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Stratigraphic Notes—Volume 1, 2022

Professional Paper 1879–1

U.S. Department of the Interior
U.S. Geological Survey

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Edited by Randall C. Orndorff, Nancy R. Stamm, and David R. Soller

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Chapters

Abbreviations

BGN	U.S. Board on Geographic Names
B.P.	before present ("present" is 1950 C.E.)
b.y.	billion years
C.E.	Common Era
CGMW	Commission for the Geologic Map of the World
CMU	Correlation of Map Units
DMU	Description of Map Units
FGDC	Federal Geographic Data Committee
Ga	giga-annum (or billion [10^9] years ago)
GNC	Geologic Names Committee
GNR	geologic names review
ICS	International Commission on Stratigraphy
ISG	International Stratigraphic Guide
ISSC	International Subcommission on Stratigraphic Classification
ka	kilo-annum (or thousand [10^3] years ago)
k.y.	thousand years
lat	latitude
LMU	List of Map Units
long	longitude
Ma	mega-annum (or million [10^6] years ago)
m.y.	million years
N.	north
NACSN	North American Commission on Stratigraphic Nomenclature
NAD83	North American Datum of 1983
NASC	North American Stratigraphic Code
NCGMP	National Cooperative Geologic Mapping Program
NGMDB	National Geologic Map Database
Q	Quaternary
R.	range
SE	southeast

sec.	section
SI units	International System of Units
STA7	Suggestions to Authors of the Reports of the U.S. Geological Survey—Seventh Edition
SW	southwest
T	Tertiary
T.	township
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
W.	west
WGS84	World Geodetic System 1984
yr	year
yr B.P.	years before present

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Chapter A

"Stratigraphic Notes"—An Outlet For Stratigraphic Studies

By Randall C. Orndorff, Nancy R. Stamm, and David R. Soller

Introduction

Welcome to the resurrected series of U.S. Geological Survey (USGS) reports on stratigraphy, entitled "Stratigraphic Notes"; this initial volume is called "Stratigraphic Notes—Volume 1, 2022." For several decades, until the mid-1990s, the USGS published volumes of short papers that highlighted stratigraphic studies, changes in stratigraphic nomenclature, and explanations of stratigraphic names and concepts used on published geologic maps. The purpose was to encourage formal documentation on these topics. Today (2023) the need for such documentation has become especially important because of the increasing number of published field-trip guidebooks and open-file reports that use new or updated stratigraphic nomenclature; however, field-trip guidebooks and open-file reports cannot be referenced as authoritative documentation of stratigraphic studies because the North American Stratigraphic Code (NASC) considers such guidebooks and reports to be informal and does not recognize them as proper publications to formalize stratigraphic studies (see Article 4 of the NASC, in North American Commission on Stratigraphic Nomenclature [NACSN], 2021). Hence, a report series such as "Stratigraphic Notes" is needed to bridge this gap.

Discussion

The papers in the "Stratigraphic Notes" series are meant to be an outlet to communicate changes in stratigraphic nomenclature, to support geologic map publications, and to facilitate compilation of new geologic maps and their databases. The goal is to publish a new volume each year, each containing papers that present results of stratigraphic studies drawn from scientific interpretations of stratigraphic and biostratigraphic changes related to changes in environments of deposition and facies, as well as interpretations of igneous and metamorphic units.

According to strategic goals articulated by the National Cooperative Geologic Mapping Program (NCGMP), the USGS and the Association of American State Geologists (representing the Nation's State Geological Surveys) plan to develop a seamless geologic framework for the Nation (Brock, 2017). A major challenge to that goal is demonstrating how (and rectifying, if necessary) stratigraphy changes across states. As the geoscience community moves forward to reconcile stratigraphic changes across diverse boundaries that range from geopolitical to lithological, the "Stratigraphic Notes" series can be an outlet for formal publication of new or updated nomenclature that then can be included in Geolex (https://ngmdb.usgs.gov/Geolex/), which is the USGS National Geologic Map Database's (NGMDB's) geologic names lexicon. Many issues related to human-defined boundaries between map areas (for example, state lines, quadrangle boundaries) are real—stratigraphy does change laterally owing to facies changes, changes in sedimentation related to tectonics and sea level, and changes in paleoenvironments and climate. "Stratigraphic Notes" can provide a platform for discussions of these interpretations as they affect stratigraphic nomenclature.

We are serving as editors of the "Stratigraphic Notes" series with the full support and endorsement of the USGS Geologic Names Committee (GNC) and the NGMDB project. These entities recognize the importance of consistent communication in the geosciences, and, therefore, they support the stratigraphic concepts articulated in the North American Stratigraphic Code (NACSN, 2021), hereafter referred to as "the Code." The Code is published by the North American Commission on Stratigraphic Nomenclature, which consists of experts who represent geoscience organizations across the United States, Canada, and Mexico. The USGS has three (of 25) seats on the Commission.

We welcome papers for the "Stratigraphic Notes" series from geoscientists of the USGS, of State Geological Surveys funded by the STATEMAP component of NCGMP, and of academicians funded by the EDMAP component of NCGMP.[1] This initial volume includes articles that provide guidance for those who wish to submit papers to the "Stratigraphic Notes" series, as well as information on how to make your manuscripts compliant for geologic names reviews and how to organize your paper's content to facilitate inclusion of new or revised names in Geolex. Papers can be submitted for publication in "Stratigraphic Notes" by contacting the GNC (gnc@usgs.gov).

[1]STATEMAP and EDMAP are components of NCGMP that fund geologic mapping projects by State Geological Surveys and universities, respectively, as established by the Geological Mapping Act in 1992.

References Cited

Brock, J.C., 2017, A new decadal strategy for the future of geologic mapping in the U.S.: Geological Society of America Abstracts with Programs, v. 49, no. 6., https://doi.org/10.1130/abs/2017AM-299105.

North American Commission on Stratigraphic Nomenclature [NACSN], 2021, North American stratigraphic code: Stratigraphy, v. 18, no. 3, p. 153–204, https://www.micropress.org/microaccess/stratigraphy/issue-372/article-2251.

Stratigraphic Notes—Volume 1, 2022
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Chapter B

Suggestions for Proposing Changes in Nomenclature in Papers Submitted to "Stratigraphic Notes"

By Nancy R. Stamm

Introduction

The "Stratigraphic Notes" series is intended to be an outlet for publication of short papers on stratigraphy, changes in stratigraphic nomenclature, and explanation of stratigraphic names and concepts used on published geologic maps. This report provides authors with suggestions for the content and format of papers submitted to "Stratigraphic Notes" in which geologic names are proposed or their definitions and supporting information are modified. These suggestions are based on the guidance and rules found in the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature [NACSN], 2021) and from experience compiling the U.S. Geologic Names Lexicon (Geolex, https://ngmdb.usgs.gov/Geolex/). It is with the hope that authors will find these suggestions useful when organizing and presenting their observations and interpretations in a succinct and straightforward fashion, appropriate to "Stratigraphic Notes" (see also, U.S. Geological Survey, 1982, 1984, 1985, 1987, 1991, 1994a, b, 1995).

Appendix 1 contains suggested topics and their section headings and subheadings for papers submitted to "Stratigraphic Notes" on new geologic names or changes to names. Within the body of this report, guidance on the content of these sections is provided; for reasons of clarity, suggestions that pertain to changes to formal geologic names are discussed separately from those for proposing new names. Note that, herein, the term "geologic name" is used interchangeably with "geologic unit" and refers to a three-dimensional body of earth material (rock or sediment), recognized by its lithologic content and its boundaries at the surface and (or) subsurface.

Proposing Changes to Formal Geologic Names

In this section, guidance is offered for designation of a reference section, locality, or area and a principal reference section, locality, or area, followed by guidance on the more demanding changes in nomenclature (age modification, redefinition, revision, abandonment, and reinstatement). Examples of the suggested figures to include in papers are given at the end of this report.

Designation of Reference (Section, Locality, or Area)

A reference (section, locality, or area)[1] may be designated for a formal geologic unit at any time. It is suggested for completeness and so that others may examine varying characteristics and (or) boundaries of a geologic unit that are not clearly evident at the type or principal reference (section, locality, or area). When designating a reference (section, locality, or area) for a formal geologic unit, please include the following information: (1) a description of its geographic location; (2) one or more measured stratigraphic sections (if not a lithodemic unit); (3) a lithologic description of the geologic unit; (4) the nature and placement of its boundaries; and (5) its thickness. The reference (section, locality, or area) should be precisely located and described. See the "Designation of Type (Section, Locality, or Area)" section below for details.

Suggested figures to include when designating a reference (section, locality, or area) are an index map showing the area of study (see figs. 1, 2); a topographic map showing the geographic location of the reference (section, locality, or area) (see fig. 3); one or more measured stratigraphic sections (see fig. 4); and photographs.

Designation of Principal Reference (Section, Locality, or Area)

A principal reference (section, locality, or area) may be designated for formal geologic units that lack a type (section, locality, or area), notably for geologic names proposed in early reports, prior to the Committee on Stratigraphic Nomenclature's (1933) rules for classification and nomenclature of rock units. A principal reference (section, locality, or area) also may be applied to formal geologic units for which the type has become inaccessible or has been destroyed. In some cases, principal reference sections have been designated because the original type section could not be located or reconstructed (see, for example, Gill and others, 1970, p. 24). When designating a principal reference (section, locality, or area) for a formal geologic

[1]The terms "section, locality, or area" placed in parentheses indicate that either "section," "locality," or "area" may be chosen as type, reference, or principal reference (for example, "type section" or "reference area").

unit, include the following information: (1) a description of its geographic location; (2) one or more measured stratigraphic sections (if not a lithodemic unit); (3) a lithologic description of the geologic unit; (4) the nature and placement of its boundaries; and (5) its thickness. The principal reference (section, locality, or area) should be precisely located and described. See the "Designation of Type (Section, Locality, or Area)" section below for details.

Suggested figures to include when designating a principal reference (section, locality, or area) are an index map showing the area of study (see figs. 1, 2); a topographic map showing the geographic location of the principal reference (section, locality, or area) (see fig. 3); one or more measured stratigraphic sections (see fig. 4); and photographs.

Age Modification

When modifying the age of a geologic unit, indicate whether the age is changed regionally or locally, and provide the following information: (1) the reasons for divergence from ages reported by previous workers and (2) the evidence for the age change, which may be based on the following information:

- *Biostratigraphic determinations.*—If so, include (1) sample-locality information; (2) lithologic descriptions of samples; and (3) faunal and (or) floral lists.
- *Numerical age determinations.*—If so, include (1) interpretive statements about what the numerical age represents (such as cooling, exhumation, intrusion, metamorphism, or exposure); (2) descriptions of analytical techniques, calibration methods, recalculations based on new constants, and uncertainty estimates; (3) sample-locality information; (4) lithologic descriptions of samples; and (5) minerals or organic materials analyzed (for example, zircon, biotite, wood).

Sampling sites should be precisely located. Include geographic coordinates (for example, latitude [lat], longitude [long], Universal Transverse Mercator [UTM] projection); datum (for example, North American Datum of 1983 [NAD83] or World Geodetic System 1984 [WGS84]); Public Land Survey System location (section, township, range), if applicable; name and series (scale) of U.S. Geological Survey (USGS) topographic quadrangle; name of county, parish, and so forth; name of state, possession, or territory; and name of federal or state public land, if applicable.

Suggested figures to include when changing the age of a geologic unit are an index map showing the area of study (see figs. 1, 2); a topographic map showing locations of samples collected; a measured section showing stratigraphic positions of samples collected (see fig. 4); and a correlation chart (see fig. 5; note that chronostratigraphic terms [eonothem, erathem, system, series, and stage names] are used for correlations that are based on stratigraphic position, and geochronologic terms [eon, era, period, epoch, and age names] are used for correlations that are based on time).

Redefinition

A redefinition involves a change in the descriptive (lithic) term applied to a stratigraphic or lithodemic unit that does not require a new geographic term (NACSN, 2021). When redefining a geologic name, indicate whether the lithic term is changed regionally or locally. Include reasons for divergence from lithic designations of previous workers and a description of the geologic unit.

Suggested figures to include when changing the lithic term of a geologic name are an index map showing the area of study (see figs. 1, 2); a topographic map showing the geographic location of the reference (section, locality, or area) (see fig. 3); one or more measured stratigraphic sections (if not a lithodemic unit) (see fig. 4); photographs; a correlation chart (see fig. 5); and a stratigraphic table (see fig. 6).

Revision

A revision of a formal geologic unit can involve a change to its upper and (or) lower boundaries; rank; formal subdivisions; and (or) assignment to a formal geologic unit of higher rank. When revising a formal geologic unit, indicate whether it is revised regionally or locally and include the following: (1) reasons for divergence from previous workers; (2) a reference (section, locality, or area); (3) one or more measured stratigraphic sections (if not a lithodemic unit); (4) a lithologic description of the geologic unit; (5) the nature and placement of its boundaries; and (6) its thickness. The reference (section, locality, or area) should be precisely located and described. See the "Designation of Type (Section, Locality, or Area)" section below for details.

Suggested figures to include when revising a geologic unit are an index map showing the area of study (see figs. 1, 2); a topographic map showing the geographic location of the reference (section, locality, or area) (see fig. 3); one or more measured stratigraphic sections (if not a lithodemic unit) (see fig. 4); photographs; a correlation chart (see fig. 5); and a stratigraphic table (see fig. 6).

Abandonment

When abandoning a formal geologic unit, provide (1) a discussion of the reasons for abandonment, and (2) replacement name(s), which can be formal or informal, as the following example shows (from Epstein and others, 1995, p. 6):

> "The original description of the Oranda Formation includes knobby limestone at its base with shale and siltstone, in part calcareous, above. Because of difficulties in recognizing the Oranda as a readily mappable lithologic unit, we are herein abandoning the name. The lower knobby-weathering limestones are assigned to the underlying Edinburg Formation. The overlying calcareous shale and siltstone and shaly limestone are included in the base of the lower member of the Martinsburg Formation, herein named the Stickley Run Member."

Suggested figures to include when abandoning a geologic name are an index map showing the area of study (see figs. 1, 2) and a stratigraphic table (see fig. 6).

Reinstatement

The original definition of an abandoned name may be accepted or modified in the paper. When reinstating a formal geologic unit, include a discussion of (1) the reasons for reinstatement, and (2) treatment of geologic units supplanted. A supplanted unit might be described as geographically restricted, stratigraphically restricted (revised), abandoned, or not accepted (adopted) for use in the study area. If a supplanted name is not used in its type area, it cannot be used elsewhere in the paper.

Suggested figures to include when reinstating a geologic name are an index map showing the area of study (see figs. 1, 2); a topographic map showing the geographic location of the type (or principal reference) and reference (section, locality, or area) (see fig. 3); one or more measured stratigraphic sections (if not a lithodemic unit) (see fig. 4); photographs; a correlation chart (see fig. 5); and a stratigraphic table (see fig. 6).

Proposing New Formal Geologic Names

A number of requirements are necessary when proposing a new formal geologic unit. Of particular note are derivation of the name, designation of the type (section, locality, or area), and lithologic description and distinguishing features of the geologic unit.

Suggested figures to include when proposing a new formal geologic name are an index map showing area of study and, if possible, including the geographic feature from which the unit is named (see figs. 1, 2); a topographic map showing the geographic location of the type and reference (section, locality, or area) (see fig. 3); one or more measured stratigraphic sections (if not a lithodemic unit) (see fig. 4); photographs; a correlation chart (see fig. 5); and a stratigraphic table (see fig. 6).

Derivation of Name

The geographic feature from which a formal geologic name is taken must be at or near the place where the distinguishing characteristics of the geologic unit are best observed. The geographic feature should be officially recognized by the U.S. Board on Geographic Names (BGN) (https://geonames.usgs.gov/). The name of a geologic unit should be from a long-lasting geographic feature such as a river, lake, summit, ridge, valley, or incorporated municipality. Do not name a geologic unit after a person, borehole, quarry, or mine.

If a geologic unit is to be named in an area that lacks named geographic features, a new geographic name must first be proposed through and accepted by the BGN. Instructions and application forms for proposing new geographic names are available at https://www.usgs.gov/us-board-on-geographic-names/how-do-i. These forms need to be completed at an early stage in the preparation of a paper.

Authors are responsible for avoiding duplication of names. An author planning to propose a new formal geologic unit should check Geolex (https://ngmdb.usgs.gov/Geolex) and associated U.S. Geological Survey Geologic Names Committee (GNC) records (notably, see "USGS Index Cards" at https://ngmdb.usgs.gov/Geolex/stratres) to determine that a geographic name has not been used for another previously named geologic unit in the United States. After confirming the availability of the name, the author should reserve the name with the GNC secretary (GNC@usgs.gov).

Designation of Type (Section, Locality, or Area)

The type (section, locality, or area) of a formal geologic unit is designated at the same time the unit is proposed. The type (section, locality, or area) must be at or near the geographic feature for which the geologic unit is named, and it should be precisely located and described.

Location

The location of the type (section, locality, or area) should include geographic coordinates (for example, latitude [lat], longitude [long], Universal Transverse Mercator [UTM] projection); datum (for example, North American Datum of 1983 [NAD83] or World Geodetic System 1984 [WGS84]); Public Land Survey System location (section, township, range), if applicable; name and series (scale) of USGS topographic quadrangle; name of county, parish, and so forth; name of state, possession, or territory; and name of federal or state public land, if applicable.

The location description should include enough detail so that another person could locate the type (section, locality, or area) in the field, as in the following (fictitious) example:

> The type section is designated in an east cut bank of an unnamed tributary to the Illinois River, about 500 feet (150 meters) north of State Route 71 (Hiawatha Pioneer Trail) near the western edge of Starved Rock State Park, about 1.5 miles (2.4 kilometers) southeast of the confluence of the Vermilion and Illinois Rivers, and about 1.5 miles (2.4 kilometers) northeast of the city of Oglesby, in SW¼SW¼SE¼ sec. 19, T. 33 N., R. 2 W., lat 41°18′37″ N., long 89°02′14″ W., NAD83, La Salle 7.5′ USGS quadrangle, LaSalle County, northern Illinois.

Unit Description and Distinguishing Features

A formal geologic unit should be described "so clearly that any subsequent investigator can recognize that unit unequivocally" (NACSN, 2021, see Article 9, p. 170). Characteristics of the rocks or sediments may include

lithology (dominant and subordinate), color (fresh and weathered), degree of induration, grain size and shape, mineralogy, bedding characteristics, thickness, nature and placement of boundaries, biologic remains, geochemistry, geophysical properties (including magnetic signatures), geomorphic expression, and structural orientations. Characteristics that differentiate a geologic unit from other units should be discussed.

Important Topics to Discuss when Proposing Changes in Nomenclature

Whether proposing changes to existing nomenclature or introducing new geologic names, the following items are considered important topics to discuss in your submitted paper.

Historical Background of Previous Usage

Please include a discussion on the historical background of previous studies and nomenclature used, especially if the proposed change (for example, naming or revising a geologic unit) partly or wholly replaces an existing formal or informal geologic unit. Include information on the derivation of the name and the type or principal reference (section, locality, or area) from the original and (or) principal publication.

Suggested figures to include when discussing previous nomenclature of a geologic unit are an index map showing the area of study (see figs. 1, 2) and a stratigraphic table (see fig. 6).

Boundaries

The nature and placement of the upper and lower boundaries of a geologic unit should be discussed. Suggested figures to include when discussing the boundaries of a geologic unit are an index map showing the area of study (see figs. 1, 2) and photographs.

Geographic Extent and Thickness

The geographic extent and lateral variations of a geologic unit should be discussed. If known, the maximum, minimum, and (or) average thickness of a geologic unit also should be discussed.

Suggested figures to include when discussing the geographic extent and thickness of a geologic unit are an index map showing the area of study (see figs. 1, 2); one or more measured stratigraphic sections (if not a lithodemic unit) (see fig. 4); and a correlation chart (see fig. 5).

Age and Correlation

If known, the geologic age of a unit, as well as correlations with other units within or near the study area, should be discussed. Include evidence such as biostratigraphic and numerical age determinations. If the age is being modified in the paper, please refer to the "Age Modification" section above. Inclusion of a correlation chart (see fig. 5) is suggested when discussing the age and correlation of a geologic unit. Chronostratigraphic terms (eonothem, erathem, system, series, and stage names) are used for correlations that are based on stratigraphic position, and geochronologic terms (eon, era, period, epoch, and age names) are used for correlations that are based on time.

Inferred Geologic History

The inferred geologic history of a geologic unit should be supported by evidence (for example, field observations, laboratory results) given in the paper.

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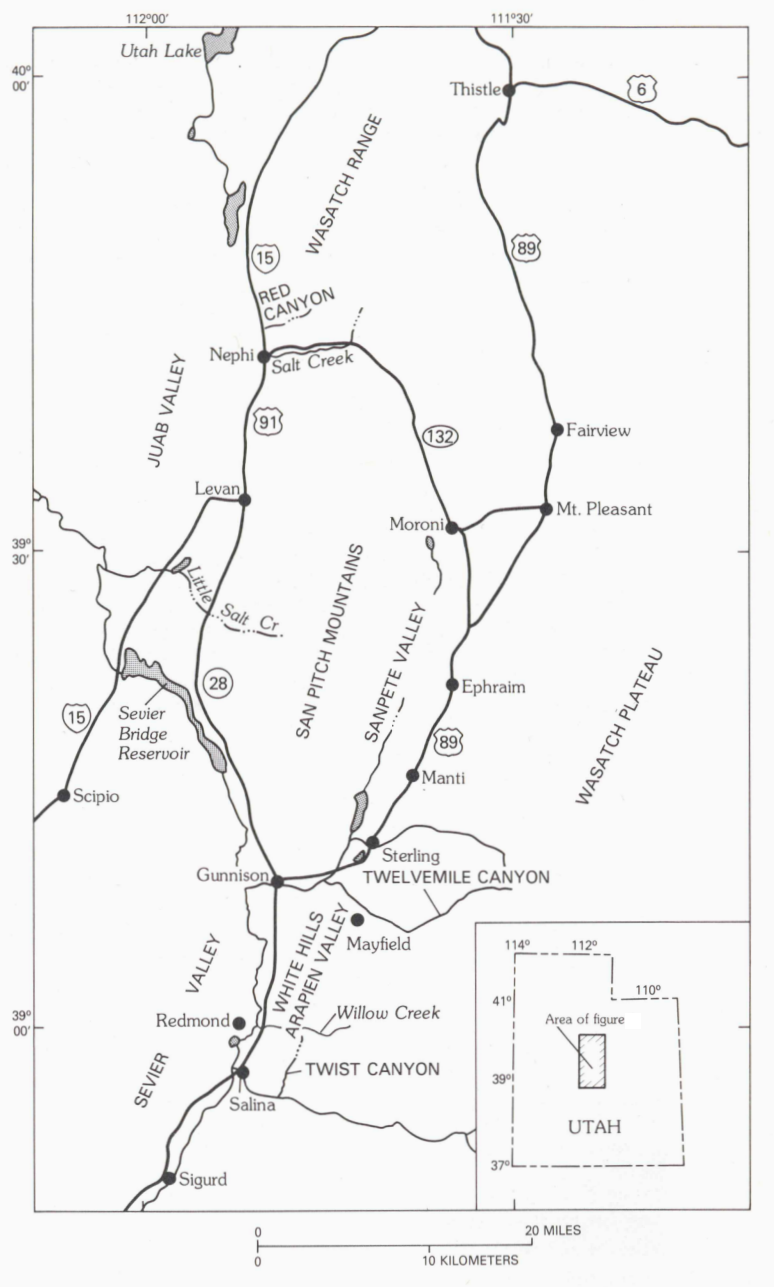

Figure 1. Example of index map showing area of study (entire figure) and locations of geographic features. Modified from Witkind and Hardy (1984, their fig. 1).

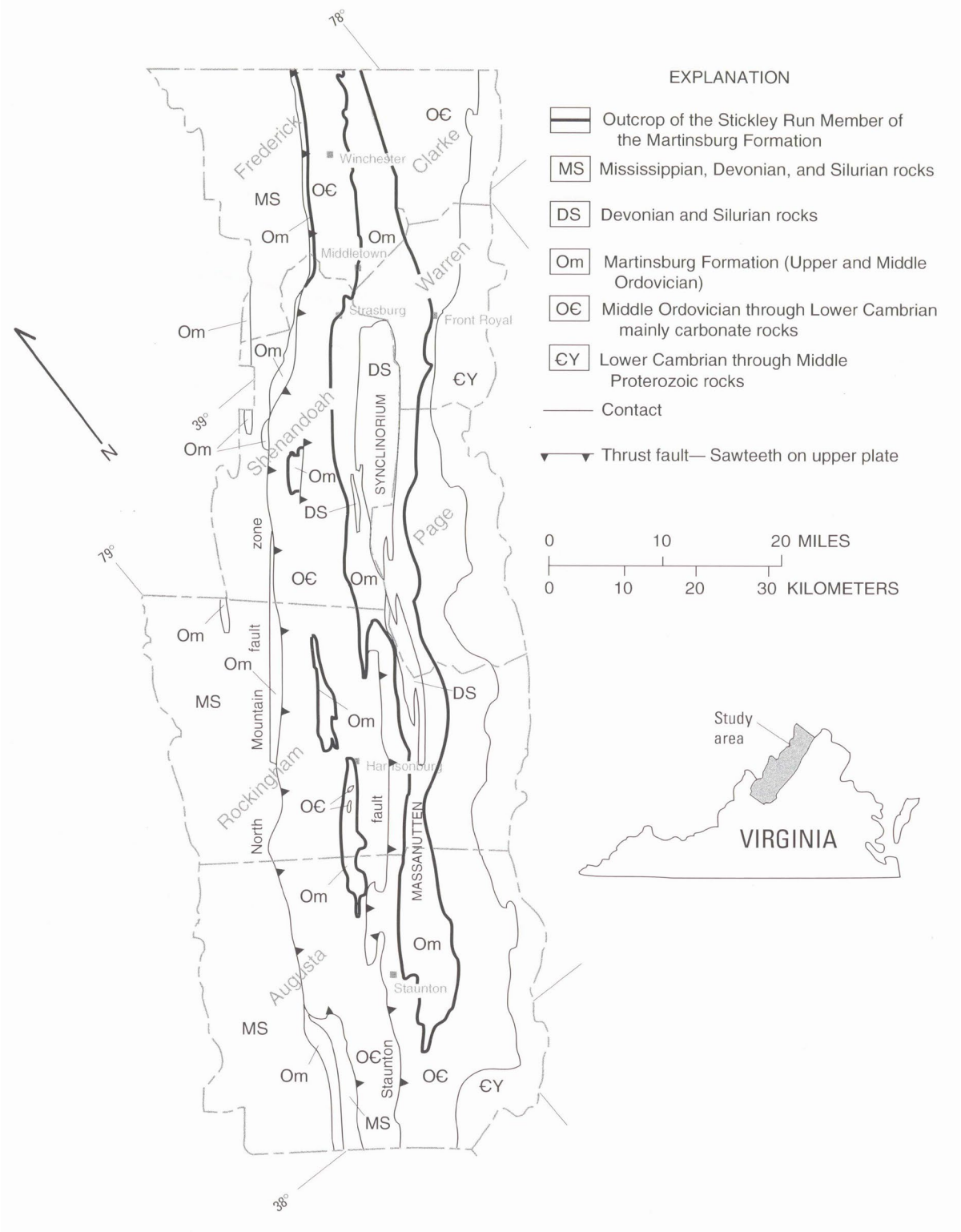

Figure 2. Example of generalized geologic map showing area of study and lines of outcrop of unit (in this case, the Stickley Run Member of the Martinsburg Formation). Modified from Epstein and others (1995, part of their fig. 1).

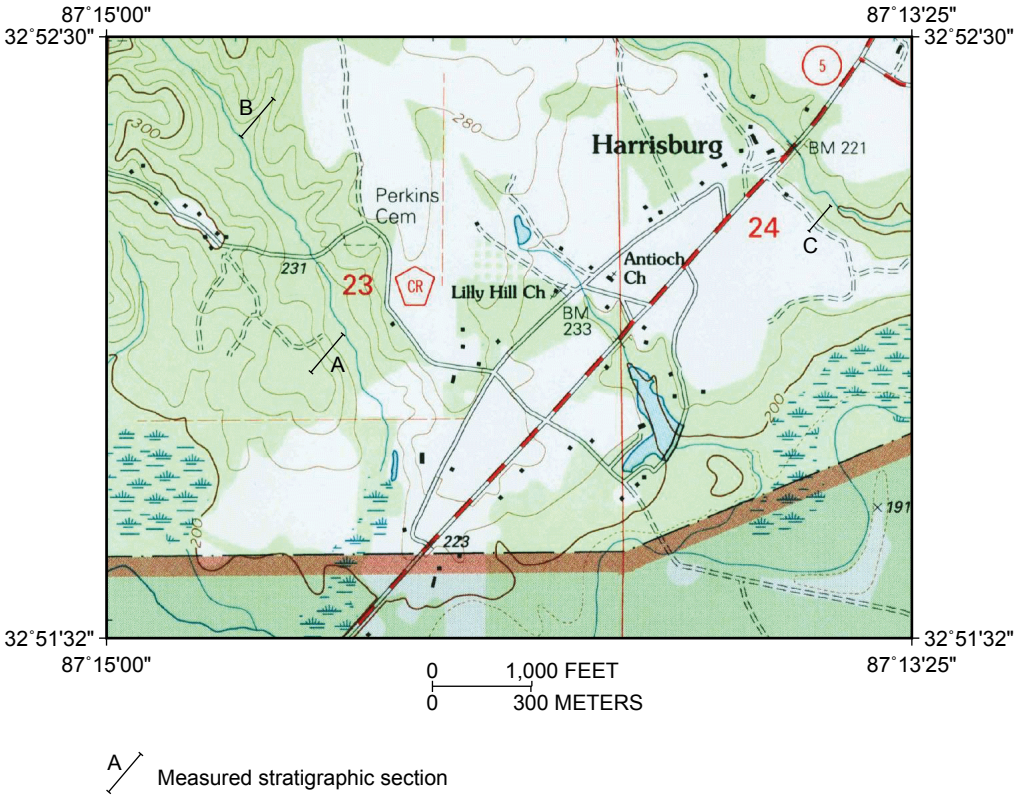

Figure 3. Example of part of U.S. Geological Survey (USGS) topographic map (in this case, northwest corner of Harrisburg, Alabama, 7.5' quadrangle, 2002) showing geographic locations of (fictitious) type (A) and reference (B, C) measured stratigraphic sections. High-resolution GeoTiff of topographic map downloaded from USGS topoView (https://ngmdb.usgs.gov/topoview), cropped, and saved as 300-dots-per-inch image file using Adobe Photoshop.

Table 1. Type section of part of the Stickley Run Member of the Martinsburg Formation, along a roadcut on the southeast side of the northbound lane of U.S. Highway 11, immediately east of Cedar Creek, about 2.5 mi (4 km) southwest of Middletown, Va., at lat 39°00'57" N., long 78°18'52" W. (locality a in fig. 3).

[Rock-color terms from Goddard and others (1948). Measurements were made in feet]

Martinsburg Formation (part): Stickley Run Member (part):	Thickness Feet	Thickness Meters
16. Limestone, thin-bedded and laminated, and calcareous shale; medium-dark-gray (*N* 4) limestone beds as much as 9 in. (23 cm) thick. Covered above to Cedar Creek	28.0	8.5
15. Shaly limestone, laminated to thin-bedded (<0.5–3 in. (1–8 cm) thick), medium-dark-gray (*N* 4), medium-olive-gray (5*Y* 5/1)-weathering, very fine grained, interbedded with grayish-black (*N* 3) calcareous shale	21.0	6.4
14. Limestone, thin-bedded and laminated, medium-dark-gray (*N* 4), and calcareous shale	4.6	1.4
13. Same as unit 15	10.3	3.1
12. Limestone, thin-bedded and laminated, medium-dark-gray (*N* 4), and calcareous shale; limestone beds as much as 6 in. (15 cm) thick and making up about 30 percent of the unit	7.3	2.2
11. Same as unit 15. Some of the limestone beds as much as 6 in. (15 cm) thick	20.8	6.3
10. Shaly limestone, laminated, medium-dark-gray (*N* 4)	4.0	1.2
9. Same as unit 15	17.3	5.3
8. Metabentonite, moderate-yellowish-brown (10*YR* 5/4)-weathering, sheared, interlayered with calcite slickenside	0.2	0.06
7. Calcareous silty limestone, medium-dark-gray (*N* 4), medium-olive-gray (5*Y* 5/1)-weathering, that stands out in relief	1.1	0.3
6. Shaly limestone, laminated to thin-bedded (<0.5–3 in. (1–8 cm) thick), medium-dark-gray (*N* 4), medium-olive-gray (5*Y* 5/1)-weathering, very fine grained, composing about 8 percent of unit and interbedded with grayish-black (*N* 3) calcareous shale in graded and upward-fining cycles 1–6 in. (2–15 cm) thick (fig. 5). Base of each cycle abrupt	11.3	3.4
5. Shaly limestone, medium-dark-gray (*N* 4), medium-olive-gray (5*Y* 5/1)-weathering, very fine grained, containing graptolites; stands out in relief. Abrupt lower contact. Not fissile like underlying shales	0.3	0.1
4. Calcareous shale, platy to laminated, grayish-black (*N* 3), and minor laminae of dark-gray (*N* 3), medium-dark-gray (*N* 4)-weathering, shaly limestone, which stand out in slight relief. Partly covered near base; may include thin metabentonite. Lower contact with Edinburg Formation is abrupt	13.5	4.1
Incomplete thickness of Stickley Run Member	139.7	42.6
Edinburg Formation:		
3. Limestone, medium-dark-gray (*N* 4), medium-gray (*N* 5)- to light-olive-gray (5*Y* 6/1)-weathering, very fine grained, poorly bedded	1.5	0.5
2. Limestone, dark-gray (*N* 3), medium-dark-gray (*N* 4)-weathering, knobby (nodules average about 4 in. (10 cm) long), very fine grained, interbedded with dark-gray (*N* 3) to medium-dark-gray (*N* 4), medium-gray (*N* 5)-weathering, calcareous silty shale	6.0	1.8
1. Limestone, dark-gray (*N* 3), medium-dark-gray (*N* 4)-weathering, very fine to fine-grained, medium- to thick-bedded, unevenly bedded, fossiliferous	51.0	15.5
Incomplete thickness of Edinburg Formation	58.5	17.8

Figure 4. Example showing measured section of unit (in this case, type section of the Stickley Run Member of the Martinsburg Formation), located near Middletown, Virginia. From Epstein and others (1995, their table 1). Note that "table 1" refers to table in Epstein and others (1995); note also that table title contains important locality information and that "fig. 3" in table headnote and "fig. 5" in bed no. 6 refer to figures in Epstein and others (1995). Rock-color terms (for example, *N* 4, *5Y* 5/1) are from Goddard and others (1948). Other abbreviations: cm, centimeter; in., inch; km, kilometer; lat, latitude; long, longitude; mi, mile; N., north; Va., Virginia; W., west.

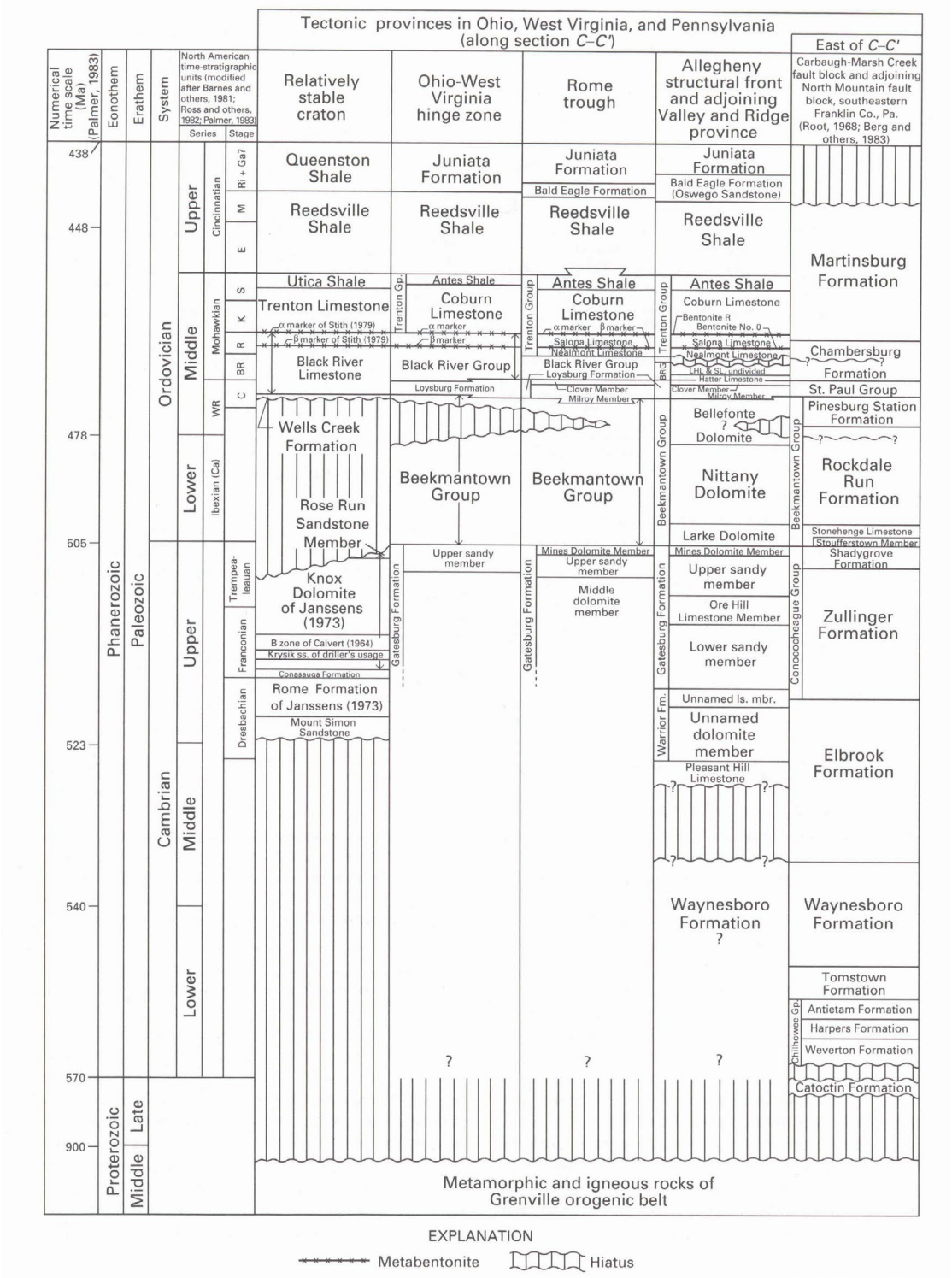

Figure 5. Example of correlation chart showing stratigraphic relations among units (in this case, Proterozoic and lower Paleozoic rocks in subsurface of parts of Ohio, West Virginia, and Pennsylvania). From Ryder and others (1992, their fig. 2). North American series- and stage-name abbreviations: BR, Blackriveran; C, Chazyan; Ca, Canadian; E, Edenian; Ga, Gamachian; K, Kirkfieldian; M, Maysvillian; R, Rocklandian; Ri, Richmondian; S, Shermanian; WR, Whiterockian. Group- and formation-name abbreviations: BRG, Black River Group; LHL, Linden Hall Limestone; SL, Snyder Limestone. Other abbreviations: Co., County; Fm., Formation; Gp., Group; ls., limestone; Ma, mega-annum (or millions of years before present [A.D. 1950]); mbr., member; No., number; Pa., Pennsylvania; ss., sandstone. Note that chronostratigraphic terms (eonothem, erathem, system, series, and stage names) are used for correlations that are based on stratigraphic position, and geochronologic terms (eon, era, period, epoch, and age names) are used for correlations that are based on time.

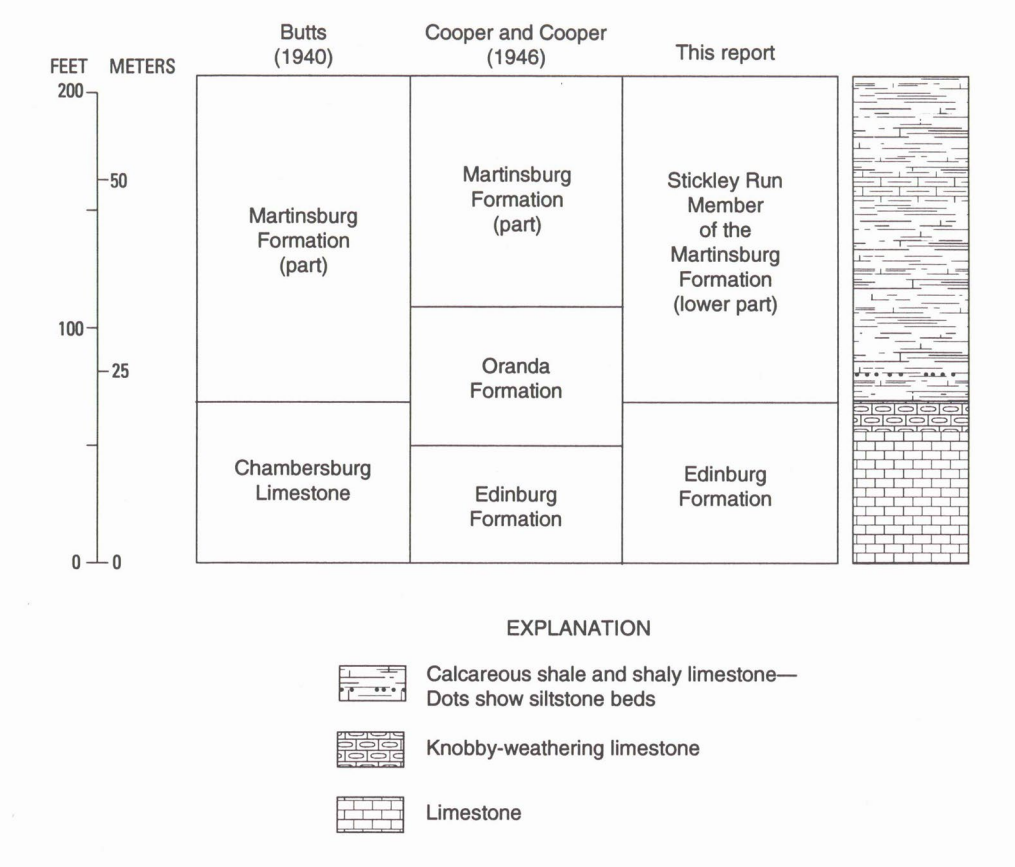

Figure 6. Example of stratigraphic table showing history of nomenclature in study area (in this case, located in northern Shenandoah Valley, Virginia). From Epstein and others (1995, their fig. 2; referred to as "this report" in figure). Graphic columnar section illustrates placement of lower boundary of unit (in this case, the Stickley Run Member of the Martinsburg Formation).

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Chapter B, Appendix 1. Suggested Format for Proposing New Formal Geologic Names or Changes to Existing Names in Papers Submitted to "Stratigraphic Notes"

In the introduction section of the paper, provide a brief description of the study area and geologic setting and a summary of the proposed changes to the geologic nomenclature. In the body text, discuss the geology of an area chronologically—the oldest unit first and the youngest last. However, when describing areas in which geologic information is based largely on subsurface records such as groundwater aquifers or oil fields, it may be advantageous to discuss the stratigraphy from youngest to oldest (top to bottom). The following organization is recommended for each instance of a new or modified geologic unit.

[Geologic Name] (Named)

Place the geologic name in the heading, followed by "Named" in parentheses—for example, "Hoopers Island Formation (Named)." Include an introductory paragraph stating the reasons for proposing the new formal geologic name. For clarity, the designation of category (for example, lithostratigraphic, lithodemic) must be stated. The subheadings listed below are topics to be discussed when defining new formal geologic names:

- Historical Background
- Derivation of Name
- Type (Section, Locality, or Area)[2]
- Reference (Section, Locality, or Area) [optional]
- Unit Description and Distinguishing Features
- Boundaries
- Geographic Extent and Thickness [indicate if thickness is unknown]
- Age and Correlation [indicate if age is unknown]
- Inferred Geologic History [optional]

[Geologic Name] ([Type of Modification])

Place the geologic name in the heading, followed by the type of modification in parentheses—for example, "Dakota Sandstone (Revised)." Suggested terms to indicate the type of modification are "Abandoned," "Age Modified," "Redefined," "Revised," and "Reinstated." Include an introductory paragraph stating the reasons for modifying the formal geologic name. Indicate whether the change in nomenclature is regional or local. The subheadings listed below are topics to be discussed when modifying formal geologic units:

- Historical Background
- Principal Reference (Section, Locality, or Area) [include if designated herein]
- Reference (Section, Locality, or Area) [optional]
- Unit Description and Distinguishing Features
- Boundaries
- Geographic Extent and Thickness [indicate if thickness is unknown]
- Age and Correlation [indicate if age is unknown]
- Inferred Geologic History [optional]

[2]The terms "section, locality, or area" placed in parentheses indicate that either "section," "locality," or "area" may be chosen as type, reference, or principal reference (for example, "type section" or "reference area").

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Chapter C

Divisions of Geologic Time—Major Chronostratigraphic and Geochronologic Units

By Randall C. Orndorff,[1] Nancy R. Stamm,[1] David R. Soller,[1] Lucy E. Edwards,[1] Julie A. Herrick,[1] Leslie F. Ruppert,[1] Janet L. Slate,[1] and Berry H. Tew, Jr.[2]

Introduction

Effective communication in the geosciences requires consistent use of stratigraphic nomenclature, especially divisions of geologic time. A geologic time scale is composed of standard stratigraphic divisions that are based on rock sequences and is calibrated in years (Harland and others, 1982). Over the years, the development of new dating methods and the refinement of previous ones have stimulated revisions to geologic time scales.

Since the mid-1990s, geologists from the U.S. Geological Survey (USGS), State geological surveys, academia, and other organizations have sought a consistent time scale that can be used in communicating ages of geologic units in the United States. Many international debates have occurred over the names and boundaries of units, and various time scales have been used by the geoscience community in years past (for example, U.S. Geological Survey Geologic Names Committee [USGS GNC], 2007, 2010, 2018). However, the numerical ages assigned to geochronologic units frequently change as the science of stratigraphy moves forward. Once ratified, changes in numerical ages are recorded by the International Commission on Stratigraphy (ICS) on their website (https://stratigraphy.org/chart). In addition, such advances in stratigraphy and changes in geochronology require that any time scale be periodically updated. Therefore, the time scale presented in this report (hereafter referred to as "Divisions of Geologic Time") is dynamic, and it is modified as needed to include accepted changes of unit names and boundary age estimates (USGS GNC, 2007, 2010, 2018).

Time Scales

For consistent usage of time terms, the USGS Geologic Names Committee (GNC) and the Association of American State Geologists has developed the "Divisions of Geologic Time" time scale. The update (circa 2023) to the "Divisions of Geologic Time" time scale, which is included herein (fig. 1), contains the major chronostratigraphic and geochronologic unit names and their boundary-age estimates, as ratified by the International Commission on Stratigraphy [ICS] (2022). It is worth noting that scientists may use other published time scales (for example, Palmer, 1983; Harland and others, 1990; Haq and van Eysinga, 1998; Gradstein and others, 2012; Ogg and others, 2016; Walker and others, 2018), provided that the time scales used are specified and appropriately referenced.

Formal Chronostratigraphic (Position) and Geochronologic (Time) Units

Any chronostratigraphic or geochronologic unit listed in the updated "Divisions of Geologic Time" time scale (fig. 1) is considered formal and, thus, is capitalized. The "Divisions of Geologic Time" time scale shows the formally named chronostratigraphic (position) and geochronologic (time) units (that is, the eonothems or eons; erathems or eras; systems or periods; subsystems or subperiods; and series or epochs). Workers should refer to the ICS time scale (ICS, 2022) for stage or age units.

The Archean Eonothem (or Eon) is divided into the Eoarchean, Paleoarchean, Mesoarchean, and Neoarchean Erathems (or Eras). The Proterozoic Eonothem (or Eon) is divided into the Paleoproterozoic, Mesoproterozoic, and Neoproterozoic Erathems (or Eras), and these are further subdivided into systems (or periods). The Paleoproterozoic is divided into the Siderian, Rhyacian, Orosirian, and Statherian Systems (or Periods); the Mesoproterozoic is divided into the Calymmian, Ectasian, and Stenian Systems (or Periods); and the Neoproterozoic is divided into the Tonian, Cryogenian, and Ediacaran Systems (or Periods).

Although the Upper (or Late) Cambrian Series (or Epoch) has been named Furongian in the ICS time scale, the GNC does not recognize this name and will not recognize it nor include it in the "Divisions of Geologic Time" time scale until all series (or epochs) of the Cambrian System (or Period) are named.

Most systems (or periods) of the Paleozoic and Mesozoic Erathems (or Eras) are subdivided into formally named series (or epochs), which traditionally use the formal terms Lower, Middle, and Upper (or Early, Middle, and Late). However, the international geoscience community is working towards applying formal names to these subdivisions that are based on stratigraphic sections at specific localities worldwide. As of this writing (2023), only the series (or epochs) of the Silurian and Permian Systems

[1]U.S. Geological Survey.

[2]Geological Survey of Alabama.

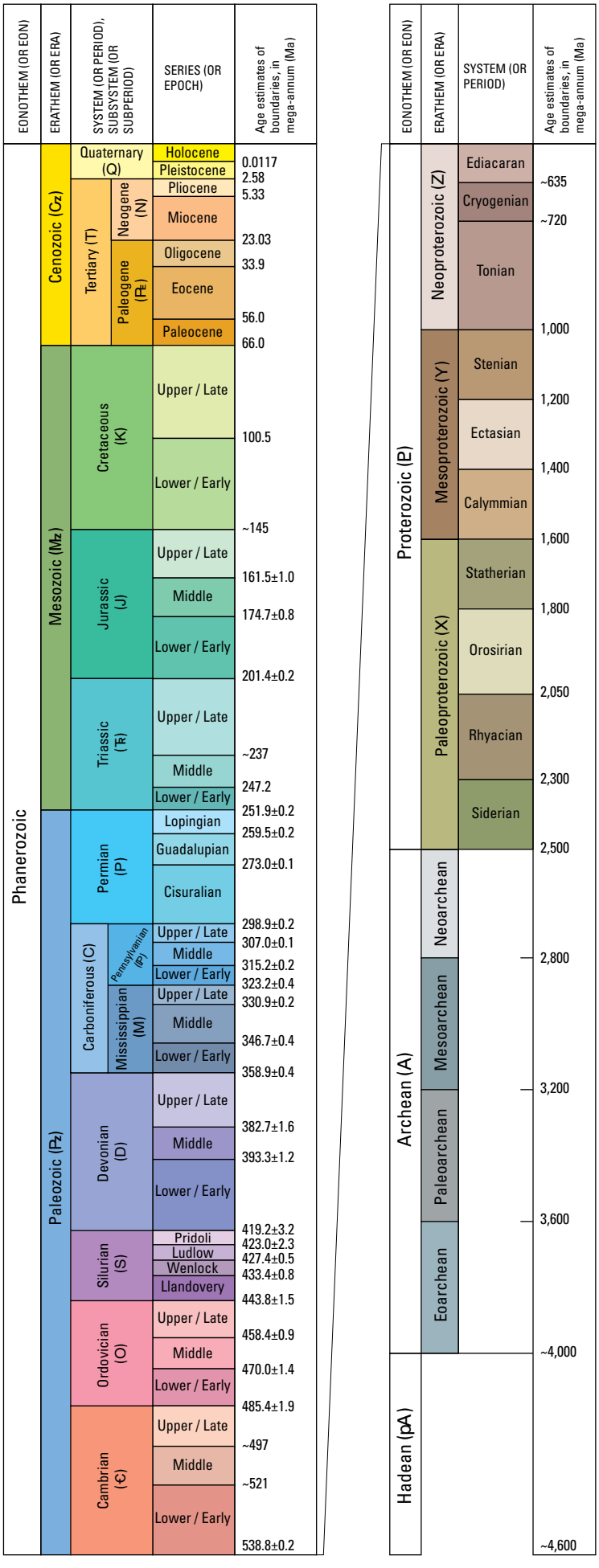

Figure 1. Chart showing updated divisions of geologic time, modified from U.S. Geological Survey Geologic Names Committee (2018). Chart shows major chronostratigraphic and geochronologic unit names as approved by U.S. Geological Survey (USGS) Geologic Names Committee (GNC), as well as updates to their boundary-age estimates as ratified by International Commission on Stratigraphy (2022) and accepted by GNC. Most box heights are generally scaled to relative duration of time periods named; however, different scaling factors are used for some time periods (for example, Quaternary System [or Period] is much shorter than Tertiary System [or Period]), and Proterozoic Eonothem [or Eon] on right is much longer than Phanerozoic Eonothem [or Eon] on left). Stratigraphic-age symbols, which were formally approved as Federal standard (Federal Geographic Data Committee, 2006; see also, USGS, 2006), are shown in parentheses.

(or Periods) have been formally named (fig. 1). Although the use of these formal series (or epoch) names is preferred, use of the informal (lowercase) terms lower, middle, and upper (or early, middle, and late) is still acceptable as subdivisions for these two systems and periods.

The Cenozoic Erathem (or Era) is divided into the Tertiary and Quaternary Systems (or Periods), and these are further subdivided into subsystems (or subperiods) and series (or epochs). The Quaternary is divided into the Pleistocene and Holocene Series (or Epochs), and the Tertiary is divided into the Paleogene and Neogene Subsystems (or Subperiods). The Paleogene is further subdivided into the Paleocene, Eocene, and Oligocene Series (or Epochs), and the Neogene is further subdivided into the Miocene and Pliocene Series (or Epochs).

Precambrian

For many years, the term Precambrian has been used for the division of time that is older than the Phanerozoic Eonothem (or Eon). For consistency with the time scale in "Suggestions to Authors of the Reports of the U.S. Geological Survey—Seventh Edition" [STA7] (Hansen, 1991), the GNC considers the term Precambrian to be informal and without specific stratigraphic rank (although it is traditionally capitalized).

In technical discussions and for new geologic mapping, researchers should avoid using the term Precambrian. Instead, they should use more accurate age divisions of the Proterozoic Eonothem (or Eon) when specifying ages older than the Phanerozoic Eonothem (or Eon). However, the informal term Precambrian may still be used in general discussions and when communicating with the public.

Cenozoic

A controversial issue during the first decade of the 21st century has been the position of the base of the Quaternary System (or Period) and its status as a formal division of time. However, the GNC still recognizes it as a system (or period) (Orndorff and others, 2010), mainly because the stratigraphic-age symbol "Q" (for Quaternary) has been used on geologic maps for more than a century and is still widely used today. After much debate, the International Union of Geological Sciences formally ratified a new definition of the base of the Quaternary System (or Period) and the corresponding base of the Pleistocene Series (or Epoch) (Gibbard and others, 2010), changing it from 1.806 mega-annum (Ma; see section below, entitled "Age Terms") to 2.58 Ma. These new definitions have been incorporated into the updated "Divisions of Geologic Time" time scale (fig. 1).

Although the Tertiary System (or Period) is not recognized by many international time scales, the GNC believes that it is important to recognize it as a system (or period) (Orndorff and others, 2010), mainly because of the long-term, persistent use of the map stratigraphic-age symbol "T" (for Tertiary) on geologic maps. However, the GNC also encourages use of the terms Paleogene and Neogene, rather than Tertiary, in geologic reports and on geologic maps.

Anthropocene

The term Anthropocene is often used by both scientists and nonscientists to highlight the concept that we are living in a time when human activities are having significant effects on the global environment. However, the Anthropocene is not recognized by the GNC, and it currently has no formal status in the updated "Divisions of Geologic Time" time scale (fig. 1). If international agreement is reached eventually, the Anthropocene could become a new series (or epoch) above the Holocene Series (or Epoch).

Age Terms

The age of a stratigraphic unit or the time of a geologic event may be expressed in years before present ("before present" is considered to be before 1950 C.E.). The North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 2021) recommends using the following abbreviations for ages, specified in International System of Units (SI units): ka, for kilo-annum or thousand (10^3) years ago; Ma, for mega-annum or million (10^6) years ago; and Ga, for giga-annum or billion (10^9) years ago.

Durations of time are expressed in thousand years (k.y.), million years (m.y.), and billion years (b.y.). For example, one might say, "Deposition began at 85 Ma and continued for 2 m.y."

Stratigraphic-Age Symbols

The present set of stratigraphic-age symbols was adopted by the Federal Geographic Data Committee (FGDC) in 2006 as the Federal standard (FGDC, 2006; USGS, 2006) to facilitate the consistent communication of geologic time and map-unit names. These stratigraphic-age symbols (shown in parentheses on figure 1) can be used on geologic maps, in geologic reports, in geodatabases, and in other geologic representations that require symbolizing geologic ages and map-unit names. The stratigraphic-age symbol font FGDCGeoAge, which contains all the Federally accepted stratigraphic-age symbols (FGDC, 2006), was developed by the USGS and was also released to the public in 2006 (available at USGS, 2006).

Map-Unit Colors

Geologic maps use color schemes to show the geologic ages of map units, and color has been used to show ages on USGS geologic maps since the late 1800s. The color schemes are based on standards and conventions related to the geologic time scale. Two different color schemes are commonly used, one by the

USGS and another by the Commission for the Geologic Map of the World (CGMW).

In 2006, the GNC recommended that the USGS color scheme be used for regional- or large-scale (for example, 1:250,000 scale or larger) geologic maps of the United States. A set of standardized USGS colors was published in the FGDC Digital Cartographic Standard for Geologic Map Symbolization (FGDC, 2006; see also, USGS, 2006), and it was intended for use on geologic maps of any scale.

For international maps or for smaller scale maps (for example, 1:5,000,000 scale or smaller) of the United States or North America, the GNC has recommended the use of the international (CGMW) color scheme. Specifications for the CGMW colors are provided in in Gradstein and others (2012).

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U.S. Geological Survey Professional Paper 1879–1, 2023

Chapter D

Guidance on Geologic Names Usage for Authors and Peer Reviewers of Geologic Maps and Reports—A Primer on Stratigraphic Nomenclature

By Randall C. Orndorff

Introduction

Consistent and effective communication is essential for scientific publications. Scientific communication requires clear explanations and precise discussion of data and interpretations.

> "Authors must strive for clarity, consistency, and correct usage of both formal and informal terminology because of the complex interactions between time and space interpreted from the presently existing stratigraphic record" (Owen, 2009).

The importance of consistent stratigraphic nomenclature as a means of effective geologic communication has been recognized since the U.S. Geological Survey (USGS) established the Geologic Names Committee (GNC) in 1899 to evaluate and address issues of stratigraphic nomenclature. The GNC currently consists of geologists from the USGS and the Association of American State Geologists.

In an effort towards codifying stratigraphic nomenclature, the North American Commission on Stratigraphic Nomenclature developed the North American Stratigraphic Code (referred to hereafter as "the Code"; North American Commission on Stratigraphic Nomenclature [NACSN], 2021) in 1983 by revising and updating preexisting codes that were then in use, such as the International Stratigraphic Guide [ISG] (International Subcommission on Stratigraphic Classification [ISSC], 1976; see also, ISSC, 1994).

Consistency in geologic names usage increases accuracy and quality of scientific publications. All formal USGS publications require a geologic names review (GNR) if any stratigraphic, lithodemic, geochronologic, or chronostratigraphic terminology is used. This review of, and guidance for, geologic names usage and stratigraphic principles should be referred to by authors and peer reviewers, not just those who conduct GNRs, and its guidance should be incorporated into their publications to improve geoscience communication. The notes and guidance in the sections that follow should be considered by USGS geologists and editors while writing or reviewing manuscripts that include geologic names and stratigraphic concepts. This primer may also be used by geologists and editors outside of the USGS for consistency with their publications.

Why Geologic Names (and Geologic Names Reviews) are Important

A geologic names review is an important part of producing and publishing a geologic map—it involves much more than spell checking geologic names and correcting usage of rank and rank terms. It also includes making sure publications are in conformance with the Code (NACSN, 2021) or the ISG (ISSC, 1994). It also is important to help make sure that stratigraphic consistency is maintained between the discussion, Correlation of Map Units (CMU), Descriptions of Map Units (DMU), and Lists of Map Units (LMU), as well as between figures and tables in reports and on geologic maps.

The standard database of geologic names and units for the United States and its territories, Geolex (https://ngmdb.usgs.gov/Geolex/), is an important resource for geologists to consult for current and historical nomenclature, age designations, and the areal extents of units. Many other resources (see appendix 1) may be consulted, and links to many of these resources can be found on the National Geologic Map Database (NGMDB) website, under Standards (https://ngmdb.usgs.gov/Info/standards/). The GNC periodically publishes an updated time scale that can be used when defining stratigraphy and using chronostratigraphic and geochronologic units (see, for example, Orndorff and others, 2023 [this volume]).

Geologic Names and Ages—Important Things to Consider When Preparing a Geologic Map or Conducting a Geologic Names Review

Stratigraphic units can be either lithostratigraphic (geologic or material rock units such as groups, formations, and members), chronostratigraphic (time-material units or bodies of rock that follow the law of superposition), or geochronologic (nonmaterial or temporal units that are based on the divisions of geologic time). Each of these unit types is well defined in the Code (NACSN, 2021).

The following sections cover specific principles regarding temporal units and geologic or material rock units, as well as on geologic names and ages, that authors will need to consider as they define their stratigraphy on geologic maps or in reports. Editors and persons who are conducting GNRs will also need to consider these principles during their reviews.

Temporal (Geochronologic or Time) and Chronostratigraphic (Position) Units

Geochronologic and chronostratigraphic units do not describe the lithology or stratigraphic ranking of geologic materials; rather, they communicate the relative ages or positions of deposits and rocks and the concepts of geologic time (that is, ages that are based on the divisions of geologic time). The meanings of these types of temporal and chronostratigraphic units are different, and care should be taken to use their correct terms.

Position Versus Time

A common mistake authors make is mixing terms for position (lower and upper) and time (early and late). By convention, position (chronostratigraphic) terms are used when discussing or describing sedimentary rocks and deposits, and time (geochronologic) terms are used when discussing or describing ages of igneous rocks or events. Chronostratigraphic units can be equivalent in age to geochronologic units, but their terms are different. For example, the geochronologic unit Miocene Epoch is equivalent in age to the chronostratigraphic unit Miocene Series. Table 1 shows the hierarchy and terms of chronostratigraphic and geochronologic units used in some geologic time scales.

Exceptions to this convention are the ages of lithodemic units (that is, intrusive and high-grade metamorphic rocks), which do not follow the law of superposition. Geochronologic (time) terms are used when discussing or describing the ages of these types of rocks.

Fluvial-terrace deposits are another potentially confusing exception. Most geologic units, especially volcanic rocks, are numbered from oldest to youngest: the first (oldest) bed or lava flow in a series is numbered 1, and progressively younger beds or flows are numbered 2, 3, 4, and so on. However, fluvial-terrace deposits are deposited as stream systems downcut the topography (fig. 1); thus, the youngest deposits (Qt1 in fig. 1) in the first terrace appear on the landscape in the lowest position, and the oldest deposits (Qt3 in fig. 1) are in the highest position. Therefore, they typically are numbered from youngest to oldest. It is appropriate to use geochronologic (time) terms when discussing or describing the ages of fluvial-terrace deposits.

Formally Named Chronostratigraphic and Geochronologic Units

All formally named chronostratigraphic units and their equivalent geochronologic units (that is, all eonothems [or eons], erathems [or eras], systems [or periods], series [or epochs], and stages [or ages]), as defined in the Code, are capitalized. Any chronostratigraphic or geochronologic unit listed in the current USGS time scale (Orndorff and others, 2023 [this volume]) is considered formal and, thus, is capitalized.

Table 1. Rank hierarchy of types of chronostratigraphic (position) terms and their equivalent geochronologic (time) terms, showing examples of their ages.

[Modified from Owen (2009)]

Chronostratigraphic (position) term	Example of chronostratigraphic age	Geochronologic (time) term	Example of geochronologic age
Eonothem	Phanerozoic Eonothem	Eon	Phanerozoic Eon
Erathem	Cenozoic Erathem	Era	Cenozoic Era
System	Quaternary System	Period	Quaternary Period
Series	Pleistocene Series	Epoch	Pleistocene Epoch
Stage	Gelasian Stage	Age	Gelasian Age

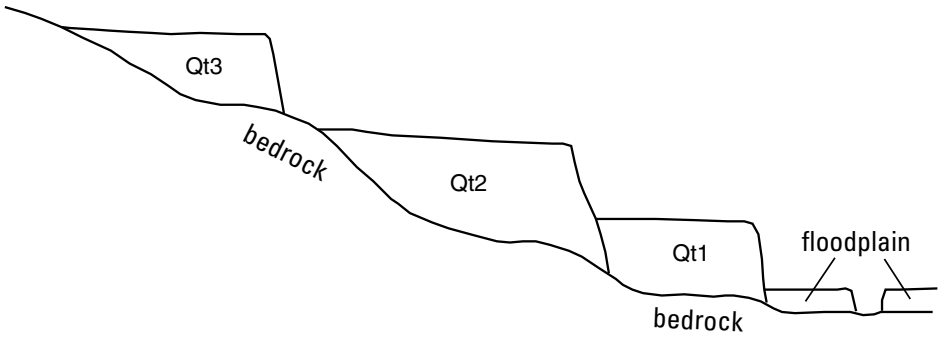

Figure 1. Diagrammatic cross section of fluvial landscape, showing relative positions of terrace deposits and their numbering from youngest to oldest (Qt1, Qt2, and Qt3, respectively).

Formal Names for Series (or Epochs)

The Cenozoic Erathem (or Era) is divided into the Tertiary and Quaternary Systems (or Periods). The Tertiary is divided into the Paleogene and Neogene Subsystems (or Subperiods), and these are further subdivided into the following formally named series (or epochs): the Paleogene, into the Paleocene, Eocene, and Oligocene Series (or Epochs), and the Neogene, into the Miocene and Pliocene Series (or Epochs). The Quaternary is divided into the Pleistocene and Holocene Series (or Epochs).

The Paleozoic and Mesozoic Erathems (or Eras) are divided into systems and periods as well: the Paleozoic, into the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Systems (or Periods); and the Mesozoic, into the Triassic, Jurassic, and Cretaceous Systems (or Periods). Traditionally, these Paleozoic and Mesozoic Systems (or Periods) also have been divided into formally named series or epochs by adding "Lower" (or "Early"), "Middle," or "Upper" (or "Late") to the system or period name. However, the International Commission on Stratigraphy is currently (2023) in the process of replacing these added time and position terms with formal series and epoch names (Orndorff and others, 2023 [this volume]). As of this writing (2023), assigning formal series and epoch names to the Paleozoic and Mesozoic Systems (or Periods) has been completed only for the Silurian and Permian Systems (or Periods).

Table 2 lists the formally named temporal and chronostratigraphic units (that is, systems [or periods] and series [or epochs]) in the Paleozoic, Mesozoic, and Cenozoic Erathems (or Eras) used in geologic time scales and their currently accepted (formally named) time and position subdivisions.

Table 2. Formally named erathems (or eras), systems (or periods), and series (or epochs) and their currently accepted (formally named) age and position subdivisions.

[--, not applicable]

Erathem or era	System or period	Currently accepted (formally named) series, epoch, position, or time subdivision		
		As a series or epoch	As a position subdivision	As a time subdivision
Cenozoic	Quaternary	Holocene Pleistocene	--	--
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	--	--
Mesozoic	Cretaceous	--	Upper Lower	Late Early
	Jurassic	--	Upper Middle Lower	Late Middle Early
	Triassic	--	Upper Middle Lower	Late Middle Early
Paleozoic	Permian	Lopingian Guadalupian Cisuralian	--	--
	Pennsylvanian	--	Upper Middle Lower	Late Middle Early
	Mississippian	--	Upper Middle Lower	Late Middle Early
	Devonian	--	Upper Middle Lower	Late Middle Early
	Silurian	Pridoli Ludlow Wenlock Llandovery	--	--
	Ordovician	--	Upper Middle Lower	Late Middle Early
	Cambrian	--	Upper Middle Lower	Late Middle Early

The term Precambrian has been used for many years to refer to the division of time that is older than the Phanerozoic Eonothem (or Eon). However, the GNC considers the term Precambrian to be informal and without specific stratigraphic rank (although it traditionally is capitalized). Thus, the term Precambrian should not be used in new geologic mapping when specifying ages older than the Phanerozoic Eonothem (or Eon); instead, the more accurate age divisions of the Proterozoic Eonothem (or Eon) such as the Mesoproterozoic Erathem (or Era) should be used.

Informal Subdivisions of Series and Epochs

Sometimes it is necessary for authors to use terms that are either more detailed or more generalized than what is formally accepted when describing their geologic units. However, subdivisions of any chronologic or geochronologic unit not listed in table 2 are considered informal and, thus, are lowercased, as are all their time (late or early) and position (upper or lower) divisions. The following list contains examples of such informal usage:

- The late Quaternary is shorthand for the late part of the Quaternary Period
- The middle Miocene, for the middle part of the Miocene Series (or Epoch)
- The early Eocene, for the early part of the Eocene Epoch
- The upper Neogene, for the upper part of the Neogene Subsystem
- The lower Tertiary, for the lower part of the Tertiary System
- The Late Cretaceous, for late in the Cretaceous Period
- The early Silurian, for the early part of the Silurian Period
- The late Mesozoic, for the late part of the Mesozoic Era
- The upper Paleozoic, for the upper part of the Paleozoic Erathem
- The late Proterozoic, for the late part of the Proterozoic Eon

It is worth noting that the current USGS geologic time scale (Orndorff and others, 2023 [this volume]) shows only formally named subdivisions; thus, if a subdivision is not listed in the time scale, it is considered informal and should be lowercased.

When Lithostratigraphic Units Span Chronostratigraphic or Geochronologic Units (Using "to" Versus "and" Versus "or")

A lithostratigraphic unit can be assigned to more than one chronostratigraphic or geochronologic unit. In these cases, the choice of conjunction is important, as the following rules and examples indicate:

- The term "to" should be used to mean relatively continuous deposition or time; for example, "Ordovician to Devonian" includes the Silurian
- The term "and" should be used to indicate that a significant amount of strata or time is missing; for example, "Ordovician and Devonian" excludes the Silurian
- The term "or" should be used to mean a single horizon of unknown age or one that has one age and cannot span time; for example, use "Ordovician or Silurian" when referring to a horizon of unknown age

Lithostratigraphic Units

Lithostratigraphic units are the foundation for delineating bodies of rock and are recognized and defined by observable rock characteristics.

Hierarchy of Lithostratigraphic Rank Terms

Rank terms of lithostratigraphic units must follow the hierarchy set forth in the Code (NACSN, 2021). Table 3 lists the types of lithostratigraphic units in the correct hierarchical order.

It is important to assign the correct lithostratigraphic rank to a parent geologic unit and its subunits by following the order shown in table 3. Note that the rank of a geologic unit cannot also be assigned to one of its subunits.

Formal Versus Informal Geologic Unit Names—Uppercase Versus Lowercase

A sometimes confusing aspects of stratigraphic nomenclature is knowing when to capitalize names of geologic units and when to use lowercase. Simply stated—all words (other than articles) in formally named geologic units, as defined in the Code, are capitalized. This includes all formal lithostratigraphic names (that is, group, formation, and member names) that follow the Code. Conversely, all lithologic terms in informally named stratigraphic units are lowercased, as are their assigned lithostratigraphic-unit ranks (that is, member and submember names).

Table 3. Rank hierarchy of types of geologic (stratigraphic or lithodemic) units.

[Modified from Owen (2009). --, not applicable]

Stratigraphic unit	Lithodemic unit
Supergroup	Supersuite
Group	Suite
Formation	Complex
Member	--
Submember	--
Bed, flow, tongue	--

When using or determining formal versus informal geologic unit names, authors should first consult Geolex (https://ngmdb.usgs.gov/Geolex/) to find out if a name already has formal designation. If you are mapping a formally named unit, it is important that its formally accepted nomenclature be maintained, unless you have a valid reason for revising the name or its stratigraphic or lithodemic unit designation (for more information, see discussion in the section below entitled "Naming, Revising, and Abandoning Formal Geologic Units"; see also, Stamm, 2023 [this volume]).

If you are naming a newly mapped informal unit, the name of the informal unit should consist of the lithology of the unit (in lowercase), followed by the name of the place where it was examined. For example, an informal unit could be named "the rhyolite of Devils Gate" or "the rhyolite at Devils Gate" but not "the Devils Gate rhyolite." However, do not use a place name that already has a formal or informal unit named for it.

If you are mapping an informally named unit that has already been named by a previous mapper, the reference to that mapper's work needs to be added—as in this "fictitious" example of an informally named unit, "the Acme sandstone of Doe (1966)"—the first time the name appears in each stand-alone part of a report.[1] Thereafter, and succeeding usage of the name in a stand-alone part of a report can be written as "the Acme sandstone."

[1]Stand-alone parts of a report are the abstract or executive summary, the main body of the report, the summary or conclusions, the acknowledgments, the Description of Map Units, and each figure, table, and appendix.

Undivided Versus Undifferentiated Units

The terms "undivided" and "undifferentiated" have different meanings when used in map-unit descriptions to denote the combining of geologic units or lithologies.

The term "undifferentiated" should be used when combining rock types or when a map unit is not separated into different lithological elements, as in the following examples:

- Surficial deposits, undifferentiated
- Undifferentiated lava flows
- Gabbro and diorite, undifferentiated
- Silurian sedimentary rocks, undifferentiated

The term "undivided" should be used when map units have been combined or when a parent unit is being mapped in addition to its formal or informal subunits, as in the following examples:

- Lincolnshire and New Market Limestones, undivided
- Helderberg Group, undivided
- Painted Hill Formation, undivided (in this case, both the parent unit [the Painted Hill Formation] and its basalt and conglomerate subunits are mapped; see example shown in figure 2)

Conversely, a formation is not "undivided" if it is only mapped as its subunits (formal or informal). Figure 2 shows a few examples of "undivided" units and several that are not.

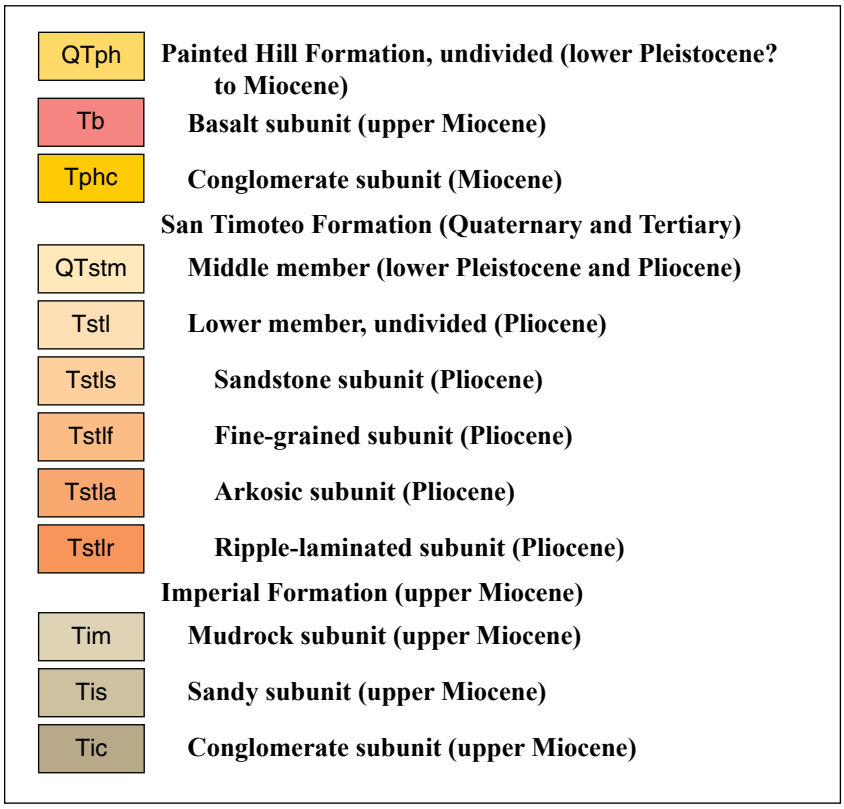

Figure 2. Part of a List of Map Units, showing two examples of "undivided" units and several that are not undivided. In the Painted Hill Formation, parent unit QTph is undivided because it is mapped separately, in addition to its two subunits (Tb and Tphc). In contrast, the San Timoteo Formation parent unit is not undivided because it is not mapped separately; it is mapped only as its middle and lower members (QTstm and Tstl, respectively). In addition, the lower member is undivided because it is both mapped separately (Tstl) and as its four subunits (Tstls, Tstlf, Tstla, and Tstlr). The Imperial Formation is not undivided because it is only mapped as its three subunits (Tim, Tis, and Tic).

Using Question Marks to Express Uncertainty

The query (question mark) can be used to indicate that either the identification or the age of a geologic unit is uncertain. In the written parts of a report (that is, in the discussion, in unit descriptions in the DMU, in figure captions and explanations, and within tables), the query is placed (in parentheses) immediately following the part of the interpretation that is uncertain. For example, the query in "the Morrison(?) Formation" indicates that the rocks may or may not be part of the Morrison Formation. The query after an age designation, such as "the Miocene(?) Imperial Formation" indicates that the rocks may or may not be Miocene age.

The only exception to this convention is when a unit name and age are listed in bold in an LMU or at the beginning of a unit description in the DMU. In these cases, unit ages are shown in parentheses, and so the parentheses are omitted around the query to avoid doubling up of parentheses, as the following example shows (see also, fig. 2):

QTph **Painted Hill Formation, undivided (lower Pleistocene? to Miocene)**

In the graphic parts of a report (that is, on the map or in a figure), a query can be added to a map-unit label to indicate that the identification of a geologic unit is uncertain. The query should be placed at the end of the unit label, without parentheses (for example, "Qls?").

Note that a query is never added to a unit label in the CMU, DMU, or LMU, even if the unit is queried on the map. Note also that uncertainty in the location of a unit should not be expressed by using a queried map-unit label but rather by the style (dashed or dotted) of the line symbol (contact or fault) that bounds it.

Other Considerations When Preparing a Geologic Map or Report or Conducting a Geologic Names Review

Informal Time and Age Terms and Suggested Alternative Terms for Position, Place, Quantity, or State

A common mistake made by authors is to incorrectly use time (or age) terms when describing the position, place, quantity, or state of a geologic unit, entity, or observation. Table 4 compares some commonly used informal time or age terms with some suggested alternatives that should be used instead to indicate position, place, quantity, or state of being.

Time Duration Versus Points in Time

Different abbreviations are used to designate either a point in time (age) or a duration or span of time. Points in time (ages) are referenced to the present, whereas a duration of time lacks a specific reference to the present (for example, yr is the abbreviation for a single year; k.y., for a thousand years; m.y., for a million years; and b.y., for a billion years). Points in time (ages) are specified in International System of Units (SI units) abbreviations (ka, for kilo-annum, or thousand years ago; Ma, for mega-annum, or million years ago; and Ga, for giga-annum, or billion years ago). Note that, when using points in time, the redundant terms "ago" and "before present" are not used. The exception is radiocarbon ages, which are given in years before present (yr B.P.); the abbreviation "B.P." means before 1950 C.E.

Table 5 compares the abbreviations that should be used when designating either a point in time (age) or a duration or span of time.

Table 4. Comparison of informal age and time terms and suggested alternative terms that should be used for position, place, quantity, or state.

[Modified from Owen (2009)]

Age or time term	Suggested alternative term to be used for position, place, quantity, or state
Age term versus position term	
late	upper
early	lower
latest	uppermost
earliest	lowermost
younger	higher
older	lower
youngest	highest
oldest	lowest
post-, after	above
pre-, before	below
Time term versus term for place, quantity, or state	
when	where
then	there
now	here
while	whereas, although
sometime(s)	someplace(s), some of
always	everywhere, all of
never	nowhere, none of
at times	in some places
infrequent	scattered, sparse, rare
often, frequent(ly)	abundant, common(ly)
infrequent(ly)	rare(ly)
usual(ly)	typical(ly)
occasional(ly)	local(ly)
during	in, over
further	farther
occurs	is found, is present, is mapped, is exposed, crops out

Table 5. Standard abbreviations for durations of and points in time.

Duration of time (interval)	Abbreviation	Point in time (age)	Abbreviation
thousand years	k.y.	kilo-annum (or 10^3 [thousand] years ago)	ka
million years	m.y.	mega-annum (or 10^6 [million] years ago)	Ma
billion years	b.y.	giga-annum (or 10^9 [billion] years ago)	Ga

Order of Map Units and Their Ages in Discussions Versus in CMUs, DMUs, LMUs, and Other Map Elements

In discussions on geologic maps or in reports, the stratigraphy and map units are discussed in order from oldest to youngest (or lowermost to uppermost), by convention. For example, basement rocks are discussed before surficial deposits, followed by discussion of the structure and other topics. To maintain this order in the discussion, unit ages are given from oldest to youngest, as are isotopic ages (see examples below).

In contrast, units that are graphically displayed in stratigraphic sections and correlation charts are shown in stratigraphic or geochronologic order, with the youngest units at the top and the oldest units at the bottom. Similarly, when depicting stratigraphy in a CMU, it is customary to show the youngest units at the top and the oldest at the bottom. Thus, it follows that map units in a DMU or LMU, as well as in illustration explanations and captions and in tables, are listed or described in order from youngest to oldest (or uppermost to lowermost) (fig. 3), by convention. The same principle applies to isotopic ages that are provided in a DMU, table, or illustration explanation or caption. Therefore, when providing ages or positions of map units in a DMU or LMU, they should be in youngest (uppermost) to oldest (lowermost) order.

The following examples illustrate the ways that units are listed and ages are cited when they are mentioned in different parts of a report.

- In the discussion of a report:
  - The geology is discussed in oldest-to-youngest order
  - When a unit is mentioned, its age is given from oldest to youngest—for example, "mapped as the Silurian and Devonian Helderberg Group"
  - When multiple units are mentioned, they are listed in oldest-to-youngest order—for example, "overlies the Cretaceous granitic rocks of Montara Mountain and the upper Miocene and Pliocene Purisima Formation"
  - Isotopic ages are given in oldest-to-youngest order—for example, "Lava flows range in age from 75.3 to 62.1 Ma"
- In the CMU:
  - Units are depicted in stratigraphic order (top to bottom, youngest to oldest)
  - Unit ages are given from youngest to oldest—for example, "Purisima Formation (Pliocene and upper Miocene)"
- In the DMU and LMU:
  - Units are listed in stratigraphic order (top to bottom, youngest to oldest)
  - Unit names and ages are shown in bold
  - Unit ages are given from youngest to oldest—for example, "Purisima Formation (Pliocene and upper Miocene)"
- Within a unit description in the DMU:
  - When a unit is mentioned, its age is given from youngest to oldest—for example, "mapped as the Devonian and Silurian Helderberg Group"
  - When multiple units are mentioned, they are listed in youngest-to-oldest order—for example, "overlies the Pliocene and upper Miocene Purisima Formation and the Cretaceous granitic rocks of Montara Mountain"
  - Isotopic ages are given in youngest-to-oldest order—for example, "Age of lava flows, 62.1 to 75.3 Ma"
- In illustrations:
  - Units are shown in the explanation in stratigraphic order (top to bottom, youngest to oldest)
  - Unit ages are listed in the explanation and in the caption from youngest to oldest
  - When multiple units are mentioned in the caption, they are listed in youngest-to-oldest order
- In tables:
  - Units are listed from youngest to oldest

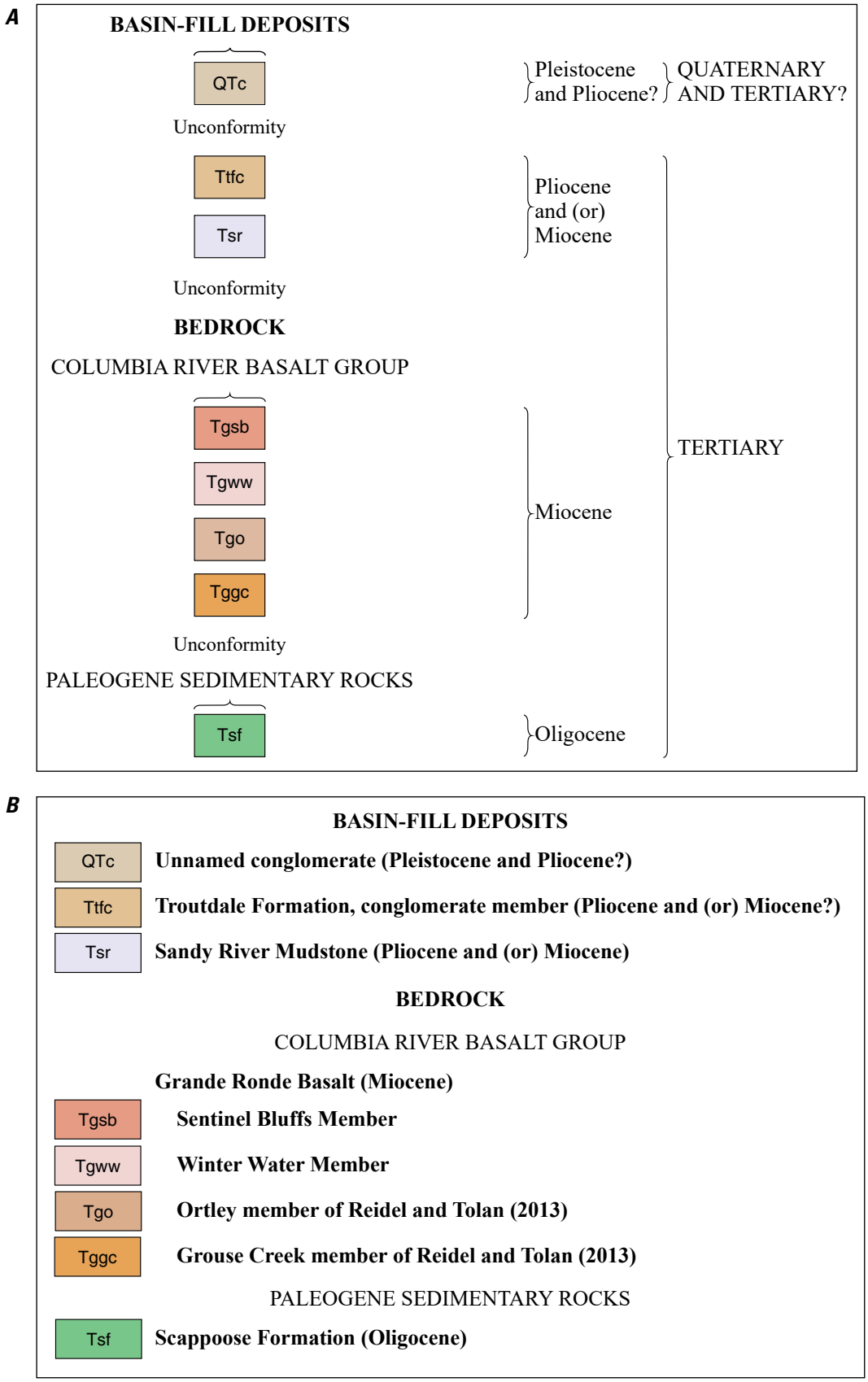

Figure 3. Parts of a Correlation of Map Units (CMU) and its corresponding List of Map Units (LMU), excerpted from Evarts and others (2016). *A*, CMU depicting map units and ages from youngest (or uppermost) to oldest (or lowermost). *B*, LMU for CMU shown in *A*, showing listing of map units and ages from youngest (or uppermost) to oldest (or lowermost).

- Unit ages are listed from youngest to oldest
- When multiple units are mentioned, they are listed in youngest-to-oldest order

An exception to the conventions outlined above are ages of events such as volcanic eruptions. Events have a beginning and an end, and so it is logical that the age of an event is given from its beginning to its end (that is, from oldest to youngest), regardless of where it is mentioned in a report.

Misuses—Slang, Abbreviations, and Imprecision

It is important not to use slang or unaccepted abbreviations because doing so may negatively impact the accuracy and precision of the use of geologic or temporal units and terms. High-quality scientific publications require proper and consistent usage, as outlined in this report. The following list contains some common examples of slang or otherwise unacceptable usage:

- Do not say "Cambro-Ordovician"—Say "Cambrian-Ordovician" (for example, "the Cambrian-Ordovician boundary")
- Do not abbreviate "Formation" or other formal rank names in discussions, DMUs, or LMUs—If you must use abbreviations in tables or on figures because of limited space, be sure to define the abbreviations in the table headnote or in the caption
- Do not use geologic unit names to imply time (for example, do not say "the pre-Dakota unconformity" or "Beekmantown time")
- Do not use map-unit labels in place of geologic unit names in DMUs or discussions—If you must use unit labels in a DMU to avoid the excessive repetition of a unit name or because of limited space, be sure to spell out the full unit name the first time it is used in the description
- Never use the same name for a geologic unit's rank and for one of its components (for example, "the Helderberg Formation of the Helderberg Group" cannot exist)
- Do not add a lithologic term to the end of a formation or group name (for example, do not say "the Elbrook Formation limestone"—Say "limestone of the Elbrook Formation")
- Do not say "the lower Choptank Formation," which implies that you have two different formations—Say "the lower part of the Choptank Formation"

Naming, Revising, and Abandoning Formal Geologic Units

As geoscience progresses, a need often arises to either formalize, revise, abandon, or reestablish geologic names. Geologic mapping is a catalyst of these changes where units need to be mappable. Sedimentary facies can change across different regions, and the thicknesses of units and the nature of contacts may change, owing to unconformities; in such cases, a formal unit may be better represented as a formation in one area but as a member in another. The Code (NACSN, 2021) lays out the procedures for changing stratigraphic nomenclature (see articles 3–20). Additional guidance and discussions on this topic are provided in Stamm (2023 [this volume]).

How You Can Enhance or Update Geolex

As previously noted, Geolex (https://ngmdb.usgs.gov/Geolex/), which is part of NGMDB, serves the geologic communities with current and historical information on formally named lithostratigraphic units. As Geolex is the standard reference for the Nation's stratigraphic nomenclature, its purpose is to aid authors and reviewers on the definitions and usage of geologic names.

As authors name, revise, or publish new comprehensive stratigraphy, it is important to notify the NGMBD—specifically, the GNC (gnc@usgs.gov)—so it can keep Geolex up to date. Authors can help ensure that Geolex continues to meet its goals (see Stamm, 2023 [this volume]) by following these guidelines:

- If your manuscript has a comprehensive discussion of stratigraphy or extensive use of geologic nomenclature, please forward it to the GNC staff (gnc@usgs.gov)
- If you notice changes from other publications that are not yet included in Geolex, please inform the GNC staff (gnc@usgs.gov) by forwarding the reference citation and a note that explains the discrepancy

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Chapter E

Guidelines for Conducting Reviews of Geologic Names and Aquifer Names in U.S. Geological Survey Hydrogeologic Maps and Reports

By Steven D. Craigg and Randall C. Orndorff

Introduction

The U.S. Geological Survey (USGS) is officially charged with assessment of various aspects of geology and hydrogeology throughout the Nation. Hence, USGS publications adhere to broadly uniform procedures in the classification and nomenclature of geologic and hydrogeologic units. Responsibility for this uniformity is under the technical guidance of the Geologic Names Committee (GNC), which formulates general policy and advises on specific nomenclatural issues. Central to the GNC proceedings is the North American Stratigraphic Code (hereafter referred to as "the Code") (North American Commission on Stratigraphic Nomenclature [NACSN], 2021).

Geologic reports typically contain geologic maps and cross sections, geologic unit names, lithologic descriptions, and stratigraphic correlation charts, as well as results of drilling activities and structure-contour, depth-to-top, depth-to-base, or sediment-thickness maps. Groundwater-resource maps and other hydrogeologic maps and reports can also contain many of these same elements. Groundwater-resource reports rarely contain original geologic mapping, revisions of stratigraphic nomenclature, or redefinitions or changes in the ranks or ages of geologic units; however, these reports usually contain descriptions and classifications of hydrogeologic units, and they also may introduce new or modify existing aquifer nomenclature.

The following general guidance is published for those designated as geologic and aquifer names reviewers.

Performing Geologic Names Reviews of Hydrogeologic Maps and Reports

All formal USGS publications that use geologic-unit names and (or) ages, including hydrogeologic maps and reports, must have a geologic names review (GNR) (see discussion in Orndorff, 2023 [this volume]). Such reviews generally consist of verifying the usage of geologic unit names, ranks, ages, and areal extents in a report, as well as if the usage is accepted by an authoritative agency (that is, by USGS, State geological survey, or other entity) and if usage follows the Code (NACSN, 2021). During these reviews, geologic names usage is verified against various lexicons, references, and other resources as appropriate. Geologic names reviewers scrutinize the entire body of a report, including the discussion and (if applicable) the Description of Map Units (DMU), Correlation of Map Units (CMU), maps, cross sections, illustrations, tables, and other correlation charts, to check that geologic nomenclature is used correctly.

Essential Publications and Resources for Geologic Names Reviewers

Several publications and online resources are available to assist geologic names reviewers. The Code (NACSN, 2021) defines procedures for classifying and naming formal geologic units, and it is recommended that designated reviewers have access to this publication. The review process can be greatly expedited by using the USGS National Geologic Map Database's online lexicon "Geolex" (available at https://ngmdb.usgs.gov/Geolex/). Geolex is an extensive, searchable database for geologic-unit names, ranks, and ages, and it contains a direct link to the Code (NACSN, 2021). Another essential resource is the time scale "Divisions of geologic time—Major chronostratigraphic and geochronologic units," published and periodically updated by the USGS (U.S. Geological Survey Geologic Names Committee, 2018; see also, Orndorff and others, 2023 [this volume]).

Older, hard-copy USGS publications such as "Lexicon of Geologic Names of the United States (Including Alaska)" (Wilmarth, 1938) and subsequently published lexicons of geologic names (Wilson and others, 1957, 1959; Keroher and others, 1966; Keroher, 1970; Luttrell and others, 1981, 1986, 1991) remain useful resources in conducting GNRs, as are previous editions of "Stratigraphic Notes" (U.S. Geological Survey, 1982, 1984, 1985, 1987, 1991, 1994a, b, 1995). A resource for geologic names reviewers is the chapter on geologic nomenclature in USGS' Suggestions to Authors (Hansen, 1991 [STA7], p. 43–64). Another useful publication for reviewers is the USGS' Water Resources Division Publications Guide (Alt and Iseri, 1986, p. 187–197), which contains a, concise discussion of geologic names.

State geological surveys also maintain geologic names databases. Various materials in previously published reports are commonly cited by authors; these should be obtained and checked by the reviewer if appropriate.

Elements of a Geologic Names Review of USGS Hydrogeologic Maps and Reports

Designated geologic names reviewers need to carefully scrutinize hydrogeologic maps and reports to ensure that the geologic nomenclature is used correctly and consistently. The following is a brief discussion of the elements to check when performing a geologic names review on a hydrogeologic map or report[1] (a more comprehensive discussion of these elements is provided in Orndorff, 2023 [this volume]):

- Stratigraphic names are consistently used.
- Stratigraphic nomenclature follows the Code.
- Source of the geologic nomenclature used, including on correlation charts and maps, is cited where appropriate (for example, "the geologic nomenclature used in this report is that of the Georgia Geologic Survey").
- Names (including spelling and capitalization) and ages of formal and informal geologic units are proper and consistent.
- Formal ranks of units (Group, Formation, Member, and so on) are used correctly, and the ranking of units to represent parent-child relations among units is logical and accurate.
- Chronostratigraphic (position) and geochronologic (age) terms (System or Period, Series or Epoch, and so on) and their subdivisions, both formal (Lower or Early, Middle, Upper or Late) and informal (lower or early, middle, upper or late), are used correctly and consistently.
- Abbreviations are used properly to designate either points in time (ages) or durations of time:
  - Durations of time lack a specific reference to the present (yr, single year; k.y., thousand years; m.y., million years; b.y., billion years).
  - Points in time (ages) are specified in International System of Units (SI units) abbreviations (ka, kilo-annum, or thousand years ago; Ma, mega-annum, or million years ago; Ga, giga-annum, or billion years ago). The redundant terms "ago" and "before present" are not used, except for radiocarbon ages, which are given in years before present (yr B.P.); the abbreviation "B.P." means before 1950 C.E.
- In the discussion text of a hydrogeologic map or report, stratigraphy is discussed in order from the oldest to the youngest unit (for example, bedrock units are discussed before surficial units, followed by a discussion of the structure, and so on). To reinforce this, units are mentioned (and unit ages are provided) in oldest-to-youngest order within the discussion.
- In the DMU of a hydrogeologic map or report (and, if applicable, in the corresponding List of Map Units [LMU]), units are listed in stratigraphic order, from youngest to oldest, and the ages of units are specified in youngest-to-oldest order. To reinforce this, when mentioning other units within the text of the map-unit descriptions, ages are provided (and other units are listed) in youngest-to-oldest order.
- In the CMU, time-stratigraphic relations of the units are correct, as indicated by age brackets and headings; the ranks of units (System or Period, Series or Epoch, and so on) are used correctly; the ages of units are listed correctly and are given in youngest-to-oldest order; and the geologic nomenclature (unit names and ages) is consistent with the discussion and the DMU.
- In explanations and captions for illustrations, units are listed from youngest to oldest (top to bottom), and ages are given in youngest-to-oldest order.
- On correlation charts in illustrations, units are shown from youngest to oldest (top to bottom), and ages are given in youngest-to-oldest order; time-stratigraphic relations and ranks and ages of units are correct; and nomenclature is cited where appropriate.
- In illustrations and tables that are modified from a previous publication, the sources for geologic nomenclature are cited in the caption for illustrations or, for tables, in headnotes or footnotes.

[1]Note that the content of this discussion is only appropriate for GNRs of hydrogeologic maps and reports. Geologic maps and reports typically require a more rigorous, comprehensive GNR; when performing a GNR on a geologic map or report, please follow the guidance provided in Orndorff (2023 [this volume]).

Some Common Problems Encountered During a Geologic Names Review of Hydrogeologic Maps and Reports

Common misuses of geologic nomenclature include the improper use of time, age, and rock-position terms, and sometimes these types of terms are used interchangeably in a report (see examples in table 1). The examples provided in table 1 are only a select few nomenclatural issues that reviewers may encounter. Owen (1978, 2009) provided an extensive discussion on this topic. In addition, a comprehensive guide for handling these issues is presented in Orndorff (2023 [this volume]).

Performing Aquifer Names Reviews

When aquifers are being discussed in a map or report, an aquifer names review is needed. For USGS hydrogeologic maps and reports, aquifer names reviews typically are conducted concurrently with, or just after, the GNR.

Table 1. Examples of correct and incorrect usage of chronostratigraphic (position) and geochronologic (time) terms for ages.

Incorrect usage	Problem	Correct usage
Upper Cretaceous age	Upper is a position term, not a time term	Late Cretaceous age
Lower Cretaceous age	Lower is a position term, not a time term	Early Cretaceous age
Late Jurassic Series	Series is a chronostratigraphic (position) unit, but Late is a geochronologic (time) term	Upper Jurassic Series (position), or Late Jurassic Epoch (time)
Lower Jurassic Epoch	Epoch is a geochronologic (time) unit, but Lower is a chronostratigraphic (position) term	Early Jurassic Epoch (time), or Lower Jurassic Series (position)
Late Triassic Period	Late Triassic is a formally recognized subdivision (epoch, not period) of the Triassic	Late Triassic Epoch
In the Late Miocene …	Late Miocene is not a formally recognized subdivision of the Miocene (and so is lowercased)	In the late Miocene …
The Lower Paleocene strata …	Lower Paleocene is not a formally recognized subdivision of the Paleocene (and so is lowercased)	The lower Paleocene strata …

Essential Publications and Resources for Aquifer Names Reviewers

Recognizing the need for consistent use of aquifer nomenclature, USGS published guidelines for aquifer names reviewers in "Aquifer Nomenclature Guidelines" (Laney and Davidson, 1986). An updated version of this report was provided in the chapter "Guidelines for Naming Aquifers" in STA7 (Hansen, 1991, p. 65–82). In addition, brief discussions of aquifer nomenclature were included in the USGS' Water Resources Division's publications guide (Alt and Iseri, 1986, p. 198–200) and illustration standards (Miller and Balthrop, 1995).

These guidelines not only contain uniform aquifer-naming conventions, but they are flexible enough to address aquifer nomenclature issues in a wide variety of hydrogeologic settings and at various study-area scales. It is worth noting, however, that the aquifer names reviewer needs to exercise common sense in applying these guidelines because, in some States, certain aquifer names are considered "traditional" and are "grandfathered in" by historical precedent; such terms also may have legal implications (water rights and use). Therefore, a reviewer should not compel an author to change such established nomenclature. The USGS' Regional Aquifer-System Analysis project established regional nomenclatures that are contained in USGS' Hydrologic Atlas 730 (U.S. Geological Survey, 2000) and its various segments (see, for example, Planert and Williams, 1995; Trapp and Horn, 1997; Miller, 1999). These regional nomenclatures should not be modified by reviewers unless they are subsequently revised or updated in a Bureau-approved USGS publication. In addition, USGS has put forth a National Aquifer Code Reference List, which may be useful for looking up aquifer names (available online at https://water.usgs.gov/ogw/NatlAqCode-reflist.html).

Elements of an Aquifer Names Review of USGS Groundwater-Resource and Other Hydrogeologic Maps and Reports

As is stated in the Code (NASCN, 2021, p. 166), most aquifer (and confining unit) names are considered informal and, thus, are lowercased: "Most economic units, such as aquifers, oil sands, coal beds, quarry layers, and ore-bearing 'reefs,' are informal, even though they may be named." However, a few notable examples exist (NASCN, 2005, p. 1560): "Some such units, however, are so significant scientifically and economically that they merit formal recognition as beds, members, or formations." A significant example of a formalized name is the Floridan aquifer system, which consists of the Upper and Lower Floridan aquifers.

Similar to the elements for a GNR listed in the previous section, designated aquifer names reviewers need to scrutinize the following elements of a report to ensure that aquifer names and other hydrogeologic nomenclature are used correctly and consistently:

- In all parts of a hydrogeologic map or report, aquifer-nomenclature schemes generally follow the guidelines in Laney and Davidson (1986) and STA7 (Hansen, 1991); however, exceptions may occur owing to historical-use precedence.
- New aquifer nomenclature is not introduced, unless absolutely necessary. Such newly introduced nomenclature may be superfluous, subsequently proliferating and cluttering the hydrogeologic literature and, thereby, confusing later workers.
- Aquifer names (including spelling and capitalization) are correctly and consistently used.

- Source of the hydrogeologic nomenclature is cited where appropriate (for example, "the hydrogeologic nomenclature used in this report is that of the New Mexico Bureau of Mines and Mineral Resources").
- In the discussion of a report, the hydrogeology typically is discussed from top to bottom (as strata would be penetrated by a well); however, this order can differ, depending on the thrust and logic of the report.
- In illustration explanations, units are shown in stratigraphic order (youngest to oldest).
- On correlation charts in illustrations, units are shown in stratigraphic order (youngest to oldest); time-stratigraphic relations of units are correct; rank and ages of units are correct; and nomenclature is cited where appropriate.
- In illustrations and tables that are modified from a previous publication, the sources for aquifer nomenclature are cited in the caption for illustrations or, for tables, as footnotes.

Some Common Problems Encountered During an Aquifer Names Review

A common aquifer nomenclature problem is using a hydrogeologic unit that has its rank included in the aquifer name (see table 2). Other common problems include the improper use of time, age, and rock-position terms (sometimes these types of terms are [incorrectly] used interchangeably in a report), and geologic age terms that are used for aquifer names (for example, Late Cretaceous aquifer system); however, terms such as "water from Upper Cretaceous rocks" and so forth are acceptable. For further clarification of and suggestions for aquifer naming schemes, refer to Laney and Davidson (1986) and STA7 (Hansen, 1991, p. 65–82). Note that the examples in table 2 are only a select few nomenclatural issues that reviewers may encounter.

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Table 2. Examples of correct and incorrect usage of aquifer names.

Incorrect usage	Problem	Correct usage
Floridan aquifer	The Floridan is a system that includes other named aquifers and other hydrostratigraphic units (no "Floridan aquifer" exists)	Floridan aquifer system
Upper Floridan aquifer system	Upper Floridan is an aquifer within the Floridan aquifer system	Upper Floridan aquifer
Black Mingo Group aquifer	Lithostratigraphic units are not included in hydrostratigraphic nomenclature	Black Mingo aquifer
Dakota Sandstone aquifer	Lithologic modifiers are not used in hydrostratigraphic nomenclature	Dakota aquifer

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