and at Township 55 along the east border (see Figure 1). The township grid has since been extended northward to the border with the Northwest Territories.

Townships are divided into 36 sections (Figure 2), each of which in turn is subdivided into 16 legal subdivisions (LSDs). Sections and LSDs are also divided into quarter sections—southeast, southwest, northeast and northwest: quarter sections are more commonly used in the agricultural industry; LSDs are more commonly used in the oil and gas industry.

Referring to DLS Locations

The terms 'Township', 'Range', 'Section' and 'Legal Subdivision', and the location relative to a meridian (*e.g.*, 'west of the Second Meridian') should be written in full upon first mention in the text of a publication, with the abbreviation included after in parentheses. The abbreviations used by the Saskatchewan Geological Survey for DLS land designations are LSD - legal subdivision; Rge. - Range; Sec. - Section; Tp. - Township; location relative to a meridian (*e.g.*, west of the Second Meridian) - W2M.

The abbreviations 'Tp.' or 'T', 'Rge.' or 'R', 'Sec.' or 'S' may be used in figures and tables, as long as they are explained in a legend or footnote, or in the caption.

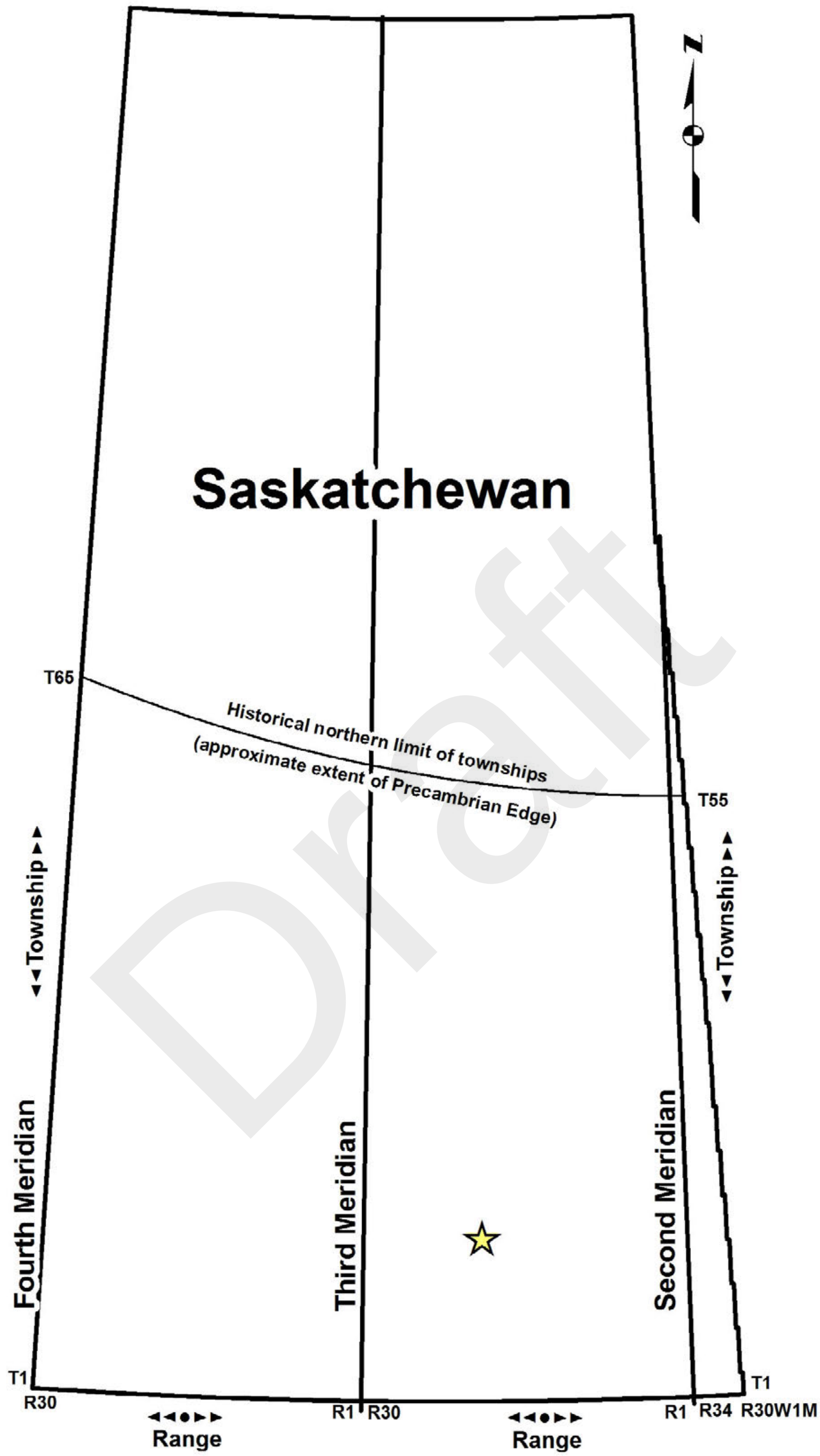

Figure 1 – Dominion Land Survey (DLS) system meridians, townships (T) and ranges (R) in Saskatchewan. Ranges are numbered consecutively westward from each meridian and townships are numbered consecutively northward from the U.S. border. So, for example, the location of the yellow star is Township 16, Range 16 west of the Second Meridian. Note that the DLS grid in Saskatchewan starts at Range 30 west of the First Meridian (R30W1M) in the southeast corner of the province.

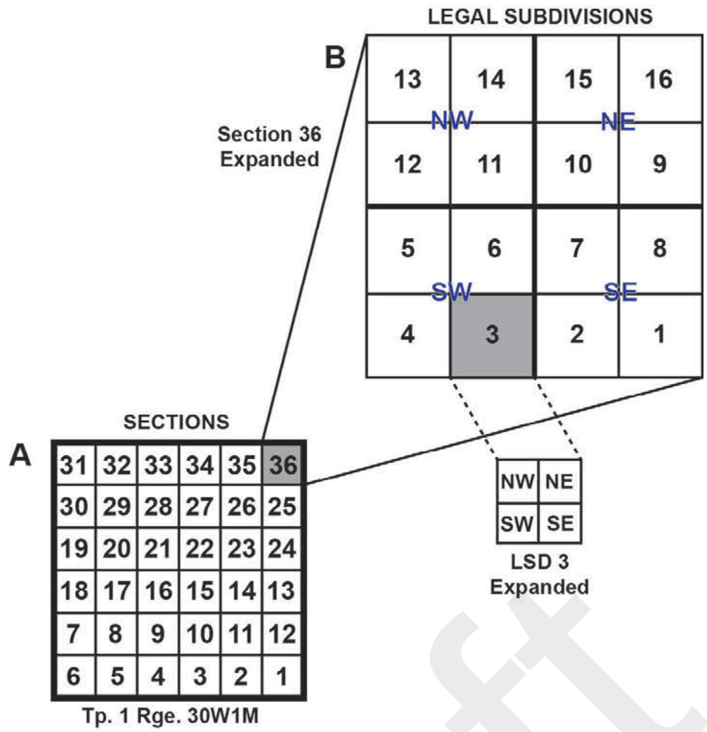

Figure 2 – A) Each township in the DLS system is subdivided into 36 sections. B) Sections, in turn, are divided into 16 legal subdivisions (LSDs). Both sections and LSDs may also be subdivided into quarters: southeast (SE), southwest (SW), northeast (NE) and northwest (NW). The description for the location of the LSD infilled in grey is LSD 3, Sec. 36, Tp.1, Rge. 30W1M.

The following examples illustrate the full and abbreviated formats used to express various possibilities for DLS locations within the main text of a publication.

- When the location is being given to the nearest range:
  Range 30 west of the First Meridian (Rge. 30W1M)
- When the location is being given to the nearest township:
  Township 2, Range 2 west of the Second Meridian (Tp. 2, Rge. 2W2M)
  Townships 23 to 27, Ranges 23 to 25 west of the Third Meridian (Tp. 23 to 27, Rge. 23 to 25W3M)
- When the location is being given to the nearest section:
  Sections 30 and 31, Township 15, Range 21 west of the Second Meridian (Sec. 30 and 31, Tp. 15, Rge. 21W2M)
- When the location is being given to the nearest quarter section:
  Southwest quarter, Section 2, Township 1, Range 30 west of the Second Meridian (SW2-1-30W2M)
- When the location is being given to the nearest legal subdivision (sixteenth section):
  Legal Subdivision 4, Section 5, Township 1, Range 30 west of the First Meridian (4-5-1-30W1M)
- When the location is being given to the nearest quarter of a legal subdivision (sixty-fourth section):
  Southwest quarter, Legal Subdivision 4, Section 5, Township 1, Range 30 west of the First Meridian (SW4-5-1-30W1M)

If DLS locations are used extensively throughout the text and/or tables and figures of a publication, authors may choose to include a preliminary page that lists the abbreviations with their full formats instead of including the abbreviated formats after the first use of each DLS location with new descriptors.

Well/Wellbore Identification in Saskatchewan

Wells and wellbores drilled in Saskatchewan are assigned an identifying number based on the location of the well/wellbore within the Dominion Land Survey (DLS) system. This identifying number, often referred to as the 'Unique Well Identifier' (UWI), consists of 16 characters, each of which gives a reader an indication of where in the province the well or wellbore is located, or some other information about the well/wellbore.

For example, a well or wellbore with the DLS location 101/03-04-039-13W3/00 tells you that

- the location is being reported in the Dominion Land Survey system (signified by the initial character '1');
- the well/wellbore has a 'location exception code' (second and third characters) of '01' (this code is determined and assigned by the Saskatchewan Ministry of the Economy and, for a non-horizontal well/wellbore, provides more detail on its location within a legal subdivision, which in this case places the well/wellbore in the centre of the legal subdivision);
- the well/wellbore is located in Legal Subdivision 3 (fourth and fifth characters);
- within Section 4 (sixth and seventh characters);
- of Township 39 (eighth, ninth and tenth characters);
- in Range 13 west of the Third Meridian (eleventh to fourteenth characters).

The final two characters—in this example '00'—are the 'event sequence code', another code determined and assigned by the Saskatchewan Ministry of the Economy. The event sequence code gives information about the well or wellbore such as whether it's an original oil well (as in this example), a re-entry to a previously drilled well at the same DLS location, a recompletion well, *etc.*

Information that may be added to the DLS location includes the name of the company that drilled the well or wellbore (*e.g.*, Ceepee, Husky), the pool in which the well/wellbore is located (*e.g.*, Riley Lake, Glen Ewen) and the well/wellbore licence (*e.g.*, 58H014, 97I438). If used, the company and pool names are placed before the DLS location and the well/wellbore licence is placed at the end, separated by a semicolon and a space, as shown below.

Ceepee Riley Lake 101/03-04-039-13W3/00; 58H014

Husky Glen Ewen 111/16-23-002-01W2/01; 97I438

Although DLS well/wellbore designations should be repeated in full at every use, it is not necessary to repeat the company and pool names or the licence number. If not repeating the full well/wellbore name, precede the reference to the DLS location by the word 'well', as shown in the second example below.

The oil production from Ceepee Riley Lake 101/03-04-039-13W3/02; 97I438 for 2014 is shown in Table 1. **[full well/wellbore name given]**

The type well for the Bakken Formation is well 141/15-31-003-11W2/00. **[only DLS location given]**

Part 2 – Putting it all Together: SGS Style

Aside from ensuring the correct use of grammar, spelling, *etc.*, in all its publications, the Saskatchewan Geological Survey tries to impart a standard look to all its publications. Following are some guidelines to help you prepare your *Summary* paper, report or data file to SGS style standards.

Preparing Your Text

There is no need for authors to apply styles (*e.g.*, font type or embellishments such as bold or italics) to the text in their paper or report. All submitted text will have styles (as specified in Appendix 5) applied by the editor as part of the editing process. The only things we ask are that

- text is submitted in Microsoft® Word® format;
- the editor is given a clear indication of what heading and subheading levels you want;
- paragraphs are not indented: the only instances where you may need to indent text is when you have a block quotation, or for lists;
- only one space is used between sentences, and after colons and semicolons; and
- when referring to map units, the word ‘unit’ should precede each unit designation, even when it is in parentheses (*e.g.*, “The samples were taken from outcrops of units 3 and 5.”, “The deformation is more intense in the felsic metavolcanic rocks (unit Fv).”).

Text in figures and tables, however, is left mainly to the author’s discretion, as long as the pointers in the sections on ‘Preparing Your Figures’ and ‘Preparing Your Tables’ are followed.

Titles and Headings

In keeping with the ‘keep it simple’ principle stressed in Grant (2003), there is no need for a publication title (or a heading, for that matter) to begin with ‘The’. The only exception to this rule is when the title would otherwise begin with a number, which is a more serious transgression.

Titles and headings are always title case, meaning that all proper nouns and significant words have an initial capital letter (*e.g.*, ‘Rare Earths in Saskatchewan: Mineralization Types, Settings and Distribution’).

The title should include enough information for a reader to tell at a glance whether or not the publication might be of interest to them. The location of the study area within the province should form part of the title, accompanied by a compass-direction modifier and/or an NTS/Township and Range designation, if appropriate.

> Lithogeochemistry of the Hanson Lake Assemblage, Flin Flon Domain, Northern Saskatchewan
>
> A New Look at Copper-Nickel Mineralization in the Tantato Domain, Rae Province
>
> Geological Compilation of the Janice Lake Area, Wollaston Domain (Parts of NTS 74A/14 and /15, 74H/02)
>
> Sub-Mesozoic Unconformity Subcrop Map, West-central Saskatchewan

Titles for data file reports, in particular, benefit from the inclusion of NTS or Township and Range designations, so that the data contained in the file may be more easily integrated into the *Saskatchewan Geological Atlas*.

> Stratigraphy of the Jackfish, Cree and Mirror Basins from Multiparameter Drill Logs, Athabasca Basin, Saskatchewan (Parts of NTS 64E, 64L, 74E to 74P)
>
> Trace Element and Other Analyses of Paleozoic Brines from Southeastern Saskatchewan (Townships 1 to 13, Ranges 5 to 21 W2M)
>
> Thickness of Potash-rich Members of the Devonian Prairie Evaporite in Saskatchewan (Townships 1 to 50, Range 30W1M to Range 30W3M)

The inclusion of an NTS designation in a title is especially important for publications dealing with unsurveyed parts of the province.

Try to avoid using abbreviations in titles; the exception is for titles or headings that relate to geochronological or geochemical methods and results.

> U-Pb Geochronology and Sm-Nd Isotopic Tracing Results from the Saskatchewan Sub-Phanerozoic Project

If a study area or study topic encompasses two or more prominent topographic features, stratigraphic horizons or lithotectonic entities (*e.g.*, Clam Lake and Trout Lake; Alida Beds and Frobisher Beds; Flin Flon Domain and Glennie Domain), the study area or topic is referred to as 'The Clam and Trout Lakes Area', 'Stratigraphy of the Alida and Frobisher Beds', 'The Flin Flon and Glennie Domains'.

When the name of the study area is formed from two or more dissimilar features (*e.g.*, Pine Channel and Fond du Lac River; Alida Beds, Kisbey Interval and Frobisher Beds), the area name should include all features (*e.g.*, 'Pine Channel and Fond du Lac River Areas').

The word 'Area' should always be included after the area name.

> Geological Compilation of the Janice and Burbidge Lakes Area
>
> Reconnaissance Mapping of the Pine Channel and Axis Lake Areas

If you choose to join two or more proper nouns in a title, they are joined by an en dash when the title is formed: 'The Clam–Trout Lakes Area'; 'The Alida–Kisbey–Frobisher Stratigraphic Interval'; 'Structure of the Flin Flon–Glennie Complex'.

Note the use of a colon rather than a dash in the following 'hanging' title:

> Geological Mapping of the Beaverlodge Area, Northeastern Saskatchewan (Part of NTS 73P/10): Preliminary Results

There is a limit to the level of NTS detail that should be included in a title. For example, although the following NTS specification 'NTS 93E, 93L, 93M, south half 94D, east half 103I and southeast corner 103P' could reasonably be included in the introduction of the report, it should be abbreviated in the title as follows:

> Geology and Mineral Deposits of the Skeena Arch, West-central British Columbia (Parts of NTS 93E, L, M, 94D, 103I, P): Update on a Geoscience BC Digital Data Compilation Project

For *Summary* papers or reports that have an associated map or maps, the map title(s) should include some indication of the type of map (*e.g.*, bedrock, surficial, geochemical, stratigraphic, structural) as well as an indication of the NTS area or Township and Range:

> Bedrock Geology of the Otter–Althouse Lakes Area, Western Kisseynew Domain (Part of NTS 73P/10)
>
> Quaternary Geology of the Janice and Burbidge Lakes Area (Parts of NTS 74A/14 and /15)
>
> Ice-flow Indicator Map, Pine Channel and Fond Du Lac River Areas (Parts of NTS 74O/01, /02, /07 and /08)
>
> Isopach Map of the Patience Lake Member of the Devonian Prairie Evaporite in Saskatchewan

Keywords

All manuscripts submitted for publication by the SGS require an accompanying list of keywords. These may be integrated right into the Word file of the manuscript (in the case of reports and *Summary* papers), or listed on the *Record of Manuscript Submission* (in the case of data files and other publications).

A 'keyword' is a unique relevant geological idea that bridges the gap between a searcher with a question and a document with the answer. Keywords are a means of allowing a publication to be 'found' by internet search engines, ensuring our publications get the most exposure possible. The person best equipped to select keywords for their publication is the author. Below are a few guidelines.

- The list of keywords should be short (preferably 10 words or less) and prepared for someone who has a knowledge of geology in general but less familiarity with the geology specific to Saskatchewan.
- Age and general location are important keywords to include.
- Names of formations, groups, major intrusive bodies and major structural features are generally included.
- Routine chapter headings such as 'Structural Geology' or 'Economic Geology' would not be included unless the subject is covered in greater than usual detail.
- Minerals of possible economic interest should be given as keywords.

- If an idea is presented in enough detail to make its retrieval worthwhile, or is new or significant, however briefly mentioned, it should be a keyword.
- Reject keywords that are vague ('analysis', 'soils') in preference for keywords that give a better sense of what the report discusses (*e.g.*, 'U/Pb analyses', 'pedogenic processes').
- Be specific—'uranium' rather than 'radioactive minerals'.
- Conversely, choose a single keyword or phrase to encompass as many different ideas as possible: 'radioactive minerals' rather than 'uranium, thorium, potassium'.

Although the title is the element of a publication that is accorded the most importance when a match to a searched word or term is discovered by online search engines, finding multiple matches of searched words or terms in the same document is also important. Repeating keywords or terms in the title and abstract of a publication increases the chance that the publication will be found by online search engines.

Company and Organization Names

"A company's registered name is its legal identification and the full legal name should always be written out [at least] the first time it is used in a manuscript." (Grant, 2003, p.13). When a company name and its geographic location are mentioned, as in the case of the lab that did the analyses, the location should be placed in parentheses:

> Acme Analytical Laboratories Ltd. (Vancouver, British Columbia)
>
> Activation Laboratories Ltd. (Ancaster, Ontario; satellite labs are called Actlabs Geraldton, Actlabs Labrador, *etc.*; labs in South America have Spanish names)
>
> ALS Chemex (Vancouver, British Columbia)
>
> Becquerel Laboratories Inc. (Mississauga, Ontario)
>
> Saskatchewan Research Council Geoanalytical Laboratories (Saskatoon, Saskatchewan)

The same guidelines apply to geophysical exploration companies.

Use the full company name the first time it appears in the text, with the short form after in brackets, then use the short form afterward.

Names of People and Titles

For all publications, the names of all authors—and the affiliation(s) for all authors—must be included with the information supplied to the production editor. If you have external co-authors, ensure that you get their proper initials and surname spellings.

Further to the guidelines on p.24 of Grant (2003), titles and professional affiliations should not be used in conjunction with people's names in the text, especially on the title page and in the acknowledgments. Exceptions to this rule are as follows:

- Use a title and/or affiliation to lend credence to someone's statement, as in

  According to Dr. A. Bailes, P.Geo., the gold values in the initial press release were considerably overstated.
- Use a title in documents where official accreditation is acknowledged (*i.e.*, the seal of a P.Geo. or P.Eng.).

Throughout the text, use formal language when referring to other people (including initials rather than first names and no personal pronouns), as in

> The author is indebted to E.C. Syme and M.A.F. Fedikow for their insightful comments.

First names and personal pronouns are accepted in the acknowledgments.

There should be no space between a person's initials, and a period after each initial, even in a compound first name (*e.g.*, 'Marie-France Dufour' becomes 'M.-F. Dufour').

Following German practice, the grammatical requirement to capitalize the first word of a sentence takes precedence over the lower casing of name particles such as ‘van’.

The order of components in author affiliations is as follows:

Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, 1000-2103 11th Avenue, Regina, SK S4P 3Z8

University of Regina, Department of Geology, 3737 Wascana Parkway, Regina, SK S4S 0A2

Natural Resources Canada, Geological Survey of Canada, 601 Booth Street, Ottawa, ON K1A 0E8

Retired staff members should be acknowledged as ‘Saskatchewan Geological Survey (retired)’ and former staff members should be acknowledged as ‘formerly Saskatchewan Geological Survey’ anywhere that this might be required (*e.g.*, author affiliation footnote in a *Summary of Investigations* paper), as in the following example:

[2] Formerly Saskatchewan Geological Survey; currently Claude Resources Inc., 200, 224-4th Avenue South, Saskatoon, SK S7K 5M5

Author affiliations should not include an email address.

Geographic Names

Geographic names that are not in the *Canadian Geographical Names Data Base* (CGNDB) at Natural Resources Canada (http://www4.rncan.gc.ca/search-place-names/search?lang=en) are considered unofficial. For final reports and maps, all geographic names will be checked against the *Canadian Geographical Names Data Base* and, if not in the database, the author will be contacted for resolution of the problem. For Open File and other less rigorously edited publications, if an author uses an unofficial place name, it must be placed in single quotations and include ‘(unofficial name)’ after its first use in the text (*e.g.*, ‘Fish Lake’ (unofficial name)). The following footnote must accompany the first use of any unofficial name: “Unofficial settlement and lake or river names will appear in single quotation marks when first mentioned. The quotation marks will be subsequently dropped.”

If the unofficial name is a former name for the entity, it may be included in parentheses (in the text only) after the first use of the official name, in the following form:

Apetowachakamasik Lake (also known unofficially as 4-Mile lake)

Big Island Lake (also known unofficially as Manistikwan lake)

Standardization of Rock and Mineral Names

Consistency in the naming of rocks, minerals, soil types, *etc.*, is important in all SGS publications. For this reason, the SGS is in the process of choosing appropriate sources for in-house naming standards. The following sources have been adopted to date.

For igneous intrusive rocks:

Streckeisen, A. (1976): To each plutonic rock its proper name; Earth-Science Reviews, v.12, p.1-33.

For metamorphosed clastic sedimentary rocks:

Maxeiner, R.O., Gilboy, G.F. and Yeo, G.M. (1999): Classification of metamorphosed clastic sedimentary rocks: a proposal; *in* Summary of Investigations 1999, Volume 1, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 99-4.1, p.89-92.

For grain size classification:

Wentworth, C.K. (1922): A scale of grade and class terms for clastic sediments; Journal of Geology, v.30, p.377-392.

For migmatitic rocks and their textures:

Sawyer, E.W. (2008): Atlas of Migmatites; Canadian Mineralogist Special Publication 9, Mineralogical Association of Canada, Quebec, Canada, 373p.

For mineral abbreviations:

Whitney, D.L. and Evans, B.W. (2010): Abbreviations for names of rock-forming minerals; American Mineralogist, v.95, p.185-187.

For accepted spelling and capitalization of formally recognized stratigraphic units:

Mossop, G.D. and Shetsen, I. (comps.) (1994): Geological Atlas of the Western Canada Sedimentary Basin; Canadian Society of Petroleum Geologists and Alberta Research Council, 510p.
URL <http://www.ags.gov.ab.ca/publications/wcsb_atlas/atlas.html>.

Reporting Ore Grades

It's acceptable to give ore grades and other measurements in Imperial units if that's how they're reported in the original source, but the metric values must be in parentheses following (*e.g.*, 'Ridgeway, New South Wales: 53 million tons grading 4.26 million oz. Au (2.5 g/t) and 0.77% Cu'). If there was a figure for contained copper, which is normally given in pounds, it would go in parentheses after 'Cu'.

If reporting reserves or resources calculations and estimates that are non NI 43-101–compliant, the calculations or estimations must be preceded by the word 'historical' (*e.g.*, "Historical reserves of 47,235 tons grading 0.75% Ni were reported from this showing.").

The SGS follows the guidelines in NI 43-101 for capitalization of terms such as 'Reserves', 'Resources', *etc.*

Lists

If a serial or vertical list in an SGS publication comprises items for which a certain ranking of importance or other significance is intended, the list should be numbered, with the number followed by a closing parenthesis, as in the following examples:

[serial list]

The strata in the study area span three periods: 1) the Triassic, 2) Jurassic, and 3) Cretaceous.

[vertical list]

The three periods spanned by the strata in the study area are

1) Triassic,

2) Jurassic, and

3) Cretaceous.

When a list item itself contains a list with commas, the items in the primary list should be separated by semicolons rather than commas:

Four lithofacies have been identified: 1) oolitic, bioclastic, oncolitic and peloidal packstone to grainstone; 2) oolitic, bioclastic and intraclastic mudstone to wackestone; 3) dolomudstone; and 4) siltstone to sandstone.

The four lithofacies that have been identified in this study are

1) oolitic, bioclastic, oncolitic and peloidal packstone to grainstone;

2) oolitic, bioclastic and intraclastic mudstone to wackestone;

3) dolomudstone; and

4) siltstone to sandstone.

There should not be a mix of sentence fragments and complete sentences in the same list.

Captions

Captions for all SGS figures and tables are in sentence case and must be a single ‘paragraph’. An en dash separates the figure or table number from the caption text. Text that would be in italics in the main body of the report are non-italics in the caption.

> *Table 1 – Results of platinum group element and gold analyses for selected samples of mafic rocks from the Bassett Lake intrusion (sample locations shown in Figure 2).*
>
> *Figure 1 – Stratigraphic correlation chart showing the relative position of the McLaren and Waseca members of the Mannville Group in Saskatchewan (*modified from *Saskatchewan Ministry of the Economy, 2014).*
>
> *Figure 9 – Discrimination plot showing compositional fields of the vacant-subgroup 1 species foitite and magnesiofoitite, of the alkali-subgroups 1 and 2 species schorl and dravite, and the oxy species of the tourmaline supergroup (Henry* et al.*, 2011).*
>
> *Figure 4 – Example of Upper Shoreface facies, from CPEC et al Hartaven 132/07-02-010-09W2; 98C138, at 2420.3 to 2420.2 m depth: dark grey, fine-grained, silty sandstone mostly bioturbated by* Asterosoma *(As),* Palaeophycus *(Pa),* Planolites *(Pl) and* Thalassinoides *(Th). Scale bar is 1 cm.*

In a multipart figure, the descriptions of the parts should be separated by semicolons if there’s an introductory phrase (as in the first example below), or by periods if there’s no introductory phrase and the description of each part is a complete sentence (as in the second example) or the introductory phrase itself is a complete sentence (as in the last example).

> *Figure 2 – Outcrop photographs of **A)** granitic gneiss collected in suspected structural inlier; **B)** homogeneous granodiorite of the Nemeiben Lake intrusive suite; **C)** monzonite of the Rachkewich Lake pluton; and **D)** tightly folded (F_2) layering in feldspathic quartzite of the Sturdy Island assemblage.*
>
> *Figure 1 – **Left:** Location map showing the study area in southeastern Saskatchewan and configuration of the Williston Basin (*modified from *Nimegeers, 2006). **Right:** Map showing the distribution of wells examined in the study area.*
>
> *Figure 4 – Concordia diagram **(A)** and combined probability density diagram/histogram **(B)** for feldspathic quartzite of the Sturdy Island assemblage. See text for discussion.*
>
> *Figure 5 – **A)** Core photograph of mudstone with good dissolution porosity (Po): Frobisher Beds, 1185.5 m, 01/02-27-005-01W2; 85K115 (well 12 on Figure 1). **B)** Photomicrograph of peloidal intraclastic wackestone with intraclasts (In), peloids (Pe), and pore space (Po); the thin section is stained with Alizarin Red: Alida Beds, 1116.1 m, 01/16-10-005-32W1; 55C028 (well 18 on Figure 1). Photo is taken under cross-polarized light.*
>
> *Figure 7 – Vein relationships in the Dubyna pit wall and road-cut exposure illustrate the complicated history of ore emplacement. **A)** Outcrop photo showing albitized leucogranite cut by yellow-brown, subvertical dolomite veins in the Dubyna pit wall. **B)** Road-cut photo showing wide, subvertical dolomite-calcite-quartz vein cutting albitized Donaldson Lake granite. Note dolomite forms the margins of the large veins, followed by calcite with quartz in the core. The calcite-quartz vein is in turn cut by drusy quartz-dolomite veins.*

Figure captions are placed below a figure, left justified, unless the caption text spans less than a complete line, in which case the caption is centred below the figure. Table captions are placed above a table, always left justified.

Footnotes

Cite footnotes using numbers rather than symbols and include the footnote at the bottom of the page on which it’s cited.

Author’s or Editor’s Note

If you wish to insert a note in your text (as the author) or the text of someone else (as the editor), use square brackets and the following format:

> [author’s note: foliated and massive Andrew Lake granitoid, respectively]
>
> [editor’s note: not submitted with the original manuscript]

Quoted Text

There are two ways to include quoted text within a report: 1) within a sentence if the material quoted is short or only part of a sentence; and 2) as a separate, indented paragraph if the material quoted is lengthy or comprises a complete paragraph:

> Moreover, the "vast majority" (Webb, 1985, p.378) or "overwhelming majority" (Jackson and O'Dea, 2013, p.786) of species identified within the horizon in this area of the province are benthic species. [short quotes contained within a sentence]
>
> As mentioned in Steed *et al.* (2010),
>
> "... the outcrops in this area are composed of a variety of mafic to ultramafic metavolcanic rocks, associated volcano-sedimentary deposits, and rare plutonic intrusions." [lengthier quote as a separate, indented paragraph; the elipses indicate that the text is only a partial quote]

Copyright

It is impossible to over-emphasize the importance of obtaining permission from the holder of copyright before using illustrations or even lengthy quotations. "Giving credit to the copyright owner or the author does not constitute license to reproduce material without written permission." (Grant, 2003, p.4). Although it is legal to reword information without having to seek copyright permission (but ethical to credit the source), it is neither ethical nor legal to make a few minor changes to an illustration in order to avoid having to obtain permission.

Data or other information that is subject to copyright include figures, photos and tables from external sources (*e.g.*, companies, organizations, other publications, websites), photographs that include individuals (including SGS staff or other employees of the ministry) or proprietary trademarks.

It is the author's responsibility to obtain copyright permission. The permission request should be sent off as soon as you decide to include the illustration or quotation. Suggested wording for a copyright permission request is included in Appendix 6.

Authors must submit a copy of the correspondence granting permission to reproduce to the production editor.

When permission is granted, credit can be given in one of the following ways:

- In the caption of the illustration:

  > *Figure 1 – Location and regional tectonic setting of the Beaverlodge area (*modified from *Ashton* et al.*, 2007).*
  >
  > *Figure 3 – Geology of the pit at the McBratney Lake occurrence, showing the location and extent of channel samples (mapping by P. Lewis, 2001; published with permission of Fort Knox Gold Resources Inc.).*

  ('*From*' is used if the figure is unchanged from the original; '*after*' and '*modified from*' are used if changes have been made to the original figure. In figure captions, where the text is already in italics, these terms are not italicized.)

- In the 'Acknowledgments' section:

  > We thank the following publishers and professional organizations for granting permission to reproduce copyrighted material (with the figure number used in our study):
  >
  > American Association of Petroleum Geologists (Figure 26)
  >
  > Canadian Journal of Earth Sciences (Figures 13, 28)
  >
  > Canadian Journal of Remote Sensing, Canadian Aeronautics and Space Institute (Figures 5, 6)

The first example, which requires that the appropriate reference be included in the list of references, is the minimum possible and may not be sufficient for some copyright holders. It is therefore important to include, in your request for copyright permission, the format of the proposed acknowledgment.

Please note that permission is required from the original publisher or holder of copyright for further use.

Permission should be obtained in writing from anyone whose face can be seen in a photo, even if they are an employee of, or contractor for, the SGS. However, if an author uses their own image, then consent is implied. There should be no credits on photos taken by any of the co-authors of a report.

Google Maps™ and Google Earth™

Because SGS publications are noncommercial, you don't need to request permission if you don't alter an image taken from Google Maps™ and Google Earth™ products and you give appropriate credit to Google and any relevant third party. This credit includes ensuring that the attribution statement on the image is legible, as mentioned in the permissions guidelines at http://www.google.com/intl/en/permissions/geoguidelines.html. A suggested reference for a Google Maps image is:

> Google (2014): Google Maps™ satellite image of Clam Lake, Saskatchewan; Google, image, URL <http://maps.google.ca/maps> [©2014 Google - Imagery, ©2014 TerraMetrics, Map data, 22 June 2014].

Citations and References

Grant (2003) treats this topic extensively, and is therefore a good source for guidance. See in particular the sections on 'Citations' (Grant, 2003, p.137), 'Referencing Electronic Sources' (Grant, 2003, p.149) and 'In Press' (Grant, 2003, p.154). The points presented below are expansions of, or clarifications, additions or exceptions to Grant's rules.

All references cited in a publication—including those in the text, in figures or tables, in figure or table captions, and in appendices—must be included in a list of references, and all references in the list of references must be cited in the publication. The exception is if the publication has a bibliography rather than a list of references. A bibliography is a compilation of references relevant to a topic and, as such, can contain references that are not cited in the publication.

Citations

As outlined in Grant (2003), note that

- personal communications are cited as '(B. Rostron, personal communication, 2013)'.
- a manuscript that is in preparation cannot be included in the reference list but must instead be cited parenthetically in the text, in the following format (note that a year is not required):

  (G.K.S. Jensen, work in progress)
- you must be specific in citing material: statements such as '(see forthcoming isopach and structural maps)' are vague and give a reader no indication of how they can find the cited material once it's published.
- statements such as 'and references therein' should be avoided in a citation.
- when several references are cited together, they should be listed by year (oldest first), with assessment files, if any, at the end; if there is more than one reference cited for a given year, arrange them alphabetically by author, as in the following example:

  Regional maps of the area (Wilson, 1965; Dunn, 1975; Ehret and Kissling, 1985; Wilson and Pilatzke, 1985; Cen and Hersi, 2006a, 2006b; Cen, 2009; Eggie *et al.*, 2001; Saskatchewan Ministry of the Economy assessment files 74N07-0126, -0159 and -0262) include observations related to the units examined in this study.

Contrary to what is stated in Grant (2003),

- work can be cited as an unpublished report, but not included in the reference list, if it was the source of the statement being made and is unlikely to be included in a publication. Examples would be:

  The following descriptions are paraphrased from D.K. Tinkham *et al.* (unpublished report, 2013).

  The mineralization is described as disseminated sulphides and stringers associated with a mafic magmatic breccia hosted by leucogabbro (unpublished report prepared for Crean Minerals, 2006).

(An unpublished company report provided to the author by the company on the condition that it not be disseminated would also be handled in this manner; the author must have permission from the company to use information from the report. An unpublished work that could legitimately be included in the reference list is Eckstrand *et al.* (2004), under the 'Unpublished Report' section of Appendix 7.)

- Circumstances occasionally require the citation of data, either in your possession or in that of another worker, that has not been published; such a situation would be handled by a citation in the format '(A. Bailes, unpublished data, 2007)'; there is no reference associated with this citation.

Note also that

- there should be no reference citations in the abstract.
- when two or more references with the same author(s) are in press, they should be cited as 'Zwanzig (in press a, in press b)' or '(Corkery *et al.*, in press a, in press b)'.
- in a list of reference citations for publications by the same author or authors within the same year, leave the year in front of the second and all subsequent instances (*e.g.*, Ashton *et al.*, 2015a, 2015b, 2015c not 2015a-c). (Note that, to be able to cite Ashton *et al.*, 2015a, 2015b, 2015c, all authors must be the same in all publications cited for that year. If there are differences, the citations should be written as, for example, '(Ashton, Black *et al.*, 2015'; Ashton, Slimmons *et al.*, 2015a, 2015b)'.
- it's not necessary to include the name of the author of a publication being referenced in addition to a complete citation to the reference; for example, "Grant mapped the area for the British Columbia Geological Survey (Grant, 1986)…" can be shortened to "Grant (1986) mapped the area for the British Columbia Geological Survey …".
- citations to other papers in the same compendium volume should be in the form '(Hildegaard, this volume)', with no bibliographic reference; citations to figures in other papers in the volume should be in the form '(Hildegaard, Figure 1, this volume)'.
- citations to other papers in the same *Summary of Investigations* volume should be in the form '(Morelli, this volume, Paper A-8)', and the cited paper should be in the reference list; citations to figures in other papers in the same *Summary of Investigations* volume should be in the form '(Morelli, Figure 1, this volume, Paper A-8)'.
- in a *Summary of Investigations* paper, if there is a citation to another paper in the volume by an author for whom there is a citation to another publication in the same list, it should be handled as '(Hanson, 2013a; Hanson, this volume, Paper A-4)' to avoid confusion, not as '(Hanson, 2013a, this volume)'.
- assessment files should be cited as '(Saskatchewan Ministry of the Economy (ECON) Assessment File 74N07-0126)' the first time and '(ECON Assessment File 74N07-0126)' subsequently; they should not be included in the reference list.
- confidential assessment files cannot be cited because the content cannot be divulged and the publication is therefore not accessible to the reader for verification of critical information; if written permission to include information from a confidential assessment file has been obtained from the property holder (not the author of the assessment file), the citation should be in the form '(confidential ECON Assessment File 74N07-0126; reproduced by permission of [insert name of property holder here])'. Authors must submit a copy of the correspondence granting permission to reproduce to the production editor for tracking and filing.
- internal files should not be referenced, since the public can't access them.
- when citing information from other publications, it can be run into the text of a sentence (*e.g.*, "The accepted age for these rocks is 1350 Ma (Wright *et al.*, 2015).") or set within brackets (*e.g.*, "Helium can also be produced from rocks with uranium and thorium concentrations similar to that of the average shale (3.7 ppm U, 12 ppm Th; Brown, 2010).").
- if you wish to cite information that is cited in a source you've read but you haven't read the original source, both sources should be included in the reference list and the citation should read as follows:

  "…where calcium is precipitated as 'caliche' or 'calcrete' (Larsen and Chilingar (1967), cited in Wright (1986))."

- fossil identifications often require a complex citation format because the short identification report is generally included in a larger publication, as in the following:

  (identified by A.E.H. Pedder and B.L. Mamet in Read and Okulitch (1977) and M.L. Orchard in Milford (1984))

Citing Figures, Tables and Other Sections or Chapters

Each figure, table and appendix in a publication must be cited in the text at least once. When citing figures, tables and appendices, these words are always capitalized (*e.g.*, Table 1; Figure 3; Appendix 2). When citing multiple figures or tables within a sentence, they are written as "Tables 1 and 2 and Figures 3 to 5 indicate that….". When citing multiple figures or tables in a paranthetical sense, they are written as '(Tables 1, 2)', '(Figures 1 to 4)', '(Appendices 1, 3, 7)'. Citations to multiple parts of figures are treated the same way: 'Figures 3A, 3C and 3F' within the sentence and '(Figures 3A, 3C, 3F)' in parentheses.

References to specific samples in a table should be treated within a sentence as "...samples 18 and 36 in Table 5 show…." and in parentheses as "(Table 5, samples 18, 36)".

When citing another section or chapter within the same publication, the section heading or chapter title should be enclosed by single quotation marks, *e.g.*, "...see 'Introduction' ", "...as stated in 'Chapter 3: Metamorphism' ".

If a preliminary map or maps being released in conjunction with a paper in *Summary of Investigations* is cited in the text of that paper, it should be cited as "..as shown on the associated map (Knox and Lamming, 2015)." and the map(s) included in the list of references for the paper.

In the following example, Table 1 and Figures 3 to 5 are from the present report and Figure 4 is from the Bamburak *et al.* (1990) reference:

> (Table 1, Figures 3 to 5; Bamburak *et al*., 1990, Figure 4)

Within a single set of parentheses, use a semicolon to separate a citation to a figure in the present report from a citation to another publication, as in the following examples:

> Comparison of earlier mapping and the present work (Syme, 1995; Figure 2) indicates….
>
> …was based on the geochemical results from this survey and the earlier work (Figure 8; Fedikow, 1998, Figure 3)

In the second example, Figure 8 is from the present report and Figure 3 is from the Fedikow (1998) report.

In the following example, Figure 4A is from the present report, not from the reference, but that isn't clear:

> …on the Zr/Ti *versus* Nb/Y classification diagram of Pearce (1996) (Figure 4A).

When the figure citation is placed closer to its description, there is no confusion:

> …on the Zr/Ti *versus* Nb/Y (Figure 4A) classification diagram of Pearce (1996).

References

The SGS follows the guidelines for content and format of references laid out in Grant (2003), with the following exceptions:

- The name of the publisher or publishing organization is not italicized; however, italics are used for the word 'in' when it precedes the name of the compendium volume in which a reference is found.
- The names of journals, publishers and other organizations are written in full.
- The following abbreviations are used in references:

compiler, compilers	comp., comps.
editor, editors	ed., eds.
number(s)	no.
page(s)	p.

part(s)	pt.
volume(s)	v.

- Page ranges are written 'p.3-10'; total number of pages is written '339p.'
- The country name need not be included in text and references after the names of Canadian provinces and American states.

Below are general guidelines for writing references. See Appendix 7 for examples of SGS reference formats.

References are arranged in alphabetical order, first by the senior author, then by the junior author(s), then by year of publication, from oldest to newest. Note that, no matter how many authors there are, there is no comma in front of the 'and' that precedes the final author name. This method of ordering references results in the following:

Grant, B. (1975)
Grant, B. (1985a)
Grant, B. (1985b)
Grant, B. and Holden. G.W. (1975)
Grant, B., Holden, G.W. and Matthews, W. (1995)
Grant, B. and Rogers, T. (1990)
Grant, B., Rogers, T., Allison, J.T. and Smithers, K. (1999)
Grant, B., Rogers, T., MacKenzie, R.S. and Smithers, K. (1995)
Grant, B., Sales, G.E. and MacKenzie, R.S. (1994)

The two references with the same senior author and the same publication year but different co-authors would be cited in the text as 'Grant, Holden *et al.*, 1995' and 'Grant, Rogers *et al.*, 1995'.

Authors' first name or names are given as initials only, following their surname and separated from the surname by a comma. There is a period after each initial of an author's name and no space between them (*e.g.*, Jensen, G.K.S.). For compound first names, there should be a period after each initial (*e.g.*, Chang, V.T.-C., Dufour, M.-F.).

The alphabetical order for author surnames that contain spaces or apostrophes is the same as if those spaces or apostrophes weren't present, as indicated below:

D'Amato, G.
Deary, I.J.
de Groot, R.
de Groot, W.
de Jong, E.
Delfino, R.J.
DeLucia, E.
D'Souza, R.M.
Lafrance, B.
Le Bas, M.J.
LeFever, J.A.
O'Nions, R.K.
Sainte-Beuve, C.-A.
Saint-Gaudens, A.
San Martin, J. de
St. Laurent, L.S.
van Geldern, R.
Von Osinski, W.P.C.

An author name such as 'Miles St. John Windsor, III' would be treated in the reference list as 'Windsor, M.S.J., III'.

Similarly, an author name such as 'Philip Daniel Beauchamp, Junior' would be treated in the reference list as 'Beauchamp, P.D., Jr.'

It is not necessary to include the 'III' or 'Jr.' in the citation within the text.

Also note that

- '*et al.*' should not be used to replace author names in the reference list: all authors, regardless of how many there are (as in the following extreme example), must receive acknowledgment for their work.

  Gradstein, F.M., Cooper, R.A., Sadler, P.M., Hinnov, L.A., Smith, A.G., Ogg, J.G., Villeneuve, M., McArthur, J.M., Howarth, R.J., Agterberg, F.P., Robb, L.J., Knoll, A.H., Plumb, K.A., Shields, G.A., Strauss, H., Veizer, J., Bleeker, W., Shergold, J.H., Melchin, M.J., House, M.R., Davydov, V., Wardlaw, B.R., Luterbacher, H.P., Ali, J.R., Brinkhuis, H., Hooker, J.J., Monechi, S., Powell, J., Röhl, U., Sanfilippo, A., Schmitz, B., Lourens, L., Hilgen, F., Shackelton, N.J., Lasker, J., Wilson, D., Gibbard, P. and van Kolfschoten, T. (2004): Geologic Time Scale 2004; Cambridge University Press, Cambridge, UK, 589p.

- A repeating, identical authorship should not be replaced in second and subsequent references by ellipses, underscores or dashes.

  Grant, B. and Rogers, T. (1990)
  Grant, B. and Rogers, T. (1992)

  not

  Grant, B. and Rogers, T. (1990)
  ———— (1992)

- Titles of publications in references cannot be changed, even if they use different capitalization rules or spell things differently than the SGS does.
- Titles of papers, maps and government monographs are in sentence case (*i.e.*, only the first word is capitalized, and all proper nouns), whereas titles of books are in title case (all significant words and proper nouns are capitalized). Final 'Reports' by government agencies are treated as books, but Open Files, Miscellaneous Reports and other less formal publications are not. University theses are not considered as books.
- Manuscripts can only be considered 'in press' if they have been accepted for publication by the journal.
- Oral presentations by SGS authors that are on the ministry's website can be cited, but it's the author's responsibility to provide the appropriate URL as part of the reference.
- Multiple maps in the same series should not be included in the same reference; list them individually unless you mean to cite the entire series, then the reference to the entire series should be listed (*e.g.*, the Saskatchewan Phanerozoic Fluids and Petroleum Systems maps; see 'Series of Maps' in Appendix 7).
- A URL can be included for any reference that is available online, using the format in Appendix 7; the date in brackets is the date you last accessed the URL.
- Note that a 'date accessed' is not necessary when giving a URL for a publication that is not expected to change, for example, a *Summary of Investigations* paper posted on the ministry website, or a paper in a compendium published in 1995. If the URL is for a publication or website that is updated often, then a 'date accessed' is required.
- If a publication date isn't given for data on a website that is being referenced, use the 'year of download' or the year it was accessed as the publication date.
- Data and/or datasets downloaded from the Internet and used to create illustrations must be cited and have a complete reference, including a URL and the download date, so ensure that you obtain the information for the reference while downloading the data.
- If it is necessary to cite software manuals, they should be treated in the same manner as unpublished industry reports. Strictly speaking, they have not been published because they are not available separate from the software package. The statement "not available in libraries" could be added in parentheses at the end of the reference.
- If it is necessary to cite unpublished mining company reports, the author citing them must either 1) have the company's permission to use the information; or 2) if the report is on SEDAR, include the URL for the SEDAR website in the reference. If a company has provided an unpublished report to the author on the condition that it not be disseminated and the author has permission to reproduce information from the report, it should be cited in

the text as unpublished (*e.g.*, Bailes, unpublished report prepared for HudBay Minerals Inc., 2011) and not included in the reference list.

- The Digital Object Identifier (DOI) is a permanent identifier given to a World Wide Web file or other internet document so that, if its internet address changes, users will be directed to the new address.[2] Because DOIs are being used more commonly, particularly by electronic-only journals, they should be included at the end of the reference in the format shown below (note the absence of a period at the end of the reference).

  Gapais, D., Potrel, A., Machado, N. and Hallot, E. (2005): Kinematics of long-lasting Paleoproterozoic transpression within the Thompson Nickel belt, Manitoba, Canada; Tectonics, v.24, TC3002, doi:10.1029/2004TC001700

  If an author provides a URL and a DOI, keep both because it never hurts to give as much information as possible; the DOI should be placed last.

- Two publications should not be combined into one reference, as was attempted in the following instance:

  British Columbia Ministry of Energy and Mines (1995): National Geochemical Reconnaissance 1:250 000 Map Series, Terrace and Prince Rupert (NTS 103I, J), British Columbia RGS 42 – Geological Survey of Canada Open File 772, URL <http://www.empr.gov.bc.ca/Mining/Geoscience/Geochemistry/RegionalGeochemistry/Pages/103IJ.aspx> [September 2011].

  The samples were collected in 1978 and the original results published in 1981 as a Geological Survey of Canada open file. The samples were reanalyzed in the 1990s and the new results published as a British Columbia Geological Survey regional geochemical survey. Both of the relevant publications should therefore be referenced separately:

  Ballantyne, S.B., Hornbrook, E.H.W. and Johnson, W.M. (1981): National Geochemical Reconnaissance, Prince Rupert-Terrace, British Columbia (NTS 103I and part of 103J); Geological Survey of Canada, Open File 772, 93p.

  British Columbia Ministry of Energy and Mines (1995): Regional geochemical survey, Terrace and Prince Rupert (NTS 103I, J); British Columbia Ministry of Energy and Mines, BC RGS 1/42, URL <http://www.empr.gov.bc.ca/Mining/Geoscience/Geochemistry/RegionalGeochemistry/Pages/103IJ.aspx> [accessed September 2011].

[2] Definition from Wikipedia, the free encyclopedia

Preparing Your Figures

- Figures in the text are numbered Figure 1, Figure 2, *etc.*, figures in appendices are numbered Figure A1-1, Figure A1-2, *etc*.
- Use italic font for names of hydrographic (drainage) features.
- Annotations on photos, text on figures and in figure legends should have the first letter of all text strings capitalized (*e.g.*, 'Foliation symbol', 'Well location').
- Any text in figures and on photos should use Arial and Symbol fonts only. If you are using any unusual fonts (for example, striation symbols on a figure), embed them in the file.
- All symbols and abbreviations on a figure must be explained in a legend or in the caption.
- If you have two or more figures in the same publication with the same legend elements, the symbols for these elements should be consistent in all figures in which they are present.
- Font size for any text on figures and photos should be no smaller than 7 points. The text should be black or a colour that makes it readily visible against whatever background on which it's placed.
- For figures with pattern fills, use coarse patterns. Screen tints (greyscales) may lose up to 5% of their blackness when converted to PDF. If screen tints are used, limit them to no more than 3 per figure. Only screen tints that are 20, 40 and/or 60% black should be used.
- Use line weights of 0.75 points (0.008 inches) or thicker. Line weights of 0.5 points or less will not reproduce well when converted to PDF.
- Map-based figures must have a north arrow and scale bar, and geographic coordinates of some type (latitude-longitude, UTM, Township-Range), except on very small-scale maps (*e.g.*, a location map that shows the entire province, placed as an inset in a figure).
- Photos must have a scale bar or some other indication of scale (*e.g.*, ruler, rock hammer, field pack, compass, field assistant).
- If the author has used data/datasets from other sources for the base of a figure, a citation and reference to the source of the base data must be included.
- If using an image from a website or a publication not produced by the SGS, you may need to request permission for its use. Check the publication or website from which the image was obtained for their regulations on reproducing copyrighted material. If permission is required to reproduce an image, it is up to the author to obtain this permission and to forward the permission to the production editor prior to the image's use. Regardless of whether copyright permission is required or not, the image's caption must reflect the source, whether it be '*after*,' '*modified from*' or '*adapted from*'. Refer to Grant (2003, p.156) for definitions of these terms.
- In a figure of two or more parts, or a plate of two or more photographs, the individual parts/photos should be labelled with bold, upper case letters: A, B, C, *etc*. The preferred location for the identifying letters is in the upper left corner of each part or photo; however, if the content precludes this placement, the letters should be placed where they are most easily visible.
- Composite figures must be submitted as a single file.
- All figures should be submitted in Adobe® Illustrator®, and each figure must be submitted as a separate file. Submission of files in CorelDraw® will be considered on a case-by-case basis.
- If a figure comprises a single photo with no annotation or other embellishment, submit the figure as a JPEG or TIFF file.
- All linework, symbols and text must be able to be easily read at the <u>final</u> size (if necessary, reduce the figure on a photocopier to check readability).
- Do not 'link' your photos in the Illustrator® file; instead, choose 'Place' to insert your photos and make sure the 'Link' option is not checked.

- Images should have no ‘hidden’ components (*i.e.*, don’t cover up unwanted areas of graphics with white boxes), and no part of your figure should be linked to another program (for example, charts or graphs that were originally created in Excel® and then copied and pasted into your figure may contain a link back to the original Excel® file).
- Only the layers that show the elements you want shown should be included. All other layers should be deleted.
- Make sure images have been cropped to the borders of the figure.
- All figures must be submitted in **final publication size**. Maximum figure dimensions are:

Letter-sized pages:	portrait orientation – must not exceed 16.5 cm wide by 21.0 cm high landscape orientation – must not exceed 22.5 cm wide by 16.0 cm high
Legal-sized pages:	portrait orientation – must not exceed 16.5 cm wide by 30.0 cm high landscape orientation – must not exceed 30.0 cm wide by 16.5 cm high
Ledger-sized pages:	portrait orientation – must not exceed 22.0 cm wide by 37.0 cm high landscape orientation – must not exceed 38.0 cm wide by 22.0 cm high

- Full-page figures must allow appropriate space for captions.

For photos, ensure that

- they are used judiciously (*i.e.*, they should illustrate unique features critical to the text discussion, and not be ‘just another outcrop of pillow lava’) and are good quality images (*e.g.*, not pixelly or grainy);
- they are submitted at a resolution that gives a manageable file size (ideally 300 dpi at the final physical size); and
- permission to publish has been received in writing from any individuals shown in a photo, including SGS staff or other employees of the ministry.

Preparing Your Tables

- Tables in the text are numbered Table 1, Table 2, *etc.*, tables in appendices are numbered Table A1-1, Table A1-2, *etc*.
- Tables comprising mainly or only text, and short tables with few columns, are best created in Microsoft® Word®; tables with large amounts of data, such as results of geochemical analyses, are best created in Excel®.
- Each table should be submitted as a separate file (*i.e.*, one worksheet per Excel® file or one Word® file per table) at final print size.
- Column heading text should be in bold and title case (*e.g.*, ‘Sample Locations,’ ‘Description of Units’).
- The first word in all text strings in the table should have the first letter capitalized (*e.g.*, ‘Texture is fine- to medium-grained, colour is brownish red’).
- Tables of geochronological and other types of analyses should include UTM coordinates or Township/Range designations for each sample, and, if using UTM coordinates, the caption or a footnote should indicate the NAD and zone (*e.g.*, ‘UTM coordinates are in Zone 13, NAD83.’).
- Any footnotes should be cited using numbers rather than symbols.
- Ensure that the number of digits after a decimal point is the same for all values given in the same table (*i.e.*, 10.23, 9.61, 8.00 not 10.23, 9.6, 8), unless they’ve come from the lab that way.
- Judicious use of colour shading in tables is acceptable <u>if it makes the table easier to read</u>. The colour hue and saturation should be appropriate for both printing and viewing on a computer.

Preparing Appendices

- Appendices are numbered Appendix 1, Appendix 2, *etc*.
- Page numbers in appendices follow sequentially from the last page of the main body of the text.

SGS Publication Types and Content

The Saskatchewan Geological Survey releases the results of its research in a number of types of publications. The major publications series are described briefly below. A more detailed list of contents–and examples–are presented in Appendix 8 for *Summary of Investigations* papers, Data File reports, and Open File reports.

Final Report

These reports contain the results of comprehensive geological studies. They are typically final reports on multi-year projects, and are based on original research that may also include reviews of pre-existing databases. These reports have undergone rigorous editing. In addition to maps, other accompanying or supplementary components may include GIS/ArcReader projects, digital data, databases, *etc*. Some 'Reports' simply comprise a map. Reports are numbered sequentially (*e.g.*, Report 265, Report 266); numbering is assigned by the production editor.

Miscellaneous Report

This series includes reports, maps, groups of maps, digital maps with accompanying databases, even single page figures (for example, the annually updated *Resource Map of Saskatchewan*). Miscellaneous Reports have been numbered in a variety of ways throughout the years, from sequentially (Miscellaneous Report 1, Miscellaneous Report 2, *etc.*), to incorporating the last two digits of the year of publication (*e.g.*, Miscellaneous Report 92-6, Miscellaneous Report 94-2, *etc.*), to the current numbering system of incorporating the entire year of publication (*e.g.*, Miscellaneous Report 2014-3, Miscellaneous Report 2015-1).

Summary of Investigations

The *Summary of Investigations* (SOI) series is a separate subset of the Miscellaneous Report series. This annual publication comprises a collection of papers reporting on research carried out by staff of the SGS, or by students or other researchers who carried out work that was either funded by the SGS or made use of SGS facilities. It is divided into two volumes: Volume 1 contains papers contributed by staff or researchers with the Petroleum Geology Unit; Volume 2 contains papers contributed by staff or researchers with the Minerals and Northern Geology Unit. As with the Miscellaneous Report series, SOIs have been numbered in a variety of ways throughout the years (details on past numbering methods for the *Summary of Investigations* are given in the 'Referencing Publications by the Saskatchewan Geological Survey' section of Appendix 7). Examples of the current numbering format for the SOI series of Miscellaneous Reports are: Miscellaneous Report 2016-4.1, for Volume 1; and Miscellaneous Report 2016-4.2 for Volume 2.

Contributed papers may be accompanied by one or more maps, or associated with another publication such as a Data File. Maps accompanying the papers are numbered Miscellaneous Report 2016-4.2-(1), Miscellaneous Report 2016-4.2-(2.1), Miscellaneous Report 2016-4.2-(2.2), *etc*.

Open File

Information on specific geological topics or the results of other activities of the SGS that may be of immediate interest to the public are released in the Open File series. Open Files can be reports (with or without accompanying maps), stand-alone maps, databases of geochemical analyses, *etc*. This series is designed for rapid release of data and ideas. Open Files are not necessarily subjected to extensive editing prior to release. Open Files are numbered by the year of publication and a sequential number within that year (*e.g.*, Open File 2016-1, Open File 2016-2). Open File numbers are assigned by the production editor.

Prospect Saskatchewan

The 'Prospect Saskatchewan' series of informational brochures is produced by staff of the Petroleum Geology Unit. These brochures are intended to highlight prospective areas in the province for petroleum and gas, and other resources in the Phanerozoic rocks underlying the province. They have undergone limited editing. They are numbered sequentially (*e.g.*, *Prospect Saskatchewan* Issue #10, *Prospect Saskatchewan* Issue #11); the issue number is assigned by staff of the Petroleum Geology Unit.

Geoscience Map

Geoscience maps provide an overview of specific geoscience subjects, such as bedrock geology, depth to tops or bottoms of formations or members, deposits of metallic or industrial minerals, and glacial or surficial geology. They have undergone rigorous editing and generally are full-colour maps, at a variety of scales, printed in-house. They are numbered sequentially by year (*e.g.*, Geoscience Map 2016-1, Geoscience Map 2016-2); the map number is assigned by staff of the Minerals and Northern Geology Unit.

Data File

This series makes available all or parts of selected rock, drillcore, geochemical or geophysical databases and contains mainly unedited information. Data Files are datasets in their native format (generally Excel® spreadsheets) that may be accompanied by a report giving a brief summary of the nature of the data, where it was gathered, *etc*. Data Files are numbered sequentially, *e.g.*, Data File 1, Data File 2; the number is assigned by the production editor.

Annual Publications Related to the Saskatchewan Geological Open House

The Saskatchewan Geological Survey and the Saskatchewan Geological Society host an annual meeting at which the results of recent research by government geologists, industry geologists and students are presented in the form of talks and posters. Abstracts for talks presented at the meetings are published in an *Abstract Volume* that is distributed at the Open House and made available online afterward.

Also in conjunction with the Geological Open House, the Saskatchewan Geological Survey produces the *Saskatchewan Exploration and Development Highlights*, an annual document that contains brief details of current exploration activity and exploration expenditures in the province. This document is also distributed at the Open House and made available online afterward.

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Appendix 1 – Prepositions Associated with Commonly Used Words

The following list of prepositions associated with commonly used nouns has been compiled from the Alberta Research Council's *Style Manual* (Alberta Research Council, 1991) and the Geological Survey of Canada's *Guide to Authors* (Geological Survey of Canada, 1998).

Abbreviations used in this appendix: adj. - adjective; n. - noun; v. - verb.

ability *at* (doing); *with* (something)

abound *in* [a man abounding in natural ability]

abound *with* [a faithful man shall abound with blessings]

accommodate *to* or *with*

accompanied *with* (things); *by* (persons)

accord *with*; *of* one's own accord

account *for*

accountable *to* (persons); *for* (acts)

acquaint *with*

acquiesce *in*

acquit *of*

adapted *to* (a use); *for* (a purpose); *from*

adhere *to*

adherence *to*

adjacent *to*

adjusted *to*

advantage *of* or *over*

adverse *to*

affiliate *with* or *to*

agree *with* (persons); *to* (suggestions); *in* (thinking); *on* (a course of action)

aim *at* or *to*

alien *to*

alternate [v. and adj.] *with*

amalgam *of*

amalgamate *into* or *with*

amenable *to*

analogous *to*

analogy *between* or *with*

apart *from*

apathy *toward*

append *to*

arrive *at* or *in*

aspire *to*, *after* or *toward*

assist *at* (be present); *in* or *with* (help)

associated *with*

assume responsibility *for* (an action)
astonished *at* (disapproval); *by* (approval)
augmented *by* or *with*
averse *to* [not averse *from*]
aware *of*

based *on* or *in*
basis *of* or *for*
begin *by* (doing something); *from* (a point); *with* (an act)
benefits *of* (the benefactor)
benefits *to* (the beneficiary)
blend *with*
border *on*
bounded [not bound] *by* [exception: bound by law]
break *with* or *from*

capable *of*
capacity *for* (ability); *of* (volume)
careful *with* (an object); *of* (value); *about* (small things)
centre *on* [not *around*]
characteristic *of*
circumstances (*in* the)
coeval *with*
coincide *with*
compare *to* [only when used in the sense “to liken to”]
compare *with* [to note points of resemblance and difference]
compatible *with*
complacent *toward*
comprise [takes no preposition, so “is comprised of” is grammatically incorrect]
concordant *with*
concur *with* (persons); *in* (an opinion); *to* (an effect)
conditions (*under* the)
conducive *to*
conform *to* (adapt one’s self to); *with* (in harmony with)
consist *of* (material) [The meal consisted of fish.]
consistent *with*
contemporaneous *with*
contend *with* or *against* (enemies); *about* (issues)
content (oneself) *with*; (others) *by doing*
contrast [When ‘contrast’ is used as a verb, it is followed by *with*. Either *to* or *with* may be used when ‘contrast’ is used as a noun.]
conversant *with*
correlate *with*

correspond *to* (resemble); *with* (communicate)
culminate *in*

decide *on*
deficient *in*
demand (a thing) *from* or *of* (a person)
demand *for* (a thing)
demanding *of*
depend *on*
deprive *of*
derive *from*
destined *to* [be a leader] or *for* [great things]
detract *from*
deviate *from*
differ *with* [a person in opinion]
differ, different, *from* [not *than*, *to*]
differentiate *from*, *between* or *among*
disagree *with* (a person)
discordant *with*
distinct *from*
distinguish *from*, *between* or [rarely] *into*
divide *between* or *among*

eager *for*, *after* or *in*
eligible *for*
embark *in* [a mining venture]
emerge *from*
end *with* or *in*
endowed *with*
engaged *in*
enter *on*, *upon* or *into*
equivalent (adj.) *to* or [sometimes] *with*; (n.) *of*
essential (adj.) *to*; (n.) *of*
evidence *of* (something); *for* (a theory)
exclude *from*
exclusive *of*
expert *in*, *at* or *with*
extract *from*

faced *by* or *with*
fascinated *by* (person); *with* (thing)
find [a fault] *in* (a person or thing); [fault] *with* (a person); [satisfaction] *in* (an improvement)
fond *of*

fondness *for*
forbid (one) *to do*
free *from* or *of*
friend *of* or *to*
friendly *to* or *toward*
full *of*

give satisfaction *to* (a person)
grateful *to* (persons); *for* (benefits)

hinder *from*
hindrance *to*
hope *for* or *of*

identical *with* or *to*
identify *with*
immune *from* (an obligation or something unpleasant); *to* (a disease)
[have an] impact *on*
impervious *to*
implicit *in*
impressed *by* or *with*
incentive *to* or *for*
in contrast *to*
indicate *that* [*e.g.*, "...indicate that the TS unit is the most likely source." but "...indicate the TS unit as the…"]
indifferent *to*
infected *with* (disease, bad qualities)
infer *from*
infested *with* (insects, vermin)
influence (n.) *over*, *upon* or *with*
inherent *in*
initiative *in* (to take) [but *on* one's own initiative]
inseparable *from*
insight *into*
intention *to* or *of*
intercalated *with*
interpreted *as* [*e.g.*, "interpreted as a fault"; avoid 'interpreted to be', as this implies cause and effect]
interpreted *to* [*e.g.*, "interpreted to have formed at extremely high pressure"]
introduce *to* or *into*
invest *in* (a business)
investigation *of* or *into*
involve *in* or *with*

join *in* (a game); *with* (a person or thing)

justified *in*
juxtaposed *to*/*with* [depending on the context]

labour *at* (a task); *for* (a person or an end); *in* (a good cause); *under* (a disadvantage)
lacking *in*
liable *for* (an act); *to* (a person)
look *after* (a business); *at* (a thing); *for* (a missing article); *into* (a matter); *over* (an account)

means *to*, *of* or *for*
mix *with* or *into*
at a moment's notice
on the spur of the moment

necessary *to* or *for*
necessity *of* or *for*
negligent *of* or *in*

object *to* or *against*
oblivious *of* or *to*
occasion *of* or *for*
opposite (adj.) *to*; (n.) *of*
in the order *of*
originate *in* or *with*

parallel *to* or *with*
peculiar *to*
permeate *into* or *through*
permeated *by*
perpendicular *to*
pertinent *to*
point *at* (a thing); *to* (a fad); *with* (an object)
possibility *of*
[have] potential *for* (something or doing something)
prefer [one] *to* [the other]; *to do* [one thing rather than another]
preference *for*
prevent *from* (doing something)
proceed *against* (a person); *to* (an act not previously started); *with* (an act already started)
prohibit *from* (doing something)
provide [one's self] *with* (something); *for* (an emergency); *against* (ill luck)
pursuant *to* (*in* pursuance *of*)
pursuit *of*

qualify *for* or *as*

range *from* X to Y [not range *between*]
ready *for* (a journey); *to do* (something); *with* (a reply)
reason *for*
reckon *with* (a person, a contingency)
recommend *that* [she do]—[not *her to do*]
reference *to* [preceded by *with*, not *in*]
regard *for* (a person, one's own interest)
with regard *to* (a subject)
relieve [one] *from* (a duty); *of* (a burden or responsibility)
resemblance *to*, *between* or *among*
with respect *to* [preceded by *with*, not *in*]
the responsibility *for* (an act or situation); *of* (deciding, a position)
responsible *to* (a person); *for* (an action)
result *from* (an event); *in* (a failure)
the result *of* (an investigation)
rich *in*
right *of* (doing)
right *to* (do)

satisfied *of* (a fact); *with* (a thing)
the satisfaction *of* (knowing)
saturate, saturated *with*
secure *against* (attack); *from* (harm); *in* (a position)
sensitive *to* or *of*
similar *to*
solution *of* or *to*
strive *with*, *for* or *against*
subject *to* or *of*
substitute *for*
suggest *that* (she do) [not *her to do*] but 'suggests potential *for* a variety of deposit types'
suitable *to*, *for* or *with*
superimposed *on*

take the initiative *in*
tamper *with*
tendency *to* or *toward*
tinker *at* (gemmology); *with* (an engine)
tolerance *for*, *of* or *toward*
true *to* (form); *with* (a line or edge)

unconscious *of*
under the conditions
underlain *by*

unfavourable *to*, *for* or *toward*
useful *in*, *for* or *to*

at variance *on* (certain topics); *with* (a person)
vary *from*
versed *in*
in view *of* (circumstances)
with a view *to* (achieving a purpose)
void [devoid] *of*
vulnerable *to*

want (n.) *of*
wanting *an*
wary *of* (a danger)
way *of* (manner, method)
worthy *of*

yield *to*

Appendix 2 – Hyphenation Guidelines

The following tables illustrate the hyphenation rules for a variety of compound expressions. (*Modified from* Weatherston, 1996, p.30-32. ©Queen's Printer for Ontario. Reproduced with permission.)

Hyphenation guide for compound nouns and adjectives.

Example of Compound Type	Similar Compounds	Type of Compound (Rules)	Example of Compound Used Correctly
		Noun Forms	
diamond drilling	strip mining, borehole drilling, isostatic rebounding	object + gerund (noun formed by verb ending in 'ing') • always open • be careful not to confuse with adjective form (see Adjective Forms, below)	Diamond drilling was carried out on the property. The presence of beach terraces was interpreted as evidence of isostatic rebounding.
lapilli tuff	tuff breccia, ice margin, peat bog, fault block, sodium chloride	noun + noun • always open	The lapilli tuff in this area has a maximum fragment size of 2.6 cm. The process involves use of a sodium chloride solution.
base metal	alluvial fan, cross fault, hard rock, hot spring **but** cross-bed, cross-lamination, half-life, cross-stratification, cross-section	adjective + noun • usually open, but can vary • check Appendix 3 'Spelling and Word Usage,' and the AGI *Glossary of Geology*, especially where the adjective is 'cross'	These deposits are indicative of an alluvial fan. Cross-stratification is a common feature in these beds.
parent company	parent organization, fellow employee	word of relationship + noun • always open	The claims were staked by the parent company.
one half	two thirds, three quarters	spelled-out fraction used as a noun • always open • be careful not to confuse with adjective form (see Adjective Forms, below)	The volume of gold produced by the mine has dropped by one half.
		Adjective Forms	
highly developed folds	strongly deformed, weakly foliated, abruptly truncated, highly complex, cataclastically deformed	adverb ending in 'ly' + adjective or past participle (past tense of verb) • always open	Highly developed folding is common in the area. The rocks are weakly foliated.
well-sorted clasts	well-graded deposits, well-rounded pebbles, far-reaching events, northward-younging unit, east-striking fault	adverb + past or present participle (present tense of verb – 'ing' ending) • hyphenate before the noun being modified but leave open after the noun	The northward-younging pillowed basalt is cut by diabase dikes. The clasts are well sorted.
phenocryst-bearing rock	diamond-drilling program, electron-capturing reaction, hanging-wall rock	noun + present participle (or gerund) • hyphenate before the noun being modified but leave open after the noun	The diamond-drilling program was started in 1980. Rocks in the area are rarely phenocryst bearing.
matrix-supported conglomerate	sulphide-mineralized horizon, gravel-filled channels, bedrock-dominated terrain, mantle-derived rocks	noun + past participle • hyphenate before the noun being modified but leave open after the noun	Epidote-filled fractures are widespread near the shear zone. The conglomerate south of the main outcrop is clast supported.

Example of Compound Type	Similar Compounds	Type of Compound (Rules)	Example of Compound Used Correctly
rare-element pegmatites	regional-scale folding, iron-rich sediments, low-angle cross-lamination, high-energy zone, two-mica granite, ice-marginal deposit **but** base metal deposit, rare earth element	adjective + noun • hyphenate before the noun being modified but leave open after the noun • see exceptions in the box to the left	The gravel-rich alluvium of the fan deposit contains traces of gold. Folding in the area is regional scale.
spinel-group minerals	trace-element data, greenschist-facies metamorphism, diamond-drill hole, Timiskaming-type assemblage, iron-titanium oxides **but** platinum group element, platinum group mineral kimberlite indicator minerals	noun + noun • hyphenate before the noun being modified but leave open after the noun • see exceptions in the box to the left	Trace-element data include anomalous values for Be, Rb and Sr. Metamorphism in the area is amphibolite facies.
coarse-grained sandstone	spinifex-textured flows, lapilli-sized fragments, dark-coloured clasts, vertical-sided canyon	adjective (or noun) + noun to which the suffix 'ed' has been added • hyphenate before the noun being modified but leave open after the noun	This unit occurs as a thin flow of spinifex-textured komatiite. The calcarenite is fine grained and lacks obvious stratification.
cross-stratified sandstone	flat-lying terrain, white-weathering rocks, steep-dipping strata, medium-bedded wacke	adjective + past or present participle • hyphenate before the noun being modified but leave open after the noun	A few beds of cross-stratified sandstone can be seen in the outcrop. Foliations near the pluton are steep dipping.
branch-like veins	ripple-like forms, till-like deposits **but** businesslike childlike	noun + adjective 'like' • hyphenate before and after noun being modified when it is a temporary compound • permanent compounds are one word	Ripple-like forms are common in this unit. The deposit is till-like and contains a large percentage of gravel.
green-grey mudstone	blue-green algae, red-green colour blindness	colour term in which 2 colours (adjectives) have equal importance • hyphenate before and after noun being modified	The characteristic green-grey mudstone is present here. The sandstone is pink-brown on fresh surfaces.
pale pink granite	greenish blue, dark brown, canary yellow, light grey, olive green	colour term composed of adjective or noun + colour, where the first element modifies the second • always open	The pluton is composed of pale pink granite. The gossan rocks are rust brown.
melt-out till	follow-up study, pinch-out feature, slip-off slope, fining-upward cycle	compound adjective whose final constituent is an adverb of direction or place • hyphenate before the noun being modified	A follow-up study was started in 1991.
in-house publication	per-gram basis, out-of-province survey	preposition + noun • hyphenate before the noun being modified	High-quality maps are produced by our in-house cartography section.
ball-and-pillow structure	cut-and-fill mining, crag-and-tail feature, ball-and-socket jointing stoss-and-lee	noun + conjunction + noun • hyphenate before the noun being modified	Ball-and-pillow structures are common in these sandstones.

Example of Compound Type	Similar Compounds	Type of Compound (Rules)	Example of Compound Used Correctly
500-foot level	2-ounce sample 6-centimetre phenocryst	numeral + spelled out unit of measure • hyphenate before the noun being modified	Samples were collected from the 500-foot level of the mine.
2 m length	2.7 km wide zone 5 kg bulk sample 500 ft. level	numeral + abbreviated unit of measure • always open	A 5 kg bulk sample was collected from the esker.
three-quarters completed	two-thirds majority	spelled out fraction used as an adjective • hyphenate before and after noun being modified	Pyroxenite constitutes two-thirds of the outcrop. The project is three-quarters completed.
in situ mining	*en échelon* faults but *lit-par-lit* bedding	foreign phrase used as an adjective • leave open unless hyphenated in original language	The salt is extracted using *in situ* mining methods. *En échelon* faults strike eastward in this area.

*Hyphenation guide for prefixes and suffixes.

Prefix/Suffix	Examples	Rules
calc	calc-alkalic, calc-alkaline **but** calcarenite	• hyphenated • see exception in the box to the left
co	coexist, coefficient, coset, coleader, cooperation, coordinate **but** co-worker, co-author	• not hyphenated unless the unhyphenated form would be puzzling to the reader
fore	foreslope, foredeep, foreland	• not hyphenated
glacio	glaciofluvial, glaciolacustrine **but** glacio-eustatic, glacio-isostacy	• not hyphenated unless the word being prefixed begins with a vowel
inter	interglacial, intertidal, interstade **but** inter-reef, inter-related	• not hyphenated, unless hyphenation results in a double consonant
intra	intraclast, intragranular, intraformational, intrafacies **but** intra-arterial	• not hyphenated unless the word being prefixed begins with an 'a' or other vowel
macro	macrocrystalline, macrofacies, macrolinear, macroscopic **but** macro-organism, macro-evolution	• not hyphenated unless the word being prefixed begins with an 'o' or other vowel
meta	metagabbro, metamorphism, metavolcanic, metasedimentary **but** meta-andesite, meta-arenite, meta-igneous rock	• not hyphenated unless the word being prefixed begins with an 'a' or other vowel
micro	microgranular, microfossil, microporphyritic, microquartz, microbreccia **but** micro-ophitic	• not hyphenated unless the word being prefixed begins with an 'o' or other vowel
mid	midpoint, midrange, midway, midyear **but** mid-Paleozoic, mid-oceanic	• not hyphenated unless the word being prefixed is a proper noun, or unhyphenated form would be puzzling to the reader
multi	multicoloured, multilayered, multiscale, multistage **but** multi-element, multi-institutional	• not hyphenated unless the word being prefixed begins with an 'i' or other vowel
non	nonconformity, nonferrous, nondepositional, nonclastic	• not hyphenated
para	paraconglomerate, paragneiss, paragenetic, paracontinuity **but** para-andesite	• not hyphenated unless the word being prefixed begins with an 'a' or other vowel
phyric	quartz-phyric, feldspar-phyric	• always hyphenated

Prefix/Suffix	Examples	Rules
post	postmagmatic, postdate, postdepositional, postglacial **but** post-orogenic, post-tectonic, post-Paleozoic	· not hyphenated unless hyphenation results in a double consonant, or the word being prefixed starts with a vowel or is a proper noun
pre	preglacial, prediagenesis, Precambrian, predate **but** pre-Devonian, pre-eminent, pre-engineered	· not hyphenated unless the word being prefixed begins with an 'e' or other vowel, or is a proper noun
re	readvance, resedimented, reassess, recharge, rebound **but** re-entrant, re-evaluate **recover** = get well, **re-cover** = cover again	· not hyphenated unless the word being prefixed begins with an 'e', or to distinguish between homonyms
semi	semicircular, semicrystalline, semiprecious stone **but** semi-arid, semi-independent, semi-refined	· not hyphenated unless the word being prefixed begins with an 'i' or other vowel, or the unhyphenated form would be puzzling to the reader
sub	subaerial, subcrop, submarginal, subhydrous, subproject, subunit **but** sub-base, sub-ice, sub-Phanerozoic	· not hyphenated unless hyphenation results in a double consonant, the unhyphenated form would be puzzling to the reader, or the word being prefixed is a proper noun
super	supergroup, superterrane, supercooling	· not hyphenated
supra	supracrustal, supratidal	· not hyphenated
syn	synvolcanic, synchronous, syncline, syndepositional, synorogenic	· not hyphenated
ultra	ultramafic, ultramylonite, ultrabasic, ultraviolet **but** ultra-abyssal	· not hyphenated unless the word being prefixed begins with an 'a' or other vowel
ward	northward, southward, northeastward, southwestward	· not hyphenated

*An exception to the above rules for hyphenation of prefixes and suffixes is if the prefix or suffix is part of a suspended compound, in which case the first prefix or suffix in the suspended compound is hyphenated:

The alteration is syn- to post-orogenic.

Metamorphism was pre- to postdepositional.

The main ice flow events were oriented east- and southward.

Appendix 3 – Spelling and Word Usage

The following list has been compiled from a number of sources, including Fleischer (1983), Weatherston (1996), Geological Survey of Canada (1998), Alberta Energy and Utilities Board (1999), Neuendorf *et al.* (2005) and Grant (2003). This list is not intended to be comprehensive, but it does include words commonly used in geoscience writing, whose spelling or hyphenation (or lack thereof) is often cause for uncertainty or dissension.

Inclusion of words not in the list can be addressed on an individual basis. Authors and editing staff should address the question of whether or not to add a word considering:

- Does the word really exist?
- Correctness: Is there only one accepted way of spelling a word/combination of words or are there more ways?
- Appropriateness: In cases where there is more than one way of spelling a word or word combination and there are differences in meaning, is the use of a certain spelling appropriate?
- Consistency: Should the spelling be consistent only throughout a single document or throughout all SGS publications?

One significant deviation in this guide from many other style guides is the acceptance of both forms of words such as ‘geographic’ and ‘geographical’. Just as ‘logic’ is more appropriate than ‘logical’ in some contexts, so are words like ‘geologic’ and ‘geological’ both appropriate, depending on their use in a sentence.

There are various theories put forward for how to determine the correct use of words like ‘geologic’ and ‘geological’. Some sources define the difference as being noun *versus* adverb or adjective (‘geologic’ would be used for nouns, ‘geological’ for adverbs and adjectives). Other sources stipulate using ‘geological’ to modify man-made terms (*e.g.*, ‘geological survey’) and ‘geologic’ to modify natural things (*e.g.*, ‘geologic age’). Still other sources define the difference as being attributive adjectives (geological, geographical) *versus* nominal adjectives (geologic, geographic): attributive adjectives modify nouns (“They like telling stories of their geological feats in the bush.”); nominal adjectives act almost as nouns (“The advantage we have in the north is purely geographic.”). Given the difficulty in determining the correct use of words like ‘geographic’ / ‘geographical’ and ‘geologic’ / ‘geological’, the SGS accepts the use of both.

In addition to the list below, authors and editors may wish to consult the tables in Appendix 2 for guidelines covering hyphenation of various types of compound words and terms.

Abbreviations used in this appendix: abbrev. - abbreviated; adj. - adjective; adv. - adverb; n. - noun; pl. - plural; sing. - singular; v. - verb.

1800s, early 2000s, mid-1900s, mid ’70s

A

A horizon (A-horizon soil)
abandoned, abandoning
ablation
abridgment
abyssal
acausal (**do not use**; see ‘noncausal’)
Access®
accommodate
accreted, accretionary
acicular
acknowledgment
Acrobat®
advertise
aegirine
aerial, aerially (from the air)
aerial photograph (or ‘airphoto’ but **not** ‘air photograph’)
aging
airborne
airfall
airphoto (or ‘aerial photograph’)
airshed
alignment

alkalic (pertaining to rocks), alkaline (pertaining to chemical solutions)
alkali feldspar, alkali metasomatism
alkalis
allochthonous
all right (not 'allright' or 'alright')
all-terrain vehicle
alluvial, alluvial fan, alluvial-fan deposits
alnoite
aluminum (not 'aluminium')
amphibolite facies but amphibolite-facies metamorphism
amphibolitic
amygdaloidal
amygdule (not 'amygdale')
anaerobic (not 'anoxic')
analogous, analogy
analogue
analysis (sing.), analyses (pl.)
analyze
Antarctic
anthrax (not 'Anthrax')
anthropogenic
apex (sing.), apices (pl.; not 'apexes')
apophysis (sing.), apophyses (pl.)
appendix (sing.), appendices (pl.; not 'appendixes')
ArcExplorer
ArcGIS
archaeocyathid
Archean
archeology (not 'archaeology')
ArcInfo
ArcMap
ArcPad
ArcReader
Arctic (as in 'Canadian Arctic')
arctic environment
ArcView
areal (pertaining to area)
areally (often misspelled 'aerially')
arête
argillaceous
argillised, argillisation
argument
artifact (not 'artefact')
aseismic
ash fall, ash field
ash flow (n.), ash-flow tuff (adj.)
asymmetric (not 'asymmetrical')
Athabasca Oil Sands
Atlantic provinces (includes Newfoundland and Labrador)
augen gneiss
auger-core drilling
auger-corehole
AutoCAD®
autochthonous
autolith
axial ion-counting secondary electron-multiplier
axial plane but axial-plane cleavage

B

b-axis, b-direction, B-tectonite
B horizon but B-horizon soil
backarc
backbulge
backfill, backflow
backpressure
backscarp, backshore, backslope, backwall, backwash, backwater
ball-and-pillow structure
barchanoid
base level, base map
baseline, baseload, baserock
base metal (n.), base-metal deposit (adj.)
basinal
basin-and-range
basin-wide (adj.)
baymouth bar
bedding-parallel foliation
bedform
bedrock
bedset
bench mark
benefited, benefiting
bioerosion, biofacies, biomarker, biomass
biphase, bipolar, bivariate
bird's-eye, bird's-eye tuff
blastesis
block fault

blowdown, blowout

blueprint

Boreal Shield

border (*e.g.*, Canada–United States border: note en dash between the two proper nouns)

borehole

bottomhole, bottomset

boudin (n., indicating a single instance of the structure)

boudinage (n. and v.)

Bouguer (correction for gravity field values)

box plot

braidplain

breakdown (as in ‘mechanical breakdown of rocks’, ‘we had a breakdown in communication’)

break down (as in ‘we need to break down the results’)

break up (v.; “We will break up camp tomorrow.”)

break-up (n.; “We can’t start mapping till after break-up.”)

breakwater

Brunisol, Brunisolic

bryozoan(s)

building stone

build up (v.; “We will build up our supply of sample bags.”)

buildup (n.; “There was a long buildup to the argument.”)

built-up (adj.; “The neighbourhood is getting built-up.”)

bunkhouse

burned over

bypass

byproduct

C

C horizon **but** C-horizon soil

C-S fabrics (**not** ‘c-s fabrics’)

calc-alkalic, calc-alkaline

calcarenite

calc-silicate

campground, campsite

Canadian Shield

cannot

canvas (cloth), canvass (solicit votes)

capitalize

cap rock

carbonatize, carbonatization

carbonize, carbonization

catalogue

catalyze

catchment

categorize

cave-in

Celsius (**not** ‘Celcius’)

centre (n.), central (adj.)

centred, centring

centre point

cesium (**not** ‘caesium’)

chalcophile

channel fill, channel flow

channelling

channel mouth **but** channel-mouth bar

channelway

characterize

Charpy

chemostratigraphic

Chittick (analytical method)

circum-Pacific

civilize

claus

clay belt

clay loam

clay size particles (specific sedimentary term, see Wentworth Classification (Wentworth, 1922))

clay-sized particles (general term)

CO_2-driven

coalbed

coalbed methane

coalfield

coal measures

coalspar

coalwater

coarsening-upward sequence

coastline

co-author

code (**not** ‘codes’ when referring to a computer program)

coeval

coexist

cogasification

cogenetic

coldspring
collinear
co-locate
colorimeter, colorimetry
colour, colouration
comagmatic
commingle
compartmentalize
complement (to complete), complementary
compliment (to praise), complimentary
computerize
concordia
consensus
cookhouse
coordinate, cooperate
coproduct
cordillera (except when part of a proper name, *e.g.*, 'Cordilleran')
corehole
cores (v.; reword as 'forms the core of')
corestone
coseismic
cosmogenic
country rock (synonymous with 'wall rock')
co-worker
crag-and-tail (pl. 'crag-and-tail features', not 'crags-and-tails')
criss-cross, criss-crossing
criticize, criticizing
cross-bed, cross-bedded
cross-border (adj.)
cross-correlate, cross-correlation
crosscut, crosscutting (not 'cross-cutting')
crossfault, crossflow, crossfold
cross-laminae, cross-lamination, cross-laminated
crossline
cross pile
crossplanar
cross-polarized light, crossed polars
cross-reference (n. and v.)
cross-section
cross-stratification, trough–cross-stratification
Cryosolic, Cryosols
crystallize
curvilinear
curviplanar
cusp-ripple
customize
cut-and-fill (n. and adj.)
cutbank
cutline
cutoff

D

dam site (not damsite)
data (pl.), datum (sing.)
database, dataset
datable, datability
data point
date line
dating (not 'age dating')
debottlenecking
décollement
deep water (n.), deep-water sediments (adj.)
defence, defensive
deflatable
deflection
degasser, degassing
deglacial, deglaciation, deglaciations, late-deglacial
de-ice
de-ionize
delignification
delimit
demagnetize, demagnetization
demethanization
dendrochronology, dendrochronological
dendroclimatology, dendroclimatic
de-oil
dependant (n.; "He is dependant on his uncle for his income.")
dependent (adj.; "The outcome is dependent on the number of participants.")
depocentre, depozone
desiccate, desiccation
desilter
desirable
desorb
destabilize
devitrify
Devonian–Carboniferous (not 'Devono-Carboniferous')

dewatered
dextral, dextrally
diamond drill, diamond-drill hole (see entry for ‘drillhole’)
digital elevation model
digitize
dilational (adj.; use ‘dilation’ instead)
dipolar
dip slope
disaggregate
disappoint
disconformably
discordia
discrete (often misspelled ‘discreet’)
discrimination (not ‘discriminant’) diagram
disk, diskette
disorganize
dissect
disseminate
dissolution
dolomitized
dolostone (although use of this term is not recommended by the AGI, it is nevertheless in common use to succinctly differentiate between dolomite the rock and dolomite the mineral)
Douglas fir
downdip
downdropped, downfaulted, downwasted
down hole (as is ‘the depth down hole is ..’) but downhole (as in ‘downhole geophysical surveys’)
down-ice
download
downsection, downslope, downstream, downvalley
downthrown
downward (not ‘downwards’)
draft (preparing maps)
drag fold
dragline
drawdown
drill bit, drill chip, drill collar, drill log, drill site
drillcore (sing. and collective pl.)
drillhole (generic), diamond-drill hole (specific)
drill stem, drill stem tests
dropstone
drumlinization (use ‘drumlin formation’ instead)
ductilely (adv.)
dyke (not ‘dike’)

E

east-central
east-northeast
east-northeastward
easterly, eastward
Eastern Canada
Earth (the planet)
échelon, *en échelon* (n. and adj.)
echogram
ecoregion
ecozone
electron microprobe
elongate (v.), elongated (adj.)
eluvial
email or Email (at start of a sentence)
embarrass
embed, embedded (not ‘imbed’ or ‘imbedded’)
emphasize
emplace
enclose (not ‘inclose’)
encrustation (not ‘incrustation’)
end moraine
energy-dispersive spectrometer
en route (not ‘enroute’)
entrain, entrainment
Enzyme Leach℠
eolian (not ‘aeolian’)
epiclast, epiclastic
epicratonic
equidimensional
error-weighted mean (not ‘error-weight mean’)
eruptive (not irruptive; used in the extrusive to volcanic sense)
Esri (not ‘ESRI’ or ‘Environmental Systems Research Inc.’)
estuarine
evaporitic
exaggeration
exceedance
Excel®
exhalative (not ‘exhalitive’)
exhalite deposits (not ‘exhalites’)
existence (not ‘existance’)

extraglacial
extraprovincial

F

fallout
far-field (adj.; increasingly used in tectonics to denote that some local events may be the product of very distant effects that may cross plate tectonic boundaries; for examples see Tectonics, 1993, v.12, no.1, p.257-264 and Geology, 1999, v.27, no.7, p.633-636)
farm-in agreement
farther (distance; 'the camp is farther than you think')
faserkiesel(s)
fault block **but** fault-block mountain
fault bounded (**not** 'fault bound')
fault-controlled
fault fissure
fault scarp **but** fault-line scarp
favour, favourable
Fe^{2+}-bearing minerals
fecal (**not** 'faecal')
feces (**not** 'faeces')
feldspar (**not** 'felspar')
feldspar-phyric **but** feldspar-pyroxene–phyric
feldspathic (**not** 'feldspatholithic')
felsenmeer(s)
Fe-oxide (analogous to 'K-feldspar')
Fe-poor, Fe-rich
ferromagnesian
fetid (**not** 'foetid')
fiducial
field trip, field trip guidebook
fieldwork
finalize
fining-upward sequence
fjord (**not** 'fiord')
fireclay
first-order magnitude
flatland
flight line
float plane
floodplain, floodwater, floodway
flow line
flowmeter
flowsheet
flowslide, flowtill
fluid flow **but** fluid-flow systems
fluorite, fluorspar
fluviodeltaic
fluvioglacial (can also use 'glaciofluvial')
fluviolacustrine
focused, focusing
footnote
footwall
forearc
forebulge, foredeep, foreland, foreslope, foreshore
foregoing (preceding), forgoing (going without)
fore reef
foreset
foreword (beginning statement), forward (ahead)
formulas (**not** 'formulae')
fossilize
frac (slang for hydraulic fracturing; usage should be limited)
frac fluids (prefer 'fracturing fluids'; usage should be limited)
frac sand (prefer 'proppant sand'; usage should be limited)
fracking (**not** 'fraccing'; slang for 'hydraulic fracturing'; usage should be limited)
fracturing fluids (preferred to 'frac fluids')
freehold lease **but** Crown lease
freeze-and-thaw **or** freeze-thaw (but be consistent)
freeze-up (n.)
freshwater (n. and adj.)
frost heave, frost table
fulfill, fulfilled **but** fulfilment
further (in addition; 'further to what she was saying')

G

gamma ray **but** gamma-ray log
gangue
gas field (**not** 'gasfield')
gastropod
gauge
generalize
geobarometer, geobarometric
geobotany
geochronologically
geopositioning
GeoRef (AGI geoscience reference database)

georeference
geoscience, geoscientific, geoscientist
geospatial
geostatistical
geotectonic
geothermometer
glacial lake (n.), glacial-lake deposit (adj.)
glacial Lake Athabasca
glacial maximum, 'the global Last Glacial Maximum'
glaciation, glaciations
glaciodynamics (not 'glacio-dynamics')
glacio-eustatic, glacio-isostasy
glaciofluvial (can also use 'fluvioglacial')
glaciogenic
glaciolacustrine
global mean sea level
glomeroporphyritic (not 'glomerophyric')
gloryhole
gouge
grainstone
graticule
gravelly
Gray Luvisol, Gray Luvisols
Grenville (not 'Grenvillian')
grey
greywacke
gridline
ground ice but ground-ice layer
ground level
groundmass
ground-truth (v.), ground-truthed (adj.)
groundwater (n. and adj.)
guidebook
gully (not 'gulley'), gullies

H

hachured (not 'hatchered')
Hadrynian
half-life
halfway
half width
halo (sing.), haloes (pl.; not 'halos')
hand-held instrument
hand-picked/picking (v. and adj.)
hand specimen
hand sample (implies it is representative)
hand-sample–scale
hanging wall
harass
harbour
hard copy (n.; 'print a hard copy'), hardcopy (adj.; hardcopy documentation)
hardpan
hardwood
headframe
headland
headwall
headwater
heat flow but heat-flow map
heavy rare earth element(s) (abbrev. 'HREE' for sing., 'HREEs' for pl.)
hematiferous (not 'hematitiferous')
hematite (not 'haematite')
hematized (not 'hematitized'), hematization
heterogeneous, heterogeneity, heterogeneities
heterolithic (not 'heterolithological')
hillshading (n.), hillshaded (adj., not 'shaded-relief')
hillside, hilltop, hillslope
hinge line
historic (when used to mean important in history; "The election of the first woman president was an historic occasion.")
historical (when used to mean belonging to the past; "Historical reserves (non NI 43-101–compliant) of 47,235 tons grading 0.75% Ni were reported from this showing.")
Holocene (not 'Recent')
homogeneity
homogeneous (not 'homogenous')
honeycomb
hornfelsed
host rock
hot spring
Hudson Bay Lowland (not 'Lowlands')
hybridize
hydraulic fracture
hydraulic fracturing (preferred to 'frac' or 'fracking')
hydraulicking
hydroclimatic
hydrocracking
hydroelectric

hydrogeochemistry
hydrogeology
hydrographic
hydrostratigraphy, hydrostratigraphic
hydrotreater
hyperextended, hyperextension

I

iceberg
ice cap but Barnes Ice Cap (part of a proper name)
ice-collapse feature
ice dam
ice divide but Keewatin Ice Divide (part of a proper name)
ice field but Columbia Icefield (part of a proper name)
ice flow (n.), ice-flow deposit (adj.)
ice front
ice margin but ice-margin retreat
ice sheet but Laurentide Ice Sheet (part of a proper name)
impassable (not 'impassible')
incise (not 'encise')
InDesign®
index (sing.), indices (pl.; not 'indexes')
inductively coupled plasma–mass spectrometry
infill, infilling, infilled
infrared (not 'infra-red')
in-house (adj.)
injectability (not 'injectivity')
innermost
inshore
in situ (n. and adj.; not hyphenated)
install, installed but instalment
interbed, interchannel, interclast, interflow, intergranular, interlayer, interpillow
inter-element
interfinger (not 'interdigitate')
interglacial but Sangamonian Interglacial (part of a proper name)
internet (not 'Internet')
inter-reef, inter-related
interstadial
interstice, interstitial
interstream, intertidal
intertongue, intertonguing
inter-well
intraclast, intracontinental, intracratonic, intracrustal, intraformation, intraglacial
intra-oceanic
inward (not 'inwards')
iron formation (n.), iron-formation units (adj.)
iron oxide copper-gold deposit
isopach, isopleth
isostasy
isotopically
italicize

J

jack pine (not 'jackpine', 'Jackpine' or 'Jack Pine')
joint block, joint plane, joint set

K

kame-and-kettle (adj.)
kaolinized (not 'kaolinitized'), kaolinization
karst development (not 'karsting')
karsted
kelly
kelly bushing (abbrev. 'KB')
kelyphite
kettled
kettle hole
K-feldspar (not 'K-spar')
kickoff point
kimberlite indicator mineral (abbrev. 'KIM' for sing., 'KIMs' for pl.)
knorringitic
knowledge base (n.), knowledge-base (adj.)
komatiitic
Kriging (as in 'Kriging algorithm')

L

L-tectonite (not 'l-tectonite')
labelled, labelling
laborious
labour
lake basin
lakebed, lakefront, lakeshore, lakeside
lake ice
lakewater (n. and adj.)
lamina (sing.), laminae (pl.)
lamproite, lamproitic

landform, landmark, landmass, landslide
land ice
landlocked
Landsat (satellite)
land use **but** land-use planning
lapilli tuff (n.)
large igneous province (**not** ‘Large Igneous Province’)
Last Glacial cycle, Last Glacial Maximum
late glacial **but** Lateglacial period
Late Wisconsinan
Laurentide
lebensspur (sing.), *lebensspuren* (pl.)
left-lateral fault, left-lateral moraine
lens (sing.), lenses (pl.)
leucodiorite, leucogabbro, leucogneiss, leucogranite, leucotonalite **but** leuco–quartz diorite
levée
level (lower case, as in ‘300 m level’)
levelled, levelling
lherzolitic
licence (when used as a noun, to identify persons, places or things, as in ‘well licence’)
license (when used as a verb, to indicate an action, state or occurrence, as in ‘the well was licensed’)
light rare earth element(s) (abbrev. ‘LREE’ for sing., ‘LREEs’ for pl.)
limnological
limy (for mineral; ‘limey’ for fruit)
lineament (**not** ‘linear’)
lineated, lineation
line cutter, line cutting
line-kilometre(s)
linework
liquefaction
lithified
lithogeochemistry
lithophile
LITHOPROBE (geoscience program)
lithospheric
lithostratigraphic
lit-par-lit
localize
lodgment (**not** ‘lodgement’)
LogFAC
long range **but** long-range plans
longshore
Lower Red Beds
low-grade deposit, low-nutrient water
lustre
Luvisol, Luvisolic

M

macrobioerosion
macroclimate, macrocryst, macrodiamond, macrofossil, macrofracture
macroscale (adj.)
magnetize
mainland
maintain, maintenance
man-made
map area (map <u>sheet</u> is the piece of paper)
MapInfo®
mappable
map unit, map legend
Maritime provinces (does not include Newfoundland and Labrador)
Maritimes (does not include Newfoundland and Labrador)
matrices (**not** ‘matrixes’)
maximize
(the) Maximum Ice Extent
maximums (**not** ‘maxima’)
meagre
megacrystic, megafauna, megathrust
melagabbro
mélange
melt out **but** melt-out till
meltwater
Mercator
Mesoarchean (**not** ‘Middle Archean’)
Mesoproterozoic (**not** ‘Middle Proterozoic’)
meta-andesite, meta-arkose
metabasalt, metaconglomerate, metadiorite, metagabbro, metagreywacke
meta-igneous
metalliferous, metaluminous
metallogenic, metallogenesis
meta-rhyolite
metasedimentary, metasiltstone, metavolcanic
meter (instrument), metre (SI unit of measure)
methanogenesis

metreage

microbioerosion, microcontinent, microdiamond, microdisk, microdisseminated, microfauna, microfold

micro cross-lamination

microfrac

micromorphology

micro-organism, micro-oil

micropit

microprobe

microsiemens (not ‘microSiemens’)

Microsoft® Outlook

Microsoft® PowerPoint®

Microsoft® Word

microspatial, microstructural

microtexture

microthermometric

Mid-Atlantic Ridge

midcontinent

mid-Cretaceous (not ‘Middle Cretaceous’)

middle rare earth element(s) (abbrev. ‘MREE’ for sing., ‘MREEs’ for pl.)

midfan

mid-ocean ridge, mid-ocean–ridge basalt

midpoint

migmatitic, migmatize

milepost, milestone

millsite, minesite

mine (lower case, even when part of a name)

mineable (not ‘minable’), mineability

mineralize, mineralization

mineralogical

minewater

minifrac

minimize

minimums (not ‘minima’)

Mississippian

Mississippi Valley–type deposit

misrun

mitigatory

Mobile Metal Ion™ (MMI™)

mobilize

modelled, modelling

mollusc

monkeyboard

monobore

monolithic (not ‘monolithologic[al]’)

monophase

monosulphide

morainal (not ‘morainic’)

morphometric

mould, mouldic (*e.g.*, mouldic porosity)

mountain pine beetle

mountainside

mousehole

moutonnée

mud ball, mud boil, mud chip, mud clast, mud crack, mud drape, mud flat, mud mound

mudbank, mudflow, mudslide

mud fill (n.), mud-filled cavity (adj.)

mud rock

mudstone

multi-agency

multibeam

multicoloured

multidisciplinary

multi-element (adj.; *e.g.*, ‘multi-element analysis’)

multiphase, multipool, multiscale, multistage, multiwell

multiyear

multizone

Mylar™

mylonitized

N

NAD83

naphtha

nappe (not italicized)

Na-pyrophosphate leach

narrows (n., a narrow part of a water body; takes either singular or plural verb)

NATMAP (Federal-Provincial geoscience program)

nearby

near-field (adj; synonymous with local scale or proximal; see ‘far-field’)

nearshore

near-surface (in the geophysical sense)

near-zero mean

neighbour, neighbourhood

Neoarchean (not ‘Late Archean’)

Neoglacial

Neoproterozoic (not ‘Late Proterozoic’)

netback
nonbedded, noncalcareous
noncausal (not 'acausal' or 'noncausative')
non coaxial **but** non-coaxial strain
nonconfidential, nonconventional, nonroutine
nonconformable, nondeposition
non-destructive
nondissociated
nonfossiliferous
nonglacial, nonglaciated
nonkimberlitic
nonmarine, nonmeteoric, nonmicaceous, nonporous
nonmobilized
non NI 43-101–compliant
nonoxidized, nonpotassic, nonsulphide
nonreservoir
nonribbed, nonvegetated
non-uniform
Noril'sk-type
north-central
northeast, northeasterly, northeastward
Northern Hemisphere
northernmost
north-northeast, north-northeastward
northward
nuclide (not 'nucleide')

O

occurrence (lower case, even when part of name)
off-axis (as in 'off-axis hydrothermal system')
offlapping, offshore
offset, offsetting
offsite
oikocryst
oil field (*e.g.*, 'Shaunavon oil field trend')
oil sands (capitalize formally named areas: *e.g.*, Athabasca Oil Sands Area, Peace River Oil Sands)
oil well
olefins
Omarolluk Formation erratics (greywacke erratics with hemispherical voids or pits; abbrev. 'Omars')
ongoing
onlap, onlapping
online
onset
onshore
onsite
on strike
ooidal
opencut (n. or adj.)
open hole **but** open-hole logging
open pit (n.), open-pit mine (adj.)
ordinarily
orebody
ore deposit **but** ore-deposit model
organize, organization
orient (not 'orientate'), orientation
original-gas-in-place
orogen
orogenesis (synonymous with 'orogeny')
orogeny, orogenies
orographic
ostracode
outcrop (n.; not 'outcropping')
outcropping (v.)
outermost
outgoing
out-of-date (adj.)
outward (not 'outwards')
overbank
over-emphasize
overmature
overpressure
overproduction (specific term related to allowable rates of production for gas wells)
overriding, overrun, overthrust, overturn, overwash
oxide-facies iron formation
oxidize, oxidation (not 'oxidization')
oxy-fuel

P

pack ice
packstone
Paleoarchean (not 'Early Archean')
paleoatmosphere
paleoautochthonous
paleoceanography
paleoclimatic
paleodose
paleoecological

paleoenvironment, paleoenvironmental
paleoflood
Paleogene
paleoglacier
paleohydrology
paleokarst
paleolimnological
paleomagnetic
paleontology (**not** 'palaeontology')
paleo-plate tectonics
paleopole
Paleoproterozoic (**not** 'Early Proterozoic')
paleosol, paleosurface, paleovalley
paleovegetation, paleowind
Paleozoic
palsa (sing.), palsas (pl.)
palynological
paraffin
paragenetically
paragneiss
parallel, paralleled, paralleling
paralyze
peatland
pebble conglomerate, quartz-pebble conglomerate
penecontemporaneous
peneplain (n.)
peneplane (v.)
penetratively (adv.)
pentanes
peperite, peperitic
peralkalic (pertaining to rocks), peralkaline (pertaining to chemical solutions)
percent, percentage
pericratonic
peridotitic
periglacial (**not** 'paraglacial')
per mil (**not** 'per mille', 'per mill', 'permil' or 'promille')
permeametry
persistent
Phanerozoic
phenocryst
photoelectric
photogeology
photogrammetric
photointerpretation
photolineament
photomap
physicochemical
physiography
picroilmenite
pinch out (v.; 'the veins pinch out eastward'), pinch-out (adj.; 'this is a pinch-out structure')
pipeline
pit (lower case, even when part of a name)
planar-e (euhedral crystal texture, strictly for dolomite)
planar-s (subhedral crystal texture, strictly for dolomite)
plateau (sing.), plateaus (pl.; **not** 'plateaux')
platinum group element(s) (abbrev. 'PGE' for sing., 'PGEs' for pl.)
platinum group mineral(s) or metal(s) (abbrev. 'PGM' for sing., 'PGMs' for pl.)
platy (**not** 'platey')
point bar
polarize
polyline
polylithic (**not** 'polylithologic[al]')
polyphase
pore pressure **but** pore-pressure gradient
pore water (n.), porewater (adj.)
porphyritic, phyric ('the rock is quartz-porphyritic' or 'the rock is quartz-phyric' (the latter is preferred); for textures keep as one word, *e.g.*, 'glomeroporphyritic')
porphyroblast
porphyroblastesis
porphyroclast
postcollisional, postglacial
postdate, postdepositional
post-emplacement
postmagmatic, postmineral
post-orogenic
post-Paleozoic
PostScript™
post-tectonic
potassium feldspar
pothole
PowerPoint®
practice (n.; 'the doctor has a private practice')
practise (v.; 'the doctor practises privately')
Prairie provinces

Prairies

Precambrian (not ‘Pre-Cambrian’), Precambrian Shield

precede (go before, not ‘preceed’)

precollisional, predeformational

preconcentration

predate

predominantly (not ‘predominately’)

pre-empt, pre-exist

prefeasibility

preglacial, premetamorphic

pre-orogenic

pre-rifting

presettlement

pretest

prioritize

procedure

proceed (continue)

prodelta

proglacial

prograde

program (not ‘programme’)

proppant sand (preferred to ‘frac sand’)

prorateable

prospect (lower case, even when part of a name)

Proterozoic

protocontinent

protocraton **but** proto-Rae craton

protolith

protomylonite

province-wide

pseudokimberlitic

psammopelite, psammopelitic

pseudomorphic

pseudo ripple mark

pseudotachylite

publicly (not ‘publically’)

pulverizer

pumpjack

pyroclastic

pyroxenitic

Q

QEMSCAN® (integrated mineralogical analysis system)

QuarkXPress™

quartzofeldspathic

queryable (avoid using by rewording sentence)

quicksand

R

RADARSAT (satellite)

radioactive

radiogenically

radioisotope

rainfall, rainwash

rain gauge

rainwater (n. and adj.)

rare earth element(s) (abbrev. ‘REE’ for sing., ‘REEs’ for pl.; not ‘rare earths’)

rare element (any element of which the concentration in the Earth’s crust is <0.01%)

rare-element content (adj.)

rarify

rat tail (miniature crag-and-tail)

reaccess

reactivate, reactivation

readvance, readvances

realize

reanalyze

reburial

recalibrate

Recent (use ‘Holocene’)

reclassify, reclassification

recognize, recognition

recomplete, recompletion

reconfigure, reconfiguration

recrystallize

recurrence

re-date

redbed

redeposition

redirect

redistribution

redox

re-entry, re-entrant

re-establish, re-evaluate, re-examine

re-form (form anew)

reform (make better)

regardless (not ‘irregardless’)

regional-scale map
rehydration
reinject
relic (n., = artifact)
relict (adj., = residual)
relog
remanent magnetism (**not** ‘remnant magnetism’), remanent magnetization
remineralize
remobilize, remobilization
reopen, reorganize
re-release
resedimentation
resistant, resistance
resistivity
restabilize
re-stake
restimulate, restimulated
résumé
retrothrust
revegetated
reverify
revisit, revisited
rheological
rhythmite
right-lateral fault
rigour **but** rigorous
ripple bedding, ripple drift, ripple marks
ripple cross-lamination
rip-up(s), rip-up clasts
river bank, river bed, river bottom, river valley
rivershed, riverhead
riverwater (n. and adj.)
roadbed, roadcut, roadside, roadway
roche moutonnée (pl. *roches moutonnées*)
rock burst
Rock-Eval 6 (if keyword, use without version number)
rockfall, rockslide
rock saw, rock type, rock unit
rollout
rudstone
runoff
runout

S

S-asymmetric, S-asymmetry
S-C fabrics (**not** ‘s-c structures’)
S-fold
salic
saltwater (n. and adj.)
samarium-neodymium (**not** ‘neodymium-samarium’)
sand and gravel are (when referring to the commodity)
sand and gravel is (when referring to the geological unit)
sandbank, sandbar, sandbody, sandface, sandhills, sandspit
sand dune, sand flat
sand size particles (specific sedimentary term, see Wentworth Classification (Wentworth, 1922))
sand-sized particles (general term)
sandy loam
saprolitic
sapropelic
saussuritized
scalable
scanning electron microscope
ScanSAR (satellite)
scatterplot
schlieren
seabed, seabottom, seacoast
seafloor, seafloor spreading
sea ice (n.), sea-ice extent (adj.)
sea level (n.), sea-level rise (adj.)
Seasat (satellite)
seawater (n. and adj.)
secondary ion mass spectrometry
Second Prairie Level
sedimented
sedimentological, sedimentologically
seismic, seismicity
selvage (**not** ‘selvedge’)
semi-annual, semi-anthracite, semi-arid
semicircular
semiconformable
semiconsolidated
semiquantitative
semi-refined
sensu lato, *sensu stricto*

separate
seriation
sericitized
serpentinized
set-back, set-back distance
severely
shaded-relief (adj., use ‘hillshaded’ instead)
shallow-marine environment
Shallow Unconventional Shale Gas Project
shallow-water carbonate platform
shaly (not ‘shaley’)
shape-fabric (n.)
shapefile
shear zone
sheetlike
shoreface, shoreline
shore ice
shortwave (adj.)
showing (lower case, even when part of a name)
shut-in pressure, shut-in well
shutoff
siderophile
side-scan (adj.; *e.g.*, side-scan sonar)
sidestream, sideroad, sidewall
siliceous
silt loam
silt size particles (specific sedimentary term, see Wentworth Classification (Wentworth, 1922))
silt-sized particles (general term)
siltstone
sinistral, sinistrally
sinkhole
site, site-specific
sizable (not ‘sizeable’)
sketch map
slipface
slope wash
small-diameter hole
snowbank, snowdrift, snowfall, snowfield, snowline
sodicity
Soil Desorption Pyrolysis℠ (selective extraction)
Soil Gas Hydrocarbons℠ (selective extraction)
source rock, source water
south-central
southeast, southeasterly, southeastward
southernmost
south-southwest, south-southwestward
southward
spall, spalled, spalling
specialty (not ‘speciality’)
specialize
spectrophotometry
spectroradiometer
sphagnum moss
spheroidally
spring water (n. and adj.)
stabilize
stand-alone
standardize
steatitized (not ‘steatized’), steatitization
stereometer
stereopair, stereoplot, stereotriplet
stillstand
stillwater
stockwork
stony (not ‘stoney’)
strandline
strand plain
stratabound
stratified, stratiform
stratigraphic
streambed, streamcut, streamflow
striplog
subaerial
subalkalic, subalkaline
subangular
subarctic, subarea
sub-base, sub-basement, sub-basin, sub-bituminous, sub-bottom
subcalcic
subchondritic
subcircular
subconchoidal
subcontinental
subcrop, subcropping
subdiscipline
subdomain, subformation, subgroup, subunit
subdune
sub-economic
subfracture

subglacially
subgreywacke
subhorizontal
sub-ice
sublithospheric
submicron
subophitic
subparallel
sub-Phanerozoic
subpopulation
subproject
subprovince
subsample
sub-seafloor (not ‘subsea-floor’)
subsection
subsolidus
subsurface
subtidal
subtill
subvertical
sub–wave-base (adj.)
SulFerox®
sulpharsenide
sulphate (not ‘sulfate’), sulphide (not ‘sulfide’)
sulphide-facies iron formation
sulphidization (not ‘sulphidation’, ‘sulfidization’ or ‘sulfidation’)
sulphur (not ‘sulfur’), sulphurous (not ‘sulfurous’)
summarize
suncrack
supercession (n., the part lying above)
supercool, supercritical
superfamily, supergroup
supersede (v.)
suprasolidus
suprasubduction
surface water
surmise
sustainability
syenite
symmetry
synchronous
syncollisional, syndeformational, syndepositional, synmetamorphic, synorogenic, synvolcanic
syneresis (not ‘synaeresis’)
syngas (synthesis gas)
synshear, synkinematic
syntectonic but syn- to post-tectonic
synthesize
syn- to post-Martin group

T

tableland
tectonize, tectonism
tectonomagmatic, tectonometamorphic, tectonosedimentary, tectonostratigraphic, tectonostratigraphy
televise
tephra
terrain (physiography)
terrane (geological)
Terrasol Leach℠ (selective extraction)
test hole
textbook
thalweg(s) (not ‘talweg’)
thermocracking
thermodynamic
thermomechanical
thermotectonic, thermotectonism
thickening-upward sequence
thin section (n.), thin-section examination (adj.)
thinning-upward sequence
three-dimensional
thrust block, thrust fault
tidewater
timberline
time frame (not ‘timeframe’)
timeline, timelines
toeset
topoline
topset
topsoil
total, totalled, totalling
toward (not ‘towards’)
townsite
trace element (n.), trace-element data (adj.)
transcrustal, transcurrent
transect
translocated
transmissible, transmissibility

transmission electron microscope
transpression, transpressional
transtension, transtensional
travel, travelled, travelling
traveltime (in the geophysical sense)
treeline
tricone
trigoniid (sing.), trigoniids (pl.; not ‘trigonia’)
trimline
tuff breccia (n.)
turbidite, turbiditic
two-dimensional
twofold

U

ultrabasic, ultramafic, ultrasonic, ultraviolet
ulvöspinel
unabraded, uncompacted, undeformed, uneroded
undercut, underflow, underthrust
underestimate, underutilize
undergo, undergoes
underlie, underlying
under pressure (when used in the sense ‘the rocks were under pressure for over 2 billion years’)
underpressure (when used in the sense ‘this is an underpressure well’)
under production (when used in the sense ‘the building was under production for 2 years’)
underproduction (specific term related to allowable rates of production for gas wells)
understorey
underwater
undulose
uniaxial
United States (not United States of America)
unnamed, unrimmed, unsampled
unsorted (not ‘non-sorted’ or ‘non sorted’)
updip, upglacier, uphole
upflow zone (a zone covering a certain stratigraphic interval that is characterized by hydrothermal fluid flow from depth toward shallower crustal levels, the seafloor, or the surface)
up-ice
uppermost, uppermost catchment area
upsection, upslope, upstream, upvalley
upthrown
upward (not ‘upwards’)
upwelling
uraniferous
usable (not ‘useable’)
utilize, utilizing

V

V-shaped valley, the valley is V-shaped
valley bottom, valley fill, valley floor
valleyside
vapour but vaporize
varicoloured
variegated
vari-textured
vein (lower case, even when part of a name)
vein fault, vein zone
veinlet
ventifact
vergence
vibroseis (no initial capital or trademark because trademark expired)
ViewLog®
vigour but vigorous
vitroporphyritic
volcaniclastic
volcanogenic massive sulphide deposit (abbrev. ‘VMS deposit’; not ‘volcanic massive sulphide deposit’)
volcano-plutonic, volcano-sedimentary, volcano-tectonic
vug, vuggy

W

wackestone
wall rock (synonymous with ‘country rock’) but wall-rock alteration
washout
wasterock, wastewater
watercourse, waterfall, waterflood
waterfowl
waterfront, waterline, watershed, waterway
water-laid (not ‘waterlain’)
water level
water table (n.), water-table level (adj.)
water well
wave base but sub–wave-base depths
waveform, wavelength

wavelength-dispersive X-ray fluorescence (not 'wavelength-dispersive X-ray spectrometry')

wave-rippled (as in 'wave-rippled cross-lamination'; not 'wave ripple')

way-up indicators

web page but website

wellbore, wellcore

wellhead, wellhead injection pressure

well log, well record

well point but well-point data

well pressure but well-pressure survey

wellsite, wellwater

west-central

westerly, westernmost, westward

Western Canada

whereas

whichever

whole rock but whole-rock geochemistry

widespread

windfall

wireline, wireline test, wireline well log

Wisconsinan (not 'Wisconsin'; there is no Wisconsin Ice Sheet, only the Laurentide and Cordilleran ice sheets that covered the northern half of North America during the Wisconsinan glacial stage)

workflow

worksite

worldwide

World Wide Web

X

xenocryst

xenolith (not 'zenolith')

X-ray

Y

younging

Yukon (not 'Yukon Territory')

Z

Z-asymmetric, Z-asymmetry

Z-fold

Ziploc®

zonation

Appendix 4 – Abbreviations

The following list of abbreviations was originally compiled from Weatherston (1996), Geological Survey of Canada (1998), Alberta Energy and Utilities Board (1999) and Grant (2003), and has been supplemented with legitimate abbreviations encountered during the course of editing projects.

Those entries with an asterisk in the second column are standard abbreviations that do not have to be defined at first use because they are well known and, in some cases, occur as dictionary entries.

BIL, .bil	*	Band inter-leave format (used by ArcInfo® and others for raster data)
BMP, .bmp	*	Windows bitmap
CDR, .cdr	*	CorelDraw™
CVS, .cvs	*	Canvas
DOC, .doc, .docx	*	Microsoft® Word
DWG, .dwg	*	AutoCAD® drawing
DXF, .dxf	*	AutoCAD® data exchange format
EPS, .eps	*	Encapsulated PostScript™
GIF, .gif	*	CompuServe bitmap
HTML		Hypertext Markup Language
JPEG, .jpg	*	Joint Photographic Experts Group bitmap
PDF, .pdf	*	Adobe Acrobat® portable document format
PNG, .png		Portable Network Graphics
PPT, .ppt		Microsoft® PowerPoint®
RTF, .rtf	*	rich text format
SGML		Standard Generalized Markup Language
TIFF, .tif	*	tagged information file format
TXT, .txt	*	American Standard Code for Information Interchange (ASCII) text
WMF, .wmf	*	Windows metafile
XLS, .xls, xlsx	*	Microsoft® Excel® spreadsheet
XML		Extensible Markup Language
XMML		Extensible Mining Markup Language

°	*	degrees of arc
'	*	minutes of arc [use the symbol rather than single quotation mark]
"	*	seconds of arc [use the symbol rather than double quotation mark]
‘ ’	*	single opening and closing quotation marks
“ ”	*	double opening and closing quotation marks
° API	*	American Petroleum Institute measure of oil weight (space between symbol and abbreviation)
°C	*	degrees Celsius (no space between symbol and abbreviation)
°F	*	degrees Fahrenheit (no space between symbol and abbreviation)
2-D		two-dimensional
3-D		three-dimensional
SM		service mark [generally superscripted]
™	*	trademark [generally superscripted]
®	*	registered [generally superscripted]
©	*	copyright [generally superscripted]
@	*	at, apiece
% R_o		vitrinite reflectance
%	*	percent
‰		per mil
$	*	dollar(s)
-	*	hyphen

–	*	en dash
—	*	em dash
…	*	ellipsis
+	*	plus (arithmetic operator)
-	*	minus (arithmetic operator)
×	*	multiplied by (arithmetic operator)
/ or ÷	*	divided by (arithmetic operator)
=	*	equals
±	*	plus or minus (space before but not after in radiometric ages, *e.g.*, ‘2600 ±3 Ma’; no space in mineral assemblages, *e.g.*, ‘biotite±phlogopite’)
>	*	greater than
<	*	less than
≥	*	greater than or equal to
≤	*	less than or equal to
≠		not equal to
≈ or ≅	*	approximately equal to
~	*	approximately (except with radiometric dates; see entry for ‘*ca.*’)
Ω		(upper-case Greek letter *omega*) electrical resistance (ohm)
α		(lower-case Greek letter *alpha*) alpha particle, absorption coefficient, is proportional to
β		(lower-case Greek letter *beta*) beta particle
γ		(lower-case Greek letter *gamma*) gamma ray, conductivity, gamma [this unit of magnetic induction is not an accepted SI unit of measure; see nT, nanoTesla]
δ		(lower-case Greek letter *delta*) chemical shift
ε		(lower-case Greek letter *epsilon*) relative deviation (*e.g.*, ε_{Nd}; see ‘Chemical Elements’ section)
κ		(lower-case Greek letter *kappa*) magnetic susceptibility
λ		(lower-case Greek letter *lambda*) radioactive decay (rate) constant, absolute activity, thermal conductivity, wavelength
μ		(lower-case Greek letter *mu*) micro [as a prefix]; micron [this unit of length is not an accepted SI unit of measure; use ‘micrometre (μm)’ instead]
μg	*	microgram
μL	*	microlitre(s)
ϕ		(lower-case Greek letter *phi*) grain size
ρ		(lower-case Greek letter *rho*) density, reflectance, resistivity
σ		(lower-case Greek letter *sigma*) electrical conductivity, standard deviation
χ		(lower-case Greek letter *chi*) magnetic susceptibility
χ_e		electric susceptibility
10TM		10 Degree Transverse Mercator

A

A		ampere(s)
A		uppermost soil horizon (**not** ‘a horizon’)
Ǻ		ångström(s) [this unit of length is not an accepted SI unit of measure]
a		year(s) [since many readers will be unfamiliar with this, we suggest the use of ‘year’ (not abbreviated); see also ‘yr.’]
AAS		atomic absorption spectroscopy or spectrophotometry
ABA		acid-base accounting
AD	*	in the year of our Lord (Latin *anno Domini*), but the term CE (Common Era) should be used instead; AD should always be placed before the numerals (*e.g.*, AD 1066)

ADT		Applied Drilling Technology, ADT log
AEM		airborne electromagnetic
AES		atomic emission spectroscopy
AFM		alkalis-iron-magnesium (*after* Irvine and Baragar, 1971)
AFMAG		audio-frequency magnetic
AG		autogenous grinding
AGI		American Geological Institute
AGRU		acid gas removal unit
AIM		Alternative Investment Market (on London Stock Exchange)
AIT		array induction tool
a.m.		before noon (Latin *ante meridiem*)
AM		airborne magnetic
AMS		accelerator mass spectrometry
API	*	American Petroleum Institute, both the organization and measure of oil weight; use abbreviation when it appears as a unit of measure (*e.g.*, '22° API gravity oil'), but write out when the sense is the name of the organization
approx.	*	approximate, approximately
APWP		apparent polar wander path
ARC(s)		island-arc magma(s)
ARD		acid rock drainage
ARI		azimuthal resistivity imager
art.	*	article [use only in references]
ASCII	*	American Standard Code for Information Interchange
asl	*	above sea level
ASME		American Society of Mechanical Engineers
ASTM		American Society for Testing and Materials
ASV		annular safety valve
ASX		Australian Securities Exchange
atm		standard atmosphere
ATV(s)		all-terrain vehicle(s)
av.		average

B

B		middle soil horizon (not 'b horizon')
B.A.	*	Bachelor of Arts
BABB		backarc-basin basalt
bbl	*	barrel, barrels
BC	*	before Christ, but the term BCE (before the Common Era) should be used instead; BC should always be placed after the numerals (*e.g.*, 500 BC)
BCE		before the Common Era
bcf	*	billion cubic feet
BGP		base of groundwater protection
BHA		bottomhole assembly (toolstring on coiled tubing or drill pipe)
BHP		bottomhole pressure
BHT		bottomhole temperature
BLS		below land surface
BMA		bulk mineralogical analysis
BOP		blowout preventer
BP	*	before present (specifically, before 1950)
BPV		back pressure valve
Bq		becquerel(s)
BRT		below rotary table (used as a datum for depths in a well)

B.Sc.	*	Bachelor of Science
Btu	*	British thermal unit(s)
b.y.	*	billion years (use only with age range/duration)

C

C	*	Celsius, carbon (element)
C		lowermost soil horizon (**not** 'c horizon')
C$	*	Canadian dollars [dollar values are always in Canadian currency, unless otherwise noted. This abbreviation is only to be used where American or Australian dollars and Canadian dollars are mentioned in the same publication.]
ca.	*	about (Latin *circa*) [use only for radiometric dates, not for measurements]
CAD	*	computer-aided drafting
CAI		conodont colour alteration index
CALI		caliper log
CBM		coalbed methane
CD-ROM(s)	*	compact disc(s)–read-only memory (or just CD/CDs)
cf / cu. ft.	*	cubic foot (feet)
cf.	*	confer, compare (Latin *conferre*)
cfm		cubic feet per minute
CFM	*	calcium-iron-magnesium
ChRM		characteristic remanent magnetism
CHUR		chondritic uniform reservoir
CIL		carbon-in-leach (metallurgical process)
CIP		carbon-in-pulp (metallurgical process)
CIPW (norm)	*	Cross, Iddings, Persson and Washington norm
cm	*	centimetre(s)
cm^3	*	cubic centimetre(s)
CMP		common midpoint (geophysics)
CN^-		cyanide
CND		compensated neutron density log
CNGR		compensated neutron gamma ray log
CNL		compensated neutron log
c/o	*	care of
Co.	*	Company
Conc.	*	Concession
cont.	*	continued [use only in tables]
Corp.	*	Corporation
cpht		carats per hundred tonnes
cps		counts per second
Cr#		chromium number [a unitless parameter calculated as $100 \times CrO / (CrO + FeO^t)$]
Cr.	*	Creek [use only in figures, tables and maps]
CRM(s)	*	certified reference (rock) material(s)
CSMT		core sampler tester log
CSPG		Canadian Society of Petroleum Geologists
cu.	*	cubic (*e.g.*, cu. ft.)
c.v.	*	summary of a career (résumé; Latin *curriculum vitae*)

D

D		darcy(ies) [this unit of permeability is not an accepted SI unit of measure; 1 darcy = 9.869233 × 10^{-13} m^2]
d		day(s)

dB		decibel(s)
ddh		diamond-drill hole(s) [use only in figures, tables and maps]
DEEP-EM		surface pulse-EM survey
DEM(s)	*	digital elevation model(s)
dGPS	*	differential Global Positioning System
DIL		dual induction log
DLL		dual laterolog
DLS	*	Dominion Land Survey
DPT		Deeper Pool Test (Lahee classification)
Dr.	*	Doctor, Drive
DRI		drift log
DST(s)		drill stem test(s)
DSU		drilling spacing unit
DVD-ROM(s)	*	digital video disc(s)–read-only memory (or just DVD/DVDs)

E

E		east [use only in conjunction with strike and dip measurements (*e.g.*, 015°/68°E) and longitude (*e.g.*, 106° 10′ E)]
ECD		equivalent circulating density
ECP		external casing packer
ed., eds.		editor, editors
e.g.	*	for example (Latin *exempli gratia*) [always followed by a comma]
Eh		standard oxidation-reduction potential
EL		electric log
EM		electromagnetic
E-MORB		enriched mid-ocean-ridge basalt
EMW		equivalent mud weight
EOR		enhanced oil recovery
ERT		emergency response training
Esri	*	not ESRI or Environmental Systems Research Institute Inc.
et al.	*	and others (Latin *et alii*, *et aliae*) [use only in citation of references]
etc.	*	and the rest, and so forth (Latin *et cetera*)
eV		electron volt(s)
EXTECH		<u>Ex</u>ploration <u>Tech</u>nology Initiative [GSC program]

F

F		Fahrenheit
FAG		fully autogenous grinding
Fig./fig.		figure(s) [use only in figures, tables and maps]
Fm/fm	*	Formation/formation [use only in figures, tables and maps]
ft.	*	foot (feet)
FTIR		Fourier-transform infrared spectroscopy
FUS-ICP-ES		fusion inductively coupled plasma–emission spectrometry
FUS-ICP-MS		fusion inductively coupled plasma–mass spectrometry

G

G	*	gauss
G	*	giga (10^9), the SI symbol for a billion
g (**not** gm)	*	gram(s)
Ga	*	billion (*i.e.*, 10^9) years before present; Ga should always be placed after the numerals (*e.g.*, 2.5 Ga)

GAC		Geological Association of Canada
Gal		gal(s) [unit of acceleration used in the science of gravimetry; a Gal is one centimetre per second squared (1 cm/s^2)]
gal.	*	gallon(s)
GC		gas chromatography
GC-MS		gas chromatography–mass spectrometry
GEM		Geo-mapping for Energy and Minerals (federal government program)
GEM-2		Geo-mapping for Energy and Minerals, Phase 2 (federal government program)
GIIP		gas initially in place
GIS	*	geographic information system
GJ		gigajoule(s)
GLR		gas-to-liquid ratio
GOC		gas-oil contact
GOR		gas-to-oil ratio
Gp/gp	*	Group/group [use only in figures, tables and maps]
GPS	*	Global Positioning System
GR		gamma ray log
GRAD		gradiometer log
GRAV		gravimetric
GRN		gamma ray neutron log
GSC	*	Geological Survey of Canada
GSA	*	Geological Society of America
GW		gigawatt(s)
GWC		gas-water contact
GWh		gigawatt-hour(s)
GWR		gas-to-water ratio

H

h	*	hour(s)
ha	*	hectare(s)
HFSE(s)		high-field-strength element(s) [Nb, Ta, Zr, Hf, Ti]
HLEM		horizontal-loop electromagnetic
Hon.		Honourable
hp		horsepower
HP		hydrostatic pressure
HPLC		high-performance liquid chromatography
HREE(s)		heavy rare earth element(s) [Eu, Ga, Tb, Dy, Ho, ER, Tm, Yb, Lu, Y; see 'LREE(s)', 'MREE(s)']
H_2S		hydrogen sulphide
Hwy.		Highway
Hz		hertz

I

Is.	*	Island(s), Isle(s) [use only in figures, tables and maps]
ibid.	*	in the same place (Latin *ibidem*) [Do not use for citations, except when pages, figures, tables, *etc.* have been cited above, and you wish to refer to the same page or figure.]
ICAP		inductively coupled argon plasma spectrometry
ICP		intermediate casing point (oil and gas industry)
ICP-ES		inductively coupled plasma–emission spectrometry[3]

[3] The method for the major oxides is fusion ICP-ES, giving an abbreviation of FUS-ICP-ES, and the method for the trace elements is fusion ICP-MS, giving an abbreviation of FUS-ICP-MS. The combined abbreviation 'FUS-ICP/ICP-MS' is wrong because it doesn't make sense.

ICP-MS		inductively coupled plasma–mass spectrometry
ID		inner or internal diameter (of a tubular component such as a casing)
ID-TIMS		isotope dilution–thermal ionization mass spectrometry
i.e.	*	that is (Latin *id est*) [always followed by a comma]
IEL		induction electrical log
IJL		injection log
IL		induction log
in.	*	inch(es)
INAA		instrumental neutron activation analysis
Inc.	*	Incorporated
IP		induced polarization
IR		infrared
ISBN	*	International Standard Book Number
ISO		International Organization for Standardization
IUGS		International Union of Geological Sciences

J

J		joule(s)
JORC		Australasian Joint Ore Reserves Committee
Jr.	*	Junior [as part of a person's name]

K

K	*	Kelvin
k	*	kilo (10^3), the SI symbol for a thousand
ka	*	thousands of years before present
K-Ar	*	potassium-argon
KB		kelly bushing
kb	*	kilobyte(s) (**not** kilobar)
kbar	*	kilobar (1 kbar = 10^5 kPa)
kcf	*	thousand cubic feet
KE		kinetic energy
kg	*	kilogram(s)
KIM(s)		kimberlite indicator mineral(s)
kJ	*	kilojoule(s)
km	*	kilometre(s)
km/h	*	kilometre(s) per hour
K_{max}		permeability
KOP		kickoff point (directional drilling)
kPa	*	kilopascal(s)
kt	*	kilotonne(s)
kV	*	kilovolt(s)
kVA	*	kilovoltampere(s)
kW	*	kilowatt(s)
kWh	*	kilowatt-hour(s)

L

L	*	litre(s) [symbol L for litre(s) is used to distinguish this symbol from the numeral 1]
L.	*	Lake [use only in figures, tables and maps]
LA-MC-ICP-MS		laser-ablation, multiple-collector, inductively coupled plasma–mass spectrometry
lat.	*	latitude [use only in parenthetical text, figures, tables, maps or mineral deposit descriptions]
lb.	*	pound(s)

LC		liquid chromatography
LE		licence exception
LiDAR		light detection and ranging
LILE(s)		large-ion lithophile element(s)
line-km		line-kilometre(s)
LIP(s)		large igneous province(s)
LL		laterolog
LNG		liquefied natural gas
loc. cit.	*	(*loco citato*) in the place cited [requires a publication and page reference]
log		logarithm
LOI		loss-on-ignition
long.	*	longitude [use only in parenthetical text, figures, tables, maps or mineral deposit descriptions]
LPG		liquefied petroleum gas
LREE(s)		light rare earth element(s) [La, Ce, Pr, Nd, Sm; see ‘HREE(s)’, ‘MREE(s)’]
LSD	*	legal subdivision [used to describe location relative to the Township and Range grid of the Dominion Land Survey system (*e.g.*, LSD 11-7-39-2W3M)]
Ltd.	*	Limited [only abbreviated when part of a company name]

M

M	*	mega (10^6), the SI symbol for a million
m	*	metre(s)
masl		metres above sea level
mbsl		metres below sea level
mA	*	milliampere(s)
Ma	*	million (*i.e.*, 10^6) years before present [use with ages]
M.A.	*	Master of Arts
MAC		Mining Association of Canada
max.		maximum [use only in figures, tables and maps]
Mb	*	megabyte(s)
Mb/mb	*	Member/member [use only in figures, tables and maps]
mD (**not** md)		millidarcy(ies) [this unit of permeability is not an accepted SI unit of measure; 1 millidarcy = 9.869233 x 10^{-16} m^2]
meq		milliequivalent(s)
Mer.		meridian
Mg#		magnesium number [a unitless parameter calculated as 100 × MgO / (MgO + FeO^t)]
mg	*	milligram(s)
mGal		milligal(s) [see note under ‘Gal’]
min	*	minute, minutes
min.		minimum [use only in figures, tables and maps]
misc.	*	miscellaneous [use only in figures, tables and maps]
MJ	*	megajoule(s)
mKB	*	metre(s) at kelly bushing
mL	*	millilitre(s)
ML		microlog
MLL		microlaterolog
µL	*	microlitre(s)
mm	*	millimetre(s)
MMI™		Mobile Metal Ion™
MMI-M™		Mobile Metal Ion–Multi-Element™
MMI-ME™		Mobile Metal Ion–Multi-Element Enhanced™
mmol	*	millimole
MMSIM(s)		metamorphic massive sulphide–indicator mineral(s)

mol %	*	molecular percent
mol	*	mole [amount of a substance that contains as many atoms, molecules, ions, or other elementary units as the number of atoms in 0.012 kilogram of ^{12}C (also called ‘gram molecule’), or the mass in grams of this amount of a substance, numerically equal to the molecular weight of the substance (also called ‘gram-molecular weight’)]
mol. wt.		molecular weight
MORB		mid-ocean–ridge basalt
m.p.		melting point
MPa (**not** Mpa)	*	megapascal(s)
mPa	*	millipascal(s)
MREE(s)		middle rare earth element(s) [in the newer three-fold classification, light rare earth elements are La to Sm, middle rare earth elements are Eu to Ho, and heavy rare earth elements are Er to Lu]
MS		mass spectrometry
ms	*	millisecond(s)
mS	*	millisiemen(s)
m/s	*	metre(s) per second
M.Sc.	*	Master of Science
msl		mean sea level
MSWD		mean square of weighted deviates [not capitalized when written out]
Mt.	*	Mount (plural Mts.)
Mtn.	*	Mountain (plural Mtns.)
mV	*	millivolt(s)
MW	*	megawatt(s)
mW	*	milliwatt(s)
MWh	*	megawatt-hour(s)
m.y.	*	million years [use only with age range/duration]

N

n		refractive index (italicized)
N/n		number (when meant in the statistical sense; of population/sample; used in tables and figures, with explanantion given in a legend or in caption)
N		newton(s)
N		Normal (1 gram equivalent weight of solute per litre of solution; italicized)
N	*	north [use only in conjunction with strike and dip measurements (*e.g.*, 105°/17°N) and latitude (*e.g.*, 56° 15′ N)]
n/a		not applicable, not available [use only in figures, tables and maps]
NATMAP		National Geoscience Mapping Program (Federal-Provincial geoscience program)
N.B.	*	note well, mark well (Latin *nota bene*)
n.d.		variable: no date given, no data, not determined [use only in figures, tables and maps, and explain in caption or footnote]
NEB		National Energy Board
NGR		natural gamma ray log
NGSC		National Geological Surveys Committee
NI 43-101		National Instrument 43-101
N-MORB		normal (N-type) mid-ocean–ridge basalt
No., no.	*	number(s) [when used in a general sense, *e.g.*, ‘No. (correponds to those shown on Figure 1’); use only in figures, tables, maps and references or if it is part of a formal name (*e.g.*, No. 1 mine)]
NORM		naturally occurring radioactive material
NPV		net present value
NPW		New Pool Wildcat (Lahee classification)

NRCan		Natural Resources Canada
NRM		natural remanent magnetism
NSERC		Natural Sciences and Engineering Research Council of Canada
nT		nanotesla (measure of magnetic susceptibility, preferred to gamma, *γ*)
NTP		normal temperature and pressure
NTS	*	National Topographic System

O

OD		outer diameter (of a tubular component such as a casing)
OGIP		original gas-in-place
OIB(s)		oceanic-island basalt(s)
Omars		Omarolluk Formation erratics (greywacke erratics with hemispherical voids or pits)
OOIP		original oil-in-place
op. cit.		in the work or article cited (Latin *opere citato*), with no page reference [Use for general reference to articles by authors cited earlier in the same paragraph or page. Do not use (*ibid.*) as a substitute for (*op. cit.*).]
OUT		Outpost (Lahee classification)
OWC		oil-water contact

P

P		pressure, probability, power (italicized)
p.	*	page(s) [use only in reference list or where citing a page number in a reference citation in the text]
Pa		pascal(s)
PCB(s)	*	polychlorinated biphenyl(s)
PDA		personal digital assistant
PDAC		Prospectors and Developers Association of Canada
PDF	*	Adobe® Portable Document Format (file, files)
P.Eng.		Professional Engineer
pers. comm.	*	personal communication [abbreviation is used only in figures, tables, maps, with a date given; always written out in citations, *e.g.*, 'G. Beakhouse, Tamara Minerals, personal communication, June 10, 2016']
PF-ICP-MS		peroxide-fusion inductively coupled plasma–mass spectrometry
PGE(s)		platinum group element(s)
P.Geo.		Professional Geoscientist
PGM(s)		platinum group mineral(s) or metal(s)
pH	*	negative log of hydrogen ion concentration (acidity or alkalinity)
Ph.D.	*	Doctor of Philosophy
p.m.	*	after noon (Latin *post meridiem*)
POR		density porosity log
ppb	*	parts per billion (*i.e.*, 10^{9})
ppm	*	parts per million (*i.e.*, 10^{6})
ppma		parts per million atoms
ppt		parts per trillion (*i.e.*, 10^{12})
PR	*	Provincial Road
Prof.	*	Professor
PS	*	postscript (Latin *post scriptum*)
PSA		particle-size analysis
psi	*	pounds per square inch
psia		pounds per square inch absolute pressure
psig		pounds per square inch gauge pressure

PSV		pressure safety valve
Pt.	*	Point [use only in figures, tables and maps]
PTH	*	Provincial Trunk Highway
pub.	*	publication, publish, published
PЄ		Precambrian [use only in figures, tables and maps]

Q

QA-QC		quality assurance–quality control
QEM-SEM		quantitative electron microscopy–scanning electron microscopy
QFM	*	quartz-feldspars-mafics (*after* Streckeisen, 1976)
Q_{max}		maximum daily allowable
QP		qualified person (under the terms of NI 43-101)

R

R.	*	River [use only in figures, tables and maps]
RAM	*	random-access memory
Rb-Sr	*	rubidium-strontium
REE(s)		rare earth element(s)
ref.	*	reference [use only in figures, tables and maps]
RESI		resistivity log
rge., Rge.	*	range(s) [upper case for formal Range locations; use only in figures, tables, maps]
RIMS		resonance ion mass spectrometry
RIP		resin-in-pulp (metallurgical process)
R.M.		Rural Municipality, Regional Municipality
RNA		ribonucleic acid
ROM	*	read-only memory
ROS		remaining oil saturation
ROW		right-of-way
rpm		revolution(s) per minute [in scientific or technical work, rev/min is used]
rps		revolution(s) per second [in scientific or technical work, rev/s is used]
RR		railroad, rural route [used in tables and figures, with explanantion given in a legend or in caption]
RSD		relative standard deviation [need not be preceded by ‘%’]
Rwy.	*	Railway

S

s	*	second(s)
S	*	south [use only in conjunction with strike and dip measurements (*e.g.*, 105°/17°S) and latitude]
SAG		semi-autogenous grinding
SAR		synthetic aperture radar
SD		standard deviation
SDP^{SM}		Soil Desorption Pyrolysis^{SM}
Sec.	*	section(s) [used to describe location relative to the Township and Range grid of the Dominion Land Survey system]
SEDAR	*	System for Electronic Document Analysis and Retrieval [the official site that provides access to most public securities documents and information filed by issuers with the 13 provincial and territorial securities regulatory authorities in the SEDAR filing system]
SEDEX		sedimentary exhalative
SEM		scanning electron microscope
SEM-EDS		scanning electron microscope–energy dispersive spectrometry
SEM-EDX		scanning electron microscope–energy dispersive X-ray spectrometry

sg		specific gravity
SGH^{SM}		Soil Gas Hydrocarbons^{SM}
S_h		hydrate saturation (as a fraction or percent)
SHRIMP		sensitive high-resolution ion microprobe
SI	*	Système international d'unités (International System of Units)
SIE		specific ion electrode (for determination of fluorine)
sic	*	so, thus (Latin *sik*)
SIMS		secondary-ion mass spectrometry
SICP		shut-in casing pressure
SIP		shut-in pressure
SIRM		saturation isothermal remanent magnetism
s.l.		in the broad sense (Latin *sensu lato*)
SMOW		standard mean ocean water
SP		spontaneous- or self-potential (as in 'self-potential geophysical survey')
sp.	*	species, specimen(s) (pl. spp.)
SPLP		synthetic precipitation leaching procedure
sq.	*	square (*e.g.*, sq. in., sq. ft., sq. yd.)
SPOT	*	Système Pour l'Observation de la Terre [Earth observation satellite]
SPT		Shallower Pool Test (Lahee classification)
Sr.	*	Senior [not to be used in the sense of 'senior partner', *i.e.*, not 'Sr. partner']
SRM(s)		standard reference material(s)
SRTM		Shuttle Radar Topography Mission
s.s.		in the strict narrow sense (Latin *sensu stricto*)
St.	*	Street, Saint
Ste.		Sainte
STP		standard temperature and pressure
SX-EW		solvent extraction–electrowinning

T

T	*	temperature
T	*	tesla
t	*	tonne (= metric ton)
T_{CHUR}		Sm-Nd model age relative to chondritic uniform reservoir
T_{DM}		Sm-Nd model age relative to depleted mantle
TCLP		toxicity characteristic leaching procedure
TD		total depth [measured along the actual path of a well]
TDS		total dissolved solids
TE-TIMS		thermal extraction–thermal ionization mass spectrometry
TGI		Targeted Geoscience Initiative (federal government program)
TIMS		thermal ionization mass spectrometry
TOC		total organic carbon
TSX	*	Toronto Stock Exchange
tp., Tp.	*	township(s) [upper case for formal Township locations]
TVD		true (or total) vertical depth [measured vertically from surface down to a specific point along the path of a well]

U

UHF		ultrahigh frequency
UK	*	United Kingdom
U-Pb	*	uranium-lead
U.S.	*	United States

US$	*	American dollars
USGS		United States Geological Survey
UTM	*	Universal Transverse Mercator
UV		ultraviolet
UV VIS		ultraviolet-visible light spectroscopy

V

VAR		volt-ampere reactive
var.	*	variety
VHF		very high frequency
VLEM		vertical loop electromagnetic
VLF-EM		very low frequency electromagnetic
VMS		volcanogenic massive sulphide
VOC(s)		volatile organic compound(s)
vol. %	*	volume percent
vs.	*	against (Latin *versus*)

W

W		watt(s)
W		west [in text, use only in conjunction with strike and dip measurements (*e.g.*, 175°/32°W) and longitude or Township and Range designation (*e.g.*, Range 10W2M)]
WAG		water-alternate-gas ratio
WDXRF		wavelength-dispersive X-ray fluorescence or wavelength-dispersive X-ray spectrometry
WDS		wavelength-dispersive spectrometry
WHMIS	*	Workplace Hazardous Materials Information System
WOR		water-to-oil ratio
wt. %	*	weight percent

X

XRD		X-ray diffraction
XRF		X-ray fluorescence
XRS		X-ray spectroscopy

Y

yd.	*	yard(s)
yr.	*	year [if an abbreviation is required for a unit of measure, it can sometimes be less confusing to use this; see also ‘a’]

Appendix 5 – Style Specifications

a) The following table lists the various styles to be used for all types of reports produced by the Saskatchewan Geological Survey, including Open File Reports, Miscellaneous Reports, Final Reports and papers for *Summary of Investigations*. Note that, although specifications are given for exact spacing above and below the various heading levels and other elements, each publication is unique in its proportion of figures to text; an editor may need to tweak some of these paragraph spacing specifications in order to eliminate—or at least reduce—unnecessary blank spaces.

Element	Specifications
Margins of Word File	Top - 0.8"; bottom, left and right - 1.0"; gutter - 0"; header and footer - 0.5" from top and from bottom
Report Title	Arial Narrow 18 pt., bold; title case; centred; paragraph spacing - 0 pts. before, 16 pts. after; line spacing - single
Author Name(s)	Arial Narrow 12 pt., italics; *Firstname Init. Lastname*; centred; paragraph spacing - 0 pts. before, 6 pts. after; line spacing - single
'Recommended Reference' Statement (also use this style for statement of accompanying publication)	Arial Narrow 8 pt.; left justified; border above paragraph - single solid line, ¾ pt. line width, extending from left to right margin, 'From Text' - 2 pts. from top, 1 pt. from bottom, 4 pts from left and right; paragraph spacing - 0 pts. before, 2 pts. after; line spacing - single (if there is an accompanying publication, the statement 'This report is accompanied by ..' is 4 pts. below the example reference for the main publication)
Example Reference (also use this style for accompanying publication example reference)	Arial Narrow 8 pt.; indent 0.1" from left; hanging indent 0.25"; paragraph spacing - 0 pts. before, 4 pts. after; line spacing - single (if there is more than one accompanying publication, put a paragraph spacing of 4 pts. between each reference)
Abstract Header	Arial Narrow 12 pt., bold, italics; centred; paragraph spacing - 15 pts. before, 6 pts. after; line spacing - single
Abstract Text	Arial Narrow 10 pt., italics; left justified; paragraph spacing - 0 pts. before, 8 pts. after; line spacing - single
Keywords	Arial Narrow 10 pt.; left justified; 'Keywords:' is bold, non-italics, all other words are italics, non-bold; no period at end of text string; paragraph spacing - 0 pts. before, 8 pts. after; line spacing - single
Author Affiliation	Arial Narrow 8 pt.; left justified; border above paragraph (for first author affiliation only) - single solid line, ¾ pt. line width, extending from left to right margin, 'From Text' - 2 pts. from top, 1 pt. from bottom, 4 pts. from left and right; paragraph spacing - 0 pts. before and after; line spacing - 'exactly' 8 pts.
Disclaimer	Arial Narrow 8 pt.; left justified; paragraph spacing - 4 pts. before, 0 pts. after; line spacing - 'exactly' 9 pts.
Footer Text and Page Numbers	Arial Narrow 9 pt., italics; paragraph spacing - 0 pts. before and after; line spacing - 'exactly' 9 pts.
Heading Level 1 - SOI Paper	Arial Narrow 14 pt.; title case; left justified; hanging indent 0.25″; outline numbered, numbering style 1., 2., 3. ...; paragraph spacing - 10 pts. before, 6 pts. after; line spacing - single
Heading Level 1 - All Other Reports	Arial Narrow 14 pt.; title case; left justified; hanging indent 0.25″; paragraph spacing - 10 pts. before, 6 pts. after; line spacing - single; border below paragraph - single solid line, ½ pt. line width, extending from left to right margin, 'From Text' - 1 pt. from top and bottom, 4 pts. from left and right; all level 1 headings start a new page (see example Open File Report, Appendix 8C)
Heading Level 2 - SOI Paper	Arial Narrow 12 pt., bold; title case; left justified; hanging indent 0.25″; outline numbered, numbering style a), b), c) .....; paragraph spacing - 6 pts. before and after; line spacing - single
Heading Level 2 - All Other Reports	Arial Narrow 12 pt., bold; title case; left justified; hanging indent 0.25″; paragraph spacing - 6 pts. before and after; line spacing - single
Heading Level 3 (all reports)	Arial Narrow 11 pt., bold; title case; left justified; hanging indent 0.25″; paragraph spacing - 6 pts. before and after; line spacing - single

Element	Specifications
Heading Level 4 (all reports)	Arial Narrow 11 pt., italics; title case; left justified; hanging indent 0.25″; paragraph spacing - 6 pts. before and after; line spacing - single
Paragraph Text	Arial Narrow 11 pt.; left justified; paragraph spacing - 0 pts. before, 8 pts. after; line spacing - single
Quotation	Arial Narrow 10 pt.; left and right indents 0.25"; paragraph spacing - 0 pts. before, 6 pts. after; line spacing - single.
Bulleted List	Arial Narrow 11 pt.; 'bulleted list'; align left; 0" indent on right and left, hanging indent of 0.25"; paragraph spacing - 0 pts. before each bullet, 3 pts. after; line spacing - single.
Last Item in Bulleted List	Same as 'Bulleted List' but with 8 pts. space after paragraph
Vertical Numbered List	Arial Narrow 11 pt.; 'numbered list', numbering style 1), 2), etc.; other specifications as for 'Bulleted List'
Last Item in Vertical Numbered List	Same as 'Vertical Numbered List' but with 8 pts. space after paragraph
Captions	Arial Narrow 10 pt., italics; figure/table number (*i.e.*, Figure 1, Table 1) and any part designators (*i.e.*, A), B), *etc.*) italics <u>and</u> bold; paragraph spacing - 4 pts. before, 6 pts. after; line spacing - single
Table Column Headers	Arial Narrow 9 pt., bold; title case; paragraph spacing - 2 pts. before and after; line spacing - single
Table Text	Arial Narrow 9 pt.; all text strings in table begin with first word capitalized; paragraph spacing - 2 pts. before and after; line spacing - single
Table Properties	Row - **don't** 'allow lines to break across page'
Footnotes	Arial Narrow 8 pt.; border above paragraph - single solid line, ¾ pt. line width, extending from left to right margin; 'From Text' - 2 pts. from top, 1 pt. from bottom, 4 pts. from left and right; paragraph spacing - 6 pts. before, 0 pts. after; line spacing - 'exactly' 9 pts
References	Arial Narrow 10 pt.; hanging indent 0.25"; Line and Page Breaks - 'keep lines together'; paragraph spacing - 0 pts. before, 8 pts. after; line spacing - single

b) The following is a list of 'tab stops' for the footer text and page numbers for various page sizes and orientations. Footer text for left-hand side pages is simply the left margin of the page.

<u>Page Size / Orientation</u>	Tab Stop for <u>Page Number</u>	Tab Stop for <u>Right Edge Text</u>
Letter / Portrait	3.25″	6.5″
Letter / Landscape	4.5″	9.0″
Legal / Portrait	3.25″	6.5″
Legal / Landscape	6.0″	11.5″
Ledger / Portrait	4.5″	9.0″
Ledger / Landscape	7.0″	15.0″

c) Although it's difficult to set a standard style format for files submitted for a Data File, there should be a standard look to all 'General Information' tabs in Excel files.

For text on a 'General Information' tab of an Excel file for a data file, the following styles are suggested.

Element	Specifications
Data File Number	Arial 11 pt., bold; title case
Data File Title	Arial 16 pt., bold; title case
Author Name(s) and Year of Publication	Arial 16 pt.
Standard Disclaimer	Arial 9 pt.
All Remaining Text	Arial 10 pt.

Appendix 6 – Copyright Permission Requests

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To whom it may concern:

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This permission will in no way restrict re-publication of your material by you or others authorized by you. If it is not within your power to grant these rights, please let me know whom I should contact.

I propose to acknowledge the copyright holder in the following manner: ________________________________.

I expect that the publication in which I will use your material will be published on the Saskatchewan Government's website on [date], therefore a response before [2 weeks prior to publication date] would be appreciated.

Thank you for your consideration of this request.

Sincerely,

[Name and address of author]

NOTE: All requests for permission to reproduce material contained in Saskatchewan Geological Survey publications are handled by the production editor.

Appendix 7 – Reference Style Examples

The following list provides examples of SGS standards for writing references for many of the types of publications encountered in geoscience. For ease of use, the references are separated by publication type.

Book or Formal Report

Bailes, A.H. and Syme, E.C. (2012): Geology of the Flin Flon–Glennie Domains Area; Saskatchewan Ministry of the Economy, Report 57, 31p.

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Fuzesy, A. (1982): Potash in Saskatchewan; Saskatchewan Energy and Mines, Report 181, 44p.

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Irvine, J.A., Whitaker, S.H. and Broughton, P.L. (1978): Coal Resources of Southern Saskatchewan: A Model for Evaluation Methodology; Geological Survey of Canada Economic Geology Report 30 / Saskatchewan Department of Mineral Resources Report 209 / Saskatchewan Research Council Report 20, Text Volume (151p. and microfiche) and Atlas Volume (56 plates).

Lillesand, T.M. and Kiefer, R.W. (1987): Remote Sensing and Image Interpretation (Second Edition); Wiley, New York, 721p.

Soil Classification Working Group (1998): The Canadian System of Soil Classification, Third Edition; Agriculture and Agri-Food Canada, NRC Research Press, 187p.

Stevens, R.D., Delabio, R.N. and Lachance, G.R. (1982): Age Determination and Geological Studies: K-Ar Isotopic Ages; Ottawa Department of Mineral Resources, Report 15, 56p.

Tremblay, L.P. (1972): Geology of the Beaverlodge Mining Area, Saskatchewan; Geological Survey of Canada, Memoir 367, 265p.

Informal Report

Ashton, K.E. and Hartlaub, R.P. (2008): Geological compilation of the Uranium City area; Saskatchewan Ministry of Energy and Resources, Open File 2008-5, set of four 1:50 000-scale maps.

Bradley, D. and McCauley, A. (2013): A preliminary deposit model for lithium-cesium-tantalum (LCT) pegmatites; United States Geological Survey, Open-File Report 2013-1008, 7p.

Davis, W.J., Berman, R.G. and MacKinnon, A. (2013): U-Pb geochronology of archival rock samples from the Queen Maud block, Thelon tectonic zone and Rae craton, Kitikmeot region, Nunavut, Canada; Geological Survey of Canada, Open File 7409, Natural Resources Canada / Ressources naturelles Canada, 40p.

Hornbrook, E.H.W. and Garrett, R.G. (1976): Regional geochemical lake sediment survey, east-central Saskatchewan; Geological Survey of Canada, Paper 75-41, 20p.

Klassen, R.W. (2002): Surficial geology of the Cypress Lake and Wood Mountain map areas, southwestern Saskatchewan; Geological Survey of Canada, Bulletin 562, 60p., with 1:250 000-scale maps 1766A and 1802A.

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Slimmon, W.L. (2013): Geological atlas of Saskatchewan; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Miscellaneous Report 2013-7, CD-ROM, version 16.

Villeneuve, M.E., Ross, G.M., Thériault, R.J., Miles, W., Parrish, R.R. and Broome, J. (1993): Tectonic subdivision and U-Pb geochronology of the crystalline basement of the Alberta Basin, western Canada; Geological Survey of Canada, Bulletin 447, 86p.

Engineering Report

Kjartanson, B. (1983): Geological engineering report for urban development of Winnipeg; Department of Geological Engineering, University of Manitoba, Winnipeg, 78p. plus 17 maps at 1:50 000 scale and 1 map at 1:30 000 scale.

Thesis

Knox, B.R. (2012): A geological investigation of the south-central Beaverlodge Domain, southern Rae Province: with emphasis on the nature and timing of deformation and associated metamorphism; M.Sc. thesis, University of Regina, Regina, Saskatchewan, 173p.

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Ritchie, J.C. (1989): History of the boreal forest in Canada; *in* Chapter 7 of Quaternary Geology of Canada and Greenland, Fulton, R.J. (ed.), Geological Survey of Canada, Geology of Canada, no.1, p.508-512 (*also* Geological Society of America, The Geology of North America, v.K-1).

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International Atomic Energy Agency (2009): *section on* Uraniferous coal and lignite deposits; *in* World Distribution of Uranium Deposits (UDEPO) with Uranium Deposit Classification, 2009 Edition, International Atomic Energy Agency, IAEA-TECDOC-1629, p.65.

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Saskatchewan Geological Survey (2014): Production totals for current gold mining operations and published Reserves/Resources for selected gold deposits in Saskatchewan; Table 3 *in* Saskatchewan Exploration and Development Highlights 2014, p.8.

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Syme, E.C., Bailes, A.H. and Lucas, S.B. (1996): Tectonic assembly of the Paleoproterozoic Flin Flon belt and setting of VMS deposits; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Winnipeg, Manitoba, May 27 to 29, 1996, Field Trip Guidebook B1, 131p.

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Kyser, K. and Cuney, M. (2008): Geochemical characteristics of uranium and analytical methodologies; *in* Recent and Not-so-recent Developments in Uranium Deposits and Implications for Exploration, Cuney, M. and Kyser, K. (eds.), Mineralogical Association of Canada, Short Course Series, v.39, p.23-56.

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Kelley, L. (2005): Uranium exploration in southern Saskatchewan: a historical review; *in* 14th Annual Calgary Mining Forum – Investing in the Future, April 6 to 7, 2005, Calgary, Alberta, Abstract Volume, p.24.

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Early View: Online Version of Record Published Before Inclusion in an Issue

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SGS Data File Report

Bosman, S.A. and Card, C.D. (2015): Geochemical analysis of Athabasca Group drillholes in Saskatchewan (NTS 64L, 74F to 74I, 74K, and 74O to 74P) – Supplementary to Data File Reports 24, 29, 30, 31, 32, and 33; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Data File Report 36.

Saskatchewan Ministry of Energy and Resources (2010): Industry drillcore data – Regina Subsurface Core Facility – Uravan Minerals Inc., Athabasca Basin (NTS 64L, 74F to 74K, and 74N to 74P) 2010 drillcore analysed; Saskatchewan Ministry of Energy and Resources, Saskatchewan Geological Survey, Data File Report 24, URL <http://www.economy.gov.sk.ca/DF24>.

Satellite Imagery [must include date of access or download]

DigitalGlobe (2006): QuickBird-2 satellite image; DigitalGlobe, Inc., image, URL https://browse.digitalglobe.com/imagefinder/showBrowseMetadata?catalogId=10100100051A2800> [accessed 14 November 2012].

Google (2011): Google Maps™ satellite image of Elbow Lake, Manitoba; Google, image, URL <http://maps.google.ca/maps> [©2011 Google - Imagery, ©2011 TerraMetrics, Map data, 22 June 2011].

Shuttle Radar Topography Mission (2000): Saskatchewan digital elevation data from Shuttle Radar Topography Mission (February 11-22, 2000); United States Geological Survey, URL <https://lta.cr.usgs.gov/SRTM> [downloaded 12 September 2015].

St. John, J. (2007): Medano Creek, southern side of Great Sand Dunes, Rio Grande Rift Valley, southern Colorado, USA 3; Flickr, URL <http://www.flickr.com/photos/jsjgeology/8502689300/> [accessed 29 November 2013].

Map

Geological Survey of Canada (1966): Aeromagnetics, Ryerson Lake, Manitoba–Ontario; Geological Survey of Canada, Geophysical Series, Map 1194G, scale 1:63,360.

Macdonald, R. and Slimmon, W.L. (1985): Bedrock Geology of the Greater Beaverlodge Area, NTS 74N-6 to -11; Saskatchewan Energy and Mines, Map 241A, scale 1:100 000.

NATMAP Shield Margin Project Working Group (1998): Geology, NATMAP Shield Margin Project area, Flin Flon Belt, Manitoba/Saskatchewan; Geological Survey of Canada, Map 1968A, scale 1:100 000.

Stockwell, C.H. (1960): Flin Flon–Mandy area, Manitoba and Saskatchewan; Geological Survey of Canada, Map 1078A, scale 1:12 000, with descriptive notes.

Notes Accompanying a Map

Syme, E.C., Lucas, S.B., Zwanzig, H.V., Bailes, A.H., Ashton, K.E. and Haidl, F.M. (1998): Geology, NATMAP Shield Margin Project area of Flin Flon Belt, Manitoba/Saskatchewan; accompanying notes to Geological Survey of Canada Map 1968A / Manitoba Energy and Mines Map A-98-2 / Saskatchewan Energy and Mines Map 258A, 54p.

Topographic Map

Energy, Mines and Resources Canada (1985): 64 B/5, Pemichigamau Lake, Manitoba; Energy, Mines and Resources Canada, Surveys and Mapping Branch, topographic map (third edition), scale 1:50 000.

Series of Maps

Buckle, J.L., Carson, J.M., Miles, W.F., Ford, K.L., Fortin, R. and Delaney, G. (2011): Geophysical series, geophysical compilation, northern Saskatchewan; Geological Survey of Canada Open File 7039 / Saskatchewan Ministry of Energy and Resources Open File 2011-58, set of 10 maps at 1:750 000 scale.

Marsh, A. and Love, M. (2014): Regional stratigraphic framework of the Phanerozoic in Saskatchewan: Saskatchewan Phanerozoic Fluids and Petroleum Systems Project; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Open File 2014-1, set of 156 maps.

One in a Series of Maps

Marsh, A. and Love, M. (2014): Cretaceous Colorado Group – structure map: Saskatchewan Phanerozoic Fluids and Petroleum Systems Project; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Open File 2014-1, map 8 of 156.

Map Associated with *Summary of Investigations* Paper

Knox, B.R. and Lamming, J. (2015): Bedrock geology of the Robillard Bay area, southwestern Tantato Domain (parts of NTS 74O/07); 1:20 000-scale preliminary map *with* Summary of Investigations 2015, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.2, map 2015-4.2-(2.1).

Petroleum Technical Well File [must include date of access]

EOG Resources Canada Inc. (2004): Advanced geotechnology special core analysis for EOG Waskada 10-34-1-25W1; Manitoba Mineral Resources, Petroleum Technical Well File 5221, 245 p., URL <http://www.manitoba.ca/iem/petroleum/documents/technical/005221.pdf> [accessed 25 September 2012].

Atlas of Canada [must include date of download]

Natural Resources Canada (2007): Atlas of Canada base maps; Natural Resources Canada, Earth Sciences Sector, URL <http://geogratis.cgdi.gc.ca/geogratis/en/option/select.do?id=138> [downloaded November 2007].

Digital Elevation Data [year of publication is year of download]

GeoBase® (2011): Canadian digital elevation data; Natural Resources Canada, URL <http://www.geobase.ca/geobase/en/data/cded/index.html> [downloaded May 2011].

Landsat 7 Enhanced Thematic Mapper Plus Imagery (15 m Resolution) [year of publication is year of download]

GeoBase® (2012): Landsat 7 orthorectified imagery over Canada (1999–2003); Natural Resources Canada, URL <http://www.geobase.ca/geobase/en/find.do?produit=landsat> [downloaded January to June 2012].

Panchromatic SPOT 4/5 Imagery (10 m Resolution) [year of publication is year of download]

Geobase® (2012): GeoBase orthoimage 2005–2010; Natural Resources Canada, URL <http://www.geobase.ca/geobase/en/find.do?produit=imr> [downloaded January to June 2012].

Digital Road Network [year of publication is year of download]

GeoBase® (2013): National road network; Natural Resources Canada, URL < http://www.geobase.ca/geobase/en/data/nrn/index.html > [downloaded February 2013].

Referencing Publications by the Saskatchewan Geological Survey

There have been numerous changes over the years to the name of the ministry with which the Saskatchewan Geological Survey is affiliated. Prior to 1978, the ministry was called Department of Mineral Resources. Since then, name changes have been

- 1978 to 1981 - Saskatchewan Mineral Resources
- 1982 to 2001 - Saskatchewan Energy and Mines
- 2002 to 2006 - Saskatchewan Industry and Resources
- 2007 to 2011 - Saskatchewan Ministry of Energy and Resources
- 2012 to present - Saskatchewan Ministry of the Economy

It's important to make sure you have the correct ministry name for the year in which the SGS publication you're referencing was released.

Peculiarities of Referencing SGS *Summary of Investigations*

The Saskatchewan Geological Survey's annual report on field work and other research first became known as the *Summary of Investigations* in 1975. Prior to then, it had been known as *Summary Report of Geological Investigations Conducted in the Precambrian Area of Saskatchewan*, or *Summary Report of Field Investigations by the Saskatchewan Geological Survey*, and other variations on that theme. The report was produced by the Department of Mineral Resources, Geological Sciences Branch, Precambrian Geology Division (which changed to Saskatchewan Geological Survey in 1974), and was not given any series designation.

In 1978, the year the ministry name became Saskatchewan Mineral Resources, the *Summary* was assigned to the *Miscellaneous Report* series and was given a series number that comprised the last two digits of the year in which it was released, and a number within that series (*e.g.*, *Miscellaneous Report 78-10*). From then until 1999, the only change to the report was the change in ministry name in 1982.

The most significant change was introduced in 1999, when the *Summary* was divided into two separate volumes. In that year, the *Summary of Investigations* was given the series designation *Miscellaneous Report 99-4.1* (for Volume 1) and *Miscellaneous Report 99-4.2* (for Volume 2). From 2000 to the present, Volume 1 has been reserved for papers discussing research in the Phanerozoic strata, primarily in southern Saskatchewan; and Volume 2 for papers discussing research related primarily to the geology of the Precambrian Shield in the northern part of the province. Also since 2000, the series number designations have included all four digits of the year of publication (*e.g.*, *Miscellaneous Report 2000-4.1* for Volume 1, and *Miscellaneous Report 2000-4.2* for Volume 2). The only changes to the *Summary* since 2000 have been the changes in ministry name, as outlined above; a short interval of time when the *Summary* was released only on CD; and the decision in 2013 to only publish the papers online.

Prior to 2002, all pages within a *Summary* volume were numbered consecutively from 1; therefore all papers in the volumes had a page range (*e.g.*, p.181-184). From 2002 to the present, contributions to both volumes are assigned separate paper numbers and a total page count (*e.g.*, Paper A-1, 15p.).

Given the changes explained above, standards for referencing SGS *Summary of Investigations* (SOI) papers published from 1975 to 2002 are

1975 to 1977

Kendall, A.C. (1976): Bedded halites in the Souris River Formation (Devonian): potash mining district around Saskatoon; *in* Summary of Investigations 1976, Saskatchewan Geological Survey, Department of Mineral Resources, p.84-86.

1978 to 1998

Scott, B.P. (1978): Geological mapping, Laird Lake west area (63M-14W); *in* Summary of Investigations 1978, Saskatchewan Geological Survey, Department of Mineral Resources, Miscellaneous Report 78-10, p.13-15.

1999

Nowlan, G.S. and Haidl, F.M. (1999): New conodont data from the Ordovician-Silurian boundary interval in southeastern Saskatchewan; *in* Summary of Investigations 1999, Volume 1, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 99-4.1, p.12-16.

Yeo, G.M. and Savage, D.A. (1999): Geology of the High Rock Lake area, Wollaston Domain (NTS 74H-3 and -4); *in* Summary of Investigations 1999, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 99-4.2, p.38-54.

2000 to 2001

Christopher, J.E. (2000): The Early Mesozoic history of the Punnichy Arch, southeastern Saskatchewan; *in* Summary of Investigations 2000, Volume 1, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2000-4.1, p.45-58.

Gracie, A.J. (2000): Mineralized core collection; *in* Summary of Investigations 2000, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2000-4.2, p.95.

The examples below show how to reference papers in *Summary of Investigations* from 2002 to the present (remember to replace 'Saskatchewan Ministry of the Economy' with the appropriate former ministry name).

Volume 1

Schuurmans, E.D., Dale, J. and Salad Hersi, O. (2015): Preliminary study of paleosols in the Lower Cretaceous McLaren and Waseca members of the Mannville Group in Saskatchewan; *in* Summary of Investigations 2015, Volume 1, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.1, Paper A-3, 12p.

Volume 2

Knox, B. and Lamming, J. (2015): Details from the 1:20 000-scale mapping of the south-central Tantato Domain, Rae Province, along the northern margin of the Athabasca Basin; *in* Summary of Investigations 2015, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.2, Paper A-1, 15p.

The only exceptions to the current standard format for SOI referencing are for a few of the years when the *Summary* was released only on CD.

Other than Volume 1 in 2001, from 2001 to 2008 both volumes were released on CD only, not as printed, bound, hardcopy reports. Over the past several years the papers have been scanned and placed on the Saskatchewan government website. In certain years of publication, however, the papers in Volume 2 were divided into categories—in 2001 they were also separated onto two CDs. This division into categories has been retained on the web for some years of the *Summary* papers: specifically, for the years 2001, 2002 and 2003. For these years, it helps to know to which category a paper in Volume 2 was assigned to more easily locate the paper on the website. Therefore, *Summary* papers in Volume 2 for the years 2001 to 2003 need additional information in their reference: the following give examples of the additional information required for these years.

Kelley, L.I. and Holmden, C. (2001): Semi-quantitative assessment of groundwater flux from H, O, and Sr isotopes, Lydden Lake sodium sulphate deposit, Saskatchewan; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, Section C, Industrial Minerals Studies, p.173-184.

Rostron, B.J., Kelley, L.I., Kreis, L.K. and Holmden, C. (2002): Economic potential of formation brines: interim results from the Saskatchewan brine sampling program; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, Section C, Industrial Mineral Studies, Paper C-1, 29p.

MacLachlan, K. (2003): Preliminary investigation of the thermotectonic history of the central Rottenstone Domain, Hickson and Rottenstone lakes, Saskatchewan; *in* Summary of Investigations 2003, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2003-4.2, Section A, Northern Mapping and Supportive Investigations, Paper A-5, 20p.

Appendix 8 – Example Publications

A) Summary of Investigations (SOI)

Content of papers submitted for the annual SOI depends on the nature of the study, and to which volume it is being submitted. Regardless of the volume or nature of the study, all papers should include the following sections. (Authors are also encouraged to consult recent examples for guidance.)

- Title
- Author(s) name(s), in the format Firstname Init. Lastname (*e.g.*, Robert A. Smith)
- Author(s) affiliation and complete address(es) (*e.g.*, University of Regina, Department of Geology, 3737 Wascana Parkway, Regina, SK S4S 0A2; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, 1000-2103 11th Avenue, Regina, SK S4P 3Z8)
- Abstract
- Keywords; a list of 5 to 10 words that relate to the content of the paper
- Introduction; a brief explanation of the location of the study area and objectives of the study
- Acknowledgments
- References

Along with the sections outlined above, papers submitted for Volume 1 typically include the following:

- Stratigraphic setting - regional and local
- Study method, data collection method
- Lithofacies descriptions
- Analytical methods and procedures
- Results
- Discussion and future work

Papers submitted for Volume 2 typically discuss the following:

- General geology and regional setting
- Rock types and description
- Stratigraphy
- Metamorphism
- Structure
- Geochronology
- Geochemistry
- Geophysics
- Recommendations for future work, or future work planned

The examples that follow give a more visual idea of what constitutes a *Summary of Investigations* paper. (Note: the example for Volume 2 has been shortened somewhat.)

i) Example of *Summary of Investigations* paper for Volume 1.

Stratigraphy and Reservoir Characterization of the Upper Devonian Duperow Formation, Southeastern Saskatchewan

Chao Yang [1]

Parts of this publication may be quoted if credit is given. It is recommended that reference to this publication be made in the following form:

Yang, C. (2015): Stratigraphy and reservoir characterization of the Upper Devonian Duperow Formation, southeastern Saskatchewan; *in* Summary of Investigations 2015, Volume 1, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.1, Paper A-4, 20p.

Abstract

This paper presents a broad overview of hydrocarbon drilling activity, production, stratigraphy, reservoir petrology and characteristics of the Upper Devonian Duperow Formation in southeastern Saskatchewan. Log-to-core correlation of the pay zones, core examination and thin-section study were undertaken in the Midale Duperow pool area to improve understanding of oil reservoirs in the Duperow Formation.

The Duperow Formation in southeastern Saskatchewan records shallowing-upward cycles from subtidal to intertidal sedimentation, including bioclast-rich wacke-packstone, stromatoporoid boundstone and peloidal wackestone, grading upward to more restricted supratidal limestone, dolomudstone and evaporite. It is subdivided into the Saskatoon, Wymark and Seward members, in ascending order. The Saskatoon Member ranges in thickness from 15 to 37 m and is over 50 m thick locally. The Wymark Member is 69 to 145 m thick and is further subdivided into informal lower, middle and upper units, with thicknesses ranging from 7 to 19 m, 30 to 74 m, and 20 to 61 m, respectively. In some areas, the upper Wymark unit is terminated by the Flat Lake Evaporite, which is mostly halite and ranges in thickness from 1 to 30 m. The thickness of the Seward Member ranges from 31 to 67 m.

As of December 31, 2015, Duperow reservoirs yielded 167 x 10^3 cubic metres (1 million barrels) of oil from nine wells in southeastern Saskatchewan. The producing zone in the Midale Duperow pool is in the heavily dolomitized wackestone in the lowermost cycle of the upper unit of the Wymark Member. Core and thin-section studies show that the dominant type of porosity in the dolomitized wackestone is intercrystalline, which is enhanced by molds and vugs formed by dissolution. Porosities are altered by recrystallized dolomite, as well as replacement and infilling by anhydrite and calcite. Total porosity ranges from 6 to 22%, with an average of 13%, and permeability is up to 393 millidarcies. Core analyses, in conjunction with thin-section study, log-to-core correlation and construction of structure maps of the pay zone, suggest that dolomitization enhanced porosity, and associated structure closures may be the most effective factors for oil accumulation.

Keywords: *stratigraphy, isopach map, reservoir characterization, Devonian, Duperow Formation, southeast Saskatchewan*

1. Introduction

The Duperow Formation is a Late Devonian (Frasnian) carbonate-evaporite stratigraphic unit that was deposited on an epicratonic platform of the Williston Basin, mostly in Saskatchewan, North Dakota and Montana (Kent, 1968; Dunn, 1975; Wilson and Pilatzke, 1985; McCracken and Kreis, 2003). The Duperow Formation is the oldest stratigraphic unit of the Saskatchewan Group (Figure 1). It is one of the major oil-producing stratigraphic zones in North Dakota, where oil is produced from stratigraphic traps in the central Williston Basin, from structural traps along the Nesson anticline, from combination traps on the Billings anticline, and from unconformity traps on the eastern flank of the Cedar Creek anticline (Altschuld and Kerr, 1982; Pilatzke *et al.*, 1985; North Dakota Government, 2011;

[1] Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, 1000-2103 11th Avenue, Regina, SK S4P 3Z8

North Dakota Geological Survey, 2016). Other than the lowermost 10%, the Duperow Formation in Saskatchewan is laterally equivalent to the Woodbend Group, which includes the hydrocarbon-producing Leduc Formation reefs of the Alberta Basin (Stoakes, 1992; Switzer *et al.*, 1994). Compared to the Leduc Formation reefs in Alberta and the Duperow Formation in North Dakota, there has been a much smaller volume of hydrocarbons produced from Duperow strata in Saskatchewan, which may partly be due to the poor understanding of this play.

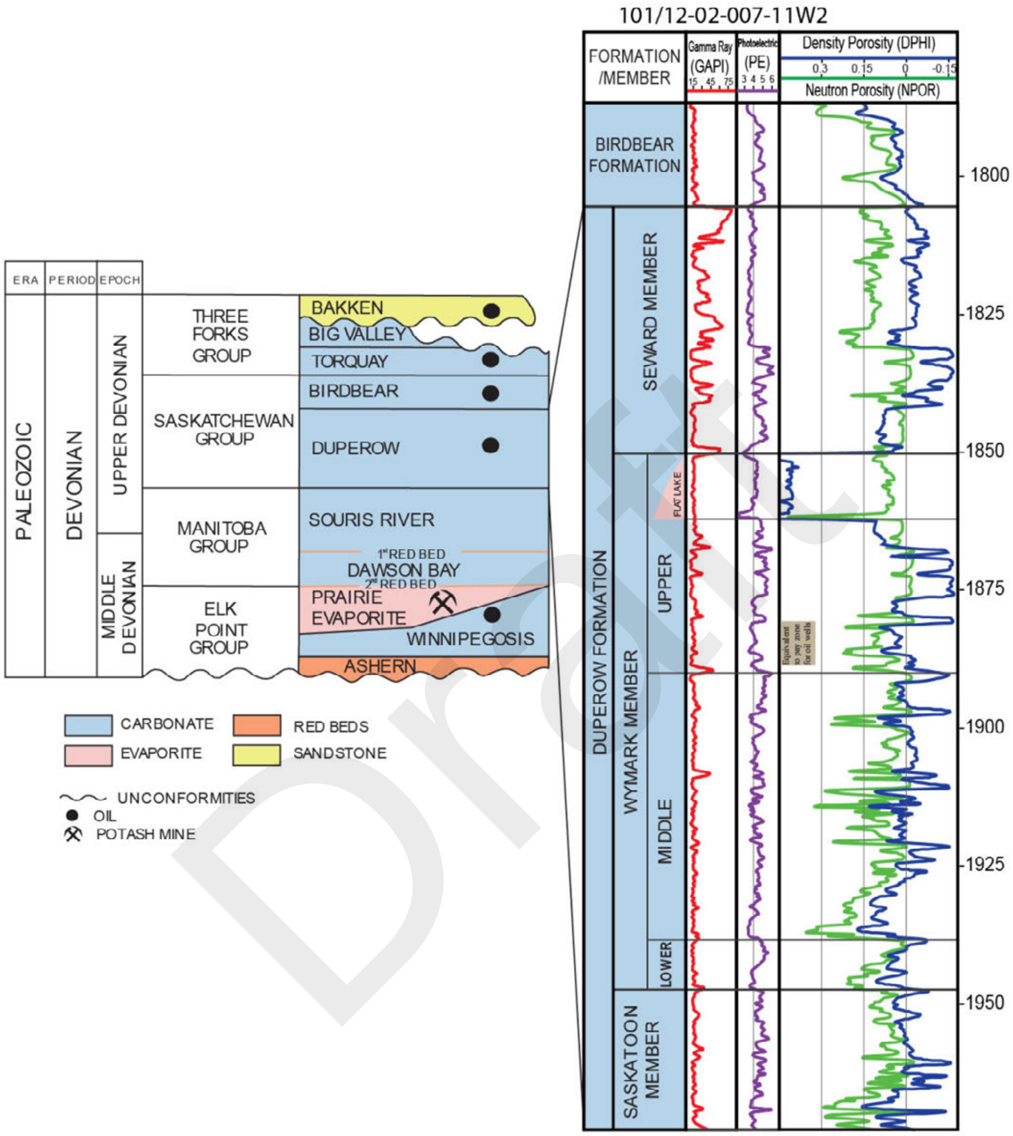

Figure 1 – Devonian stratigraphy of southeastern Saskatchewan, and internal stratigraphy of the Duperow Formation (location of type well, Longview et al Midale 101/12-02-007-11W2; 97H209, is shown in Figure 14).

The objective of this study is to map the members of the Duperow Formation in the study area (Townships 1 to 15, Ranges 1 to 25W2; Figure 2) of southeastern Saskatchewan, and to study reservoir characteristics of the Midale Duperow pool. This study is based on analysis of geophysical well logs for over 800 wells; examination of 5 cores; study of 16 thin sections from 8 wells; and compilation of core analysis data from 140 samples reported in 11 wells. To better understand the spatial distribution of each member, isopach maps were generated based on analysis of their geophysical well-log responses. A list of wells with cores and thin sections examined for this paper are shown in Table 1.

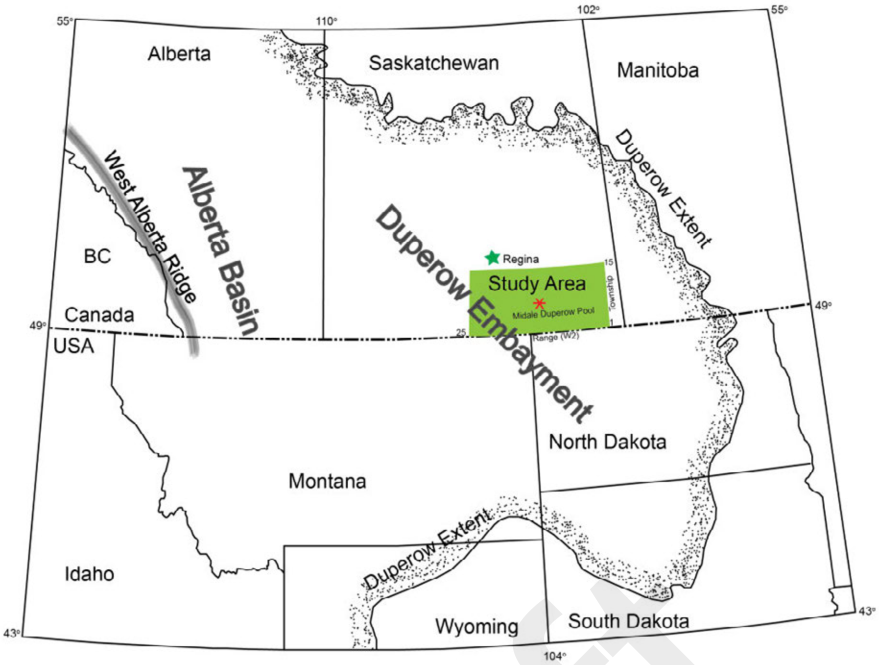

*Figure 2 – Map illustrating the distribution of the Duperow Formation and the geographic setting of the shallow-marine, semi-restricted "Duperow Embayment", a south-southeast-oriented gulf connected to the deeper Alberta Basin in the west, which is edged by the West Alberta Ridge (*modified from *Kissling and Ehrets, 1984; Ehrets and Kissling, 1985; Switzer* et al.*, 1994). The study area is shown as a green rectangle.*

Table 1 – List of cored wells, thin sections and analyzed core used for this study. Well locations are displayed in Figures 11 and 14.

Well ID	Licence Number	Depth of Cored Interval (m)	Oil Well	Core Examined	No. of Thin Sections Examined	No. of Core Analyses Reported
141/14-12-007-11W2	03J253	1855.0 - 1873.0	x	x	5	13
141/15-12-007-11W2	03F509	1856.0 - 1874.0	x	x	3	17
191/05-02-007-11W2	97I258	1880.0 - 1906.2		x	1	12
131/11-12-007-11W2	07B143	1851.0 - 1869.0		x	1	15
101/16-10-003-25W2	52E045	2205.8 - 2243.3 2261.3 - 2318.0		x		
121/09-03-007-11W2	97E084	1877.0 - 1895.0			1	
191/04-02-007-11W2	97I261	1883.4 - 1894.2			2	
101/09-32-007-06W2	85E289	1727.0 - 1745.0			2	
142/13-02-007-11W2	97J138	1880.0 - 1887.0			1	
141/03-08-001-11W2	85B212	2412.5 - 2425.9				8
101/13-03-001-15W2	66E011	2456.7 - 2475.0				24
121/07-29-006-11W2	96J008	1907.0 - 1925.0				4
191/16-34-006-11W2	97I261	1847.8 - 1894.2				10
121/06-33-007-08W2	85G136	1736.0 - 1772.1				2
121/03-11-007-11W2	97K183	1872.4 - 1884.8				6
102/15-28-012-02W2	67F054	1321.0 - 1339.3				29

2. Drilling Activity and Production

Oil has been produced from the Upper Devonian Duperow Formation in southeastern Saskatchewan since 1997. As of December 31, 2015, Duperow Formation reservoirs have yielded 167 x 10^3 cubic metres (m^3) (1 million barrels) of oil from nine wells (Figure 3, Table 2). Eight of these wells are located in the Midale Duperow pool (Township 7, Range 11W2), which was discovered in 1997. The first horizontal well into the Duperow Formation, Longview Midale 191/04-02-007-11W2; 98D042, drilled in 1998, is also the leading producing well in the Duperow Formation, having produced 37 x 10^3 m^3 of oil to the end of December 2015. The Duperow Formation, however, remains underexplored, with only 39 wells perforated in the strata in the study area, although over 800 wells have been drilled through the formation. Although the volume of oil produced from the Duperow is significantly less than that produced from Mississippian beds, the number of wells, especially horizontal wells, drilled into the Duperow Formation plays in southeastern Saskatchewan is considerably less than the number drilled into Mississippian producing horizons (Yang, 2012). This fact highlights the potential for future discoveries of oil in the Upper Devonian Duperow Formation.

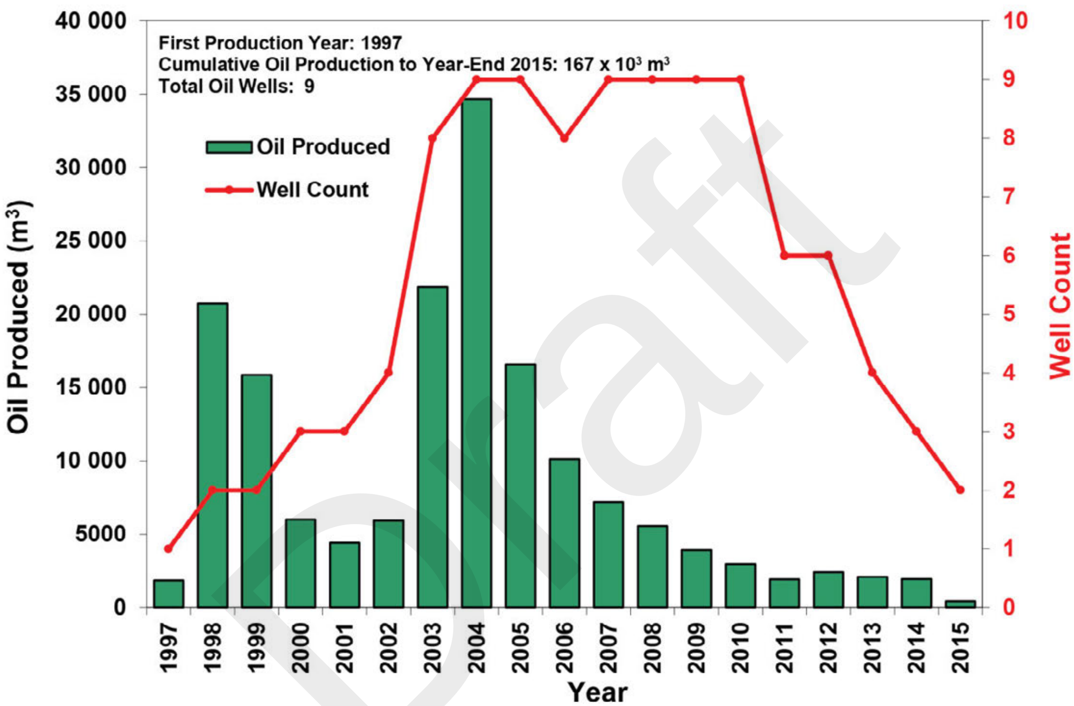

Figure 3 – Duperow Formation oil production and number of oil wells into the formation in southeast Saskatchewan from 1997 to year-end 2015. Note the decline of production in recent years, which is due to the natural decline of oil wells, a lack of new oil wells drilled and the suspension of some oil wells as a result of low oil prices.

Table 2 – List of oil wells producing from the Duperow Formation in southeastern Saskatchewan. Well locations are shown in Figure 14. Susp = suspended, Act = active.

Well ID	Licence Number	Well Name	Cumulative Oil Production (m^3)	Pay Zone Depth (m)	First Year of Production	Well Status
101/07-27-007-06W2	00H085	Northrock Kisbey South Re 7-27-7-6	2298.9	1646.5 - 1716.5	2000	Susp oil well
191/04-02-007-11W2	98D042	Longview et al Midale Hz 4A6-2-1C4-2-7-11	37 369.4	1890.7	1998	Susp oil well
141/13-02-007-11W2	97H209	Longview et al Midale 13-2-7-11	21 784.1	1879 - 1885	1997	Susp oil well

Well ID	Licence Number	Well Name	Cumulative Oil Production (m^3)	Pay Zone Depth (m)	First Year of Production	Well Status
141/14-12-007-11W2	03J253	ARC (Sask) Midale 14-12-7-11	35 851.2	1856.5 - 1863	2003	Act oil well
141/15-12-007-11W2	03F509	ARC (Sask) Midale 15-12-7-11	24 052.1	1860 - 1866.5	2003	Act oil well
132/02-13-007-11W2	02I016	Bison Midale 2-13T-7-11	16 624.7	1857.3 - 1865	2002	Susp oil well
111/03-13-007-11W2	03K198	Bison Midale 3-13T-7-11	9431.9	1856 - 1863	2003	Susp oil well
191/06-13-007-11W2	04A149	Bison Midale Hz 2B2-13-4B6-13-7-11	8105.6	1859	2004	Susp oil well
191/08-13-007-11W2	03B263	Bison Midale 4Hz 6A2-13-2B8-13-7-11	10 801.6	1860.1	2003	Susp oil well

3. Stratigraphy and Lithology

Duperow Formation strata record a rhythmic shallowing-upward or brining-upward sedimentation from normal-marine subtidal carbonates to restricted supratidal dolomudstone and evaporite (Wilson, 1965; Dunn, 1975; Ehrets and Kissling, 1985; Wilson and Pilatzke, 1985; Cen and Hersi, 2006a, 2006b; Cen, 2009; Eggie *et al.*, 2012). The Duperow Formation was deposited in a south-southeast-oriented shallow-marine inner platform embayment setting that extended southeasterly from southeastern Saskatchewan and western Manitoba, beyond the Canada–US border into North Dakota, South Dakota and eastern Montana (Figure 2). To the northwest, the embayment is connected to the Alberta Basin, where the Duperow Formation transitions into reefs and open-marine carbonates (Kissling and Ehrets, 1984; Ehrets and Kissling, 1985).

In southeastern Saskatchewan, the Duperow Formation is conformably underlain by the Souris River Formation and overlain by the Birdbear Formation (Figure 1; Dunn, 1975; Cen and Hersi, 2006a). The thickness of the Duperow Formation within the study area ranges from 112 to 233 m. The Duperow Formation is subdivided into, in ascending order, the Saskatoon, Wymark and Seward members. The Wymark Member is further informally subdivided into lower, middle and upper units, and the Flat Lake Evaporite (Kent, 1968, 1984, 1998; Cen and Hersi, 2006a, 2006b; Cen, 2009).

Based on analysis of geophysical well logs, and examination of core and thin sections, each member of the Duperow Formation consists of rhythmic layers of sedimentation that contain laterally extensive carbonates and evaporites. The boundaries between the members can best be recognized on gamma ray logs, as in Figure 1, where there is an abrupt change from around 15 API to between 40 and 70 API at the contact between each member. In core, the contacts between members are commonly placed between the base of a mudstone or argillaceous limestone/dolomudstone and the top of halite, or anhydrite, or anhydrite interlayered with dolostone.

a) Saskatoon Member

In the study area, the Saskatoon Member consists of several incomplete to complete lithological cycles that contain, in ascending order, massive to mottled argillaceous dolomudstone (Figure 4A); bioclastic (skeletal) wacke-packstone (Figure 4B); peloidal wackestone; and dolostone interbedded with nodular to thinly bedded anhydrite. Diverse fauna, including brachiopods, bivalves, corals, crinoids, algae and rare stromatoporoids, are observed in the bioclastic (skeletal) wacke-packstone. The isopach map of the Saskatoon Member (Figure 5) shows a regional thickening in a northwestward direction. The thickness of the Saskatoon Member ranges mostly from 15 to 37 m, with an average of 24.8 m. It is over 50 m thick locally in Township 2, Range 15W2.

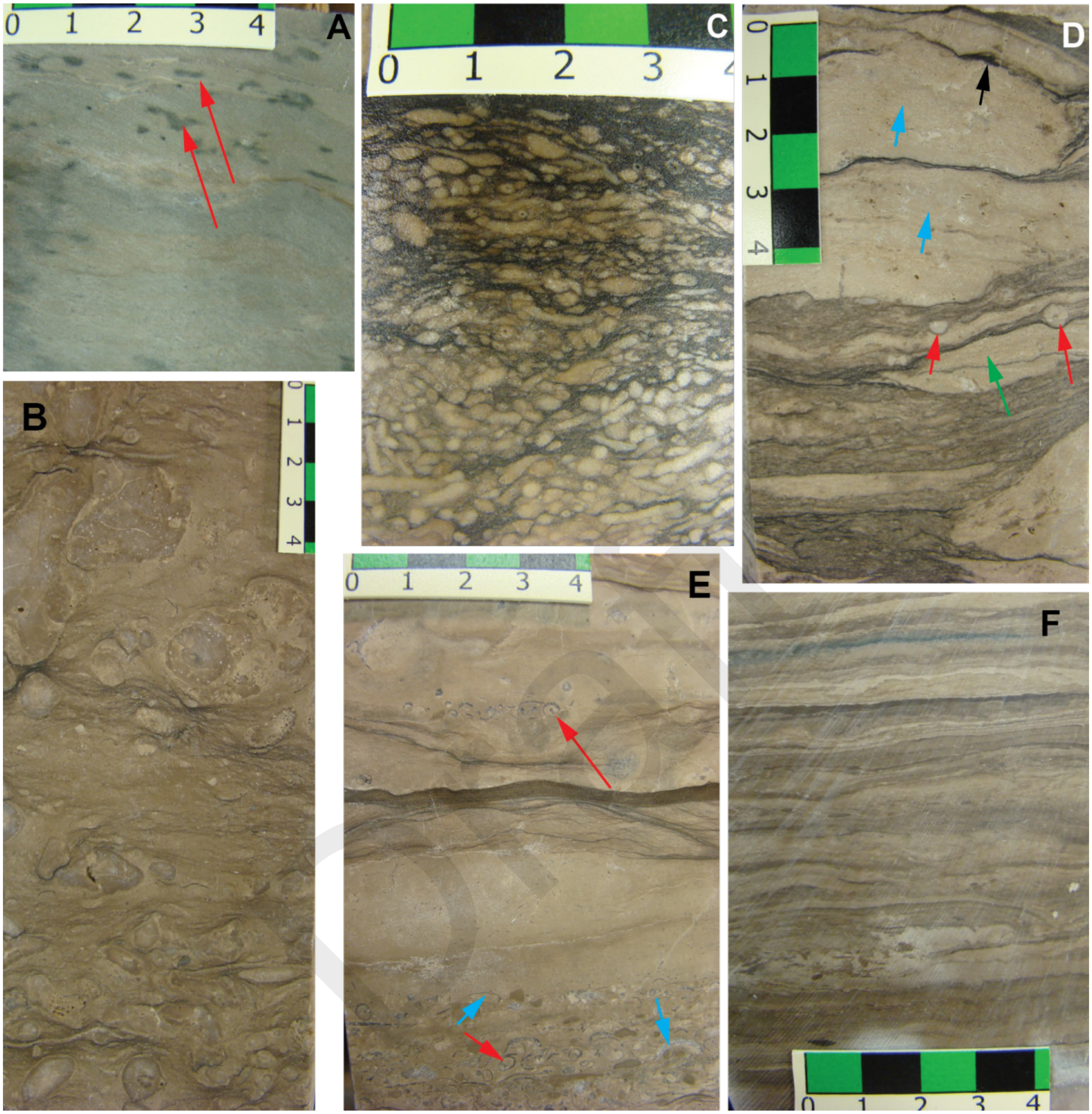

*Figure 4 – Core photographs of representative lithologies from the Duperow Formation, well Sohio Standard Gap No. 1 101/16-10-003-25W2; 52E045. Photos A and B are of the Saskatoon Member; photos C, D, E and F are of the Wymark Member. The scale in all photos is in centimetres. A) Mottled (red arrows) argillaceous dolomudstone (at depth 2315.7 m). B) Bioclastic (skeletal) wacke-packstone (at depth 2306.5 m). C) Stromatoporoid (*Amphipora*) boundstone (at depth 2282.4 m). D) Packstone with stromatoporoids (blue arrows), corals (green arrow), crinoids (red arrows), and algae (black arrow) (at depth 2283.9 m). E) Wackestone with bivalves (blue arrows) and gastropods (red arrows) (at depth 2241.0 m). F) Dolostone interbedded with nodular to thinly bedded anhydrite (at depth 2273.2 m).*

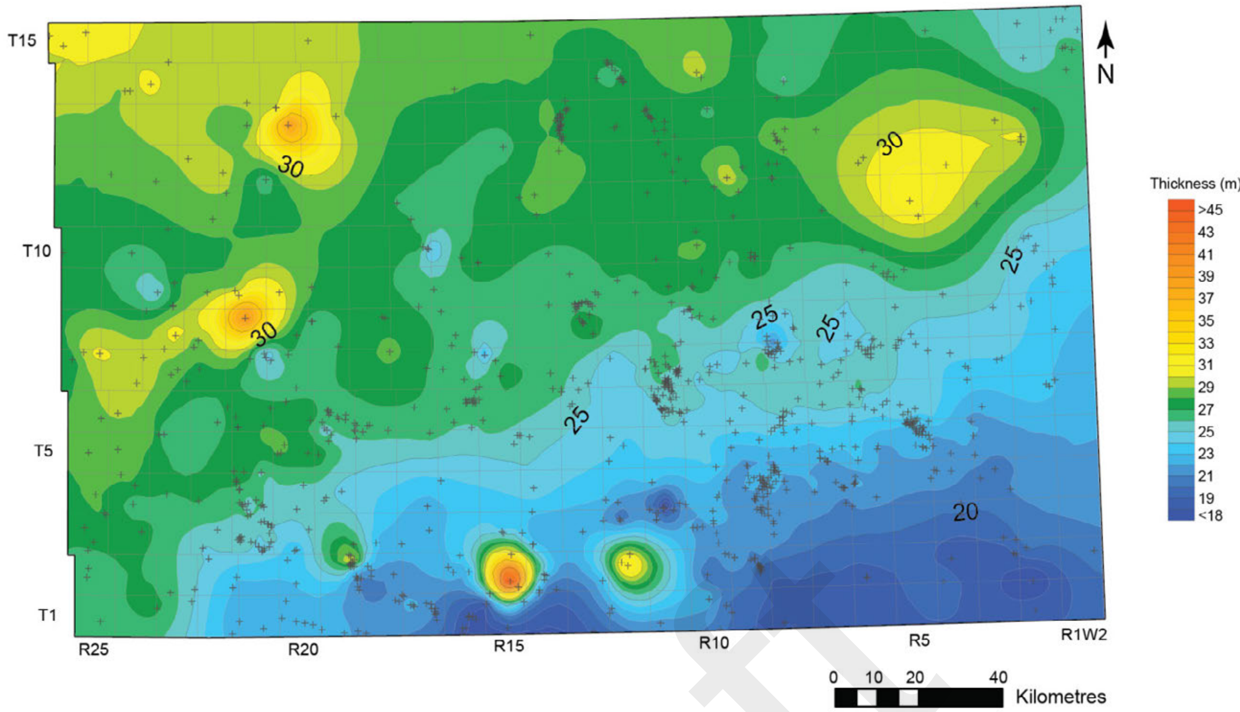

Figure 5 – Isopach map of the Saskatoon Member. T = Township, R = Range, '+' symbols show locations of wells in the study area. Contour interval is 1 m.

b) Wymark Member

The lower unit of the Wymark Member contains one complete brining-upward lithological succession that is dominated by bioclastic (skeletal) wacke-packstone and stromatoporoid boundstone (Figure 4C) underlain by argillaceous dolomudstone and overlain by laminated anhydrite. Stromatoporoids (*Amphipora*) and corals are common. The thickness of the lower Wymark unit ranges from 7 to 19 m, with an average of 9.9 m, and generally thins to 5 m toward the southeast (Figure 6), with sections over 40 m thick in Township 2, Range 12W2 and Townships 7 to 8, Ranges 23 and 24W2.

The middle unit of the Wymark Member is characterized by rhythmic complete to incomplete lithological successions. The lithology of a complete succession changes from argillaceous dolomudstone to bioclastic (skeletal) wacke-packstone, to dolostone and anhydrite beds. The lower half of this unit contains more bioclasts than the upper half of the unit. These are made up of diverse fauna, including stromatoporoids (*Amphipora*), brachiopods, bivalves, corals, crinoids, gastropods and algae (Figure 4D). The upper half contains mostly beds of oolitic and peloidal wackestone with limited bivalve and gastropod fossils (Figure 4E). Anhydrite beds are layered anhydrite or interlayered anhydrite and dolostone (Figure 4F), ranging from 0.5 to 2 m in thickness. The thickness of the middle Wymark unit ranges from 30 to 74 m, with an average of 49.6 m and an exception of 90 m in Township 2, Range 19W2 (Figure 7).

The upper unit of the Wymark Member is composed of several incomplete to complete brining-upward cycles. A complete cycle consists of, in ascending order, dark grey argillaceous dolomudstone or mudstone (Figure 8A); laminated argillaceous limestone or dolostone (Figure 8B); partially or fully dolomitized bioclastic (skeletal) and peloidal wackestone with low fossil diversity (brachiopods, corals and bivalves; Figures 8C to 8E); laminated crystalline dolostone; and anhydrite beds (Figures 8F and 8G), or halite beds where Flat Lake Evaporite exists. The stratigraphy and lithology of this unit are summarized in Figure 9.

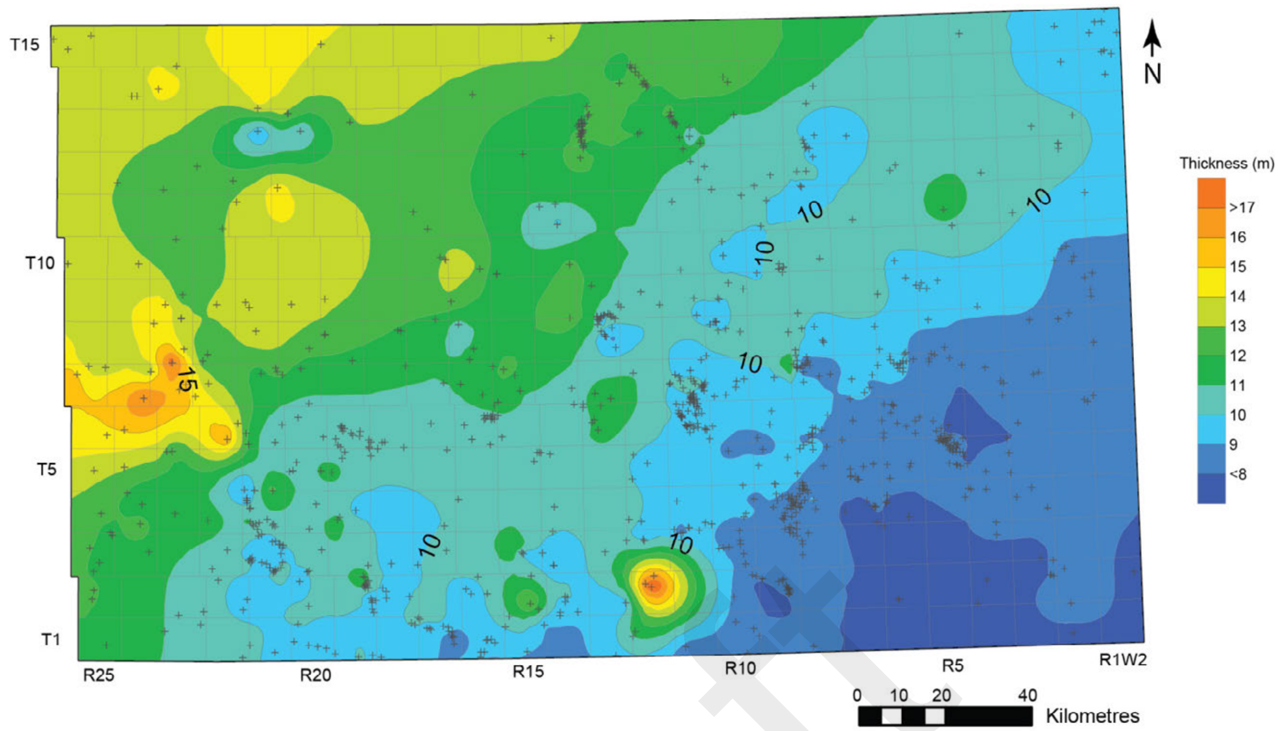

Figure 6 – Isopach map of the lower unit of the Wymark Member. T = Township, R = Range, '+' symbols show locations of wells in the study area. Contour interval is 1 m.

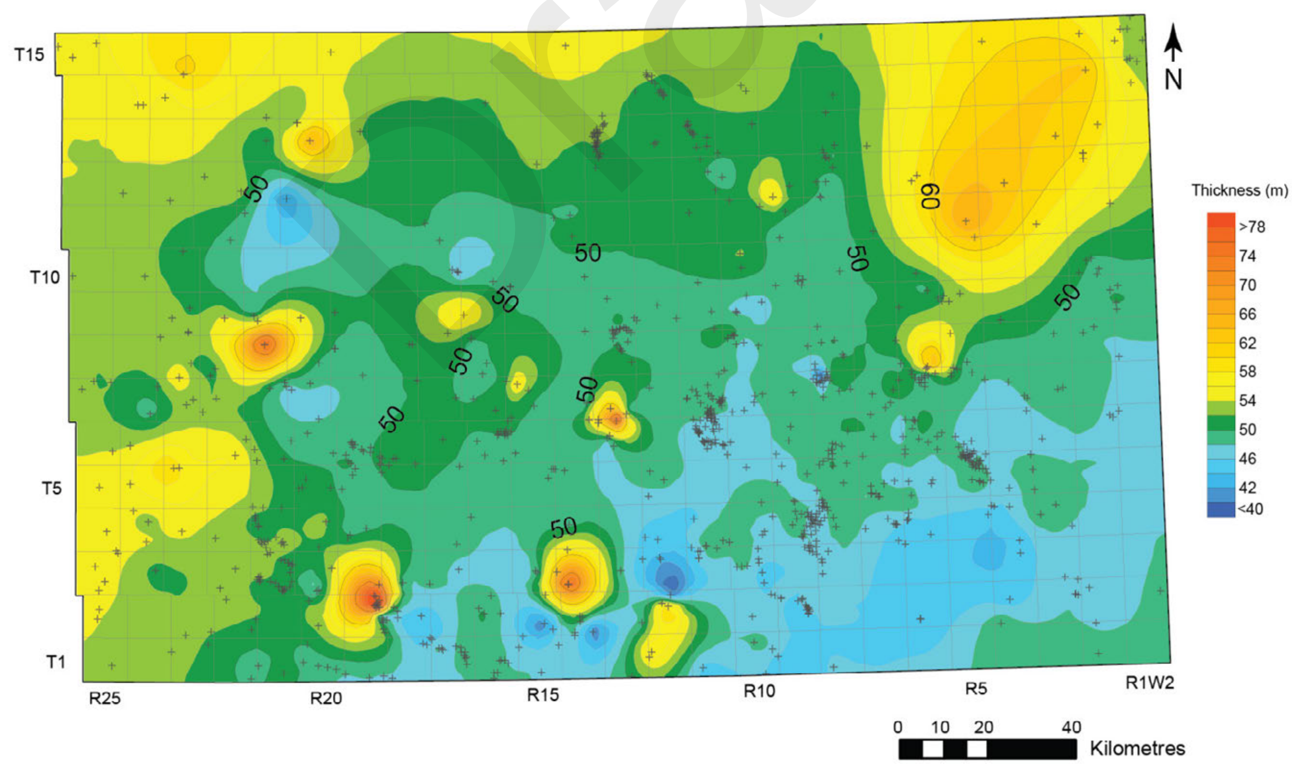

Figure 7 – Isopach map of the middle unit of the Wymark Member. T = Township, R = Range, '+' symbols show locations of wells in the study area. Contour interval is 2 m.

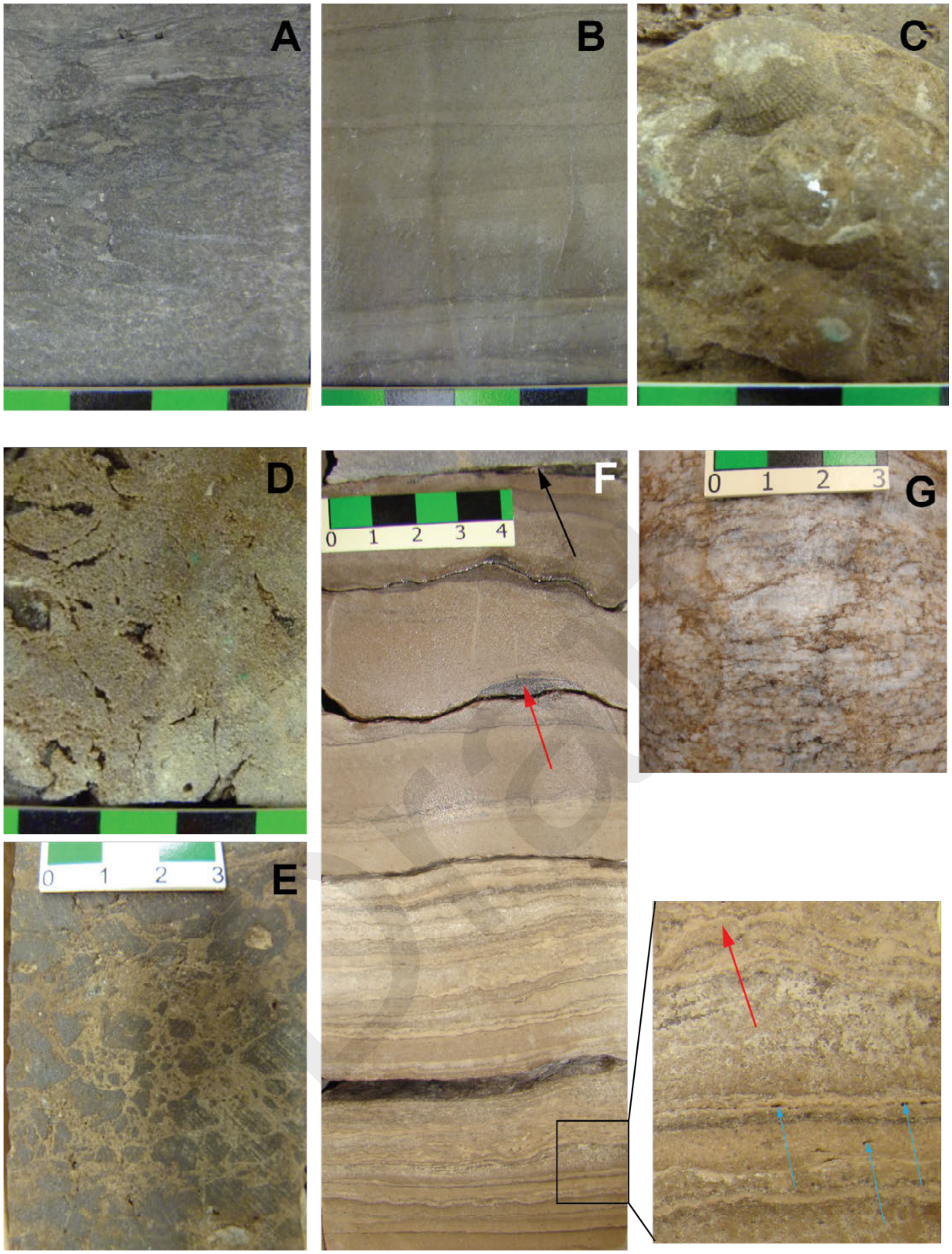

Figure 8 – Core photographs of the upper unit of the Wymark Member of the Duperow Formation. The scale in all photos is in centimetres. Photos A to F are taken from well ARC (Sask) Midale 141/14-12-007-11W2; 03J253. A) Mudstone at a depth of 1865.95 m. B) Laminated argillaceous very fine- to fine-crystalline dolostone, at a depth of 1865.3 m. C) Fossiliferous dolowackestone with brachiopods, at a depth of 1862.5 m. D) Fossiliferous dolowackestone, at a depth of 1860.75 m, showing selective dissolution of fossil fragments and the dissolution vugs partially or fully filled by anhydrite. E) Bioturbated dolowackestone, at a depth of 1859.5 m. The fully dolomitized wackestone with limited fossil diversity (photos C to E) suggests a relatively restricted intertidal depositional environment. F) Transition from algal laminated fine- to medium-crystalline dolostone with algal domes (red arrows) and bird's-eye voids (blue arrows) to anhydrite beds (black arrow), suggesting depositional environments from lower supratidal algal mat to upper supratidal sabkha. Photo taken at 1857.5 m depth. G) Nodular chicken-wire anhydrite. Sample location: well ARC (Sask) Midale 141/15-12-007-11W2; 03F509, at a depth of 1860.0 m.

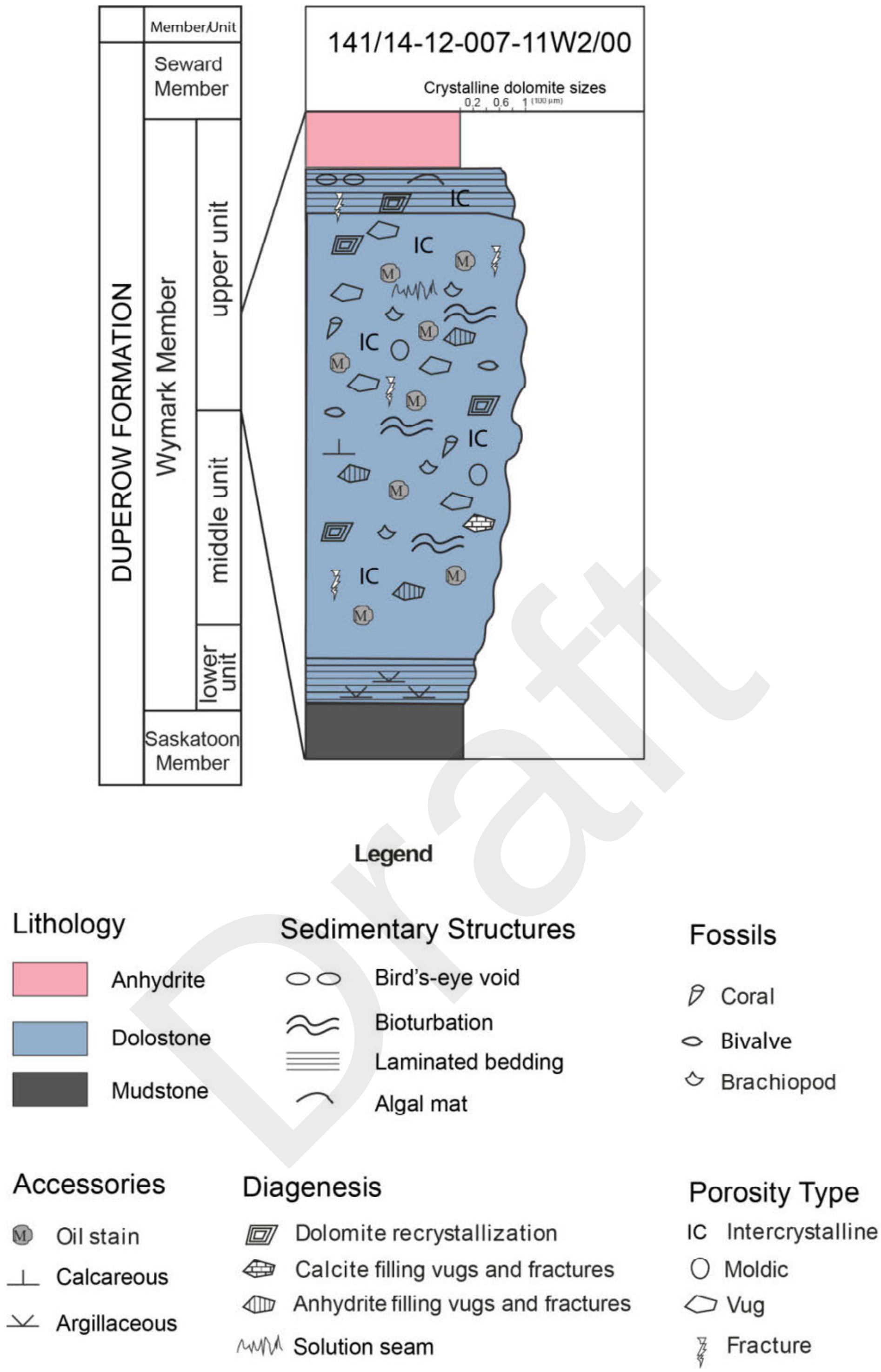

Figure 9 – Stratigraphic column showing a typical complete lithology sequence from the upper unit of the Wymark Member. Note that oil is produced from the oil-stained intervals in the middle part of the sequence.

The upper Wymark unit ranges in thickness from 20 to 61 m, with an average of 33.6 m (Figure 10). The thickest areas on the isopach map are associated with the occurrence of the Flat Lake Evaporite, that is, in the areas of Townships 1 to 15, Ranges 8 to 19W2, and Townships 3 to 7, Ranges 21 to 25W2 (Figure 11). The thickness of the Flat Lake Evaporite ranges from 1 to 30 m.

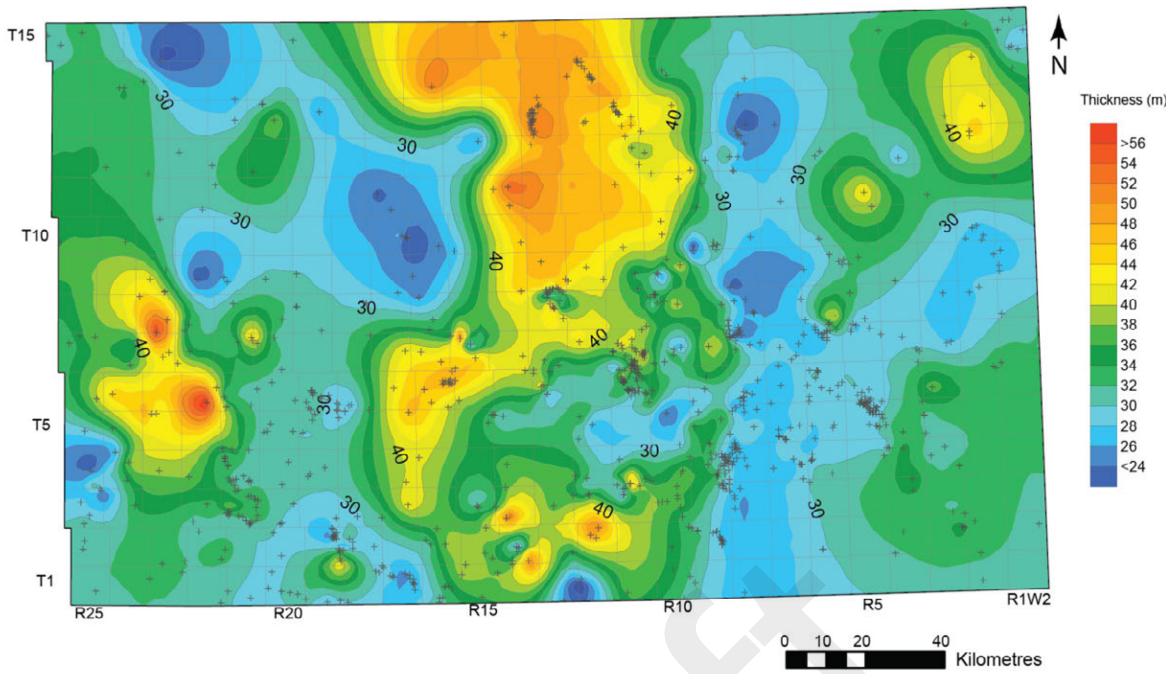

Figure 10 – Isopach map of the upper unit of the Wymark Member. T = Township, R = Range, '+' symbols show locations of wells in the study area. Contour interval is 2 m.

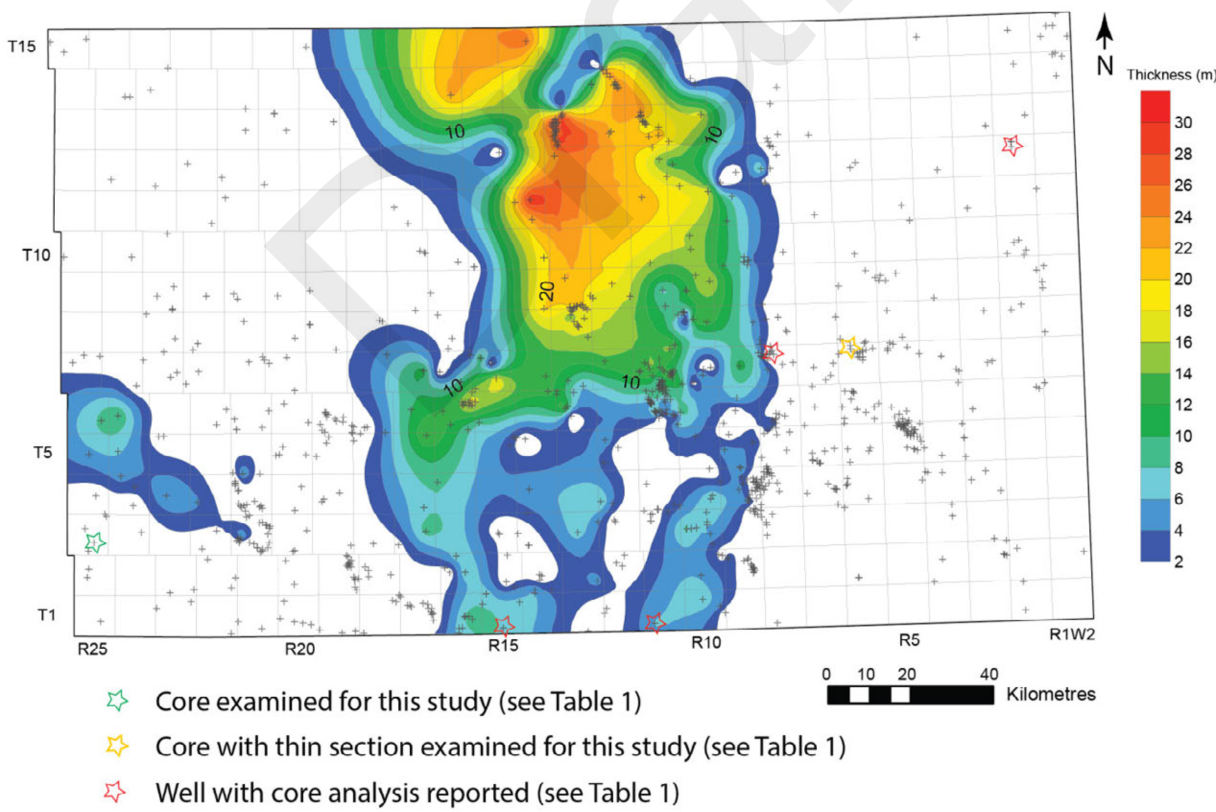

Figure 11 – Isopach map of the Flat Lake Evaporite. T = Township, R = Range, '+' symbols show locations of wells in the study area. Contour interval is 2 m.

c) Seward Member

The Seward Member, which is conformably overlain by the Birdbear Formation, is argillaceous. It is dominated by bioclastic and peloidal wackestone/packstone, dolomudstone and argillaceous dolostone. Fossils are limited to brachiopods, gastropods, bivalves and crinoids. The lower half of the Seward Member contains more anhydrite than the upper half. The thickness of the Seward Member ranges from 31 to 67 m, with an average of 46.2 m (Figure 12).

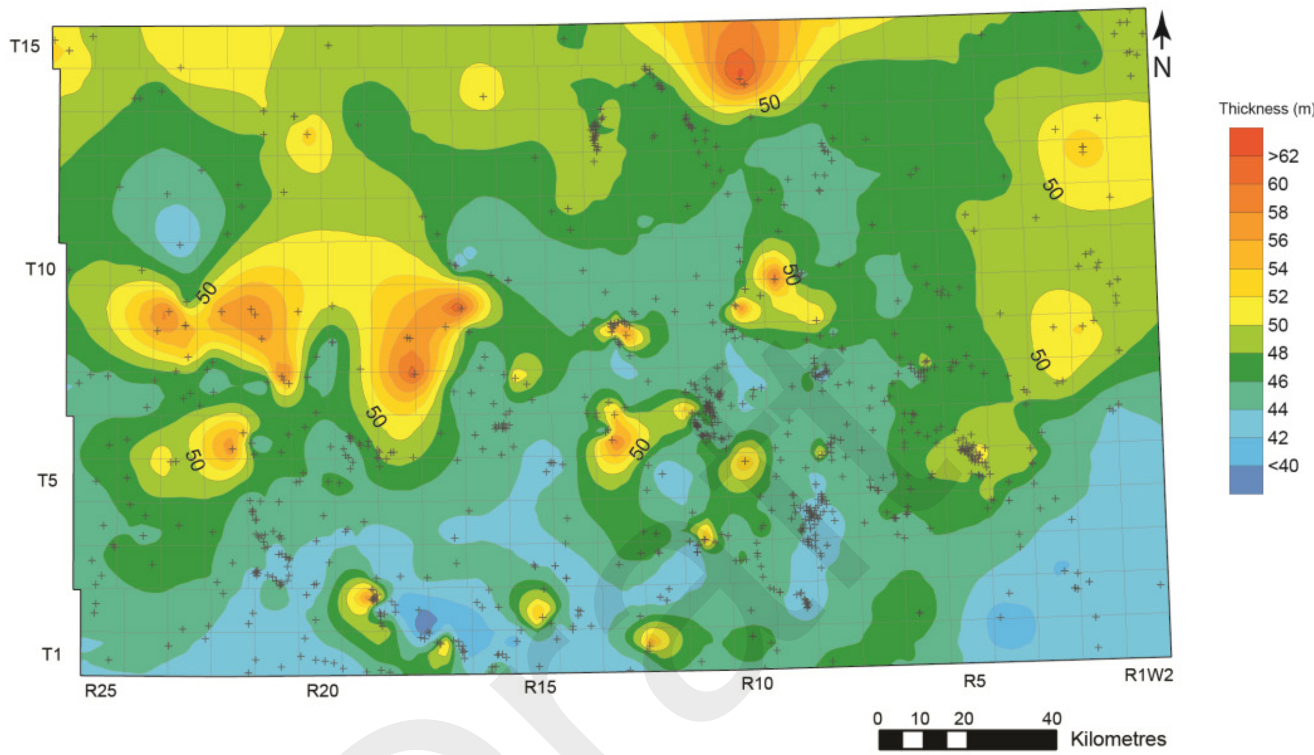

Figure 12 – Isopach map of the Seward Member. T = Township, R = Range, '+' symbols show locations of wells in the study area. Contour interval is 2 m.

4. Petrology, Diagenesis and Reservoir Characterization of the Midale Duperow Pool

Duperow Formation oil is primarily produced from dolomitized wackestone in the upper unit of the Wymark Member, which, in the Midale Duperow pool (Township 7, Range 11W2; see Figure 2) of southeast Saskatchewan, ranges in depth from 1856 to 1891 m. Duperow Formation oils are generally sweet light oil with low API gravities of 39 to 43° API, and low sulphur contents of 0.2 to 0.4%. Pour point values for Duperow Formation oil range from -60 to -33°C. Detailed core examination and log-to-core correlations from the area show that the pay zone occurs in the middle part of the first sedimentation cycle of the upper Wymark unit (Figure 13). The dolomitized wackestone and medium-crystalline dolostone in this portion of the unit (Figures 8C to 8E) are the major reservoir rocks in the Midale Duperow pool, with porosities ranging from 6 to 22% (average of 13%), and permeability ranging from 2 to 393 millidarcies (mD) (average of 93 mD). The reservoir rocks of the Duperow Formation are capped by non-permeable anhydrite beds. The structure map for the top of the pay zone in the Midale pool area (Figure 14) shows the association of oil accumulation with small-scale structural closures.

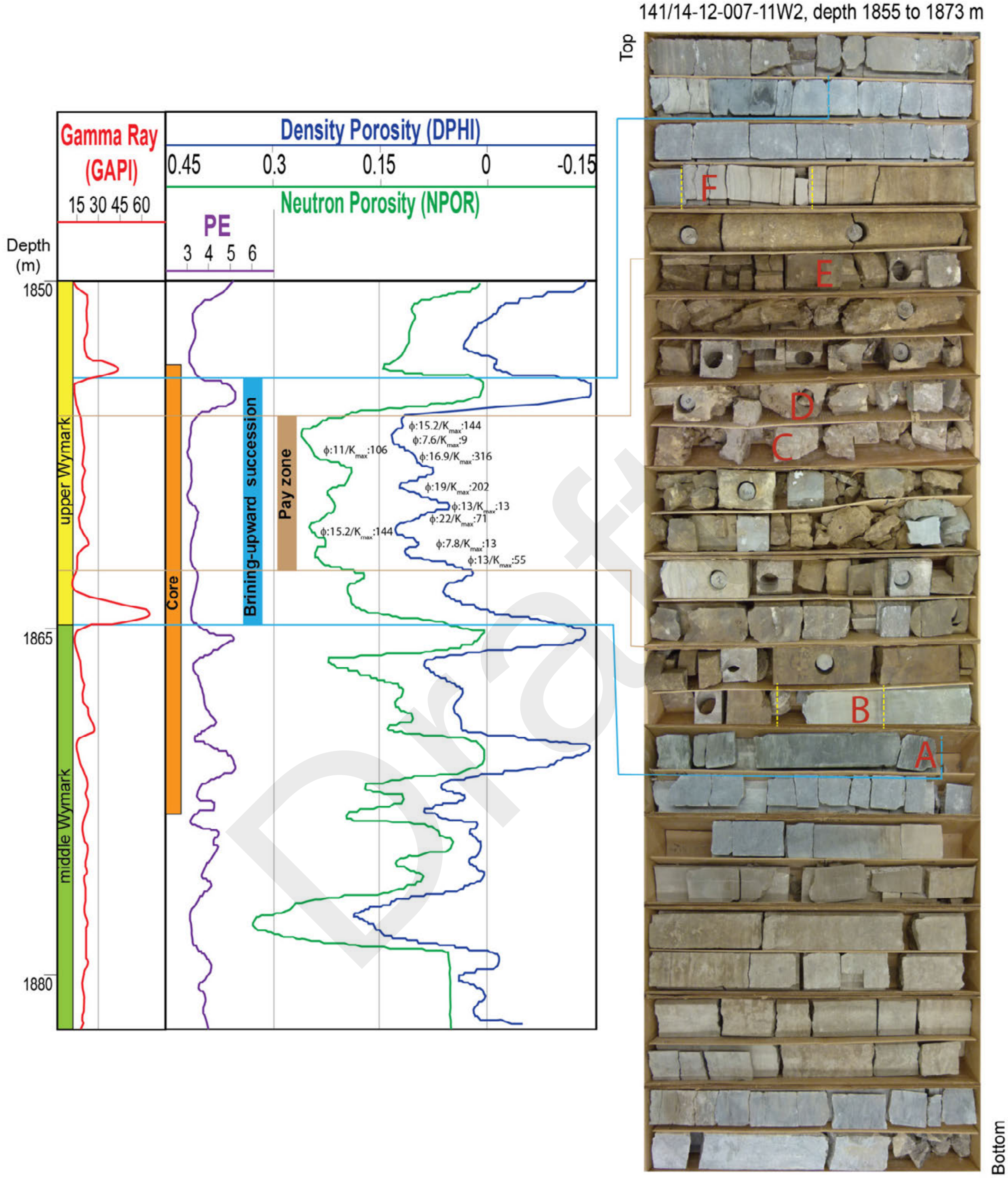

Figure 13 – Log and core correlation of the top 8 m of the middle unit of the Wymark Member and the lowermost 10 m of the upper unit of the Wymark Member of the Duperow Formation in well ARC (Sask) Midale 141/14-12-007-11W2; 03J253 (location shown in Figure 14). In 2003, this well was drilled into the Duperow Formation to a depth of 1900.9 m. The Wymark Member was partially cored in this hole from 1855 to 1873 m. To September 30, 2015, the well had a cumulative oil production of 35 851.2 m^3 (22 503 barrels) from the perforated interval between 1856.5 and 1863.0 m. Porosity (8 to 22%, average of 13.5%) and permeability (9 to 320 mD, average of 106 mD) data are taken from core analyses. Close-up photographs at core locations A to F are shown in Figures 8A to 8F, respectively. PE = photoelectric log, Φ = porosity, K_{max} = maximum permeability.

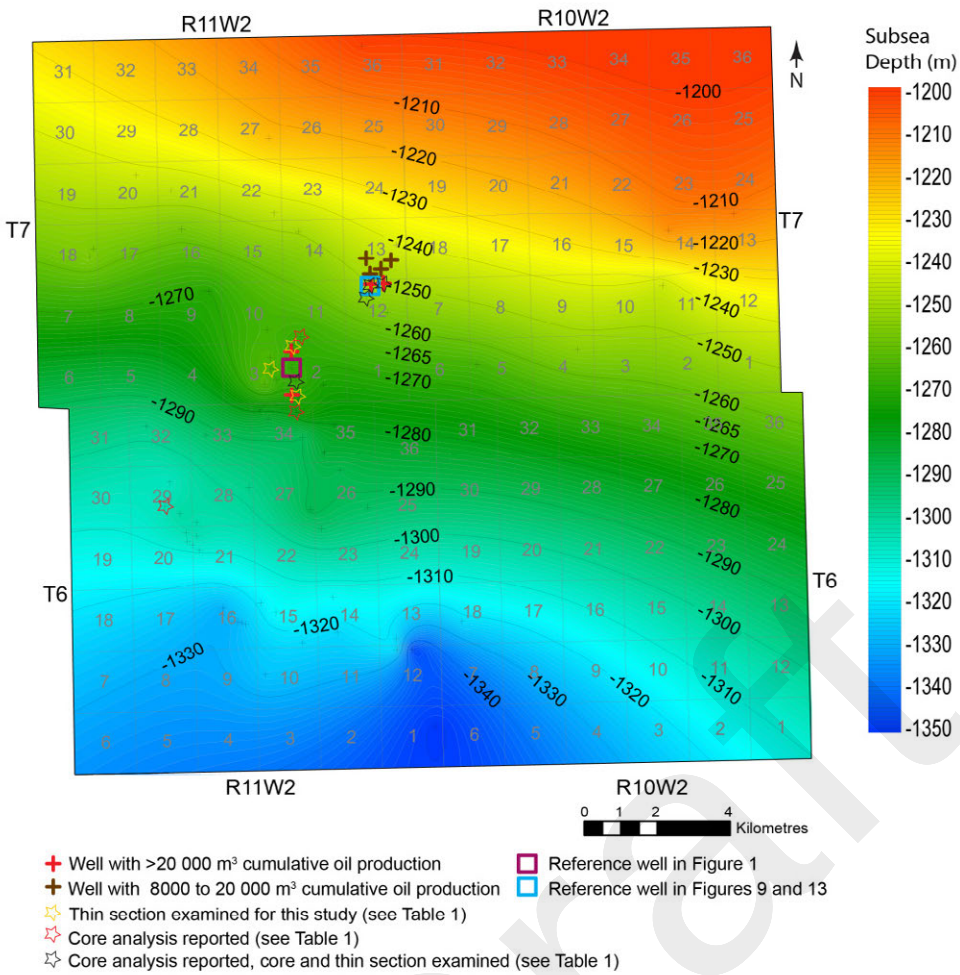

Figure 14 – Structure map of the top of pay zone in the upper unit of the Wymark Member. Note the association of oil-producing wells with small-scale structural closures. T = Township, R = Range, '+' symbols show locations of wells in the study area. Contour interval is 1 m.

Analysis of photoelectric (PE) geophysical well logs shows that oil-producing wells have a PE value of approximately 3 in the pay zone of the upper Wymark unit (Figure 13) and non-producing wells have PE values between 3.5 and 5 at a corresponding stratigraphic interval (see Figure 1), suggesting that dolomitization is more intensive in producing areas. The replacement of calcite by dolomite is also confirmed by thin-section examination within Duperow Formation reservoir rocks of the Midale Duperow pool. Oil-producing wells have better porosity in crystalline dolostones (Figure 15A) and dolomitized wacke-packstone (Figure 15B) where dolomite has replaced calcite. The pervasive dolomitization is thought to have occurred in the early stage of diagenesis, possibly shortly after burial (Kissling, 1982) and significant intercrystalline porosity was created during dolomitization. Solution seams are common (Figure 15C), suggesting solution compaction during burial processes. Locally, intercrystalline porosity has been enhanced by dolomite dissolution to form vuggy porosity where the pores are much larger than the surrounding crystals (Figure 15D). Dissolution is considered to have occurred in the meteoric environment (Cen, 2009) as a result of an influx of fresh groundwater during the latest Mississippian to the Middle Triassic, when the basin was subjected to uplift and erosion. Vuggy porosity was reduced by dolomite recrystallization, indicated by late-stage, larger euhedral dolomite crystals growing into the available vuggy pore space (Figure 15D). During a later stage of diagenesis, some solution-enlarged intercrystalline, vuggy, moldic and fracture porosity was reduced by precipitation of anhydrite (Figures 15D and 15E) or, locally, calcite (Figure 15E) and halite, as observed in cores. Hydrocarbon residue fills intercrystalline porosity between dolomite crystals (Figure 15F), suggesting oil migration postdated dolomitization. These diagenetic features strongly influence porosity and permeability and thus play a very important role in the variability of reservoir quality. The major diagenetic events, their effects on reservoir porosity and permeability are summarized in Table 3.

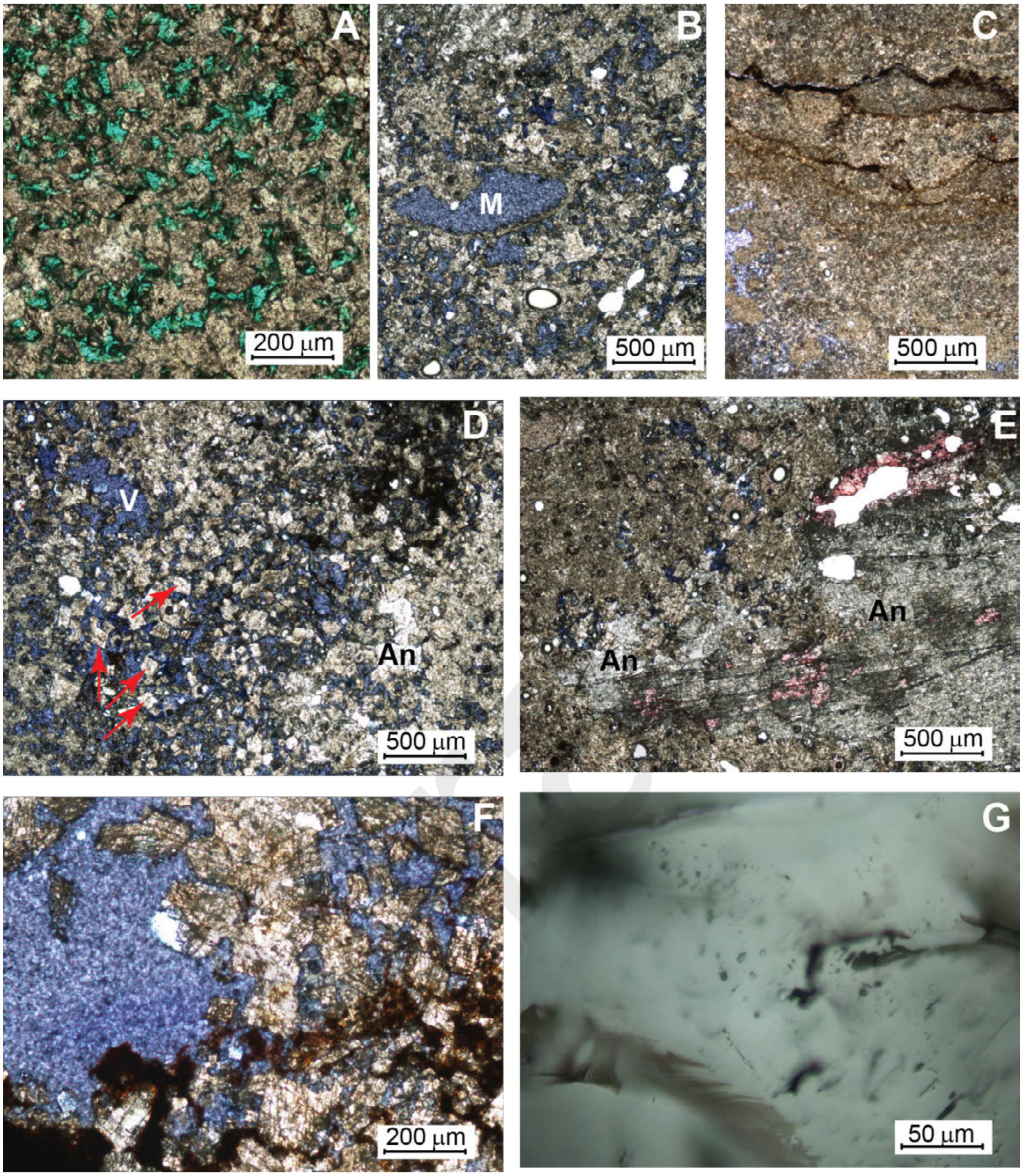

Figure 15 – Thin section photographs showing the types of porosity in Duperow Formation reservoir rocks, and the effects of diagenesis on the porosity. Porosity is shown in blue or green. A) Intercrystal porosity in fine- to medium-crystalline dolostone. Note anhedral to euhedral dolomite crystals. Sample location: Longview et al Midale 142/13-02-007-11W2; 97J138, at a depth of 1880.8 m. B) Moldic porosity (M) generated by partial dissolution of the fossil debris in dolomitized wackestone. Sample location: ARC (Sask) Midale 141/14-12-007-11W2; 03J253, at a depth of 1863.6 m. C) Solution seams, at a depth of 1857.83 m, from the same well as B. D) Vuggy porosity (V) where the pores are larger than the surrounding crystals. Vuggy porosity created by dissolution was reduced by dolomite recrystallization. Note the early-stage dolomite crystals are mostly anhedral or subhedral, but late-stage dolomite crystals growing into the available vugs are euhedral in shape and larger in size (red arrows). The oversized pore in the centre right of the photo is filled by anhydrite (An). Same sample location as B. E) Vuggy porosity created by dissolution was reduced by late-stage calcite (pink) and anhydrite (An). Same sample location as B. F) Hydrocarbon residue fills some of the pore space between the dolomite crystals, indicating oil emplacement postdated dolomitization. Sample location: ARC (Sask) Midale 141/15-12-007-11W2; 03F509, at a depth of 1866.0 m. G) Fluid inclusions in anhydrite cement, at a depth of 1859.1 m, from same well as B.

Table 3 – The major diagenetic events in the Duperow Midale pool area, and their effects on reservoir porosity and permeability.

Major Diagenetic Event	Timing	Effect on Porosity and Permeability	Characterization
Dolomitization	Shortly after burial	Increased porosity due to formation of intercrystalline pore space	Massive dolomitization altering original depositional fabrics
Compaction	During burial	Reduced porosity	Solution seams
Dissolution	Pre-Cretaceous uplift and erosion	Increased porosity and permeability due to formation of molds, vugs, fractures	Molds, large-size pores, vugs and fractures
Dolomite recrystallization	Reburial	Decreased porosity and permeability by reducing pore space and blocking pore throats	Larger-size euhedral dolomite crystals growing into vugs
Calcite, anhydrite and halite cementation	Reburial	Decreased porosity and permeability by reducing pore space and blocking pore throats	Vug-filling calcite, anhydrite and halite

Fluid inclusions are observed in thin section in anhydrite cement (Figure 15G), however, fluid inclusion microthermometry study is required to obtain temperature, pressure and fluid composition information of anhydrite precipitation.

5. Summary of Core Analyses

A total of 140 core analyses reported from 11 wells in the study area (2 oil-producing wells and 9 non-producing wells; Table 1) were used to examine the characteristics of rock properties—including porosity, permeability and grain density—of all three members of the Duperow Formation. Figure 16A is a plot of maximum permeability *versus* porosity for all 140 reported core analyses. The porosity values for both oil-producing and non-producing wells are highly variable, ranging from 0.2 to 22%, with an average of 9.5% (Figure 16A). Most (83%) of the maximum permeability values are between 0.01 and 100 mD, with an average of 70 mD and a maximum of about 400 mD. Oil-producing wells have a minimum porosity of 5%. There is no distinguishable difference between oil-producing wells and non-producing wells for the maximum permeability.

A plot of horizontal *versus* vertical permeability (Figure 16B) shows that oil-producing wells have better vertical permeability than horizontal permeability, while non-producing wells have better horizontal permeability than vertical permeability. The vertical fractures may contribute to improvement of connectivity for migration of dolomitization fluid, development of dissolution vugs and accumulation of hydrocarbons.

Grain density values range from 2575 to 2865 kg/m^3, and show a general trend of increasing grain density with increasing porosity (Figure 16C). All grain density values from the core in this study are lower than that of anhydrite (2950 kg/m^3), implying that there is limited anhydrite within these samples. Grain density values lower than the standard densities of pure limestone (2710 kg/m^3) and sandstone (2610 kg/m^3) may be caused by the presence of lower density organic materials and halite, which are observed in the cores. The cores from oil-producing wells have grain densities ranging from 2750 to 2850 kg/m^3, which are within the range for pure calcite (2710 kg/m^3) to pure dolomite (2870 kg/m^3), suggesting that the reservoir rocks are composed of dominantly calcite and dolomite, and the percentage of dolomite increases with increasing grain density toward that of pure dolomite.

Dolomitization has improved the reservoir porosity, as shown by an obvious correlation between grain density and porosity (Figure 16C). This finding agrees with the thin-section observations discussed above.

Figure 16D shows an excellent correlation between porosity and bulk density for samples from the oil-producing wells. This relationship could be significant, and potentially useful for calculating porosity using bulk density measurements from geophysical well logs when core analysis is not available.

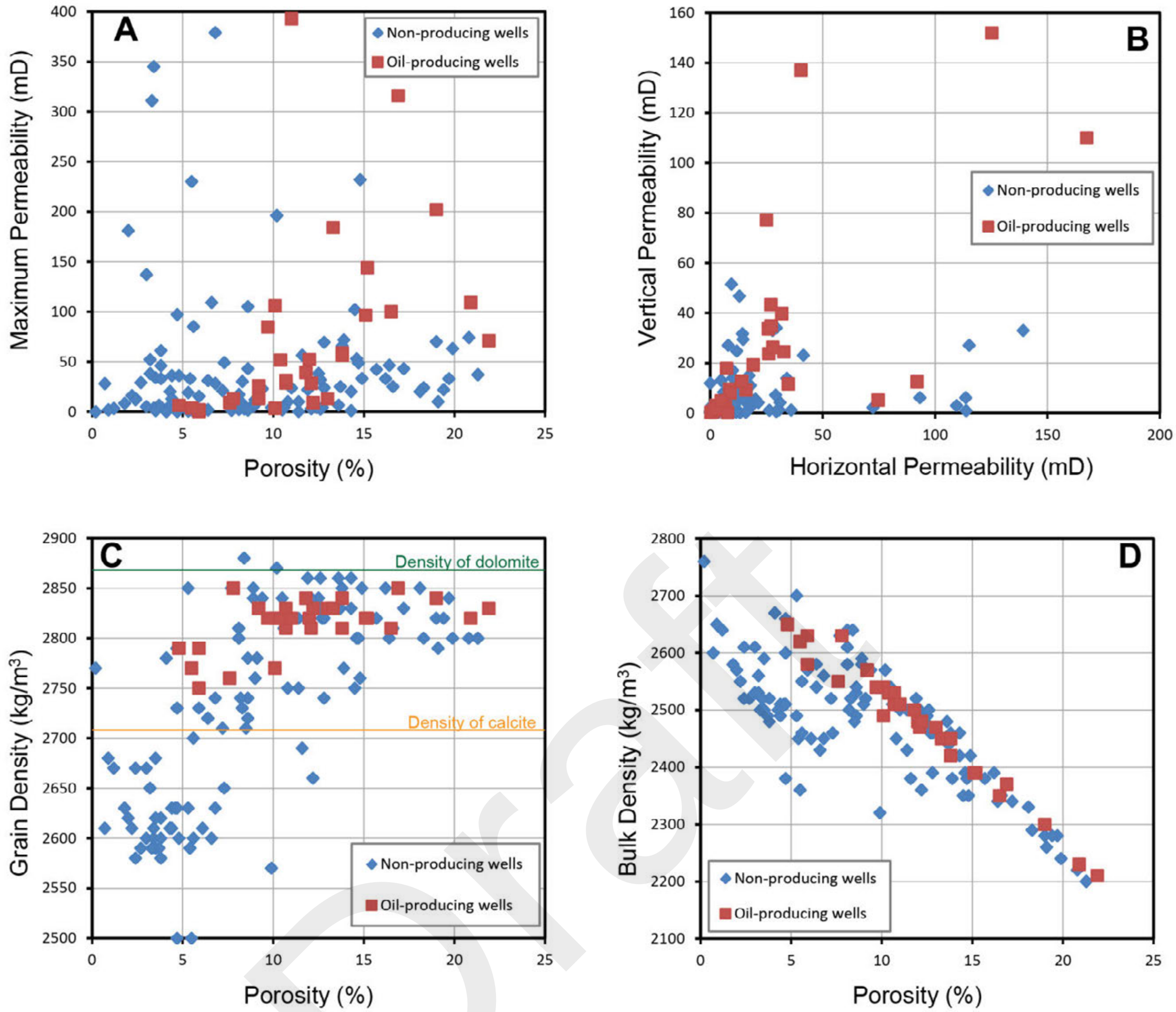

Figure 16 – Comparison of rock properties for oil-producing and non-producing wells in the Duperow Formation, based on reported core analyses of 140 samples from 11 cored wells in the study area: ***A)*** *porosity (%)* vs *maximum permeability (millidarcies (mD));* ***B)*** *horizontal permeability (mD)* vs *vertical permeability (mD);* ***C)*** *porosity (%)* vs *grain density (kg/m^3): note that the porosity increases with increasing grain density;* ***D)*** *porosity (%)* vs *bulk density (kg/m^3): note the excellent correlation between porosity and bulk density for oil-producing wells.*

6. Discussion

The source of Duperow Formation oil has not yet been established because of limited data. Organic-rich intervals in the Duperow Formation tend to be very thin and occur within both carbonate and evaporite units (Fowler *et al.*, 2001, 2002). The available data indicate that organic-rich intervals (total organic content (TOC) >5 wt. %) in the Duperow Formation with Type I organic matter occur in areas west of the Third Meridian. In southeastern Saskatchewan, intervals with mixed Type III-II to Type II organic matter that are less organic-rich (TOC <3.5 wt. %) have also been reported (Li *et al.*, 1998; Fowler *et al.*, 2001, 2003). Organic-rich samples (TOC 3.9 wt. %) have been identified in the Duperow Formation in Manitoba (Chow *et al.*, 2013), although kerogen type is not identified. Duperow Formation source rocks and petroleum systems in the US Williston Basin have been studied by Jarvie (2001) and Lillis (2013), with reported TOC values averaging 3.02 wt. % and Type II kerogen identified. In North Dakota, Duperow Formation oils are generally waxy, with moderate gravity and low sulphur content. The average values of pour point, gravity and sulphur content are 13°C, 38.7° API, and 0.2 wt. %, respectively, based on 122 samples (Jarvie, 2001; Lillis, 2013).

However, no oil-source correlation between the Duperow Formation source rocks and oils has been established, so the source of the oil in the Duperow Formation remains hypothetical.

T_{max} values (420 to 437°C) indicate that the Duperow Formation is generally immature to marginally mature in southern Saskatchewan (Fowler *et al.*, 2001, 2002, 2003; Stasiuk *et al.*, 2002). Further organic geochemistry studies are required to identify if the Duperow Formation oil is self-sourced or if it is derived from the same source rocks as the oil within the Birdbear and Winnipegosis formations in southeastern Saskatchewan.

7. Summary

The Duperow Formation in southeastern Saskatchewan is composed of cyclic shallowing-upward sequences from bioclast-rich wacke-packstone, stromatoporoid boundstone and peloidal wackestone, grading upward to dolomudstone and evaporite lithofacies. It is subdivided into the Saskatoon, Wymark and Seward members, with thicknesses ranging from 15 to 37 m, 69 to 145 m, and 31 to 67 m, respectively. In some areas (Townships 1 to 15, Ranges 8 to 19W2 and Townships 3 to 7, Ranges 21 to 25W2), the Wymark Member is terminated by the Flat Lake Evaporite, which is mostly halite and ranges in thickness from 1 to 30 m.

Current oil production from the Duperow Formation in southeastern Saskatchewan is mainly from dolostone reservoirs of the upper unit of the Wymark Member, associated with small low-relief structural closures. The reservoir rock of the Duperow Midale pool ranges in depth from 1856 to 1891 m, and is identified as brown dolostone with mostly intercrystalline porosity. Dolomitization plays a very important role in increasing porosity and permeability. Vuggy, moldic and open-fracture porosities enhanced by dissolution are common. The vugs and fractures are, in places, partially or fully filled by anhydrite, calcite and halite cements. Total porosity ranges from 6 to 22%, with an average of 13%, and permeability is up to 393 mD.

8. Acknowledgments

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9. References

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ii) Example of *Summary of Investigations* paper for Volume 2.

Details from the 1:20 000-scale Mapping of the South-central Tantato Domain, Rae Province, along the Northern Margin of the Athabasca Basin

Bernadette Knox [1] and Jaida Lamming [2]

Information from this publication may be used if credit is given. It is recommended that reference to this publication be made in the following form:

Knox, B. and Lamming, J. (2015): Details from the 1:20 000-scale mapping of the south-central Tantato Domain, Rae Province, along the northern margin of the Athabasca Basin; *in* Summary of Investigations 2015, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.2, Paper A-1, 15p.

This report is accompanied by the map separates entitled:

Knox, B.R. and Lamming, J. (2015): Bedrock geology of the Robillard Bay area, southwestern Tantato Domain (parts of NTS 74O/07); 1:20 000-scale preliminary map *with* Summary of Investigations 2015, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.2, map 2015-4.2-(2.1).

Knox, B.R. and Lamming, J. (2015): Bedrock geology of the Pine Channel area, south-central Tantato Domain (parts of NTS 74O/08 and 74P/05); 1:20 000-scale preliminary map *with* Summary of Investigations 2015, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.2, map 2015-4.2-(2.2).

Knox, B.R. and Lamming, J. (2015): Bedrock geology of the Axis and Currie lakes area, south-central Tantato Domain (parts of NTS 74O/08 and 74P/05); 1:20 000-scale preliminary map *with* Summary of Investigations 2015, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.2, map 2015-4.2-(2.3).

Abstract

In the second year of 1:20 000-scale regional mapping, work was extended to the east and north of the 2014 study area. A complex metamorphic history, multiple periods of ductile deformation and metamorphism, nickel-copper mineralization within the mafic granulite unit, and late, low-grade retrograde metamorphism were observed throughout the 2015 map area.

The south Tantato Domain is composed of garnetiferous orthogneiss, psammopelitic gneiss, garnet-bearing anatectic granite, and mafic granulite. The entire domain is intensely mylonitized and has experienced granulite facies metamorphism at ca. *2.6 to 2.55 Ga and 1.90 Ga, with local eclogite facies metamorphism reported at* ca. *1.90 Ga. The mafic granulites are intrusive into all other units and contain nickel and copper mineralization throughout the southern Tantato Domain, the largest known deposit being at Axis Lake.*

Keywords: *Tantato Domain, Rae Province, Stony Rapids, Pine Channel, Axis Lake, granulite facies, eclogite facies, metamorphism, Ni-Cu mineralization, mafic granulite*

1. Introduction

The South Tantato Bedrock Geology project is in its second year. It is designed to: 1) update the existing bedrock mapping of the southern portion of the Tantato Domain; 2) provide context for detailed studies on the Tantato Domain gold and nickel-copper mineralization, which involves detailed mineral deposit and deformation studies (see Normand, 2014 and Normand *in press*); 3) assist mineral exploration; and 4) add to the knowledge of the region's tectonic history. A regional Quaternary mapping component is aimed at understanding the glacial history and potential for drift prospecting (see Hanson, 2014, 2015). In addition, the project supports two graduate students.

[1] Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, 1000-2103 11th Avenue, Regina, SK S4P 3Z8
[2] University of British Columbia, Okanagan, 3333 University Way, Kelowna, BC V1V 1V7

Jaida Lamming is completing an M.Sc. study at the University of British Columbia, Okanagan Campus, designed to determine the timing and conditions of metamorphic monazite formation with respect to formation of ductile fabrics in granulite-facies psammopelitic gneiss of the southern Tantato Domain. Thomas Ogilvie, an M.Sc. student at Laurentian University in Sudbury, Ontario, is studying the brittle deformation that has affected the crystalline basement rocks along the northern margin of the Athabasca Basin, in order to understand structures and alteration features associated with gold mineralization in the Pine Channel area and the unconformity-related uranium mineralization associated with the Athabasca Basin.

Bedrock mapping in 2015 continued to the east and north of the area previously studied by Knox and Lamming (2014), within the 'upper deck'[3] of the southern Tantato Domain. Work was focused along: 1) the Pine Channel area of Lake Athabasca, 2) the west side of Axis and LeBlanc lakes, and 3) the contact between the upper and lower decks of the Tantato Domain (Figure 1; Hanmer, 1994). In addition to the mapping, an important objective was to test for potential correlations between the nickel-copper mineralization in the Tantato Domain (*e.g.*, Currie-Axis lakes area) and that known from the Dodge Domain (*e.g.*, Robins Lake, Opescal Lake (Knox and Ashton, 2009; Knox *et al.*, 2011)) and the Northwest Territories (Nickel King (Strongbow Exploration Inc., 2015b). By studying rock types, tectonic setting, relative timing of dyke emplacement and regional deformation, as well as results from geochemistry and geochronology, a comparison of the nickel-copper mineralization can be made.

2. Previous Work

The Tantato Domain is a portion of the south Rae Province in Saskatchewan that has been studied by numerous geologists over the years. Work has ranged from early reconnaissance-scale mapping (*e.g.*, Tyrrell and Dowling, 1896; Alcock, 1921, 1936; Bruce and Matheson, 1930) to regional systematic mapping (Colborne, 1960, 1961, 1962; Hulbert, 1986; Slimmon and Macdonald, 1987; Hanmer, 1994, 1997; Lafrance and Sibbald, 1997) and detailed analytical studies (*e.g.*, Baldwin *et al.*, 2003; Mahan *et al.*, 2003, 2006; Flowers *et al.*, 2008; Dumond *et al.*, 2010, 2015). The Tantato Domain has previously been defined as being extensively and penetratively mylonitized at granulite-facies metamorphic conditions (Hanmer, 1997). Multiple shear zones separate crustal components that originally resided at different depths in the crust (Hanmer, 1997). The lower deck of the Tantato Domain (Hanmer, 1997) is mainly composed of granitoids, psammopelitic gneisses, and mafic plutonic rocks. The south-central part of the domain (upper deck of Hanmer, 1997), which is the focus of this study, is dominated by psammopelitic gneiss and mafic granulite, with minor garnetiferous granitic orthogneiss (Knox and Lamming, 2014). High-grade metamorphic events have been reported at *ca.* 2.6 to 2.55 Ga (*e.g.*, Hanmer, 1997; Mahan *et al.*, 2006; Baldwin *et al.*, 2007; Flowers *et al.*, 2008; Dumond *et al.*, 2010, 2015) and at *ca.* 1.90 Ga (e.g., Mahan *et al.*, 2006; Baldwin *et al.*, 2007). Eclogite observed north of Axis Lake has peak conditions reported at 16 kbar and 750°C followed by isothermal decompression at ~7 kbar from 1904 and 1894 Ma (Baldwin *et al.*, 2007). Several studies have interpreted the eclogite-facies metamorphic event as having occurred in the Archean (Snoeyenbos *et al.*, 1995; Dumond *et al.*, 2015). Uplift of the Rae Province with respect to the Hearne Province along the Legs Lake shear zone and Grease River shear zone occurred at *ca.* 1.90, 1.85 and 1.80 Ga (Mahan *et al.*, 2003, 2006; Dumond *et al.*, 2008; Flowers *et al.*, 2008).

3. Unit Descriptions

All of the rocks in the following unit descriptions have been metamorphosed, deformed, and variably mylonitized. The rock codes in brackets after the unit names correspond to the rock codes used on Figure 1. All coordinates reported in this document are in North American Datum (NAD) 83, Zone 13.

[3] Hanmer (1997) divided the Tantato Domain into a 'lower deck' and an 'upper deck' based on structural divisions and the thrusting of the latter onto the former. Both of the crustal components are described as being extensively and penetratively mylonitized at granulite-facies metamorphic conditions. Although the terms remain an informal field expression, there is no attempt in this paper to show them as such by the use of quotation marks around the terms, other than at their first introduction.

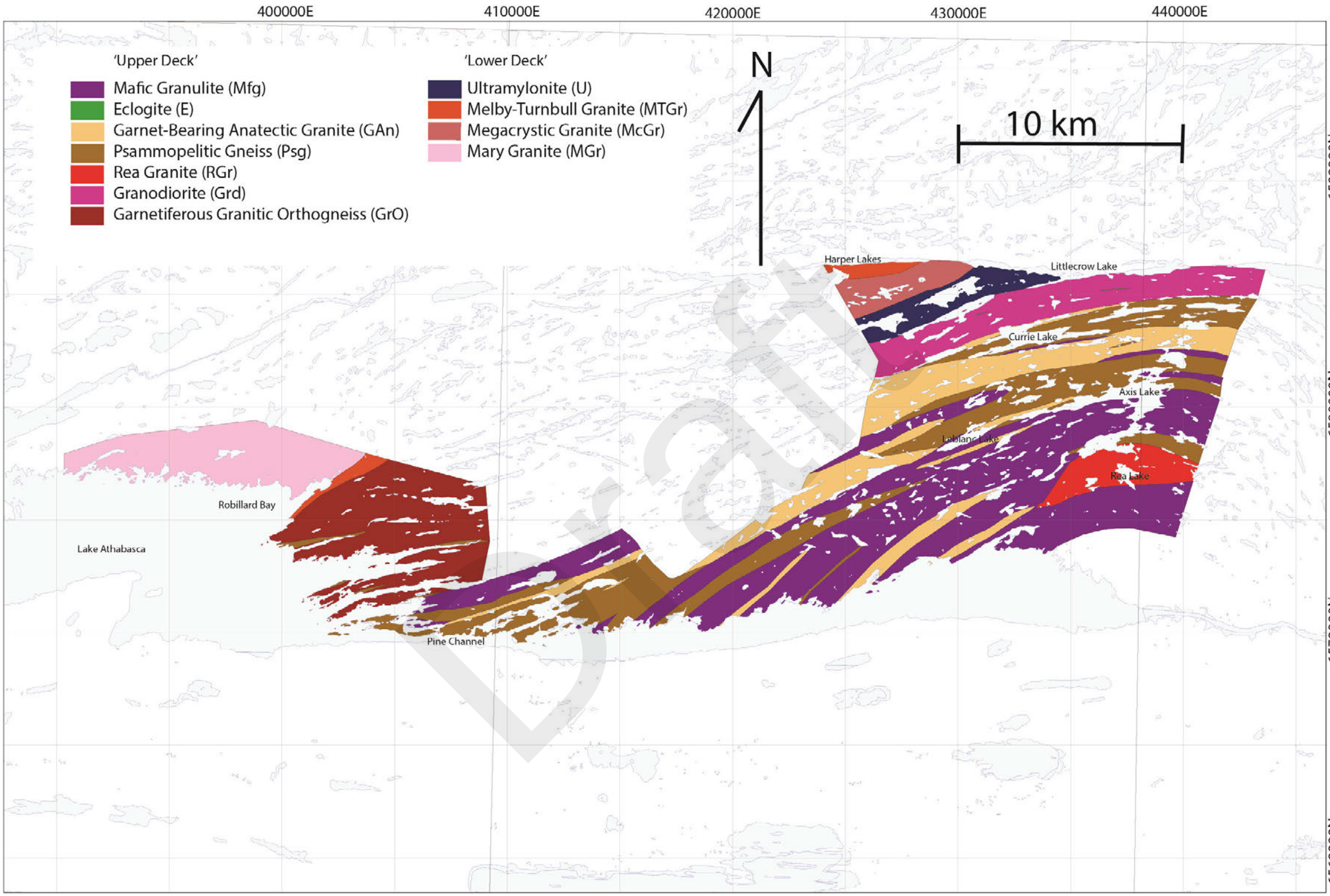

Figure 1 – Simplified geological map of the southern Tantato Domain. Note that all UTM coordinates are in NAD 83, Zone 13.

a) Lower Deck, Tantato Domain

Mary Granite (MGr)

The Mary granite lies west and north of Robillard Bay (Figure 1), in the lower deck of the Tantato Domain and represents one of the northernmost components of the present mapping campaign. The rock is mylonitic and characterized by a dark grey aphanitic matrix with a colour index of 10 to 35, resulting from pyroxene, hornblende, and biotite, with porphyroclasts of garnet and hornblende throughout (Figure 2). The pervasive and homogenous distribution of cream-coloured feldspar porphyroclasts up to 1 cm in diameter and 2 cm in length defines a strong lineation. Cream-coloured attenuated leucosomes also help to preserve the strong lineation, which has been folded numerous times (Figure 3).

The Mary granite has been previously described as a multiphase batholith that is variably strained (Hanmer, 1997; Ashton *et al.*, 2007; Dumond *et al.*, 2010), with crosscutting relationships with igneous intrusions suggestive of syntectonic mylonitization (Hanmer, 1997). A U-Pb zircon crystallization age of *ca.* 2.62 to 2.55 Ga was previously reported for various phases of the batholith (Hanmer *et al.*, 1994; Hanmer, 1997). The batholith is interpreted to have been emplaced, metamorphosed and deformed at ~1.0 GPa (10 kbars) and 700 to 900°C (Williams *et al.*, 2000).

Megacrystic Granite (McGr)

A megacrystic granite was observed south of Harper Lakes and to the northwest of Currie Lake (Figure 1). The rock has a distinct augen texture with light pink to cream, megacrystic feldspar grains set in a dark grey to green, fine- to coarse-grained matrix (Figure 4). The mafic content ranges from 25 to 35% and comprises hornblende, biotite, and local garnet. This unit lacks pyroxene, which distinguishes it from many other units in the area. The megacrystic granite is generally moderately foliated and lineated. Along its highly strained southern margin it becomes ultramylonitic and the ability to identify the protolith of the mylonite is lost (Figure 5).

Melby-Turnbull Granite (MTGr)

The 'Melby-Turnbull' granite (MtG), previously named and described by Hanmer (1997), was observed in the Robillard Bay area and a separate body is located just south of the eastern part of the Harper Lakes (Figure 1). This rock is light pink to grey and medium to coarse grained. It contains 15 to 20% mafic minerals, which consist of a mix of hornblende porphyroclasts and biotite (Figure 6). No orthopyroxene or garnet was observed and therefore the granite is interpreted to have postdated peak regional metamorphism reported at *ca.* 1.90 Ga (e.g., Baldwin *et al.*, 2007). This moderately to strongly mylonitized granite is preferentially situated along high-strain zones as well as between other, presumably older, rocks, which supports the interpretation of it being younger (Figure 1).

Ultramylonite (U)

A unit of ultramylonite 1 km thick was observed along the west shore of and west of Littlecrow Lake (Figure 1). The ultramylonite is a light to medium grey rock, which is predominantly fine grained. Medium to very coarse porphyroclasts of feldspar are present and have been subject to grain size reduction. Hornblende porphyroblasts overgrow the mylonitic fabric but have also undergone some grain size reduction and rotation (Figure 7). Quartz grains, where visible, are only weakly deformed to undeformed suggesting they postdate mylonitization.

This zone of ultramylonite had previously been mapped as a porphyroclastic variety of the Mary garnet-hornblende-two-pyroxene granite (Hanmer, 1994). A detailed transect across the ultramylonite revealed a variety of highly deformed rock types, including the megacrystic granite (GrMc) to the north and the granodiorite (GrD; see below) to the south (Figure 8). Given its mineralogy and felsic composition, the ultramylonite is thought to have been derived from the megacrystic granite and/or granodiorite.

Figure 2 – Strongly mylonitized, lineated and foliated grey 'Mary granite' crosscut by a quartz-calcite vein (UTM 401717E, 6576496N). Cream-coloured porphyroclasts of feldspar are visible in the upper half of the photo. The foliation has variable orientations, due in part to reorientation by late brittle deformation.

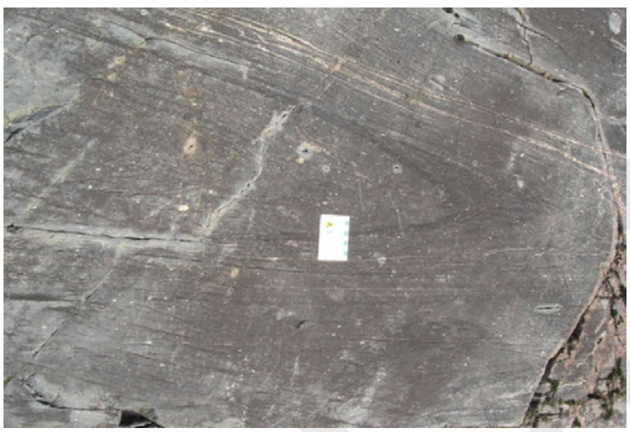

Figure 3 – Mylonitized and folded Mary granite displaying variations in the level of strain, which produced the main fabric (UTM 401717E, 6576496N). The S>L tectonite has been folded by a tight northeast-striking F_4 fold.

Figure 4 – A close-up image of the homogeneous megacrystic granite (UTM 432797E, 6586095N). In this image the variation in grain size is readily visible, with centimetre-scale feldspar megacrysts in a predominantly fine and locally coarse rock.

Figure 5 – A highly strained version of the homogeneous megacrystic granite (UTM 434596E, 6586152N). There has been a significant reduction in the grain size of all mineral grains in this rock.

Figure 6 – A close-up view of a moderately mylonitized version of the Melby-Turnbull granite. Hornblende grains are black and medium grained despite mylonitization (UTM 431727E, 6586315N).

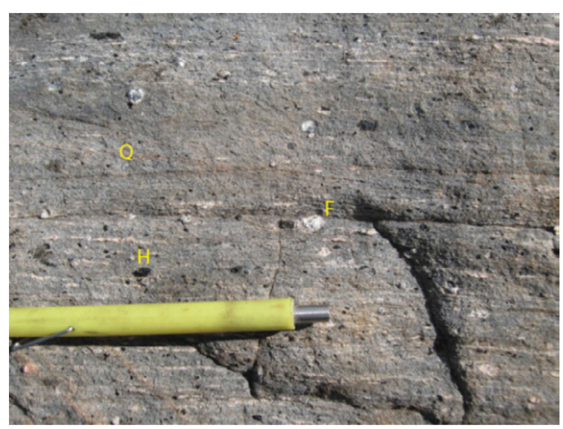

Figure 7 – Close-up image of ultramylonite (UTM 436400E, 6585821N). This rock contains deformed feldspar porphyroclasts (F) along with post-mylonitic hornblende (H) and quartz porphyroblasts (Q).

Figure 8 – The rock in this photo is the transitional phase from the megacrystic granite to the hornblende-bearing ultramylonite (UTM 433433E, 6585806N). In this outcrop the megacrystic granite is still recognizable despite significant grain size reduction.

b) Upper Deck, Tantato Domain

Granodiorite (Grd)

A unit of granodiorite occurs north of Currie Lake (Figure 1). The rock is light to dark pink to cream and medium to coarse grained (Figure 9). It has a colour index between 20 and 30, the mafic minerals consisting of pyroxene, rare garnet, and various amounts of retrograde hornblende and biotite. The most striking feature of this rock is the light pink to white leucosome layers that make up between 10 and 35% of the rock (Figure 9). The leucosome contains ~2% pyroxene. The granodiorite unit is generally weakly to moderately foliated and lineated. At its northern margin, the granodiorite becomes highly strained and is transitional into the ultramylonite unit. The leucosome layers are less mylonitized than the main granodiorite and were therefore generated during the latter stages of the main mylonitization event (Figure 10).

4. Structural Geology

Four phases of regional ductile deformation were documented by Knox and Lamming (2014) and were again observed during the 2015 field season. A strong S_1 foliation and L_1 lineation were produced during D_1 deformation. In units such as the garnetiferous granitic orthogneiss, which is thought to be Archean in age, the D_1 fabric may be composite and represent multiple deformation events. D_2 deformation produced high-amplitude, tight to isoclinal F_2 folds with axial planes that dip moderately to steeply to the northwest or southeast. L_2 lineations plunge shallowly to moderately to the southwest or northeast due to reorientation by later folding (Figure 15). F_3 folds were rarely observed but are consistent with those described by Knox and Lamming (2014), with open to close interlimb angles and moderately to steeply northeast or southwest dipping axial planes. The fourth phase of deformation produced abundant F_4 folds, which are open to close with moderately to steeply dipping axial planes (Figure 16).

The brittle deformation history of the Tantato Domain has been previously described (*e.g.*, LaFrance and Sibbald, 1997; Normand, 2014). Zones of intense fracturing with evidence of fluid alteration were observed throughout the southern Tantato Domain (Figure 17). Brittle overprinting was particularly well developed in areas previously affected by ductile shearing (Figure 18). Fault scarps throughout the map area are coincident with ductile high-strain zones and are thus interpreted as reactivated structures.

5. Metamorphism

Based on field observations, metamorphic conditions in the areas mapped in 2015 and last field season (Knox and Lamming, 2014) reached granulite facies. In mafic rock, this is exemplified by orthopyroxene-plagioclase and clinopyroxene-garnet-quartz assemblages, with the latter indicating pressures in excess of 5 to 7 kbars (Bucher and Frey, 1994). Eclogite facies rocks represent parts of the crust taken to exceptionally high pressures through tectonic transport to depths of more than 60 km below the surface (Bucher and Frey, 1994). Eclogite and eclogite facies rocks have been previously identified north of Axis Lake (*e.g.*, Snoeyenbos *et al.*, 1995; Baldwin *et al.*, 2007), where temperature-pressure conditions of 750°C and 16 kbars are thought to have been attained at *ca.* 1.90 Ga (Baldwin *et al.*, 2007). In addition, eclogite-facies garnetiferous felsic gneisses containing sapphirine, corundum and spinel have also been described in the same area (Baldwin *et al.*, 2007) and are believed to be equivalents of the psammopelitic gneiss unit in this study.

Eclogitic layers up to 15 m in minimum thickness were mapped on and north of the north shore of Currie Lake (Figure 19). Such layers are part of the mafic granulite unit and are characterized by red garnet and green pyroxene with minor feldspar rimming garnet. As outcrops of eclogite also contain a mixture of retrograde pyroxene and amphiboles, this suggests that peak eclogitic mineral assemblages have been overprinted by granulite- and amphibolite-facies retrograde conditions (Figure 20). This complex mineralogy is understandable, as preservation of eclogite is not likely in slowly cooled rocks at originally high temperatures (Bucher and Frey, 1994). These newly documented occurrences of eclogite, in addition to the those reported from Axis Lake (Snoeyenbos *et al.*, 1995; Knox and Lamming, 2014), increase the extent of known eclogite facies metamorphism to approximately 5 km across strike in the area between Axis Lake and the northern shore of Currie Lake.

6. Economic Potential in the Tantato and Dodge Domains

Magmatic nickel-copper mineralization associated with the mafic granulites has been previously documented in both the upper and lower decks of the Tantato Domain, with the deposit at Axis Lake representing the largest known concentration (Coombe Geoconsultants Ltd., 1991; Saskatchewan Mineral Deposit Index (SMDI) files #1583 to 1587, 2608, 2610, 2614, and 2718). A historic resource estimate (not NI-43-101–compliant) of 3.4 million tons grading 0.66% Ni and 0.6% Cu is quoted for this deposit (Pure Nickel Inc., 2015). Several other Ni-Cu occurrences and bedrock geochemical anomalies are known throughout the Tantato Domain (*e.g.*, Knox and Lamming, 2014; Strongbow Exploration Inc., 2015a).

Similarly, elevated Ni-Cu concentrations are known from grab samples collected across the eastern Dodge Domain (*e.g.*, Knox and Biss, 2010; Knox and Plews, 2012; Strongbow Exploration Inc., 2015a). The geology of the eastern Dodge Domain is interpreted to continue northeastward along strike across the Saskatchewan border into the Northwest Territories. At Thye Lake in the Northwest Territories, the Nickel King deposit has an NI-43-101–compliant Indicated Resource of over 11 million tonnes (t) with grades of 0.4% Ni, 0.10% Cu and 0.018% Co (Strongbow Exploration Inc., 2015b). In addition, this deposit has an Inferred Resource of 33.06 million t grading 0.36% Ni, 0.09% Cu and 0.017% Co.

Geochronology and geochemical analysis performed as part of this study (to be reported in future publications) will test the correlation of nickel-copper deposits across domain boundaries from the northern margin of the Athabasca Basin to the Nickel King deposit in the Northwest Territories.

7. Discussion and Conclusions

The southern Tantato Domain (upper deck of Hanmer, 1997) is composed mainly of garnetiferous orthogneiss, psammopelitic gneiss, garnet-bearing anatectic granite, and mafic granulite, all of which have been affected by multiple periods of ductile deformation, mylonitization, and granulite- to eclogite-facies metamorphism. With the exception of the mafic granulite, all of these rock types have been deformed by D_1 to D_4 deformation. The mafic granulite was injected after D_1 and was only affected by the latter three episodes of deformation. Regional granulite-facies metamorphic events in the Tantato Domain at *ca.* 2.55 Ga and 1.90 Ga have been well documented (*e.g.*, Hanmer, 1997; Mahan *et al.*, 2006; Baldwin *et al.*, 2007; Flowers *et al.*, 2008; Dumond *et al.*, 2010, 2015). A belt of discontinuously preserved eclogitic rocks approximately 5 kilometres wide has been documented between Axis Lake and Littlecrow Lake, although whether the timing of this metamorphism is Paleoproterozoic or Archean remains under debate.

A zone of northeast-striking ultramylonite (Littlecrow shear zone), approximately 1.5 kilometres wide, was recognized north of the granodiorite unit in the vicinity of Littlecrow Lake. This zone marks major shearing and movement along this boundary of the upper and lower decks, the significance of which had not been recognized by previous workers. This zone potentially represents a major crustal-scale boundary involving amalgamation of continental crust. In this zone, overprinting by late brittle deformation represents another crustal-scale zone of deformation with reactivation, which highlights the long history of deformation that has affected the Precambrian shield along the northern margin of the Athabasca Basin.

The southern Tantato Domain has potential for the discovery of more magmatic nickel-copper mineralization, as mafic sheets intruding psammopelitic gneisses are prevalent throughout the 2014-2015 map areas. In addition to the nickel-copper deposit at Axis Lake, mafic granulite is known to contain several other nickel-copper occurrences in the western Tantato Domain (Pure Nickel Inc., 2015), the eastern Dodge Domain (Strongbow Exploration Inc., 2015a) and along strike in the Northwest Territories (*e.g.*, Nickel King deposit at Thye Lake (Strongbow Exploration Inc., 2015b)). If these occurrences are genetically related, this would constitute a 150-kilometre-long belt of nickel-copper mineralization along the eastern margin of the Rae craton adjacent to the Snowbird tectonic zone.

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B) Data File Report

For every data file there should a minimum of two types of information submitted for editing:

- descriptive text that briefly explains the nature of the data presented in the report (this is the text that is placed on the website below the link to the actual files of data); and
- the file or files of the data.

The descriptive text for the website enables a client to determine whether or not the data file is of interest to them, without having to open or download the file or files. This text should therefore include a brief description of the nature of the data and the geographic location of the data sources.

Additional information that should be provided to the editor includes:

- title;
- author(s) name(s), with affiliation(s) and complete address(es);
- where, how and when the data were obtained.

(See below for examples of text submitted for use on the ministry website.)

In addition to the descriptive text for the website, the data file itself should contain sufficient information for a client to determine how it will be of use to them. A typical data file comprises one or two Excel files, to which have been added a ‘General Information’ tab (see examples below) and as many other tabs as are necessary for information that supplements the data. For example, adding a tab of ‘Abbreviations’ is helpful if your file contains a table of drillhole data with a column for remarks that contains uncommon abbreviations, or personal abbreviations created by the author or authors. Adding a tab of ‘References and Data Sources’ is helpful if numerous references are cited in the main table of data, or if there are numerous sources for your data.

If the information in a data file comprises tabular data, the column and row headings must clearly and concisely describe the contents of the columns and rows.

If the data file comprises analytical results, include the name and address of the laboratory that performed the analyses and the type of analytical package or packages used.

If the data file comprises or includes data from specific samples, the location of the samples must be given. Information for sample location should include eastings and northings with UTM zone, projection and datum OR for well data, well ID and well licence.

i) Examples of descriptive text for the ministry website.

DF 36: Geochemical Analyses of Athabasca Group Drillholes in Saskatchewan (NTS 64L, 74F to 74I, 74K, and 74O to 74P) – Supplementary to Data File Reports 24, 29, 30, 31, 32 and 33

by S.A. Bosman and C.D. Card 2015

A supplementary set of 260 samples from Athabasca Group drillcore was submitted to augment industry drillcore geochemical data from Data File Report (DF) 24 and the Saskatchewan Geological Survey (SGS) drillcore geochemical Data Files 31, 32 and 33, as well as SGS outcrop geochemical data in DF29 and DF30.

Drillholes sampled include: 001, 4-69, 4557-1-82, 4560-1-82, 69-1, 69-3, 86-78, BD-007, CL08-02, CLDD-2, CSP-06-001, CSP-08-001, FDL-S205E700, FLT08-08, GRL-133A, OW-02, P-052, SP-001, WL-004, WOL-24-77 and WV-5.

Drillhole locations and other details are available on the 'DDH Core Collection – Regina' layer of the Geological Atlas of Saskatchewan.

DF 40: Thickness of Potash-rich Members of the Devonian Prairie Evaporite in Saskatchewan (Townships 1 to 50, Range 30W1M to Range 30W3M)

by C. Yang 2016

The data presented in this file were used to produce the isopach, carnallitite thickness contours and K_2O grade maps for the Patience Lake, Belle Plaine and Esterhazy members of the Devonian Prairie Evaporite in Saskatchewan (Saskatchewan Geological Survey, Open File 2015-2).

This database was produced from public data for over 1600 wells, using geophysical well logs and available assay reports obtained from the Saskatchewan Ministry of the Economy, Geodata Branch, and assay data in National Instrument 43-101 industry technical reports available for download from http://www.sedar.com. The data are from the southern half of Saskatchewan, and cover Townships 1 to 50, from Range 30 west of the First Meridian (W1M) to Range 30 west of the Third Meridian (W3M).

ii) Examples of a 'General Information' tab in an Excel workbook for a Data File Report.

Data File Report 36

Geochemical Analyses of Athabasca Group Drillholes in Saskatchewan (NTS 64L, 74F to 74I, 74K, and 74O to 74P) – Supplementary to Data File Reports 24, 29, 30, 31, 32 and 33

by S.A. Bosman[1] and C.D. Card[1]

2015

Data File Report 36 consists of one part: this Microsoft® Excel® spreadsheet, which is formatted as in Data File Reports 24, 29, 30, 31 and 32, with the exception of two columns - "Lithostratigraphic Unit Code" and "Lithostratigraphic Unit Description" - as recent work is leading to changes in the nomenclature at the time of publication.

A supplementary set of 260 samples from Athabasca Group drillcore was submitted for geochemical analysis to augment previously released industry drillcore geochemical data and Saskatchewan Geological Survey drillcore geochemical data (Saskatchewan Ministry of Energy and Resources, 2010; Card *et al.*, 2011; Bosman and Card, 2012; Card and Bosman, 2012; Bosman and Card, 2013a, 2013b).

In some of the previous SGS data file releases, a 'Lithostratigraphic Unit Code' and 'Lithostratigraphic Unit Description' were included in the dataset, to reflect the interpreted lithostratigraphic unit at the time of submission. Recent work, however, is leading to changes in nomenclature and interpretations at the time of this publication, which have not been made public, therefore these two columns have been removed from this release as well as previous releases, to avoid lithostratigraphic ambiguity between the various geochemical datasets.

The samples in this report were processed at the Geoanalytical Laboratories at the Saskatchewan Research Council in Saskatoon, Saskatchewan. The samples were crushed, split, agate ground and then run with 'Sandstone Exploration Package ICPMS 1'. The package involves three separate types of analysis: inductively coupled plasma mass spectrometry (ICP–MS) partial digestion for trace elements; ICP–MS total digestion for trace elements; and ICP–Optical Emission Spectrometry (ICP–OES) total digestion for major and minor elements. Drillcores were sampled systematically at ~20 m spacing, for a total of 255 samples; 5 representative samples were also chosen: 4 of Read Formation sandstone and 1 from a yellow-stained conglomeratic unit. An additional 15 blind repeats were included in the sample run. The dataset also contains 9 lab repeats and 16 lab standards. In addition to the analyses, location data and sample descriptions are included in this release (Microsoft® Excel® format).

Drillholes sampled include: 001, 4-69, 4557-1-82, 4560-1-82, 69-1, 69-3, 86-78, BD-007, CL08-02, CLDD-2, CSP-06-001, CSP-08-001, FDL-S205E700, FLT08-08, GRL-133A, OW-02, P-052, SP-001, WL-004, WOL-24-77 and WV-5.

Drillhole locations and other details are available on the 'DDH Core Collection – Regina' layer of the Geological Atlas of Saskatchewan.

Information from this publication may be used if credit is given. It is recommended that reference to this publication be made in the following form:

Bosman, S.A. and Card, C.D. (2015): Geochemical analyses of Athabasca Group drillholes in Saskatchewan (NTS 64L, 74F to 74I, 74K, and 74O to 74P) – Supplementary to Data File Reports 24, 29, 30, 31, 32 and 33; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Data File Report 36.

References

Bosman, S.A. and Card, C.D. (2012): Geochemical analyses of Athabasca Group drillholes in Saskatchewan (NTS 64L, 74F to 74K, and 74N to 74P) – Supplementary to Data File Reports 24, 29 and 30; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Data File Report 31, URL <http://www.economy.gov.sk.ca/DF31>.

Bosman, S.A. and Card, C.D. (2013a): Geochemical analyses of Athabasca Group drillholes in Saskatchewan (NTS 64L, 74F to 74K, and 74N to 74P) – Supplementary to Data File Reports 24, 29, 30 and 31; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Data File Report 32, URL <http://www.economy.gov.sk.ca/DF32>.

Bosman, S.A. and Card, C.D. (2013b): Geochemical analyses of Athabasca Group drillholes in Saskatchewan (NTS 64L, 74F to 74K, and 74N to 74P) – Supplementary to Data File Reports 24, 29, 30, 31 and 32; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Data File Report 33, URL <http://www.economy.gov.sk.ca/DF33>.

Card, C.D. and Bosman, S.A. (2012): Geochemical analyses of Athabasca Group outcrops in Saskatchewan (NTS 64L, 74F to 74K, and 74N to 74P) – Supplementary to Data File Report 29; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Data File Report 30, URL <http://www.economy.gov.sk.ca/DF30>.

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[1] Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, 1000-2103 11th Avenue, Regina, SK S4P 3Z8

Data File Report 40

Thickness of Potash-rich Members of the Devonian Prairie Evaporite in Saskatchewan (Townships 1 to 50, Range 30W1M to Range 30W3M)

by C. Yang[1]

2016

Data File Report 40 consists of one part: this Microsoft® Excel® spreadsheet.

This data file is associated with the following publication:

Yang, C. and Love, M. (2015): Potash-rich members of the Devonian Prairie Evaporite in Saskatchewan: isopachs, carnallitite contours and K_2O grade; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Open File 2015-2, set of 3 maps.

This database was produced from public data for over 1600 wells, using geophysical well logs and available assay reports obtained from the Saskatchewan Ministry of the Economy, Geodata Branch, and assay data in National Instrument 43-101 industry technical reports available for download from http://www.sedar.com (see 'References and Data Sources' tab). The data are from the southern half of Saskatchewan, and cover Townships 1 to 50, from Range 30 west of the First Meridian (W1M) to Range 30 west of the Third Meridian (W3M).

Note: On the 'Thickness Data' tab, cells that do not contain any data indicate wells for which well logs or assays are not available to determine thickness of the potash member or carnallitite. Cells with '0.0' for thickness indicate that no potash member or carnallitite was picked based on analysis of well logs and/or assays.

Information from this publication may be used if credit is given. It is recommended that reference to this publication be made in the following form:

Yang, C. (2016): Thickness of potash-rich members of the Devonian Prairie Evaporite in Saskatchewan (Townships 1 to 50, Range 30W1M to Range 30W3M); Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Data File Report 40.

[1] Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, 1000-2103 11th Avenue, Regina, SK   S4P 3Z8

C) Open File Report

SGS reports—Final Reports, Miscellaneous Reports, Open File Reports—differ from SOI papers only in their general layout:

- reports are self-contained and therefore require a cover and other introductory pages such as a disclaimer page and a table of contents
- the first two levels of headings in reports are not numbered
- the first heading level in a report marks the start of a new page

In all other respects, the requirements for SGS reports are the same as for SOI papers (see section A in this appendix).

The following pages are an example of a typical Open File Report. (Note: the report has been shortened somewhat from its original length.)

Government of Saskatchewan

Open File Report 2016-1

Helium in Southwestern Saskatchewan: Accumulation and Geological Setting

Melinda M. Yurkowski

2016

Open File Report 2016-1

Helium in Southwestern Saskatchewan: Accumulation and Geological Setting

Melinda M. Yurkowski

2016

Printed under the authority of the
Minister of the Economy

This product is available for viewing and download at:
http://economy.gov.sk.ca/

Information from this publication may be used if credit is given. It is recommended that reference to this publication be made in the following form:

Yurkowski, M.M. (2016): Helium in southwestern Saskatchewan: accumulation and geological setting; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Open File Report 2016-1, 20p. and Microsoft® Excel® file.

Contents

Appendix

Helium in Southwestern Saskatchewan: Accumulation and Geological Setting

by Melinda M. Yurkowski[1]

Introduction and Study Area

Saskatchewan is experiencing renewed interest in the helium potential of southwestern Saskatchewan. Interest in the past, which began in the early 1950s, resulted in helium production in the early 1970s from four wells in the Swift Current area. Recently, two wells began producing helium in southwest Saskatchewan: one northwest of Swift Current and one to the southeast, near the town of Mankota.

This Open File Report has been compiled to help in the exploration for and development of helium resources in southwestern Saskatchewan. It reports the results of 1856 gas analyses, from 1477 wells, that have been tested for helium. The report also discusses potential helium sources and traps.

In the study area, the lower Paleozoic formations—in particular, the Deadwood Formation—have the highest concentrations of helium. The helium accumulations in the Deadwood Formation are assumed to be derived from the decay of uranium and thorium from a granitic source rock in the Precambrian basement, or from the shales within the Deadwood Formation itself. Exploration targets include lower Paleozoic structural highs, such as those draped over Precambrian structures, that have an effective seal to trap the small helium molecule.

The study area covers Townships 1 to 25, extending from Range 14 west of the Second Meridian (W2M) to the Alberta border (Figure 1).

Keywords: *helium, Deadwood Formation, Precambrian, Cambrian, southwest Saskatchewan, nitrogen, Wilhelm, Battle Creek, Mankota*

[1] Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, 1000-2103 11th Avenue, Regina, SK S4P 3Z8

Information from this publication may be used if credit is given. It is recommended that reference to this publication be made in the following form:
Yurkowski, M.M. (2016): Helium in southwestern Saskatchewan: accumulation and geological setting; Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Open File Report 2016-1, 20p. and Microsoft® Excel® file.

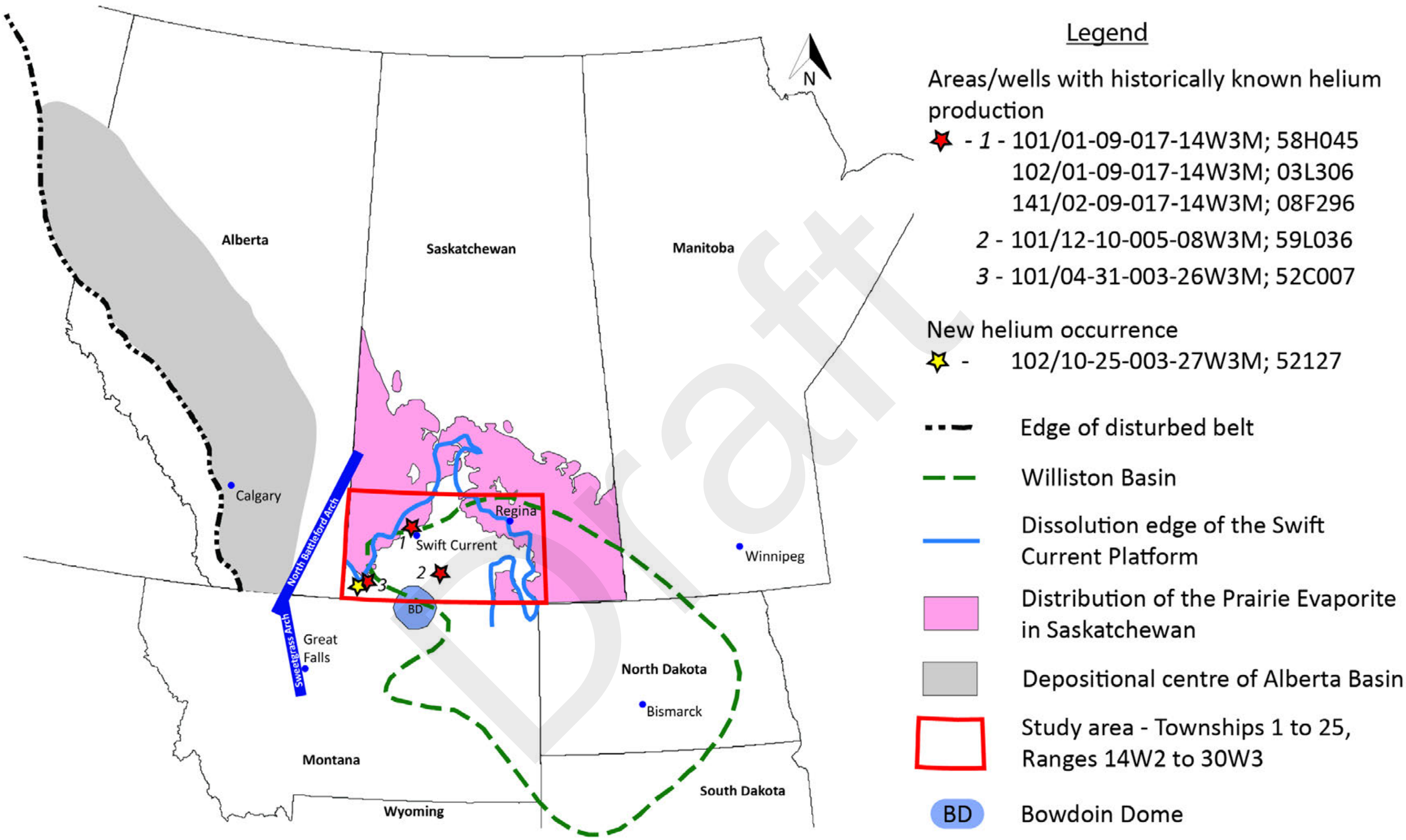

Figure 1 – Map showing the study area, the location of the present-day structural Williston Basin, the approximate centre of the Alberta Basin (Wright et al.*, 1994), and the location of wells that have produced or are producing helium (past-producing wells 02-09-017-14W3M and 12-10-005-08W3M were reporting helium production in August 2016). Also included are the structural elements within the Williston Basin and surrounding area.* Modified from *Kent and Christopher (1994), Rukhlov and Pawlowicz (2012), Anna* et al. *(2013) and Wright* et al. *(1994).*

History of Helium Exploration and Development in Saskatchewan

In 1952, the first indication of helium potential in Saskatchewan came from tests in the United Canso-Consumers Co-op Battle Creek No.4-3 well (101/04-31-003-26W3M; 52C007; well 3 on Figure 1), which showed non-flammable gas from the Devonian Duperow Formation (81.7% CO_2, 13.5% N_2, 0.14% He and 5.66% other gases) and the Dawson Bay Formation (95.16% N_2, 0.47% He and 4.47% other gases). However, exploration for helium was not pursued in Saskatchewan until 1958, when gas containing anomalous helium content was recorded in well B.A. Wilhelm 101/01-09-017-14W3M; 58H045 (area 1 on Figure 1). The gas was found in sedimentary rocks of the Upper Cambrian Deadwood Formation (Figure 2), 2000 m below ground level. The host rocks were silicified siltstones and mudstones draping a basement (Precambrian) topographic high about 14.5 km north of Swift Current (Sawatzky *et al.*, 1960). Tests indicated an inert gas that flowed at a rate of 0.02 to 0.14 million cubic metres (m^3; 1 to 5 million cubic feet (mcf)) per day and was composed of 97% N_2, 2% He and 1% CO_2.

In 1960, helium was discovered in a second well at Texaco Wood Mountain 101/12-10-005-08W3M; 59L036 (now CVE Mankota; well 2 on Figure 1), southeast of Swift Current. A drill stem test (DST) over a 6 metre (20 foot) sandstone interval gave flow rates of 0.46 to 0.57 million m^3 (16.3 to 20.0 mcf) of inert gas per day, which was composed of 96.35% N_2, 1.08% He and 2.5% other gases (exact composition unknown).

Helium production began in 1963 and continued until 1977 from four wells in Ranges 14 to 17W3M, producing a combined total of 57.2 x 10^6 m^3 of gas (2 billion cubic feet (bcf)). It is estimated that 1.4% of this production was helium.

In 2004, Industrial Air Corporation re-entered the B.A. Wilhelm 102/01-09-017-14W3M; 61E006 well (IAC Wilhelm 102/01-09-017-14W3M; 03L306), and in 2008 drilled a second well at IAC Wilhelm 141/02-09-017-14W3M; 08F296. In June of 2014, production began from the 141/02-09-017-14W3M; 08F296 well and as of the end of September 2015, 8.8 x 10^6 m^3 of gas (310,600 mcf; helium is not broken out) has been produced. The well, B.A. Wilhelm 102/01-09-017-14W3M; 61E006 has since been abandoned.

In January 2016, North American Helium Inc. began drilling for helium at NA Helium 102/10-25-003-27W3M; 52127 (yellow star on Figure 1) and in August 2016, Weil Group Resources, LLC opened a helium processing plant near Mankota, approximately 150 km southeast of Swift Current. At the end of August 2016, there were two wells reporting helium production in southwest Saskatchewan: well 12-10-005-08W3M and well 02-09-017-14W3M (identified on Figure 1 respectively as past-producing wells 2 and the third well listed under area 1).

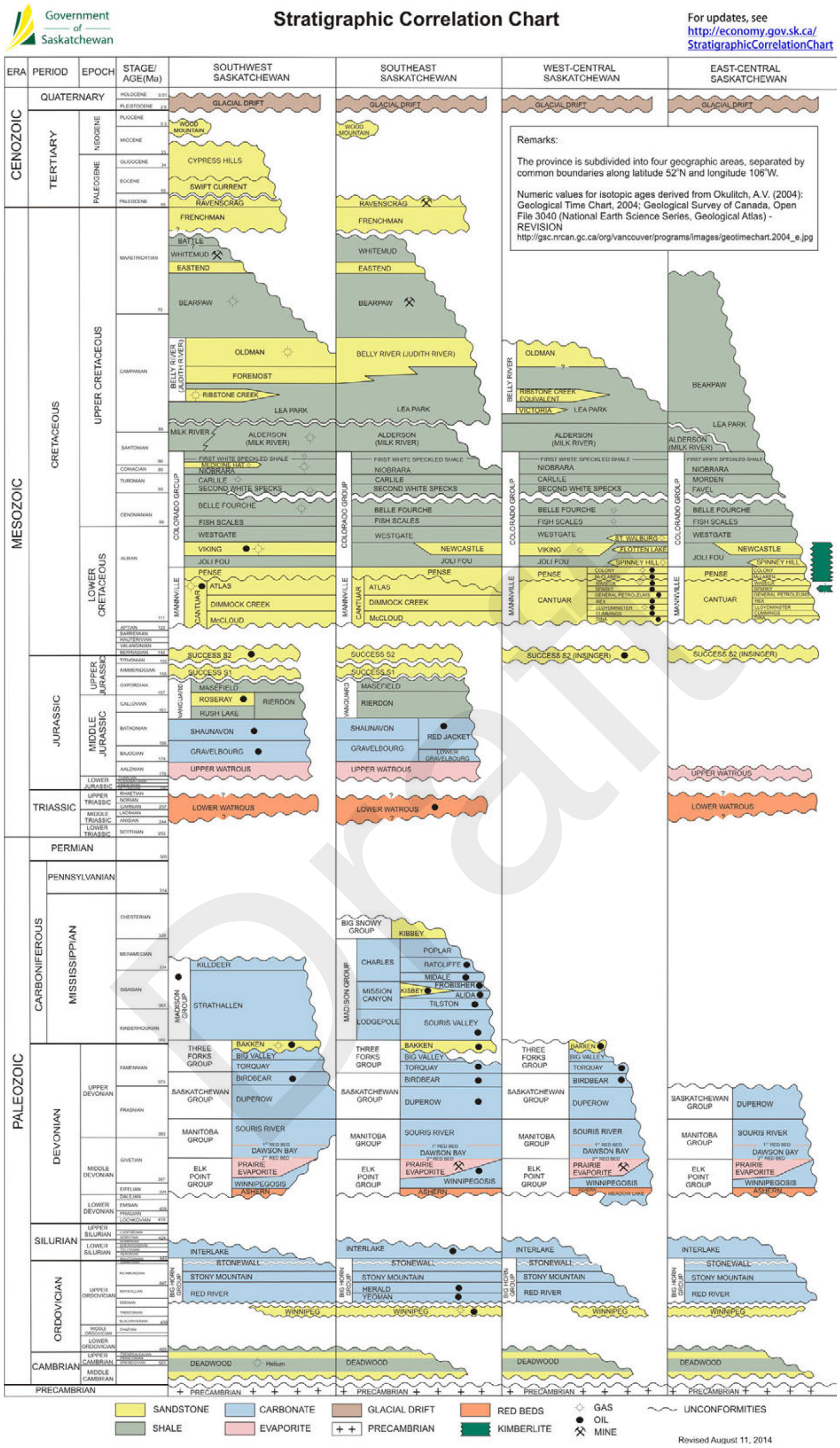

*Figure 2 – Saskatchewan's stratigraphic correlation chart (*from *Saskatchewan Ministry of the Economy, 2014). Helium has been reported in gas analyses from stratigraphic intervals spanning the Cambrian to Cretaceous in southwestern Saskatchewan.*

Understanding Helium Accumulation in the Subsurface

Although the physical processes required to trap economic amounts of helium (source, migration, carrier beds and trap with seal) are similar to hydrocarbon natural gas traps, helium differs from hydrocarbon gases in two ways: it has a non-organic source, and it occurs as a very small molecule. This means it requires a more robust seal for its reservoir than most hydrocarbons, as a helium molecule is roughly half the size of a methane molecule (Hunt, 1996).

Helium occurs in two isotopes, ^{3}He and ^{4}He (Broadhead, 2005). ^{3}He is rare and is derived from mantle gases or from neutron capture by hydrogen with lithium. Lithium occurs in continental brines or with lithium-bearing minerals such as spodumene, or in igneous rocks such as devitrified rhyolite or ash-flow tuff, and occurs naturally in low concentrations. Most helium found in the subsurface is ^{4}He, which is derived from radioactive decay of uranium and thorium.

Regardless of composition, helium is present in most hydrocarbon gases (natural gas) found in the subsurface, but generally only in trace amounts that are rarely of economic value. Helium is also sometimes produced as a secondary byproduct in association with natural gas production where natural gas is liquefied for transport, as helium can be effectively separated and concentrated in this process.

Helium also occurs as a primary commodity, often in association with nitrogen (Johnson, 2012). Where it does occur as a primary commodity, such as in Saskatchewan, scientists have proposed several geological models to explain helium generation and trapping. Some models suggest a granitic basement source, and include generation and migration methods such as diffusive migration out of basement granitic rocks or thermal release of helium from the crustal rocks (Broadhead, 2005). These models require the presence of fracture and/or fault systems that help serve as migration pathways for the helium from the impermeable granite.

Helium can also be generated by radioactive decay of uranium and thorium in orebodies within sedimentary sequences (Broadhead, 2005). It can also be produced from rocks with uranium and thorium concentrations similar to that of an average shale (3.7 ppm U, 12 ppm Th; Brown, 2010), whereby helium migrates from the uranium- and thorium-hosted minerals into stagnant pore water. Upon contact with the stagnant pore water, the helium then partitions into a gas phase. In this case, it requires a significant amount of time (hundreds of millions of years) to generate economic amounts of helium. Brown (2010) also noted that helium partitions more readily from water into gas at lower pressures, higher salinity and cooler temperatures.

Data Collection and Methods

As of January 2016, close to 38 000 oil, gas and potash wells have been drilled in the study area (Figure 3). Of these wells, 1477 were identified in Government of Saskatchewan data files as having gas analyses. Some of these wells have multiple gas analyses from various stratigraphic intervals, resulting in 1856 gas analyses for the 1477 wells.

The data for this report were gathered by manually inspecting each well file at the Ministry of the Economy that had been identified as containing a gas analysis, then tabulating all the analyses (Appendix 1). The data collected from the well files include concentrations of helium (He), nitrogen (N_2), carbon dioxide (CO_2) and hydrogen (H_2), all expressed as a mole fraction. Concentrations of other gases were reported (*e.g.*, methane, ethane and propane), but these were not compiled. The stratigraphic unit for each tested interval was defined from either stratigraphic data sourced from the Ministry of the Economy (where available and as per Figure 2), or by examination of geophysical well logs.

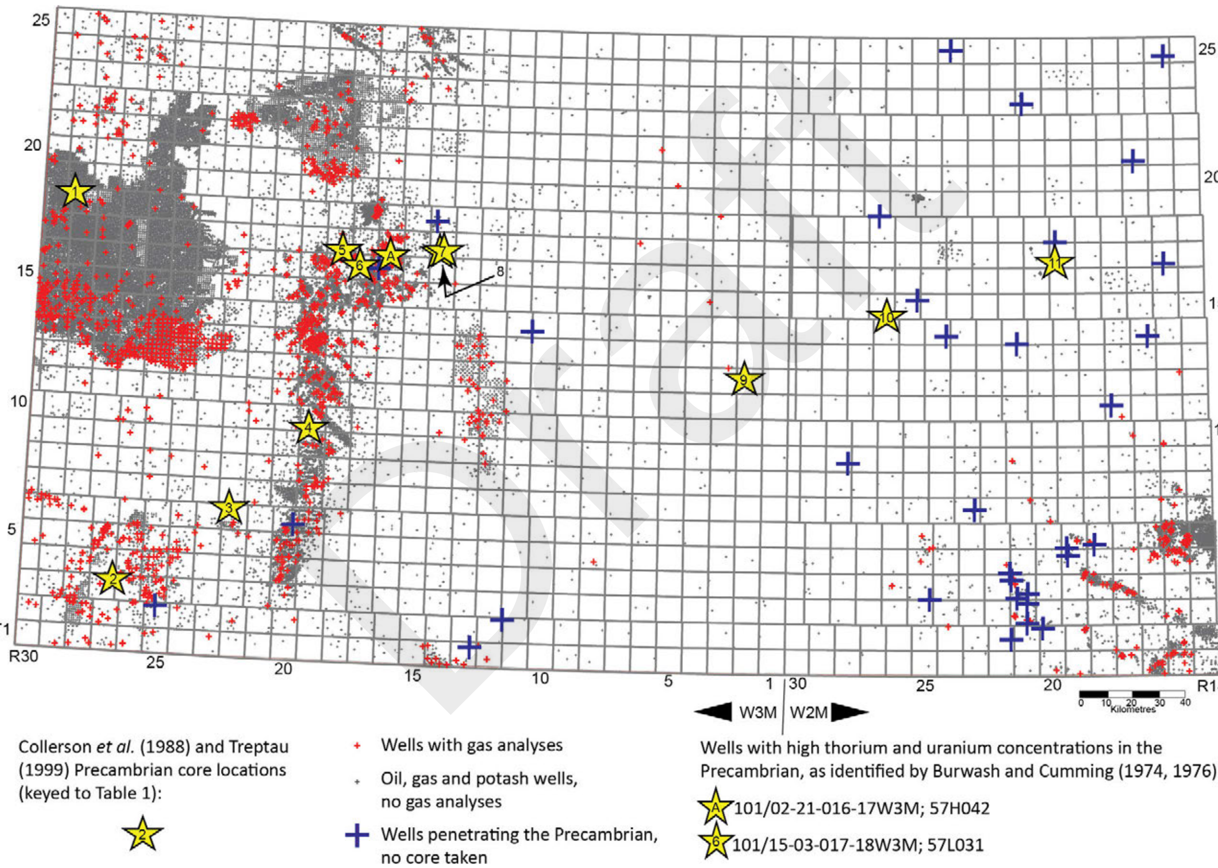

Figure 3 – Map outlining the distribution of oil, gas and potash wells (small grey crosses) in the study area and the wells with gas analyses (small red crosses). Also included is the distribution of Precambrian well penetrations, Precambrian drill cores and rock types identified by Collerson et al. *(1988) and Treptau (1999) that are shown as numbered yellow stars and correspond to the well locations in Table 1. Wells that were drilled into the Precambrian that do not have cores are identified by the larger blue crosses. The wells identified by Burwash and Cumming (1974, 1976) as having high thorium and uranium concentrations contained >46 ppm Th and >15 ppm U. Abbreviations: T - Township, R - Range, W2M - west of the Second Meridian, W3M - west of the Third Meridian.*

Table 1 – Compilation of rock types in cores that penetrated the Precambrian, as identified by Collerson et al. *(1988) and Treptau (1999).*

Well Number on Figure 3	Well Location	Licence Number	Rock Type (from Collerson *et al.,* 1988)	Rock Type (from Treptau, 1999)
1	101/01-31-018-28W3/00	56G058	Dioritic gneiss	Volcaniclastic tuff overlying tonalitic gneiss
2	101/04-31-003-26W3/00	52C007	Diopside-bearing quartzite	Quartzite
3	101/09-32-006-22W3/00	55K012	Albite granite	Alkali-feldspar granite
4	101/02-04-010-19W3/02	53H018	Granite	Pegmatitic granite
5	101/15-03-017-18W3/00	57L031	Hastingsite-bearing granite	Porphyritic granite
6	101/02-21-016-17W3/00	57H042	Biotite-bearing microcline granite	Porphyritic granite
7	101/03-10-017-14W3/00	62H013	Porphyritic microgranite rhyolite	Crystal lithic tuff
8	101/01-09-017-14W3/00	58H045	Hastingsite-biotite-bearing microgranite	Feldspar-rich rhyolitic porphyry
9	101/09-20-012-02W3/00	51I030	Volcaniclastic tuff	Not analyzed
10	101/02-11-015-26W2/00	58I075	Mesoperthite-biotite-bearing granite	Not analyzed
11	131/03-08-017-19W2/02	78L010	Megacrystic garnet-bearing granitic gneiss	Not analyzed

The helium concentrations reported in the well files are from stratigraphic intervals spanning the Cambrian to Cretaceous (Appendix 1). Of the 1856 gas analyses compiled, 890 came from the Upper Cretaceous (Eastend Formation to base of Fish Scales), 197 from the Lower Cretaceous (Viking Formation to base of Mannville Group), 398 from the Jurassic (Success Formation to base of Gravelbourg Formation), 92 from the Mississippian–Devonian (Poplar Beds to base of Bakken Formation), 24 from the Devonian (Birdbear Formation to base of Winnipegosis Formation), 18 from the Ordovician (Red River and Stony Mountain formations), and 24 from the Ordovician–Cambrian (Winnipeg and Deadwood formations). There were also 213 analyses for which the stratigraphic interval could not be determined. Given that hydrocarbon production is predominantly from the Cretaceous, it stands to reason that the number of wells analyzed is skewed toward the shallower zones.

Where available, the sampling point was recorded (*e.g.*, drill stem test, flareline valve, wellhead), though some tests were not directly from an individual well but from part of a gas gathering system (*e.g.*, battery tests, sales line). These latter results were included in the dataset even though a single helium source was not identified, as these values may still aid in understanding the regional context of helium occurrence. Some gas analyses did not indicate a sampling point from either the well or gathering system, but rather from the container in which it was received at the lab (identified as tedlar bag, can or vial). The type of container used may be more sensitive to helium leakage and may give an indication of the quality of the sample received by the lab, and so these were not excluded. Sample numbers assigned by the lab for each test were also noted, in order to identify and differentiate multiple analyses for individual wells. Remarks on the gas analyses were also recorded, where available, but were confined primarily to factors that might affect helium, nitrogen or carbon dioxide values. No gas values were culled or corrected, to avoid any bias in reporting.

The wells from which the gas analyses in Appendix 1 were compiled were drilled and tested over a span of nearly 80 years, by many different companies, and under many different circumstances; drilling and sampling technology, along with type and precision of analytical methods have changed significantly over this time period. As well, the author is unaware of any circumstances where helium concentrations can be increased during gathering and testing, but it is very easy to deplete helium concentrations during this process (*e.g.*, inadequate container selection can allow the small helium molecule to easily escape to the atmosphere). Therefore, caution is advised when using the data to plan exploration or drilling programs, since values may not be truly representative of actual reservoir conditions.

Summary

Helium was reported in gas analyses from wells in southwestern Saskatchewan as early as the 1950s, most notably from the Battle Creek, Wilhelm and Mankota areas. Helium production began in the Wilhelm pool (Township 17, Range 14W3) in 1963 and continued until 1977. Saskatchewan production of helium ceased when market conditions deteriorated, but with current improved market conditions helium production is again being reported from two past-producing wells in the southwest part of the province, one just northwest of the city of Swift Current and the other near the town of Mankota.

With the mounting interest in helium due to supply concerns, the Saskatchewan Geological Survey embarked on a program to increase understanding of the generation, accumulation and geological setting of helium resources in the province.

As a first step, an exhaustive examination of gas analyses in Ministry of the Economy well files from southwestern Saskatchewan was undertaken (this study), which identified anomalous helium concentrations in stratigraphic intervals from the Cambrian to the Cretaceous.

The results of this examination can be summarized as follows:

- The lower Paleozoic formations—in particular, the Deadwood Formation—have the highest helium concentrations in the study area (with the exception of an Upper Cretaceous helium occurrence in the extreme southwest corner of the study area).
- The two most likely models for the development of helium occurrences in southwest Saskatchewan are
    1) generation of helium by radioactive decay of uranium and thorium in Precmbrian granitic basement rocks, migration of the helium out of the impermeable granite along fracture and/or fault systems developed throughout the Phanerozoic by the numerous tectonic elements in this part of the province (in particular, the Great Falls Tectonic Zone), and entrapment of the helium in sediments draping structural highs, with effective seals such as silicified siltstone; and
    2) generation of helium by radioactive decay of uranium and thorium naturally occurring in the shales of the lower Paleozoic rocks (primarily Deadwood Formation shales), natural migration of the helium into stagnant pore water, partitioning of the helium from the water into gas, and trapping of the helium in a similar manner to the first model.
- Based on current understanding, the most viable model for exploration targets seems to be closed structures created by Cambrian to Cretaceous sediments draped over Precambrian monadnocks.

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Appendix 1 – Gas Analyses from Wells in Southwestern Saskatchewan (Townships 1 to 25, Ranges 14W2M to 30W3M) [see separate Microsoft® Excel® file]

The data in this appendix are from wells drilled within an area covered by Townships 1 to 25, Ranges 14 west of the Second Meridian (W2M) to 30 west of the Third Meridian (W3M). As of January 2016, close to 38 000 oil, gas and potash wells have been drilled in this area. Of these wells, 1477 were identified in Government of Saskatchewan data files as having gas analyses. Some of these wells have multiple gas analyses throughout the stratigraphic column, totalling 1856 gas analyses for the 1477 wells identified.

The wells presented in the spreadsheet were drilled and tested over a span of nearly 80 years, by many different companies, and under many different circumstances; drilling and sampling technology, along with type and precision of analytical methods have changed significantly over this time period. As well, the author is unaware of any circumstances where helium concentrations can be increased during gathering and testing, but it is very easy to deplete helium concentrations during this process (*e.g.*, inadequate container selection can allow the small helium molecule to easily escape to the atmosphere). Therefore, caution is advised when using the data to plan exploration or drilling programs, since values may not be truly representative of actual reservoir conditions.

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