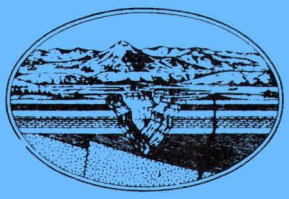
UNITED STATES
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

STRATIGRAPHIC NOMENCLATURE IN REPORTS OF THE U.S. GEOLOGICAL SURVEY



FOR OFFICIAL USE WITHIN THE GEOLOGICAL SURVEY

1974

STRATIGRAPHIC NOMENCLATURE IN REPORTS OF THE U.S. GEOLOGICAL SURVEY

By

George V. Cohee, Chairman

Geologic Names Committee

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Vincent E. McKelvey, Director

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STRATIGRAPHIC NOMENCLATURE IN REPORTS OF THE UNITED STATES GEOLOGICAL SURVEY

THE GEOLOGIC NAMES COMMITTEE

The Geologic Names Committee of the United States Geological Survey was first organized on February 17, 1899, ". . . to consider all names of geologic formations or other divisions of rock classifications with a view to determining whether they comply with the rules of nomenclature adopted for the Survey publications and to recommend such action as may be advisable in any individual case to secure unity of nomenclature under the rules."

The Committee is a group appointed by the Chief Geologist and responsible to him, through authority delegated from the Director. In addition to the Chairman, it consists of nine geologists as regular members, supported by advisory specialists, a Geologic Names Review Staff, and the Lexicon of Geologic Names unit. Specialists in the stratigraphy of rocks of different ages and in different regions are consulted when departures from official classification and nomenclature are proposed in manuscripts, and they are invited by the Chairman to participate as temporary members of the Committee when certain stratigraphic problems are brought before the full Committee for consideration.

The ever-increasing number of manuscripts received for critical review by the Committee, the corresponding increase in problems pertaining to stratigraphic nomenclature and classification, and the advantage of more direct contact with authors, led to the establishment early in 1961 of offices of the Geologic Names Committee Review Staff at the Denver and Menlo Park field centers.

FUNCTIONS OF THE GEOLOGIC NAMES COMMITTEE

The Committee is responsible for defining and recommending policy and rules governing stratigraphic nomenclature for the entire Geological Survey, subject to guidance and approval by the Chief Geologist. The Committee, acting through its Chairman and Secretary, is responsible for the technical review of stratigraphic nomenclature and classification in all manuscripts and maps originating in the U.S. Geological Survey whether they are to be published by the Geological Survey or by an out-

side organization and whether they result in whole or in part from the official work of Geological Survey members.

Where there are departures from the official classification and nomenclature, the Committee considers whether the departures should be adopted as new official usage, approved for use in the particular manuscrip without prejudice to official usage, or rejected. The basis of consideration is the Code of Stratigraphic Nomenclature. The classification and nomenclature of rock units in manuscripts that embody the results of cooperative investigations with State geological surveys or other outside organizations shall accord with the official classification and nomenclature, unless such manuscripts are published by a cooperating organization using a classification different from that of the U.S. Geological Survey. Subject to approval of the Director, the manuscript may then use the classification of the cooperating organization, with an appropriate statement of explanation.

Reports are critically reviewed by the Review Staff of the Committee under the supervision of the Secretary of the Committee. Problems are brought to the attention of either the Secretary of the Committee or the Committee Chairman. The Committee meets to discuss proposed substantial departures from the official classification and nomenclature, and its recommendations are submitted to the Chief Geologist for approval. To expedite manuscripts and to promote efficient operation, relatively minor departures from official usage need not be brought to the attention of the full Committee but may be approved by the Committee Chairman and the Secretary through conferences with the authors and specialists on the Committee. Proposal of new names, redefinition of old names, geographical extension or restriction of old names, and new age assignments of units are considered departures from official usage.

AVAILABILITY OF COMMITTEE RECORDS FOR REFERENCE

The Geologic Names Committee of the U.S. Geological Survey for many years has maintained systematic records which include not only an index to the work of the Committee throughout its history but also an index to the stratigraphic literature of the United States so far as names and classification are concerned.

Much of the information in these records is available to geologists in the following publications:

1. Wilmarth, M. Grace, 1938, Lexicon of Geologic Names of the United States: U.S. Geological Survey Bull. 896.
2. Wilson, Druid, Sando, William J., and Kopf, Rudolph W., 1957, Geologic Names of North America, Introduced in 1936-1955; U.S. Geological Survey Bull. 1056-A.
3. Wilson, Druid, Keroher, Grace C., and Hansen, Blanche E., Index to the Geologic Names of North America: U.S. Geological Survey Bull. 1056-B.

4. Cohee, George V., and West, Walter S., 1965, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1963: U.S. Geological Survey Bull. 1194-A.
5. Cohee, George V., and West, Walter S., 1965, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1964: U.S. Geological Survey Bull. 1224-A.
6. Cohee, George V., and West, Walter S., 1966, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1965; U.S. Geological Survey Bull. 1244-A.
7. Keroher, Grace C., and others, 1966, Lexicon of Geologic Names of the United States: U.S. Geological Survey Bull. 1200.
8. Cohee, George V., West, Walter S., and Wilkie, Lorna C., 1967, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1966: U.S. Geological Survey Bull. 1254-A.
9. Cohee, George V., Bates, Robert G., and Wright, Wilna B., 1969, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1967: U.S. Geological Survey Bull. 1274-A.
10. Cohee, George V., Bates, Robert G., and Wright, Wilna B., 1970, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1968: U.S. Geological Survey Bull. 1294-A.
11. Cohee, George V., Bates, Robert G., and Wright, Wilna B., 1970, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1969: U.S. Geological Survey Bull. 1324-A.
12. Keroher, Grace C., 1970, Geologic Names in the United States for 1961-1967: U.S. Geological Survey Bull. 1350.
13. Cohee, George V., Bates, Robert G., and Wright, Wilna B., 1971, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1970, U.S. Geological Survey Bull. 1354–A.
14. Cohee, George V., and Wright, Wilna B., 1972, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1971, U.S. Geological Survey Bull. 1372–A.
15. Cohee, George V., and Wright, Wilna B., 1974, Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1972, U.S. Geological Survey Bull. 1394–A.

A record of geologic names used for all stratigraphic units in the United States and its possessions is maintained by the Lexicon unit. The up-to-date file on each unit includes its age assignment, type locality, lithology, thickness and history of usage. Further information may be obtained by inquiry addressed to the National Center, Denver, or Menlo Park office of the Geologic Names Committee. The services offered by the Committee are limited to answering questions as to previous use of a geographic name as a stratigraphic name, the original and current definitions of a particular stratigraphic unit, the currently accepted age or classification and geographic distribution of any particular unit, and such general or specific information on similar matters as may be included in the Committee's records.

If a correspondent, either Survey or non-Survey, expresses his intention to use a name that has not been previously applied to a stratigraphic unit, an appropriate informal record is made to reserve the name so that others who may inquire about the name can be informed of the first author's intention. The Committee does not presume to pass judgment on the validity or use of any name outside the publications of the U.S.

Geological Survey, but its records are available for reference at all times to all geologists.

RECOMMENDATIONS FOR GEOLOGICAL SURVEY AUTHORS

The Geologic Names Committee desires to facilitate the work of authors in preparing their reports and also to clear manuscripts as quickly as possible. Concern for manuscripts that are delayed in publication because of problems in geologic nomenclature prompts these suggestions of ways in which authors can hasten the review of their reports.

ACCEPTED STRATIGRAPHIC NAMES

While preparing his report, a Geological Survey author should check with the Geologic Names Committee to determine which stratigraphic names have been accepted for use in his area by the U.S. Geological Survey. Only names that have received specific consideration by the Committee are accepted for official usage. Names that have not been accepted but that have been used by others may be used in a report to be released by the Geological Survey if they are used with a citation—for example, the Branchton Clay of Lewis (1881). If it is desirable to propose for adoption by the Geological Survey a name that has been published by non-Survey authors, the Committee should be provided a reference to the original definition, and either a quotation thereof, or a redefinition if the original description is inadequate or if the definition of the unit is changed. If the unit is to be redefined, a historical summary of use of the name should be given.

FORMATION—THE FUNDAMENTAL STRATIGRAPHIC UNIT

The formation is the fundamental unit in rock stratigraphic classification. In general, the definition of a new formation should be based upon tested mappability. Mappability at the surface is considered as delineation at scales of the order of 1:25,000. For subsurface units, established extension comparable to that implied by mappability of surface units is a similar requirement.

The term complex is applied to a mass of rock composed of diverse types of any class or classes or is characterized by highly complicated structure. Such usage permits the establishment of named mappable units within the sequence.

PROPOSING NEW NAMES IN A REPORT

If new stratigraphic names are to be proposed in a report, Geological Survey authors should send to the National Center, Denver, or Menlo Park office of the Committee, at the earliest possible date, a list of such names and the area in which they are to be used. The names will be checked and, if they are not preoccupied, will be reserved for the report. If the names are preoccupied, the author thus has an opportunity to

select other names before the report is completed. More than one choice for a name may be submitted if desired. If reserved names are not used, the Committee should be informed promptly so that availability of the names can be reestablished. The completed report should contain the following minimum information about a new name:

1. Statement of intent to introduce a name: "This unit is here named. . . ."
2. Geographic feature from which the name was taken. Specific location of one (or more if desirable) typical section near the geographic feature.
3. Description of the upper and lower contacts, where possible.
4. Summary description of the lithology.
5. When possible, an interpretation of the age and correlation.

PREPARATION OF STRATIGRAPHIC SUMMARY

Prior to completion of manuscripts involving several stratigraphic names and correlations, a stratigraphic summary including rough sketches of the proposed map explanation, correlation charts, and other diagrams pertaining to stratigraphic problems, should receive preliminary review by the Committee, if possible. Many questions may be eliminated and waste of effort avoided by such review before the manuscript and illustrations are in final form.

DISCUSSION OF STRATIGRAPHY OF AN AREA

1. The stratigraphy of an area is discussed chronologically, the oldest formation first and the youngest last. This requirement does not necessarily apply to the order of description of a measured section of a formation or the discussion of the strata penetrated in oil or water wells.
2. When a term is used for the first time in a manuscript, it is recommended that its age be given if nct indicated by the title—for example, the Black River Formation of Ordovician age.
3. The adjectives Lower, Middle, or Upper indicate stratigraphic position; time designation is shown by using Early, Middle, or Late—for example, Lower Ordovician rocks were deposited in Early Ordovician time.
4. The Lexicon should not be quoted as the authority in stratigraphic discussions. Reference should be made to the original article upon which the data in the Lexicon are based.

GEOGRAPHIC NAMES

The geographic name for a newly established rock-stratigraphic unit should be the name of a river, town, or other natural or artificial feature

at or near which the unit is typically developed. In selecting the geographic name for a new unit, reference should be made to the established geographic names on U.S. Geological Survey maps. If questions arise regarding geographic names, they should be referred to the Geographic Names Section of the U.S. Geological Survey through the Geologic Map Editor. When new rock-stratigraphic units are to be established in areas where geographic features have not been named, application to establish a geographic name for a certain feature should be made to the Geographic Names Section, through the Geologic Map Editor. Application forms and instructions for proposing new geographic names are supplied by the Geographic Names Section. Application to propose a new geographic name should be made by the author at an early stage in the preparation of his report.

USE OF DIACRITICAL MARKS ON GEOLOGIC NAMES

Diacritical marks should not be used on anglicized words of foreign origin; on place names containing both foreign and English words; or on names of foreign origin applied to places in the United States, even if the foreign names are not mixed with English words. In reports on a territory or possession of the United States whose official language is not English, place names and other foreign words, in general, are written as they are used in the native language. Since a geographic name constitutes part of a geologic name, geologic names should, in general, be written as they are used in the native language.

CONSISTENT USAGE OF TERMS

Usage of terms should be consistent, and the accepted term for the area must be used throughout the report in reference to that area. Confusion sometimes arises with terms such as the Dakota, which is a sandstone in most areas but a quartzite in other areas and is designated a formation in some areas but a group in others. The Raritan Formation is an example of another type that may cause confusion. It is divided into the Lloyd Sand Member (formal name) and a clay member (informal). In paragraph headings, maps, and the first use of the name in a paragraph, the proper reference to the formal name Lloyd would be, Lloyd Sand Member of the Raritan Formation. If the name is used several times in a paragraph, the subsequent reference might be to the Lloyd, or the Lloyd Member, but not the Lloyd Sand. The preferred usage for the informal member is clay member of the Raritan Formation rather than Raritan clay.

If there are no designated members, formal or informal, but it is desired to refer to a particular lithologic facies, the reference should indicate that the facies is part of the formation, as in sandstone of the Fountain Formation, or Fountain sandstone (informal usage). In order

to avoid frequent repetition of a geologic name in the text, the Trenton Limestone may be referred to as the Trenton, the limestone, or the formation.

In order to provide a variation in the style of expressing the age or ages of certain rocks, the author may want to make reference to the age in the following manner:

Rocks of Cambrian age
Cambrian rocks
The rock is of Cambrian age
The rock is Cambrian
Upper Cambrian rocks were deposited in Late Cambrian time
The Reagan Sandstone of Cambrian age
The Reagan Sandstone (Cambrian)

STRATIGRAPHIC UNITS OF ECONOMIC INTEREST

Beds and Zones

The names by which stratigraphic units of economic interest are known locally, such as oil sands, coal beds, and construction or ornamental stone, may be used informally in publications of the Geological Survey. However, the text should state that the names are of local usage. This decision applies to such terms as:

Big Blue sand	Blue Creek seam	Marker bed
Baker producing zone	Mineral coal bed	Sea-green slate
Button beds	Ore bed	Vermont marble
Butte coal zone	Reef beds	Bedford stone

Where the term has been replaced by a geographic formation or member name, however, the formation or member name shall preferably be used, but the economic term may be used in parentheses without quotation marks as follows:

Burgoon Sandstone Member (Big Injun or Mountain sand)
Saltsburg Sandstone Member (Little Dunkard sand)
Morgantown Sandstone (Murphy sand)
Greenbrier Limestone (Big Lime)

Aquifers

Water-bearing rock units (aquifers) also may be named, but only where stratigraphic names cannot be used; for example, where the aquifer crosses stratigraphic boundaries or where an aquifer is known to exist but the local stratigraphy has not been worked out. To avoid confusion with stratigraphic units, aquifers to be named should be given broad, regional names, such as the Floridan aquifer (lower case a).

For stratigraphic units that have been formally named and that are water bearing, the term aquifer may be used instead of the formal term; for example, Jackson aquifer for Jackson Group or Catahoula aquifer for Catahoula Formation. If a single aquifer includes two or more named units, such as the Carrizo and Wilcox Formations, the name Carrizo-Wilcox aquifer may be used.

On maps showing hydrologic units, special symbols may be used for the aquifers, such as Fa for Floridan aquifer, or Ja for Jackson aquifer.

Where formally named water-bearing stratigraphic units are called aquifers, the description and text should make clear that these are formal stratigraphic units, but are called aquifers on the map and in the report to emphasize their water-bearing character.

The term aquifer is not capitalized.

USAGE OF GROUP

As defined in the stratigraphic code, a group consists wholly of divisions defined as formations. Because groups are recognized for the purpose of expressing natural relations of associated formations, the term group should be applied only to a stratigraphic sequence consisting of formally named units. If the sequence has not been so divided, the term formation should be applied. When future work demonstrates that the sequence can be divided into formally named formations, the unit can be raised to group status, the name being retained for the group.

USAGE OF BED AND BEDS

A distinctive layer or stratum of rock may be formally designated a bed and a unit consisting of certain thin distinctive beds useful to recognize may be formally designated beds. An example is the Magoffin Beds, a well known stratigraphic unit in the Breathitt Formation, of Pennsylvanian age, southeastern Kentucky. The Magoffin Beds consist of as much as 50 meters of gray fossiliferous shale and dark-gray argillaceous limestone.

The usage of the plural Beds as a formal stratigraphic unit has been approved by the American Commission on Stratigraphic Nomenclature and this usage will be included in a future reprinting of the Stratigraphic Code.

MARINE UNITS

The American Commission on Stratigraphic Nomenclature has recommended that the identification and naming of marine stratigraphic units follow the stratigraphic code.

DIVERSE TIME TERMS

Although Phanerozoic Eon, which includes Paleozoic, Mesozoic, and Cenozoic Eras, has not been adopted by the Survey as part of its official classification, it may be used in text material when needed for convenience of reference.

The terms Eogene, Paleogene, and Neogene have been used by some European geologists as subdivisions of the Tertiary System. Eogene or Paleogene generally includes Paleocene, Eocene, and Oligocene Series, and Neogene generally includes Miocene and Pliocene Series. Some geologists, however, have included Pleistocene Series in the Neogene and some have included Holocene. These terms have not been adopted by the U.S. Geological Survey but may be used informally in texts for reference when the terms are defined.

Neoglaciation is a term used to designate a readvance of the ice following the Hypsithermal (Thermal Maximum) interval. The term should be used only in the mountain areas where cirques and glaciers formed following the Hypsithermal (Meyer Rubin, personal commun., June 23, 1969).

ABSTRACTS AND GUIDEBOOK ARTICLES

New stratigraphic names should not be introduced in an abstract to be published separately from a more complete report. The essential conciseness of an abstract does not permit the full definitions that are specified by the stratigraphic code. An informal designation should be used in an abstract for the stratigraphic unit that is to be named and introduced later in the more complete report.

In accordance with the Chief Geologist's memorandum of March 20, 1967, guidebooks shall not be used as a medium for naming new stratigraphic units. Also, see Article 13, Remarks (*e*) of the code. New stratigraphic names or changes in nomenclature should not be introduced in guidebook articles because their distribution and availability to the scientific public are limited.

OPEN-FILE REPORTS

Open-file reports will be checked by the Geologic Names Committee only upon request, but in preparing such reports the authors should check with the Committee regarding the nomenclature to be used.

An open-file report containing unpublished formal geologic names of stratigraphic units will not be approved by the Director except when it accompanies or follows a formal report in which the new names are introduced in the usual way. Age changes of established units will not be officially adopted on the basis of an open-file report.

THESES

A thesis prepared in connection with Survey work must be placed in open file but need not be processed as a regular Survey manuscript. In preparing the thesis, the author should check with the Geologic Names Committee re-

garding the reservation and introduction of new geologic names, age changes, and the map explanation.

Theses generally need not be reviewed by the Geologic Names Committee but those in which new names are introduced should be reviewed by the Committee to determine if the newly named units are adequately described.

ADMINISTRATIVE REPORTS

Unclassified reports that are prepared for other Government agencies and that are to be open filed and ultimately published should be reviewed by the Geologic Names Committee when the manuscript is completed. Such procedure will avoid review by the Geologic Names Committee after the copies have been prepared for open filing.

GEOLOGIC QUADRANGLE MAPS

On Geologic Quadrangle Maps without an accompanying text, where the authors have introduced new geologic names or have had occasion to change the age of certain units mapped, a brief description of the new name or discussion of the age change should be added at the bottom of the explanation. Because the map will be the first and, in some cases, the only published reference to the name, care should be taken by the author to include in the brief statement pertinent information about the unit, such as type locality, geographic feature from which it was named, thickness, lithology, upper and lower contacts where possible, and age and correlation where possible. When the age of a unit is changed, the justification for such a change should be given.

QUOTATION MARKS

Quotation marks are sometimes used by an author on a geologic name to indicate that the term has been abandoned or to imply misnomer or misapplication of a name. Quotes may also be used to imply equivalence in age, as in the use of the term "Trenton" limestone in the Midcontinent area. In the eastern United States, Trenton is a valid name but when used in the Midcontinent area it can only mean equivalence in age. It would be preferable for the author to state "of Trenton age," but on maps and diagrams it may be more practical to use "Trenton" with quotation marks.

Quotation marks have been used for unusual terms, such as "Coal Measures," "Calciferous," "Corniferous," "Lignitic," "Magnesian," "Lower Magnesium," "Black slate," "Aluminous slate," "Chattanooga Black Shale," "Maury Green Shale" (very early usage in some old reports), and "Big Lime." Such usage should be continued.

Economic beds such as named coal beds, oil sands, and quarry beds, and aquifers should not have quotes because they are perfectly good

names to industry and are understood to be not a part of formal stratigraphic nomenclature. Because of the varied use and implications attached to the meaning of quotation marks, their usage in a manuscript should be explained, where practicable, by a brief statement.

Red beds should be used as two words without quotation marks. When used as a unit modifier, as in red-bed facies, the words are hyphenated.

CAPITALIZATION

In accordance with the stratigraphic code the following are examples of the capitalization of geologic terms:

Paleozoic Era
Paleozoic time
Paleozoic age (informal usage of age)

Devonian System
Devonian Period
Devonian time
Devonian age (informal usage of age)

Pleistocene Series
Pleistocene Epoch
Pleistocene time
Pleistocene age (informal usage of age)
Pleistocene and Holocene Series, Epochs

Formal series subdivisions of a system are Lower, Middle, and Upper (Early, Middle, and Late).
Subdivisions of Provincial series are lower, middle, and upper (early, middle, and late).

Wisconsin Glaciation
Tazewell Stade
Two Creeks Interstade
Sangamon Interglaciation

Cenomanian Stage
Cenomanian Age
Cenomanian time
fossils of the Cenomanian Age
the Cenomanian and Turonian Stages, Ages
Cenomanian and Turonian time
of Midway and Wilcox age (informal usage of age)
Lake Bonneville stage (informal usage of stage)
of Lake Bonneville age (informal usage of age)
Lake Bonneville Group

Des Moines Series (time-stratigraphic unit)
Yavapai Series (an established series not used in a time-stratigraphic sense)

Ash Creek and Alder Groups
Chinle Formation
Church Rock Member
Church Rock and Owl Rock Members
Petrified Forest Member

Sonsela Sandstone Bed
Chinle and Moenkopi Formations
Ojo Alamo Sandstone
Kirtland Shale
Ojo Alamo and Kirtland Formations
American Falls Lake Beds
Florissant Lake Beds
Vulcan Iron-Formation
Traders Iron-Bearing Member

Soil-stratigraphic units should be capitalized—Brady Soil.
Cyclothems should not be capitalized—St. David cyclothem.
Facies should not be capitalized—Catskill facies.
Coal beds should not be capitalized—Big Horn seam or bed.
Oil sands should not be capitalized—McClosky sand.
Quarry beds should not be capitalized—Tennessee marble.
The names of intruded masses, such as pluton, stock, and batholith are not capitalized; for example, Loon Lake pluton and Idaho batholith.
Aquifers should not be capitalized—Biscayne aquifer.
Time is always considered informal.
The term age is capitalized only with the formal time unit equivalent in rank with stage.

Geologic names should be capitalized in material that is quoted indirectly from publications in which the names were not capitalized by the author. In directly quoted material, capitalization of the names should follow the usage of the author. Geologic names should not be capitalized in correlation tables, columnar sections and maps taken directly from publications in which the names were not capitalized by the author but if the correlation tables, columnar sections and maps are modified after the original material by more recent or additional data the names should be capitalized.

GEOLOGIC AGE OF METAMORPHOSED ROCKS

In assigning ages to metamorphic rocks, care should be taken to state whether depositional age is being used or the age of the metamorphism.

DESIGNATION OF PRECAMBRIAN TIME

The following formal designations of Precambrian time are now in use by the U.S. Geological Survey:

Precambrian Z—base of Cambrian to 800 m.y.
Precambrian Y—800 m.y. to 1,600 m.y.

Precambrian X—1,600 m.y. to 2,500 m.y.

Precambrian W—older than 2,500 m.y.

The scheme of subdivisions has been devised simply to facilitate depiction and analysis of the Precambrian history of the United States. The time boundaries have been chosen so as to split as few of the known epochs of sedimentation, orogeny, and plutonism as possible. The boundaries do not correspond intentionally to geologic events. The scheme is intended as an interim measure, pending development of an internationally accepted standard.

For depiction on maps, only the letter designations (W, X, Y, Z) will be shown as map symbols, and lowercase letters will indicate the group or formation names as appropriate. If a unit extends across the boundary between letter-designated units, both letters, the younger first, will be used in the map symbol. When geochronologic data are not adequate for unit assignment, only the general term Precambrian and the symbol pЄ will be used. Rock units and events within a major time unit such as W, X, Y, or Z, keyed to geochronologic data as available, will be shown on map explanations by simple sequential arrangement.

LETTER SYMBOLS ON GEOLOGIC MAPS

The only standard letter symbols used by the Geological Survey on geologic maps are the letter symbols for the system and era terms. They are as follows:

Quaternary	Q	Devonian	D
Tertiary	T	Silurian	S
Cretaceous	K	Ordovician	O
Jurassic	J	Cambrian	Є
Triassic	Ŧ	Precambrian	pЄ
Permian	P	Cenozoic	Cz
Pennsylvanian	IP	Mesozoic	Mz
Mississippian	M	Paleozoic	Pz

The letter symbol C may be used to designate Carboniferous Systems where Pennsylvanian and Mississippian Systems are not differentiated on the map. Also, the terms Carboniferous or Carboniferous Systems are not necessary on correlation charts and tables, but they may be used in texts of reports where needed for reference and correlation purposes.

The second letter of the symbol is usually the first letter (lowercase) of the formation name, as Tc for Calvert Formation of Tertiary age. If a formation name is made up of two words, there is a choice of symbols—for example, Fort Union Formation, Tf or Tfu. Tf is preferred if there is no other Tf symbol in the explanation. If members of the Fort Union are mapped, the first letter of the first part of the formation name is commonly used and the first letter of the member name—as Tfl for Lebo

Shale Member of the Fort Union Formation—thus keeping the symbol from being unnecessarily long. Series and group names are not generally indicated in the symbol. The symbol for a mapped unit that does not bear a formal name but is referred to only by rock type, as for example gneiss of Precambrian age, as a rule contains the first one or two letters of the rock—**pCg** or **pCgn**—but need not contain the age designation if the mapped area consists entirely or almost entirely of Precambrian rocks.

The symbols that are to be used on a given geologic map are dictated by practicability. The number of units and the number of systems shown, and the rock types of an area, are important factors in the choice of symbols. Only where necessary for distinction of units should more than three letters, including the age designation, be used in symbols appearing in the box on the explanation and on the map. It is advisable that symbols not be used in the texts of book reports.

MAP EXPLANATIONS

The rock units shown on the map explanation should be arranged in a chronologic sequence where practicable. Separate columns will have to be used on some map explanations, such as State geologic maps or other regional maps where rock units of the same age have different names in different parts of area covered and where it is necessary to combine into a single map unit several rock units or ages in a particular part of the map area. A new format for map explanations has been introduced recently (Figs. 1 and 2). This format should be used because of its adaptability to modern map preparation procedures.

1. Systems are in capital letters on the far right side of the explanation (fig. 1).
2. Series are in capital and lowercase letters on the right side of the explanation, indented from the system brace.
3. Groups are on the right side, indented from series brace, and in capital and lowercase letters.
4. Formation names and descriptions are to the right of the boxes (fig. 2).
5. The discussion of members or tongues of a formation should be in order of their stratigraphic position, youngest at the top, and the symbols should be in the order discussed. The symbols should precede the discussion of the member (fig. 2).
6. The position of terms of equal rank should be consistent.

Boxes in the explanation should be as simple as possible in order that the reader can readily observe the letter symbol, which is the reference to the stratigraphic unit on the map. Complex intertonguing relation of members within formations or other stratigraphic characteristics of the unit or units generally should be shown in a separate diagram below the explanation.

Avoid abbreviations, if possible, and do not abbreviate the words System, Period, Series, and Epoch. Where abbreviation is necessary in illustrations, the following are recommended:

Group	— Gp.	shale	— Sh.
Formation	— Fm.	limestone	— Ls.
Member	— Mbr.	dolomite	— Dol.
sandstone	— Ss.	conglomerate	— Cgl.
siltstone	— Sts.	quartzite	— Qtz.

Periods are generally used after these abbreviations in charts and graphs but not on maps. It is recommended that authors avoid expanding descriptive material in the explanation where possible. For book publications authors should not include in the explanation descriptive material that belongs in the text; however, for maps having an abbreviated text or no text, such as maps of the Geologic Quadrangle series, some expansion of the descriptive material in the explanation may be necessary.

If the use of a formal geologic name is questioned, the query should be placed following the geographic name, such as Morrison(?) Formation.

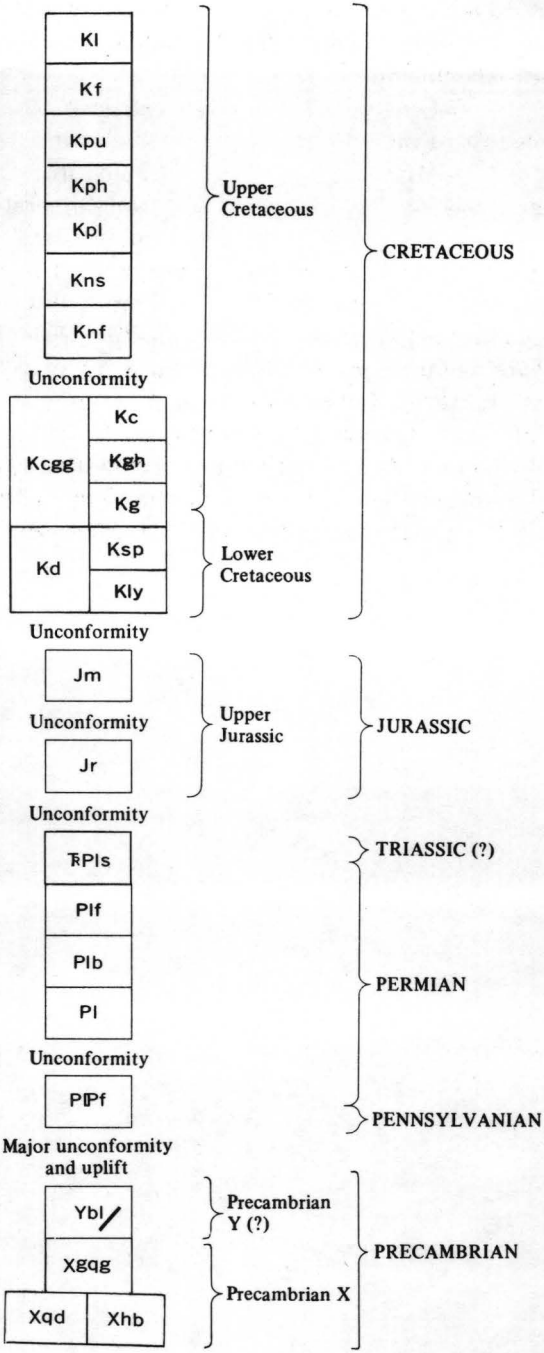
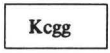
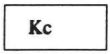


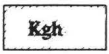
FIGURE 1. Method of showing age and correlation of map units. After Geologic Map of Morrison Quadrangle, Colorado, Map I–790–A.



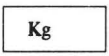
CARLILE SHALE, GREENHORN LIMESTONE, AND GRANEROS SHALE – Fossils in many parts. Total thickness 530 feet



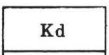
CARLILE SHALE (UPPER CRETACEOUS) – In descending order, Juana Lopez Member, grayish-brown hard calcarenite (sandy limestone composed of shell fragments); Blue Hill Shale Member, gray silty sandstone; Fairport Chalky Shale Member, yellowish-gray soft calcareous shale



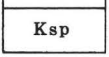
GREENHORN LIMESTONE (UPPER CRETACEOUS) – In descending order, Bridge Creek Limestone Member, gray dense limestone beds and hard gray calcareous shale; Hartland Shale Member, gray shaly calcarenite; Lincoln Limestone Member, grayish-brown thin beds of hard calcarenite and shaly calcarenite containing marker bentonite at base



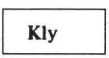
GRANEROS SHALE (UPPER AND LOWER CRETACEOUS) – Dark-gray hard clayey shale; at base dark-gray hard platy siltstone equivalent to Mowry Shale



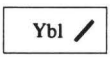
DAKOTA GROUP (LOWER CRETACEOUS) – Thickness 300 feet



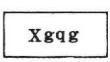
SOUTH PLATTE FORMATION (LOWER CRETACEOUS) – Contains three sandstone members separated by two shale members. Sandstone yellowish gray, well sorted, cross stratified, porous; composed of well-rounded to subrounded fine to medium quartz sand. Shale dark gray, silty, hard, parallel bedded; interbedded with thin gray sandstone layers; contains gray or white refractory clay or porcellanite layers. Asphalt occurs in a seep and with pyrite in uranium prospects near Turkey Creek. Dinosaur footprints along Alameda Parkway. Thickness about 220 feet



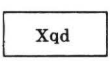
LYTLE FORMATION (LOWER CRETACEOUS) – Yellowish-gray or yellowish-brown medium- to fine-grained ironstained sandstone and conglomerate. Conglomerate generally near base composed of quartz, quartzite, chert, and some petrified wood. Silicified tree trunks in upper part of the formation. Thickness about 80 feet



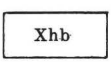
BIOTITE LATITE (PRECAMBRIAN Y?[1]) – Reddish-gray porphyritic dike rock with aphanitic groundmass; along Lariat Loop road and northwest of Mount Falcon. Chief minerals are microperthite, oligoclase, biotite, quartz, and muscovite. Possible correlative of dikes related to Pikes Peak Granite (R. B. Taylor, oral commun., 1972)



GNEISSIC QUARTZ MONZONITE AND GRANODIORITE (PRECAMBRIAN X[1]) – Medium- to coarse-grained foliated biotite quartz monzonite and granodiorite, locally prophyritic and containing laths of potassic feldspar as much as 4 mm in length. Equivalent to the Boulder Creek Granodiorite



QUARTZ DIORITE (PRECAMBRIAN X) – Black and white massive medium to coarsely crystalline bodies composed chiefly of hornblende, plagioclase, biotite, and minor quartz



HORNBLENDITE (PRECAMBRIAN X) – Greenish-black medium to coarsely crystalline bodies composed chiefly of hornblende, quartz, and accessory minerals

FIGURE 2. Method of showing description of map units. After Geologic Map of Morrison Quadrangle, Colorado, Map I–790–A.

MAJOR STRATIGRAPHIC AND TIME DIVISIONS

Subdivisions in Use by the U. S. Geological Survey			Age estimates commonly used for boundaries (in million years)[1]	
Era or Erathem	System or Period	Series or Epoch	(A)	(B)
Cenozoic	Quaternary	Holocene		
		Pleistocene	1.5-2	1.8
	Tertiary	Pliocene	ca. 7	5.0
		Miocene	26	22.5
		Oligocene	37-38	37.5
		Eocene	53-54	53.5
		Paleocene	65	65
Mesozoic	Cretaceous[3]	Upper (Late) Lower (Early)		
	Jurassic	Upper (Late) Middle (Middle) Lower (Early)	136	
	Triassic	Upper (Late) Middle (Middle) Lower (Early)	190-195	
Paleozoic	Permian[3]	Upper (Late) Lower (Early)	225	
	Pennsylvanian[3]	Upper (Late) Middle (Middle) Lower (Early)	280	
	Mississippian[3]	Upper (Late) Lower (Early)	320[2]	
	Devonian	Upper (Late) Middle (Middle) Lower (Early)	345	
	Silurian[3]	Upper (Late) Middle (Middle) Lower (Early)	395	
	Ordovician[3]	Upper (Late) Middle (Middle) Lower (Early)	430-440	
	Cambrian[3]	Upper (Late) Middle (Middle) Lower (Early)	ca. 500	
Precambrian	Time subdivisions of the Precambrian: Precambrian Z--base of Cambrian to 800 m.y. Precambrian Y--800 m.y. to 1,600 m.y. Precambrian X--1,600 m.y. to 2,500 m.y. Precambrian W--older than 2,500 m.y.		570	

GEOLOGIC NAMES COMMITTEE, U. S. GEOLOGICAL SURVEY, 1972

[1/] Estimates for ages of time boundaries are under continuous study and subject to refinement and controversy. Two scales are given for comparison:

(A) Geological Society of London, 1964, The Phanerozoic time-scale; a symposium: Geol. Soc. London, Quart. Jour., v. 120, suppl., p. 260-262.

(B) Berggren, W. A., 1972, A Cenozoic time-scale--some implications for regional geology and paleobiogeography: Lethaia, v. 5, no. 2, p. 195-215.

In addition to these, a useful time scale for North American mammalian stages is given by:

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Amer. Jour. Sci., v. 262, p. 145-198.

[2/] From Table 1: Correlation chart for the Carboniferous of north-west Europe, Russia, and North America: Geol. Soc. London, 1964[1/], p. 222.

[3/] Includes provincial series accepted for use in U. S. Geological Survey reports.

Terms designating time are in parentheses. Informal time terms--early, middle, and late--may be used for the eras, for periods where there is no formal subdivision into Early, Middle, and Late, and for epochs. Informal rock terms--lower, middle, and upper--may be used where there is no formal subdivision of an era, system, or series.

PROVINCIAL SERIES ACCEPTED FOR USE IN U.S. GEOLOGICAL SURVEY REPORTS

Series	Age	Region
Gulfian	Late Cretaceous	Texas, Louisiana, Oklahoma, Arkansas, Mississippi, and Alabama.
Comanchean	Early and Late Cretaceous	
Coahuilan	Early Cretaceous	Texas, Louisiana, Arkansas, Mississippi, and Alabama.
Ochoan	Late Permian	Texas and New Mexico.
Guadalupian	Early and Late Permian	Do.
Leonardian	Early Permian	Do.
Wolfcampian	Early Permian	Do.
Virgilian	Late Pennsylvanian	Arkansas, Oklahoma, Kansas, Missouri, Nebraska, and Iowa.
Missourian	----------do----------	
Des Moinesian	Middle Pennsylvanian	
Atokan	----------do----------	
Morrowan	Early Pennsylvanian	
Chesterian	Late Mississippian	Indiana, Kentucky, Tennessee, Illinois, Iowa, and Missouri.
Meramecian	----------do----------	
Osagean	Early Mississippian	
Kinderhookian	----------do----------	
Cayugan	Late Silurian	New York and Michigan.
Niagaran	Middle Silurian	Do.
Alexandrian	Early Silurian	Missouri, Illinois, and Michigan.
Canadian	Early Ordovician	United States.
Cincinnatian	Late Ordovician	Ohio, Indiana, Kentucky, Tennessee, Michigan, Wisconsin, and Iowa.
Mohawkian	Middle Ordovician	New York, Michigan, Wisconsin, and Iowa.
St. Croixan	Late Cambrian	Iowa, Minnesota, Wisconsin, and Michigan.

INT. 116-73

HISTORICAL DEVELOPMENT OF THE STRATIGRAPHIC CODE

In an official organization such as the U.S. Geological Survey, which is charged with examination of various aspects of geology throughout the United States, it is imperative that all publications adhere to some broad uniformity of procedure in dealing with the nomenclature and classification of stratigraphic units. A brief history of the development of the rules followed by the Survey is given here.

In 1882 the Director of the Survey published a general scheme of classification and a color scheme for geologic cartography (U.S. Geol. Survey 2d Ann. Rept., 1882, p. xi-liii). In 1889 a conference, attended by Survey Geologists, was called by the Director, and from it came the first published rules of nomenclature and classification (U.S. Geol. Survey 10th Ann. Rept., 1890, p. 63-79). In 1902 the Director invited all members of the Survey's scientific staff to submit to a special committee under G. K. Gilbert their suggestions for amending the rules of nomenclature. After a series of meetings held in that year, the committee prepared a preliminary report, including a tentative draft of proposed rules, which was circulated for criticism. These and further meetings resulted in the first extensive code of regulations for the making of the Geologic Atlas of the United States (U.S. Geol. Survey 24th Ann. Rept., 1903, p. 21-27). The rules set forth in the 10th and 24th Annual Reports were made with special reference to the folios of the Geologic Atlas. While the 24th Annual Report was still in press, the Director (letter of January 10, 1902) extended these rules as the basis for all Survey publications. The Geological Survey operated under them until publication of the 1933 Stratigraphic Code.

In 1930 the Association of American State Geologists appointed a committee to consider the subject of variation in nomenclature of identical rock units on different sides of State boundaries and invited the aid of 3-man committees from 3 other organizations, the U.S. Geological Survey, Geological Society of America, and American Association of Petroleum Geologists, to consider the general subject of stratigraphic classification and nomenclature. The 12 people in the 4 organizations were constituted as a national committee under T. W. Stanton as chairman. This committee requested the U.S. Geological Survey to codify all its rules as a basis on which the committee might operate. T. W. Stanton, H. D. Miser, and G. W. Stose, as members of the national committee, asked other members of the Geologic Names Committee, U.S. Geological Survey, to help formulate existing Survey nomenclatural procedures; J. B. Reeside, W. W. Rubey, and H. D. Miser were assigned to compile and undertake the actual drafting of the Code. The work started with the compilation of rules extracted from the 10th and 24th Annual Reports, plus a number of written rules that the Names Committee had formulated since these Annual Reports had been published. The first draft went to

two meetings of the general national committee and was returned to the Survey committee to incorporate changes and to be developed further as the national committee's Code. In 1933 the Code, "Classification and Nomenclature of Rock Units," was published in the Geological Society of America Bulletin (v. 44, p. 423-459), and in 1939 it was published in the Bulletin of the American Association of Petroleum Geologists (v. 23, no. 7, p. 1068-1088).

Steps leading to the establishment of a joint committee like that which had organized the preparation of the 1933 Stratigraphic Code were taken in May 1941, when the President of the Association of American State Geologists invited the other organizations represented in the Committee of 1930-32 to nominate geologists officially empowered to act as delegates to attend meetings in Boston on December 29-30, 1941. A similar invitation was also extended to the Geological Survey of Canada. According to the proposal, the purpose of the meetings was to determine the desirability of establishing a new joint agency designated tentatively as the Commission of Classification and Nomenclature of Rock Units. Represented at this meeting were: the American Association of State Geologists, the U.S. Geological Survey, the American Association of Petroleum Geologists, the Geological Society of America, and the Geological Survey of Canada. It was agreed that such a Commission was necessary, but the war deferred action until near the close of 1946. On December 27, 1946, a meeting was held in Chicago to which each of the above organizations sent three Commissioners, and the name was changed to the American Commission on Stratigraphic Nomenclature. Articles of organization and procedure were drawn up, and a program of work was outlined. In 1955 the membership of the Commission was expanded to include three Commissioners from Mexico, the following organizations being represented: Asociación Mexicana de Geólogos Petroleros; Sociedad Geológica Mexicana; and the Instituto de Geología de la Universidad Nacional Autónoma de México.

The first large task the Commission set for itself was the preparation of a series of reports which could serve as background material for formulating a new Code of Stratigraphic Nomenclature. The following reports were published by the Commission in volumes of the Bulletin of the American Association of Petroleum Geologists as indicated:

Report 1—Declaration on naming of subsurface stratigraphic units: Am. Assoc. Petroleum Geologists Bull., v. 33, no. 7, p. 1280-1282, July 1949.

Report 2—Nature, usage, and nomenclature of time-stratigraphic and geologic-time units: v. 36, no. 8, p. 1627-1638, Aug. 1952.

Report 3—Nature, usage, and nomenclature of time-stratigraphic and geologic-time units as applied to the Precambrian: v. 39, no. 9, p. 1859-1861, Sept. 1955.

Report 4—Nature, usage, and nomenclature of rock-stratigraphic units: v. 40, no. 8, p. 2003-2014, Aug. 1956.

Report 5—Nature, usage, and nomenclature of biostratigraphic units: v. 41, no. 8, p. 1877-1889, Aug. 1957.

Report 6—Application of stratigraphic classification and nomenclature to the Quaternary, v. 43, no. 3, p. 663-673, Mar. 1959.

At the annual meeting of the Commission on November 6, 1957, in Atlantic City, N.J., the Chairman of the Commission was given authority to set up a Coordinating Committee to arrange for the various Committees to prepare sections of the new Code. Carle H. Dane, Ronald K. DeFord, James Gilluly, Hollis D. Hedberg, Raymond C. Moore, and John Rodgers served as members of the Coordinating Committee. The Chairman of the Coordinating Committee, early in 1958, appointed the following Committees to prepare material in the special areas of their assignments for transmittal to the Coordinating Committee:

Committee on Rock-Stratigraphic Classification and Nomenclature: George V. Cohee, Chairman; Edwin D. McKee; Louis C. Sass; and Lawrence L. Sloss.

Committee on Geologic Time and Time-Stratigraphic Classification and Nomenclature: Grover E. Murray, Chairman; W. C. Bell; Marshall Kay; Harry E. Wheeler; and John A. Wilson.

Committee on Biostratigraphic Classification and Nomenclature: L. M. Thompson, Chairman; M. N. Bramlette; Lewis M. Cline; Kenneth E. Lohman; and E. T. Tozer.

Committee on Problems of the Quaternary: G. M. Richmond, Chairman; Richard F. Flint; John G. Fyles; Charles B. Hunt; William C. Putnam; C. Bertrand Schultz; and James H. Zumberge.

Committee on Problems of the Precambrian and Igneous and Metamorphic Rocks: C. H. Stockwell, Chairman; C. A. Anderson; James E. Gill; Harold L. James; and J. E. Thomson.

These Committees were asked to submit to the Coordinating Committee material for use in the new Code, following the general format of the 1933 Code—that is, in the form of Articles and Remarks. The Coordinating Committee met at various times to assemble drafts of the Code for consideration by the entire Commission. The final draft was approved unanimously by the Commission at its annual meeting in Denver, Colorado, November 2, 1960. Final editing was done by an editorial committee, and the new Code was published in the May 1961 Bulletin of the American Association of Petroleum Geologists (v. 45, no. 5, p. 645-665).

Upon completion of the new Code the Geologic Names Committee met to review and consider its adoption by the U.S. Geological Survey. On June 6, 1961, approving the Committee's recommendation, the Chief Geologist announced the adoption of the new Code by the Survey.

Following publication of the 1961 code, a few minor amendments to that code were made by the American Commission on Stratigraphic Nomenclature. Those changes were published in the Bulletin of the American Association of Petroleum Geologists as notes of the Commission and as follows:

Note 28—The American Association of Petroleum Geologists Bulletin, v. 46, no. 10, October 1962, p. 1935.

Note 30—The American Association of Petroleum Geologists Bulletin, v. 48, no. 5, May 1964, p. 710-711.

Note 33—The American Association of Petroleum Geologists Bulletin, v. 50, no. 3, March 1966, p. 560-561.

Note 35—The American Association of Petroleum Geologists Bulletin, v. 51, no. 9, September 1967, p. 1868-1869.

Note 36—The American Association of Petroleum Geologists Bulletin, v. 53, no. 9, September 1969, p. 2005-2006.

The revised code was published in June 1970 by the American Association of Petroleum Geologists and is reproduced in the following pages.

CODE OF STRATIGRAPHIC NOMENCLATURE*

AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE

Contents

* Printed by The American Association of Petroleum Geologists, Inc., Tulsa, Oklahoma, U.S.A., 1970. Copies are available from AAPG, Box 979, Tulsa, Oklahoma 74101, at $1.00 per copy postpaid; 25-percent discount to AAPG-SEPM members; 10-percent discount to nonprofit institutions.

Preamble

Article 1.—The American Commission on Stratigraphic Nomenclature,[1] recognizing the desirability of uniform usage in stratigraphic classification and terminology throughout the continent of North America, proposes the following code. The prime purpose is (i) to formulate a usefully comprehensive, yet explicit statement of principles and practices for classifying and naming stratigraphic units, and (ii) to secure the greatest possible uniformity in applying these principles and practices. This code is applicable to all kinds of rocks, sedimentary, igneous, and metamorphic. The Commission has been guided by the philosophy expressed in its reports[2] on the nature, usage, and nomenclature of rock-stratigraphic, biostratigraphic, and time-stratigraphic units. The Articles of this code are recommendations that can not be generally mandatory, but geological organizations may adopt these articles as their rules of nomenclatorial procedure.

Categories of Stratigraphic Units

Article 2.—Categories of stratigraphic units are multiple. According to different concepts and criteria, they comprise various mutually overlapping but distinct types of stratigraphic units. This code provides regulations and recommendations relating to (i) rock-stratigraphic units, (ii) soil-stratigraphic units, (iii) biostratigraphic units, and (iv) time-stratigraphic units. The code also treats two categories of units that are not in themselves stratigraphic units but are closely related. These are (v) geologic-time units, which are fundamentally related in concept to time-stratigraphic units, and (vi) geologic-climate units, which are based on Quaternary stratigraphic units.

Remark. (*a*) *Homotaxis.*—Rock-stratigraphic units or

[1] American Commission on Stratigraphic Nomenclature, 1947, Note 1—Organization and objectives of the Stratigraphic Commission: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 3 (Mar.), p. 513–518, summarizes the history leading to its formation. In 1932 a committee of representatives from four organizations, the American Association of Petroleum Geologists, the Geological Society of America, the Association of American State Geologists, and the United States Geological Survey, formulated rules for the "Classification and nomenclature of rock units." When the committee had completed its code, which was published in 1933 (see Article 3, footnote), it disbanded. The four organizations severally continued to be concerned with the problems of stratigraphic nomenclature in the United States, and at least one such problem was referred to the Committee on Stratigraphy of the National Research Council. Note 1 of the Commission on Stratigraphic Nomenclature describes its founding, proposed in 1941 and achieved in 1946, with representatives from five organizations: Geological Survey of Canada, American Association of Petroleum Geologists, Geological Society of America, Association of American State Geologists, and United States Geological Survey. The Commission became more substantially American in 1955, when it was joined by representatives of three Mexican organizations: Asociación Mexicana de Geólogos Petroleros, Sociedad Geológica Mexicana, and Instituto de Geología de la Universidad Nacional Autónoma de México.

[2] American Commission on Stratigraphic Nomenclature, 1949, Report 1—Declaration on naming of subsurface stratigraphic units: Am. Assoc. Petroleum Geologists Bull., v. 33, no. 7 (July), p. 1280–82.

——— 1952, Report 2—Nature, usage, and nomenclature of time-stratigraphic and geologic-time units: Am. Assoc. Petroleum Geologists Bull., v. 36, no. 8 (Aug.), p. 1627–1638.

——— 1955, Report 3—Nature, usage, and nomenclature of time-stratigraphic and geologic-time units as applied to the Precambrian: Am. Assoc. Petroleum Geologists Bull., v. 39, no. 9 (Sept.), p. 1859–1861.

——— 1956, Report 4—Nature, usage, and nomenclature of rock-stratigraphic units: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 8 (Aug.), p. 2003–2014.

——— 1957, Report 5—Nature, usage, and nomenclature of biostratigraphic units: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 8 (Aug.), p. 1877–1889.

——— 1959, Report 6—Application of stratigraphic classification and nomenclature to the Quaternary: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 3 (Mar.), p. 663–673.

biostratigraphic units that have a similar order of arrangement in different locations but are not necessarily contemporaneous are said to be homotaxial.[3]

Formal and Informal Names and Units

Article 3. –The code is a systematic collection of rules of formal stratigraphic classification and nomenclature. A stratigraphic unit of one of the categories mentioned in Article 2 and its name are classified as formal if they are proposed in publication in conformance with Article 13 and meet other requirements specified in the code. A valid name is preempted from use as the name of any other formal unit in the same category. (See also Articles 4i, 10 to 12, 14 to 18, 24, and 32 to 35.) Publication in abstracts, guidebooks, microfilms, newspapers, or in commercial or trade journals, even in regularly published series, is not valid publication. A stratigraphic unit and its name are classified as informal if they are not formally proposed. (See Articles 4fghi, 5c, 7a, 8ab, 10gh, 13cde, 20a, 23b, 24, 37ab, 38ac, and 40b.) The geologic vocabulary of North America contains a great many formal names of stratigraphic units, which have been proposed more or less in accordance with these rules and the rules of the previous code.[4] Many formal names antedate the rules. The names and nomenclatural history of formal units are recorded in compendia maintained by the Geologic Names Committee of the United States Geological Survey, Washington, D. C., by the Committee on Stratigraphic Nomenclature of the Geological Survey of Canada, Ottawa, Ontario, by the Instituto de Geología, Ciudad Universitaria, México, D. F., and by some state geological surveys. Information as to the status or availability of names can be obtained from these organizations on request.

Rock-Stratigraphic (Lithostratigraphic) Units

Nature of Rock-Stratigraphic Units

Article 4.—A rock-stratigraphic unit is a subdivision of the rocks in the earth's crust distinguished and delimited on the basis of lithologic characteristics.

Remarks. (*a*) *Recognition and definition.*—Rock-stratigraphic units are recognized and defined by observable physical features rather than by inferred geologic history; boundaries may be placed at sharp contacts or drawn arbitrarily within a zone of gradation. Rock-stratigraphic units are essentially the practical units of general geologic work that serve as a foundation for describing and studying lithology, local and regional structure, stratigraphy, economic resources, and geologic history.

(b) *Type section and extent.*—The definiton of a rock-stratigraphic unit should be based on as full knowledge as possible of its lateral and vertical variations, but for purposes of nomenclatural stability a type section should be designated. Extension of a defined unit to separated bodies of rock is permissible only where they are homotaxial (Article 2a).

(*c*) *Independence from inferred geologic history.*—Concepts based on inferred geologic history or biologic sequence properly play no part in the definition or differentiation of a rock-stratigraphic unit. Nevertheless, fossils may be valuable as physical criteria in defining a rock-stratigraphic unit in the same way as other physical constituents; for example, oyster-rich sandstone, coquina, algal reef.

(*d*) *Independence from time concepts.*—A rock-stratigraphic unit may possess approximately isochronous boundaries, or its boundaries may transgress time horizons. Concepts of time-spans, however measured, properly play no part in differentiating or determining the boundaries of any rock-stratigraphic unit. Either relatively short or relatively long intervals of time may be represented by a single rock unit, whether it be sedimentary, igneous, or metamorphic, but this factor is irrelevant to recognition of the unit. The accumulation of material assigned to a particular unit may have begun or ended earlier in some localities than in others; also removal of rock material by erosion, either within the time span of deposition of the unit or later, may reduce the time-span represented by the unit. The entire thickness of a body in some places may be younger than the entire thickness of the same body in other places. The definition of rock units is thus completely independent of time concepts.

(*e*) *Surface form.*—In surficial deposits, the constructional morphologic character, or primary surface form, of a rock-stratigraphic unit may be a factor in its definition, but should be subsidiary to the character of the rock itself. In any rock-stratigraphic unit, erosional morphology or secondary surface form may be a factor in the recognition of the unit but properly should play no part in the definition.

(*f*) *Aquifers, oil sands, coal beds, and quarry layers* are, in general, informal units even though named. Some such units, however, are stratigraphically significant and may be recognized formally as beds, members, or formations. The formal names should be proposed in accordance with Article 10.

(*g*) *Zone.*—As applied to the designation of rock-stratigraphic units, the term "zone" is informal. Examples are "producing zone," "mineralized zone," "metamorphic zone," and "heavy-mineral zone" (see Article 20a). A zone is set off as distinct from surrounding parts and may include all or parts of a bed, a member, a formation, or even a group.

(*h*) *Cyclothems.*—Cyclical sedimentary sequences called cyclothems have been widely recognized in the Mid-Continent and other regions. Geographic names have been given to many cyclothems. Because the criteria for the recognition of cyclothems are irrelevant to those for recognition of a formation, cyclothems can not be regarded as a part of rock-stratigraphic classification. The designation "cyclothem" should always be applied, if a geographic term is used in this way. Never-

[3] Huxley, T. H., 1862 and 1870, The anniversary address of the President: Quart. Jour. Geol. Soc. London, v. 18, p. xlii, and v. 26, p. xlii–xliv.

[4] Committee on Stratigraphic Nomenclature, 1933, Classification and nomenclature of rock units: Geol. Soc. America Bull., v. 44, pt. 2 (30 Apr.), p. 423–459; Am. Assoc. Petroleum Geologists Bull., v. 17, no. 7 (July), p. 843–863; Am. Assoc. Petroleum Geologists Bull., v. 23, no. 7 (July, 1939), p. 1068–1088.

theless, the boundaries of an individual cyclothem may actually coincide with those of a particular formation.

(*i*) *Soil* is a layer composed of products of weathering of pre-existing rocks, which may be of diverse character and geologic age. A soil differs in several respects from a rock-stratigraphic unit and should not be given formal status in the standard rock-stratigraphic classification. (See Article 18.)

Article 5.—Boundaries of rock-stratigraphic units are placed at positions of lithologic change. Boundaries are placed at sharp contacts or may be fixed arbitrarily within zones of gradation. Both vertical and lateral boundaries are based on the lithologic criteria that provide the greatest unity and practical utility.

Remarks. (*a*) *Boundary in a gradational sequence.* – A named rock-stratigraphic unit is preferably bounded by a single lower and a single upper surface so that the name does not recur in a normal stratigraphic succession. (See remark e.) Where one rock unit passes vertically or laterally into another by intergrading or interfingering of two or more kinds of rock, the boundary is necessarily arbitrary and should be selected to provide the most practical units. For example, where a shale unit overlies a unit of interbedded limestone and shale, the boundary commonly is placed at the top of the highest readily traceable limestone bed; where a sandstone unit grades upward into shale, the boundary may be so gradational as to require completely arbitrary treatment. Because of creep, it is generally best to define such arbitrary boundaries by the highest occurrence of a particular lithologic type, rather than the lowest.

(*b*) *Key beds used for boundaries.*—Key beds may be used as boundaries for formal rock-stratigraphic units over an area where the internal lithologic characteristics of the units remain relatively constant. Even though key beds may be traceable beyond the area of the diagnostic over-all lithology, an extension of the potential boundary markers does not alone justify geographic extension of a rock-stratigraphic unit. Where the rock between key beds becomes drastically different from that of the type locality, a new unit should be recognized, even though key beds are continuous. (See Article 8b.)

(*c*) *Mechanically defined boundaries.*—The continuing development and application of geophysical, geochemical, and mineralogic techniques have given rise to problems concerning both the vertical and lateral boundaries of units defined and identified by these techniques. Marker horizons based on electrical and other mechanically recorded logs may coincide with the boundaries of rock-stratigraphic units and help to delineate them (see Articles 6b and 13b). Such horizons may be discordant vertically or laterally with those of formal rock stratigraphic units. Units established by these techniques are considered informal.

(*d*) *Obscure unconformity.*—A sequence of closely similar rocks may not represent continuous deposition, but may include an obscure unconformity so that a separation into two units may be desirable. If, however, no lithologic distinction adequate to define a boundary can be made, only one unit should be recognized even though it may include rock deposited in different epochs, periods, or eras.

(*e*) *Boundaries in facies change.*—Where a unit changes laterally through abrupt gradation into or intertonguing with a markedly different kind of rock it may be desirable to propose a new unit. An arbitrary boundary, for example, a vertical cut-off, may be placed between the two units. Where the area of intergradation or intertonguing is sufficiently extensive, the rocks of mixed lithology may constitute a third independent unit. Where tongues (Article 7) of formations are mapped separately or otherwise set apart without being formally named, the unmodified formation name should not be repeated in a normal stratigraphic sequence, although the modified name may be repeated in such phrases as "the lower tongue of Mancos Shale" and "upper tongue of Mancos Shale." To show the order of superposition on maps and cross sections, the unnamed tongues may be distinguished informally by number or letters or by other means.

RANKS OF ROCK-STRATIGRAPHIC UNITS

Article 6.—The formation is the fundamental unit in rock stratigraphic classification. A formation is a body of rock characterized by lithologic homogeneity; it is prevailingly but not necessarily tabular and is mappable at the earth's surface or traceable in the subsurface.

Remarks. (*a*) *Content.*—A formation should possess some degree of internal lithologic homogeneity or distinctive lithologic features. It may contain between its upper and lower limits (i) rock of one lithologic type, (ii) repetitions of two or more lithologic types, or (iii) extreme heterogeneity of constitution which in itself may constitute a form of unity compared to the adjacent rock units.

(*b*) *Distinctive lithologic characteristics* may include chemical composition and such supplementary features as ripple marks, mud cracks, cross-bedding, the presence of fossils or unusual minerals, schistose or gneissic structure in metamorphic rocks, and texture in igneous rocks. A unit distinguishable only by its fossils is not a rock-stratigraphic unit but is properly classified as a biostratigraphic unit (see Article 4c). Lithology may be distinctively reflected by electrical, radioactive, seismic, or other properties (see Articles 5c and 13b).

(*c*) *Fundamental unit.*—Formations are the basic rock-stratigraphic units used in describing and interpreting the geology of a region. The limits of a formation normally are those boundaries of lithologic change that give it the greatest practicable unity of constitution. A formation may represent a long or short time interval, may be composed of materials from one or several sources, and may include breaks in the time-stratigraphic sequence.

(*d*) *Mappability.*—Practicability of surface or subsurface mapping is essential in establishing a formation. Mappability at the surface is considered as delineation at scales of the order of 1:25,000. In general, the definition of a new formation should be based upon tested mappability, rather than upon a type section alone, however completely exposed the type section may be.

(*e*) *Thickness* of a formation is not a determining feature in its classification. A formation has three dimensions, and its thickness may range from a featheredge at its margin to 5,000 feet or more elsewhere. Also, a formation 10 feet thick may be adjacent to another 1,000 feet thick. Exceptionally a formation may be mapped as a single line, but obviously a sequence of formations so thin becomes impractical because unmappable.

(*f*) *Sedimentary rock and extrusive igneous rock* that are intricately interbedded may be assembled into a formation under one name.

(*g*) *Volcanic rock.*—Cartographically distinguishable

sequences of volcanic rock should be treated as formations like any stratified sequence of sedimentary rocks. (See Articles 9f and 30d.)

(*h*) *Intrusive igneous rock.*—Units composed of intrusive igneous rock that are discriminated by mineralogic or textural characteristics, or chemical composition, may be classed as formations. (See Article 10i.)

(*i*) *Metamorphic rock.*—Formations composed of metamorphic rock are, like other formations, distinguished primarily by lithologic composition. The mineral facies may differ from place to place, but these variations do not necessarily require definition of a new formation. Metamorphic rocks with relict textures and structures that enable the geologist to recognize mappable units should be classified just as any normal stratigraphic sequence. Metamorphic and metasomatic rocks not classifiable by normal stratigraphic methods have to be discriminated primarily on their petrographic and structural features. (See Article 10j.)

(*j*) *Complex.*—If a mass of rock is composed of diverse types of any class or classes or is characterized by highly complicated structure, the word "complex" may be used as part of the formal name instead of a lithologic or rank term; for example, Crooks Complex.

Article 7.—A member is a part of a formation; it is not defined by specified shape or extent. A geographically restricted member that terminates on all sides within a formation may be called a lentil. A member that extends outward beyond the main body of a formation may be called a tongue.

Remarks. (*a*) *Designation of members.*—Formations may be divided into formally defined and named members. In some formations, one or more formal members are established, while the remainder of the formation is undivided or is treated as one or more unnamed members. If formations are divided into members designated solely by lithology (for example, siliceous shale member), or by letter or number, the usage is informal. Although members normally are in vertical sequence, laterally equivalent parts of a formation that differ recognizably may also be considered members; for example, the gravel member and the silt member of the Bonneville Formation.

(*b*) *Mapping of members.*—A member is established when it is advantageous to recognize a specially developed part of a varied formation. A member, whether named or unnamed, need not be mappable at the scale required for formations. Even though all members of a formation are locally mappable, it does not follow that they should be raised to formational rank, because multiplicity of formation names may obscure rather than clarify relations with other areas. A named member may extend from one formation into another.

(*c*) *Subdivision of members.*—Members may contain beds but never members of members.

Article 8.—A bed is the smallest rock-stratigraphic unit recognized in classification.

Remarks. (*a*) *Informal status of most beds.*—The designation of individual beds as formally named rock-stratigraphic units should generally be limited to certain distinctive beds which are particularly useful to recognize. Coal beds, oil sands, and other beds of economic importance are commonly named, but such units and their names are not usually a part of formal stratigraphic nomenclature. (See Article 4f and 10gh.)

(*b*) *Key or marker beds.*—Widely distributed key beds may be named, but these likewise are usually considered informal units. Individual key beds may be traced beyond the lateral limits of a particular formal unit. (See Article 5b.)

Article 9.—A group is the rock-stratigraphic unit next higher in rank than a formation; a group consists of two or more associated formations.

Remarks. (*a*) *Use and composition.*—Groups are recognized for the purpose of expressing the natural relations of associated formations having significant lithologic features in common. A group consists wholly of divisions defined as formations; in this respect, it contrasts with a formation and its members, for a formation need not be divided into members, and, even if a formation contains members, not every part of it need be assigned to any member. In some reconnaissance work, the term "group" has been applied to stratigraphic units that appear to be divisible into formations but have not yet been so divided.

(*b*) *Change in component formations.*—The component formations of a group are not necessarily everywhere the same. For example, in the upper part of Glen Canyon, Utah, the Glen Canyon Group comprises three formations, the Wingate Sandstone, the Kayenta Formation, and the Navajo Sandstone. At Serpents Trail, Colorado, it is composed of Wingate and Kayenta.

(*c*) *Change in rank.*—The wedge-out of a component formation or formations may justify the reduction of the group to formation rank, retaining the same name. When a group is extended laterally beyond where it is divided into formations, it becomes in effect a formation, even if it is still called a group. When a previously established formation is broken down into two or more component units that are formally given formation rank, the old formation, with its old geographic name, should be raised to group status. Raising the rank of the unit is preferable to restricting the old name to a part of its former limits, because a change in rank leaves the sense of the geographic part of the name unchanged. (See Article 14b.)

(*d*) *Subgroup.*—The hierarchy of rock-stratigraphic units (group, formation, member) does not always provide a sufficient number of categories for the proper relative assignment of all units. In certain areas stratigraphers have named and defined assemblages of formations within already established useful groups and called these assemblages subgroups.

(*e*) *Supergroup.*—In certain areas stratigraphers need a supergroup; that is, a formal assemblage of related groups or of formations and groups.

(*f*) *Misuse of "series" for group or supergroup.*—The term "series" has been employed for an assemblage of formations or an assemblage of formations and groups, especially in the Precambrian, but should no longer be so used. These are groups or supergroups. The term "series" has also been applied to a sequence of rocks resulting from a succession of eruptions or intrusions. In this usage "series" is usually preceded by an adjective such as eruptive, intrusive, or volcanic to indicate the origin of the rock. Here, as elsewhere in rock-stratigraphy, group should replace "series." Series is a time-stratigraphic term that should not be used in a rock-stratigraphic sense. (See Articles 6g and 30d.)

NOMENCLATURE OF ROCK-STRATIGRAPHIC UNITS

Article 10.—The formal name of a rock-stratigraphic unit of any rank is binomial, consisting of

a geographic name combined with a descriptive lithologic term or with the appropriate rank term alone. Capitalization of the initial letters of all words used in forming the names of formal rock-stratigraphic units is recommended.

Remarks. (*a*) *Source of geographic name.*—The geographic name should be the name of a natural or artificial feature at or near which the rock-stratigraphic unit is typically developed. Names derived from such changeable sources as the names of farms or ranches, churches, schools, crossroads, and small communities, are not entirely satisfactory but are acceptable if no others are available. Names for formations or other important rock units may be selected from those that can be found in an ordinary atlas, or on state or provincial, county, forest service, topographic, or similar maps. If a name that does not meet this test is used, precise description of the place from which the name is derived should be given. A subsurface unit may be given a farm name, if its type locality happens to be in some sparsely populated area with few geographic names. A unit should not be named from the source of its materials; for example, a deposit supposedly derived from the Keewatin center should not be called "Keewatin Drift."

(*b*) *Omission of part of name.*—Where frequent repetition would make a cumbersome style, and omission is compatible with clarity, the geographic name, the lithologic term, or the rank term may be used alone; as "the Burlington," "the limestone," or "the formation," for the Burlington Limestone.

(*c*) *Use of simple lithologic term.*—Where a lithologic term is used in the name of a rock-stratigraphic unit, the simplest generally acceptable term is recommended (for example, limestone, sandstone, shale, tuff, granite, quartzite, serpentine). Compound terms (for example, clay shale, hornblende-microcline-oligoclase granite gneiss) and terms that are not in common usage (for example, calcirudite, orthoquartzite) should be avoided. Combined terms, such as sand and clay, should not be used for the lithologic part of the names of rock-stratigraphic units, nor should an adjective be used between the geographic and the lithologic terms, as "Chattanooga Black Shale" and "Biwabik Iron-bearing Formation."

(*d*) A *group name* customarily combines a geographic name with the term "group," and no lithologic designation is included; for example, San Rafael Group.

(*e*) A *formation name* consists of the geographic name followed by a lithologic designation or by the word "formation." Examples: Dakota Sandstone, Mitchell Mesa Rhyolite, Monmouth Formation, Fort Covington Till.

(*f*) A *member name* combines a geographic term followed by the term "member." Where a lithologic designation is useful, it should be included as part of the name (Wedington Sandstone Member of the Fayetteville Shale).

(*g*) *Capitalization.*—When geographic names (see remark h) are applied to such informal units as oil sands coal beds, mineralized zones, and informal members (see Articles 4f and 8a), the unit term should not be capitalized. A name is not necessarily formal because it is capitalized, nor does failure to capitalize a name render it informal. Geographic names should be combined with the terms "formation" or "group" only in formal nomenclature.

(*h*) *Informal usage of identical geographic names.*—The application of identical geographic names to several minor units in one vertical sequence is considered informal nomenclature (lower Mount Savage coal, Mount Savage fireclay, upper Mount Savage coal, Mount Savage rider coal, and Mount Savage sandstone). The application of identical geographic names to the several lithologic units constituting a cycle of sedimentation is likewise considered informal.

(*i*) *Intrusive igneous rock.*—In some areas formal stratigraphic terminology is needed for intrusive igneous rocks (see Article 6h). The formal name of an intrusive rock body properly consists of a geographic term and the petrographic name of the dominant rock type; for example, Goose Lake Granodiorite. "Dike," "stock," "pluton," "batholith," and other similar names, or more general terms such as "intrusion," are not stratigraphic terms; accordingly, the names of such intrusive igneous bodies as the Idaho batholith or the Loon Lake pluton are not stratigraphic names.

(*j*) *Metamorphic rock* recognized as a normal stratified sequence should be classified as named groups, formations, and members, such as the Deception Rhyolite, a formation of the Ash Creek Group. Metamorphic or metasomatic rocks, not classifiable by normal stratigraphic methods, should be given a suitable geographic name followed by the petrographic term for the dominant rock of the unit; for example, Baltimore Gneiss. (See Article 6i.)

(*k*) *Misuse of well known name.*—A name that suggests some well known locality, region, or political division should not, in general, be applied to a unit typically developed in another less well known locality of the same name. For example, it would not be advisable to use the name "Chicago Formation" for a unit in California.

Article 11.—The rule of priority should be observed in applying names to rock-stratigraphic units.

Remarks. (*a*) *Priority* is defined as priority of date of publication. Page precedence should decide, as in other sets of rules governing scientific nomenclature.

(*b*) *Preservation of well established name.*—A name that has become well established should not be displaced, merely on account of priority, by one not well known or only occasionally used. The term "well established" is difficult to define, but acceptance of a name by several authors is generally taken as establishing it.

(*c*) *Duplication of names* should be avoided throughout North America. A name previously applied to any unit should not later be applied to another, unless alternative names are lacking, and then only if geographic and stratigraphic separation preclude confusion. Furthermore, a group and a formation within it should not bear the same name (see Article 16d), nor a formation and a member within it; for example, the lower member of the Pruett Formation should not be called the "lower Pruett member."

Article 12.—The geographic component of an established rock-stratigraphic name should not be changed.

Remarks. (*a*) *Difference in spelling of geographic name.*—A stratigraphic name repeatedly published with spelling different from that of its geographic source should nevertheless be retained. For example, Bennett Shale, uniformly used for more than thirty years, should not be altered to Bennet Shale on the grounds that the town is named Bennet. Stratigraphic names that have been spelled variously should be made uniform by adopting the form accepted by a majority, whatever the local spelling or the original spelling in geological literature. This remark should not be construed to require geologists of one native tongue to continue to use names pro-

posed for their region by geologists of a different tongue if these names are absurd or in violation of good taste.

(*b*) *Change in the name of a geographic feature* does not entail change of the corresponding name of a stratigraphic unit. The original name of the unit should be maintained. For example, Mauch Chunk Shale should not be changed to Jim Thorpe Shale because the former town of Mauch Chunk is now called Jim Thorpe.

(*c*) *Disappearance of a geographic feature* does not entail the disappearance of the corresponding name of a stratigraphic unit. For example, Thurman Sandstone, named from a former village in Pittsburg County, Oklahoma, does not require renaming.

(*d*) *Names in different countries and different languages.*—Spelling of the geographic component of a rock-stratigraphic name should conform to the usage recognized in the country that contains the type locality. It should not be altered by conversion into equivalent but different words in other languages. For example, Cuchillo should not be translated to Knife, and La Peña should retain the tilde; on the other hand, Canyon should not be translated as Cañon. Moreover, a rock unit should not be named Montchauve after Bald Mountain in Wyoming; the name Bald Mountain is preoccupied, and translation is not a proper recourse. It is proper, however, to translate the lithologic term or rank term; thus, the Edwards Limestone may be called Caliza Edwards, and Formación La Casita, the La Casita Formation.

PROCEDURE IN ESTABLISHING FORMAL ROCK-STRATIGRAPHIC UNITS

Article 13.—Establishing a formal rock-stratigraphic unit requires publication in some recognized scientific medium of a definition that includes: (i) statement of intention to designate a formal unit; (ii) selection of name; (iii) definition of unit in the type area with specific location of the type section; (iv) distinguishing characteristics; (v) definition of boundaries and contact relationships; (vi) dimensions and shape; and, as far as possible, (vii) geologic age and correlation.

Remarks. (*a*) *Specific requirements.*—The proposed unit should be described and defined so clearly that any subsequent worker can, without doubt, recognize the same unit. The intent to introduce a new name and the important facts that led to the discrimination of the unit should be clearly stated. The definition should cite the geographic feature from which the name is taken. It should cite, also, the specific location of one or more representative sections near the geographic feature. One of these sections should be designated the type section, and its description should be included. Specific reference to location in section, township, and range, or other land divisions should be included. An accurate map showing the location of the type section is desirable. Where necessary, reference sections may be designated to supplement the type section, or, when the type section is no longer exposed, a principal reference section should be established. (See remark i.) The morphological expression of the unit should be described. In defining the boundaries of a unit, it is not sufficient merely to state that the top of the *X* Formation is the base of the *Y* Formation; the criteria used in drawing the boundary should be discussed explicitly, where possible with reference to specific points in the type section or in typical sections.

(*b*) *Additional requirements for subsurface units.*—Subsurface rock units are given formal names only if such names are useful in describing the geology of the region and if the subsurface section differs materially from the equivalent rocks in outcrop. In proposing a new name for a subsurface unit, the well or mine in which the type section is present becomes the type locality. Subsurface units defined on the basis of exposures in mines should be treated similarly to other subsurface units. The following additional data are desirable:

(i) Location of the type well or mine by written description and map; name of operating company or individual; name of farm or lease; date of drilling; total depth; surface elevation; and depths to top and bottom of the new unit or mine level where it is exposed. If all the data needed to establish a type section cannot be furnished from one well, two or more wells should be used.

(ii) Sample logs of the well, or wells, maps and cross-sections of the mine, in written or graphic form, or both. The boundaries and subdivisions, if any, of the new unit should be indicated clearly on logs or charts.

(iii) Electrical or other mechanically recorded logs, preferably of several wells. The boundaries and subdivisions of the new unit should be shown at a scale large enough to permit full appreciation of detail.

(iv) Location of the depository where sets of cuttings or samples and fossil material are available for study. Such depositories may be federal, provincial, or state geological surveys, universities, and museums with proper facilities.

(*c*) *Form of publication.*– The phrase "recognized scientific medium" is difficult to determine. Availability to the scientific public is the chief determining factor regardless of size of edition or form of publication, such as type printing, mimeographing, or lithography. A publication must be generally available either on request or by purchase. Any well-known, regularly issued, numbered series, meets this requirement. Many independent or irregularly issued publications also meet it, though some notice should appear in a nationally circulated scientific journal. Names proposed in informal or restricted media, such as letters, company reports unavailable to the public, or unpublished addresses, theses or dissertations, have no status in stratigraphic literature. Microfilming or publication in newspapers and commercial or trade journals is not valid publication. (See Article 3.)

(*d*) *Casual mention of name insufficient.*—Casual mention, such as "the formation at Jonesville schoolhouse," does not establish a new name, nor does mere use as in a table or columnar section or on a map. To be valid, a new name should be duly proposed as outlined in remark *a*.

(*e*) *Publication in abstracts and guidebooks.*–New stratigraphic names should not be included in an abstract published separately in advance of a more complete report, as the essential conciseness of abstracts does not permit full definitions. New stratigraphic names should not be introduced in guidebooks. (See Article 3.)

(*f*) *References for names already established.*—Authors should refer to federal and state records of stratigraphic names to determine whether a name has been previously used. (See Article 3.)

(*g*) *Surface vs. subsurface names.*—It may be possible to correlate a named subsurface unit with a named surface unit. If the characteristics of both are so similar that two names are unnecessary, priority and usage should determine which is to be applied.

(*h*) *Type section never changed.*—Type sections can not be changed. There may be more than one typical section but only one type section.

(*i*) *Reference localities* may be established to supplement the type locality. For example, in naming weakly consolidated rocks it may be necessary to designate a type area within which the diagnostic relations are widely represented, because good exposures are evanescent. Thus the type locality contains the type section, and the type area contains the type locality. Many early definitions of stratigraphic units indicate a type area or type region without specifying a type section.

REVISION OF ROCK-STRATIGRAPHIC CLASSIFICATION AND NOMENCLATURE

Article 14.—Redefining a rock-stratigraphic unit without changing its name requires as much justification as establishing a new unit.

Remarks. (*a*) *Redefinition* is justifiable where a minor change in boundary will make a unit more natural and useful. Where revision removes only a minor part of a previously established unit, the original name may be retained for the major part.

(*b*) *Undesirable restriction.*—When a unit is divided into two or more of the same rank as the original, the original name should not be employed for any of the divisions. The retention of the old name for one of the units would preclude use of the name in a term of higher rank. In order to understand an author's meaning, a later reader must know about the modification and its date, and whether the author is following the original or the modified usage. For this reason it should be normal practice to raise the rank of a unit when it becomes everywhere subdivisible into mappable units. (See Article 9c.)

Article 15.—A change in the lithologic term applied to a rock-stratigraphic unit does not require a new geographic term.

Remark. (*a*) *Change in lithologic designation.*—Priority should not prevent more exact lithologic designation if the original designation is not everywhere applicable; for example, the term "limestone" in such names as Galena Limestone and Leadville Limestone may locally be inapplicable and therefore changed to "dolomite," even though the type section may have been correctly named. If the lithologic variation warrants neither name the term "formation" may be preferable.

Article 16.—Change in rank of a rock-stratigraphic unit does not require redefinition of its boundaries or alteration of the geographic part of its name.

Remarks. (*a*) *Change in rank.*—It is possible for a member to become a formation or vice versa, and for a formation to become a group or vice versa.

(*b*) *Examples of changes from area to area.*—The Conasauga Shale is recognized as a formation in Georgia and as a group in eastern Tennessee; the Osgood Formation, Laurel Limestone, and Waldron Shale of Indiana are classed as members of the Wayne Formation in a part of Tennessee; the Virgelle Sandstone is a formation in western Montana and a member of the Eagle Sandstone in central Montana.

(*c*) *Example of change in single area.*—It often becomes desirable to change the rank of a unit without changing its content of rocks. For example, the Madison Limestone of early work in Montana became in later work the Madison Group, containing several formations.

(*d*) *Different geographic name for unit and its parts.*—In changing the rank of a unit, the same name should not continue to be applied both to the unit as a whole and to a part of it. For example, the Astoria Group should not contain an Astoria Sandstone, nor the Washington Formation, a Washington Sandstone Member. (See Article 11c.)

Article 17.—A name for a stratigraphic unit once applied and then abandoned is available for some other unit only if the name was introduced casually, or if it has been published only once in the last several decades and is not in current usage, and if its reintroduction will cause no confusion.

Remarks. (*a*) *Obsolete names.*—Authors should refer to federal and state records of stratigraphic names to determine whether a name is obsolete. (See Article 3.)

(*b*) *Reference to abandoned names.*—When it seems useful to refer to an obsolete or abandoned formal name, its status is made clear by some such term as "abandoned" or "obsolete," or by using a phrase such as "La Plata Sandstone of Cross (1898)."

SOIL-STRATIGRAPHIC UNITS

Article 18.—A soil-stratigraphic unit is a soil with physical features and stratigraphic relations that permit its consistent recognition and mapping as a stratigraphic unit. Soil-stratigraphic units are distinct from both rock-stratigraphic and pedologic units.

Remarks. (*a*) *Distinction from rock-stratigraphic units.*—A soil-stratigraphic unit differs from a rock-stratigraphic unit in that it is formed for the most part *in situ* from underlying rock-stratigraphic units, which may be of diverse composition and geologic age. (See Article 4i.) Further, the characteristic features of soil-stratigraphic units are the products of surficial weathering and of the action of organisms at a later time and under ecologic conditions independent of those that prevailed while the parent rocks were formed.

(*b*) *Distinction from pedologic units.*—Stratigraphic relations are an essential element in defining a soil-stratigraphic unit but are irrelevant in defining a pedologic unit. A soil-stratigraphic unit may comprise one or more pedologic units or parts of units.

(*c*) *Requirements for formal status.*—A soil-stratigraphic unit should be defined on the basis of observable physical features and stratigraphic relations at a type locality and may be extended as far as it can be recognized. Boundaries may be placed at sharp contacts or within zones of gradation. The definition of a soil-stratigraphic unit should be based on as full knowledge as possible of its lateral variations and should be independent of concepts based on geologic history. Soil-stratigraphic units may parallel or transgress time horizons.

(*d*) *Rank.*—The single rank of soil-stratigraphic classification is the soil.

(*e*) *Names.*—Formal names of soil-stratigraphic units should be chosen in accordance with the rules that

govern naming of rock-stratigraphic units, and should not conflict with rock-stratigraphic or pedologic names. Names based on subjacent and superjacent rock units, for example the post-Wilcox pre-Claiborne soil, are informal.

Biostratigraphic Units

Nature of biostratigraphic units

Article 19.—A biostratigraphic unit is a body of rock strata characterized by its content of fossils contemporaneous with the deposition of the strata.

Remarks. (*a*) *Fossil remains,* both plant and animal, are widespread in sedimentary rocks, and they provide several different kinds of stratigraphic information. Because of their complexity and variety, they are particularly distinctive and identifiable rock constituents. Fossils, as the remains of once-living forms, are sensitive indicators of environment of deposition. Finally, owing to the progressive and more or less orderly evolution of organisms throughout the Phanerozoic Eon, fossils are particularly valuable in time correlation of strata and are essential in placing rocks in a world-wide geologic-time scale.

(*b*) *Contemporaneity of rock and contained fossils.*—Normally, all fossils contained in a biostratigraphic unit are remains of organisms that lived when the sediment surrounding them was deposited. The organisms may have been buried *in situ* or transported to their place of burial, but in either case they are indigenous in the sense of belonging to the deposit as contemporaneous original constituents. For example, well preserved leaves of land plants are associated with nearly complete articulated crinoids and other marine invertebrates in the Keasey Formation (Oligocene?) of northwestern Oregon.

(*c*) *Reworked fossils.*—Some sedimentary strata, however, contain reworked" fossils derived from older rocks. Examples of fossils clearly not indigenous to the rock that contains them are: (i) worn silicified Ordovician fossils in Mississippian deposits of southeastern Missouri; (ii) a mixture of weathered and nearly perfect Late Cretaceous foraminifers in the Claytone Limestone (Paleocene) of southern Alabama; and (iii) abundant Cretaceous pelecypods (*Gryphaea*) mingled with Miocene vertebrates in the Oakville Sandstone (Miocene) of southwestern Texas. These adventitious fossils may be significant from certain points of view, but they are clearly distinct from indigenous remains; they may be relevant in identifying a rock-stratigraphic unit, but are not relevant in defining a biostratigraphic unit.

(*d*) *"Leaked" fossils.*—Much less commonly organic remains have "leaked" from younger sources. Such fossils are younger than the strata that contain them. Although stratigraphic leaks are usually easy to recognize, not all are obvious, and failure to recognize them may cause serious errors. Examples are: (i) shells of Cenozoic mollusks that have burrowed into Cretaceous and even into Paleozoic strata; (ii) both microfossils and macrofossils that have been carried from younger formations through crevices into solution-made cavities in older rocks, wherein they are sealed by mineral deposits or sediment.

(*e*) *Relation of biostratigraphic units to rock-stratigraphic units.*—Biostratigraphic units are fundamentally different from rock-stratigraphic units. The boundaries of the two may coincide or lie at quite different stratigraphic horizons or cross each other. Where fossil remains are so abundant that in themselves they become lithologically important, a biostratigraphic unit may also be a rock-stratigraphic unit. Moreover, the lithologic changes that bound rock-stratigraphic units may represent changes in depositional environment that are likewise reflected in changes of fossil assemblage so that the limits of both kinds of units closely correspond. Similarly, unconformities or breaks in deposition tend to concentrate range-zone (biozone) limits at horizons of lithologic change.

(*f*) *Relation of biostratigraphic units to time-stratigraphic units.*—A biostratigraphic unit is physically bounded and extends no farther than the limits of strata characterized by a certain fossil or assemblage of fossils. Commonly, biostratigraphic evidence is the most useful means for determining time-stratigraphic boundaries, but criteria for defining biostratigraphic and time-stratigraphic units differ fundamentally.

(*g*) *Ecologic and evolutionary significance.*—Because fossils reflect both irreversible evolutionary change and adaptation to environment, all biostratigraphic units are records of both time and facies.

Article 20.—A zone is the general basic unit in biostratigraphic classification. It is defined as a stratum or body of strata characterized by the occurrence of a fossil taxon or taxa from one or more of which it receives its name.

Remarks. (*a*) *Kinds of zone.*—The unmodified term "zone" does not define a formal biostratigraphic unit, because it has been used indiscriminately for several different concepts and does not distinguish between them. Moreover, the term "zone" is not confined to biostratigraphy, for it is used in other kinds of stratigraphic classification and in other branches of geology (for example, cherty zone, concretionary zone, fault zone, zone of flowage, zone of saturation; see Article 4g). Nevertheless, reference to biostratigraphic zones claims great antiquity, if not priority. More specific definition of zones is needed to express biostratigraphic concepts accurately.

(*b*) *Definition.*—A biostratigraphic zone is defined solely by the fossils it contains, without reference to lithology, inferred environment, or concepts of time.

(c) *Scope of term "zone."*—A biostratigraphic zone may be based on all its fossils, or it may be based solely on the fossils of one phylum, or one class, or one order, etc. Thus it is possible to have differing and overlapping systems of zones variously based on foraminifers, or mollusks, or diatoms, or vertebrates, or land plants, or combinations of two or more kinds of organic remains.

(*d*) *Dimensions of zone.*—The scale of zone classification is indefinite and extremely variable. At one extreme, a zone may be a single local bed with a characteristic fossil assemblage; at the other, it is even possible to consider all Cenozoic deposits as constituting a "Zone of Mammals" and all Mesozoic deposits as constituting a "Zone of Reptiles."

(*e*) *Subzone.*—In places it may be feasible and desirable to recognize and define zonal units of lower rank. These may be designated subzones, and classified as subdivisions of the zone. It is not necessary that an entire zone should be divided into subzones.

(*f*) *Zonule.*—The smallest recognized subdivision of a zone is a zonule. Generally it consists of a single stratum or small thickness of strata. Zonules need not be vertically contiguous biostratigraphic units. A zonule may be distinguished as a minor component of a zone

without dividing the zone into subzones. In this respect, classification and nomenclature of zonules correspond to the rock-stratigraphic usage in naming members or beds (see Articles 7a and 8a).

(*g*) *Peak zone.*—A peak zone is a special kind of zone, characterized by the exceptional abundance of some one taxon for which it is named. Peak zones are informal. They may represent one or more episodes of exceptional proliferation of a taxon, not only in number of individuals, but commonly in such respects as great lateral spread, or dominance in the entire organic assemblage. Various other terms, such as epibole, acme zone, and flood zone, have essentially the same meaning as peak zone.

Article 21.—An assemblage zone is a body of strata characterized by a certain assemblage of fossils without regard to their ranges; it receives its name from one or more of these fossils.

Remarks. (*a*) *Nature.*—The bases for recognizing assemblage zones include variations in the fossil taxa, in abundance of specimens, or in both. Such variations are usually in response to environment though evolutionary change may be a factor. The assemblage zone may indicate ecologic facies or age or both. It is, however, primarily a grouping of strata according to directly observable fossil content. Assemblage zones may be based on all the fossils or only on specific kinds. The assemblage on which a specific unit is based should be defined in a specified section.

(*b*) *Naming.*—The assemblage zone is usually named from one or more taxa particularly prominent or diagnostic of the assemblage, although name-givers need not be confined to the zone or found in every part of it.

(*c*) *Example.*—The *Heterostegina* Assemblage Zone of the Gulf Coast is an example.

(*d*) *History.*—The faunizone and florizone of Buckman are close in concept to the assemblage zone but these names are not generally accepted, and their correct definitions are in dispute. Some consider a faunizone (or florizone) as formed by the overlap of biozones (see Article 22h) and as having dominantly time-stratigraphic significance; others consider a faunizone (or florizone) as a body of strata characterized by a particular fauna or flora, regardless of whether it is inferred to have time or only environmental significance. Assemblage zone as here defined is used without any implications as to either time or facies. (See also Article 23.)

(*e*) *Guide fossils.*—The fossil or fossils most characteristic of an assemblage-zone, and those chosen to name it, as well as other characteristic fossils in the assemblage, are termed guide fossils. Neither the name-givers nor the other guide fossils are necessarily restricted to the zone, nor are they found in every part of it.

Article 22.—A range zone is a body of strata comprising the total horizontal and vertical range of occurrence of a specified taxon.

Remarks. (*a*) *Nature.*—Each taxon has its own individual range zone and thus there are as many range zones as there are recognized species, genera, etc.

(*b*) *Extent.*—A range zone comprises the rocks that contain the taxon whose name it bears.

(*c*) *Example.*—The *Cardioceras cordatum* Range Zone is the total body of rock bounded by the vertical (stratigraphic) and horizontal (geographic) limits of occurrence of *Cardioceras cordatum.* Range zones do not usually coincide with assemblage zones named for the same fossil.

(*d*) *Application.*—Range zones are much used in time-correlation of strata and have furnished a basis for placing rocks in the standard geologic time scale. Because the taxa on which range zones are based are arbitrarily defined, the range zones themselves are equally arbitrary and far from precise. Obviously, moreover, they do not lend themselves to systematic partitioning of a stratigraphic section into units without gaps and overlaps, because there are inevitable gaps and overlaps in ranges.

(*e*) *Time value.*—The time represented by a range zone may be referred to as its time value; for example, the time value of the *Cardioceras cordatum* Range Zone, differs from the time value of the Assemblage Zone of *Cardioceras cordatum.*

(*f*) *Scope.*—There are no units of lesser or greater rank than the range zone to form a hierarchy of terms in this kind of biostratigraphic classification, although the range zone of a genus is likely to be greater than the range zone of any of its constituent species, the range zone of a family greater than that of any of its constituent genera, and so on.

(*g*) *Local range zone.*—The range of a taxon in any local section or area is unlikely to be its maximum range. A local range zone can be referred to simply as the range zone of the taxon in a specific, geographically located section or area; for example, "Range zone of *Dorothia bulleta* in Denmark"; "*Megalodon* Range zone in the Exshaw Creek section." The use of the German term "teilzone" or other special terms for a local range zone seems unnecessary. Obviously, the summation of all the local range zones is the range zone of the taxon. There are considerable differences in the span of local range zones in different areas because of variations in facies, migration time, and other factors. Because all local range zones can never be known, the true range zone cannot be determined.

(*h*) *Synonyms.*—In 1902 Buckman coined the term "biozone" as a time term indicating the range of a particular taxon in geologic time. Arkell[5] pointed out that H. S. Williams in 1901 had already coined the term "biochron" for this meaning. Arkell preferred to use biozone for the deposits formed during the life-span of the taxon, but whether the biozone includes all deposits equivalent in age to the life-span of the taxon or only those in which the taxon is actually found is a controversial question. The term "biozone" has been used with all three meanings; hence, it is somewhat confusing, and the term "range zone" is more readily understood. The term "teilzone" proposed by Pompeckj is replaced by the term "local range zone" (see Remark g).

Article 23.—A concurrent-range zone is a zone defined by the overlapping ranges of specified taxa from one or more of which it takes its name.

Remarks. (*a*) *Nature.*—The concurrent-range zone is one of the most useful kinds of zones. It is the principal basis of time correlation of strata. The specified taxa are only those that form a distinctive association because their ranges overlap; that is, some taxa range no higher than the zone, others range no lower, and some taxa may be confined to it. To have useful significance the concurrent-range zone must be defined explicitly by naming the taxa on whose overlap the unit is based. It is helpful to cite reference localities where the unit is

[5] Arkell, W. J., 1933, The Jurassic System in Great Britain: Oxford, p. 22–23.

exposed and the chosen taxa are adequately represented.

(*b*) *History.*—The concurrent-range zone as here defined is the zone generally recognized by stratigraphers when they use fossils in attempting time-correlation of strata. Such zones are formal zones. Historically this usage is derived from Oppel[6] who described "zone" as " . . . marked in any one place by a number of species that are constant for it. . . . " (See also Article 21d.)

(*c*) *Example.*—The *Bulimina excavata* Concurrent-range Zone (Paleocene of California) contains the lowest known occurrences of *Anomalina judas, Bulimina excavata, Cibicides fortunatus,* plus 73 additional species, and the highest known occurrences of *Ammodiscus glabratus, Bulimina exigua, Gyrodina depressa,* plus 20 additional species (V. S. Mallory, 1959).

NOMENCLATURE OF BIOSTRATIGRAPHIC UNITS

Article 24.—The name of a zone, subzone, or zonule consists of the names of the characteristic fossil or fossils combined with the appropriate zone term.

Remarks. (*a*) *Ambiguity of the unmodified term "zone."*—The formal name of any biostratigraphic unit should specify the kind of zone, for the meaning of the unmodified term is indefinite. In later references in the same paper, however, it is permissible to combine the biologic name with the unmodified term "zone," if the meaning is obvious.

(*b*) *Capitalization.*—The initial letter of formal unit terms, except the names of species, used in biostratigraphic classification should be capitalized when part of a named unit, in conformity with the usage adopted for rock-stratigraphic and time-stratigraphic units. (See Articles 10g and 32.) Examples are the *Cardioceras cordatum* Concurrent-range Zone or Zone of *Cardioceras cordatum;* the *Bolivina* Range Zone or Range Zone of *Bolivina;* the *Bifericeras bifer* Subzone and *Oxynoticeras lymense* Subzone of the *Oxynoticeras oxynotum* Concurrent-range Zone, Sinemurian, Lower Jurassic of England.

(*c*) *Generic name.*—The formal name of a zone or subzone that is based upon a certain species should always include the generic name also. In later references to the zone in the same paper, however, it is permissible to use only the initial letter of the genus preceding the specific name; for example, *C. cordatum* Zone.

(*d*) *Formal and informal names.*—Biostratigraphic units, like those of other categories (rock-stratigraphic, time-stratigraphic) may be either formal or informal (see Article 3). Formally designated units should be distinguished by use of an initial capital letter for the zone term (see Remark b), whereas an informal unit should not be so capitalized; for example, *Cardioceras cordatum* zone.

(*e*) *Duplication of names.*—The name of the same fossil should not be used for both a zone and a subdivision of that zone.

Article 25.—Names of biostratigraphic units should be changed to conform with changes in names of taxa required by international rules of biologic nomenclature.

[6] Oppel, A., 1856–1858, Die Juraformation Englands, Frankreichs und des Südwestlichen Deutschlands: Stuttgart, p. 3.

Remark. (*a*) *Reason for change.*—The names of biostratigraphic units should be modified whenever the name of the taxon is changed to conform to the international rules of nomenclature; otherwise, the biologic part of the biostratigraphic name would disagree with the name recognized by paleobotanists and paleozoologists. Until the changed name of the taxon becomes well known, it is desirable to cite both old and new names; for example, *Hyracotherium* ("*Eohippus*") Concurrent-range Zone, *Merycoidodon* ("*Oreodon*") Range Zone.

TIME-STRATIGRAPHIC (CHRONOSTRATIGRAPHIC) UNITS

NATURE OF TIME-STRATIGRAPHIC UNITS

Article 26.—A time-stratigraphic unit is a subdivision of rocks considered solely as the record of a specific interval of geologic time.

Remarks. (*a*) *Definition.*—Time-stratigraphic units depend fundamentally for definition on actual sections or sequences of rock, and without these standards they are meaningless. They are material units. Each is the record of an interval of time that extended from the beginning to the ending of its deposition or intrusion. In actual practice, the scope of a time-stratigraphic unit in its type section or type area usually is made to coincide with that of some other kind of stratigraphic unit, such as a biostratigraphic or a rock-stratigraphic unit, which thus serves as an objective reference. As time-stratigraphic units depend for definition on actual sections of rock, care should be taken to define geologic-time units in terms of time-stratigraphic units and not vice versa.

(*b*) *Principal purposes.*—Two principal purposes are served by time-stratigraphic classification: (i) correlation of rocks in one section or area with those of others on the basis of age equivalence or contemporaneity of origin; and (ii) placing the rocks of the earth's crust in a systematic geochronologic sequence, so as to indicate their relative position and age with respect to earth history as a whole.

Article 27.—Boundaries of time-stratigraphic units at the type locality or area are defined by objective criteria.

Remarks. (*a*) *Definition.*—The upper and lower limits of all time-stratigraphic units should be defined in the rock succession at a type section within the type area in order to provide a standard for the unit. In the type area the boundaries may be based on any features thought to be stratigraphically useful or may be designated arbitrarily. Preferably, they should set the unit apart as representing a significant geologic episode. Preferably also, the limits should coincide with such horizons in the type section as boundaries of formations or biostratigraphic zones. The better these objective criteria can be extended laterally as guides to placement of the rocks in time, the greater is the geographic extent of the area in which the unit can be identified accurately. Boundaries of time-stratigraphic units in other than the type area may fall within rock-stratigraphic or biostratigraphic units.

(*b*) *Historic boundaries.*—Boundaries of many of the older time-stratigraphic units were selected to coincide with hiatuses in the rock succession; others were based on lithologic change. Further, Lyell used the relative

proportions of living forms among the fossil species for classifying Cenozoic rocks into time-stratigraphic units.

Article 28.—Geographic extension of a time-stratigraphic unit from its type section or area can be accomplished only as criteria of time equivalence are available, and then only within the limits of accuracy imposed by physical (including isotopic) or paleontologic criteria.

Remarks. (*a*) *Physical criteria.*—Physically based criteria are (i) generally more useful and often more precise in local time-correlation and (ii) seldom if ever surpass paleontologic criteria for world-wide correlation. Many physical criteria may be useful; for example, isotopes, products of radioactivity, lithologic similarity, paleomagnetism, thermoluminescence, relation to adjacent strata, relation to unconformities and to intrusions.

(*b*) *Paleontologic criteria.*—Paleontologic criteria may be (i) as useful and precise as physical for local time-correlation; (ii) by virtue of progressive organic evolution, they remain the most successful means of world-wide correlation of all ranks of Phanerozoic time-stratigraphic units.

(*c*) *Ideal boundaries.*—Ideally the boundaries of time-stratigraphic units, as extended geographically from the type section, are isochronous surfaces, representing everywhere the same horizon in time; thus, ideally these boundaries are independent of lithology, fossil content, or any other material bases of stratigraphic division. In actual practice, the geographic extension of a time-stratigraphic unit is influenced and generally controlled by stratigraphic features.

(*d*) *Radiometry and isotopes.*—Age determinations by means of isotopic ratios are useful in time-stratigraphic correlation. Radiometric and isotope methods are applicable to sedimentary rocks that contain a suitable authigenic mineral. The radiocarbon method is applicable to Quaternary rocks that contain suitable carbon. Isotope methods are applicable to igneous rocks that contain a suitable primary mineral in which the normal ratio of decay products has not been altered through contamination, metamorphism, or other changes. Thus some time-stratigraphic units of sedimentary or igneous rocks can be approximately extended from their type localities.

(*e*) *Indirect radiometric and isotope methods.*—Radiometry and the study of isotopes may also be used where the rock and the dated mineral are not coeval; thus, assemblages of volcanic rock and nonvolcanic sedimentary rock may be placed within maximum and minimum age limits. The maximum age and minimum age of an assemblage may be determined in relation (i) to veins, faults, intrusive rocks, and other transecting features, (ii) to overriding metamorphism, (iii) to detrital minerals within the rock, and (iv) to unconformably subjacent igneous and metamorphic rocks. Thus it may be possible to group separate bodies of rock, not necessarily of the same age, into larger time-stratigraphic units.

(*f*) *Precambrian divisions.*—Because of difficulties of interregional correlation it is not yet possible to divide the Precambrian rocks of North America into widely applicable time-stratigraphic units. Several students prefer to limit classification and nomenclature of the Precambrian to rock-stratigraphic units. Others advocate that major time-stratigraphic divisions be used in a relative sense for a particular region (Lower Precambrian, Upper Precambrian). But some have extended such terms, intended for local use, over large areas as major time-stratigraphic units (Lower, Middle, and Upper Precambrian); and still others have defined major time-stratigraphic units at a type locality and have attempted to extend them geographically, basing their correlations on lithologic similarity, structural similarity, comparison of sequences, and relations to adjacent strata, to unconformities, and to intrusions (Archaean, Proterozoic). New Precambrian time-stratigraphic units should be introduced only when they can be useful for interregional time-stratigraphy and for geochronology.

RANKS OF TIME-STRATIGRAPHIC UNITS

Article 29.—The system is the fundamental unit of world-wide time-stratigraphic classification of Phanerozoic rocks.

Remarks. (*a*) *Definition and extent.*—The bases for original definition of the generally adopted geologic systems are remarkably varied and haphazard. The definition of any time-stratigraphic unit should properly depend on a clear original designation of a type sequence of rocks. This has not been true of the original definitions of any of the recognized systems. Almost all systems began as rather local units and many of them have been extended more or less successfully throughout the world on a time-stratigraphic basis, mainly through their fossil content. They have been revised and supplemented by work in the type areas and elsewhere. As a result the rocks included in the several systems as now recognized are only partly, or even indirectly, related to the sections originally designated.

(*b*) *Precambrian systems.*—In the Precambrian, systems still have only local significance. They have not been placed in widely accepted orderly succession and do not serve as the fundamental units of time-stratigraphic classification.

(*c*) *Subsystem.*—Some systems established in Europe have been later divided elsewhere into parts for each of which the rank of system has been claimed. As a solution to some of the resulting difficulties in nomenclature, the term "subsystem" has been proposed for these parts.

(*d*) *Erathem.*—Time-stratigraphic units composed of a sequence of systems are called erathems; for example, the Mesozoic Erathem comprises the Triassic System, the Jurassic System, and the Cretaceous System.

Article 30.—Series is a time-stratigraphic unit next in rank below system.

Remarks. (*a*) *Definition.*—The basis for definition of a series should be a clearly designated stratigraphic interval in a type area, but many of these units have come to be adopted quite generally without explicit indication of their limits.

(*b*) *Extent.*—The series may constitute a major unit in time correlation, within a province, between provinces, or between continents. Some are recognized as world-wide time-stratigraphic units; others are only provincial.

(*c*) *Intrusive rock.*—The term "series" is not restricted to stratified rocks but may be applied to intrusive rocks in the same time-stratigraphic sense.

(*d*) *Misuse of term "series."*—In stratigraphic terminology "series" should not be applied to rock-stratigraphic units. (See Article 9f.)

Article 31.—Stage is a time-stratigraphic unit next in rank below series.

Remarks. (*a*) *Use of stage.*—The stage is an important working unit in time-stratigraphic correlation and classification. Commonly it is based on a succession of biostratigraphic zones; the zones may differ in different geographic areas. Stages are often employed to relate the various kinds of minor stratigraphic units in one geologic section or area to those in another with respect to time of origin.

(*b*) *Substage.*—A substage is a subdivision of a stage and is the time-stratigraphic unit next in rank below a stage. A stage may be completely divided into substages or only certain parts of it may be recognized as substages. Nomenclatural rules for substages and procedures for establishing substages are the same as for stages.

(*c*) *Misuse of term "stage."*—The 1933 Code remarked that in America "stage" is a "time term for major subdivisions of the Pleistocene epoch," that by "long-continued custom in the United States, the time covered by a Pleistocene subdivision of formational rank is called a *stage,*" and that "correlation within" the Quaternary System is "based primarily upon the concept of widespread climatic changes contemporaneous with the several glaciations of the Pleistocene epoch." This usage is here excluded from formal stratigraphic nomenclature insofar as it conflicts with the definition of "stage" as a time-stratigraphic unit and with the requirement that "stages" be extended geographically on the basis of time-equivalent criteria (see Article 39a). The use of "stage" in the Quaternary should be the same as in the older parts of the geologic column.

(*d*) *Chronozone.*—The strata equivalent in time-span to a biostratigraphic zone or any other zone may often constitute a useful time-stratigraphic unit. Such a unit may carry the same fossil name as a biostratigraphic unit but should always be referred to as a chronozone (chronostratigraphic zone) to avoid confusion with the quite different concept of a biostratigraphic zone. Thus the biostratigraphic unit *Cardioceras cordatum* Range Zone is the total body of rock bounded by the vertical and horizontal limits of occurrence of *Cardioceras cordatum,* whereas the time-stratigraphic unit, *Cardioceras cordatum* Chronozone, is the total body of rock formed anywhere during the time-span of the *Cardioceras cordatum* Range Zone, regardless of whether or not *Cardioceras cordatum* is itself present.

NOMENCLATURE OF TIME-STRATIGRAPHIC UNITS

Article 32.—A formal time-stratigraphic unit is given a binomial name, and the initial letter of both terms should be capitalized.

Remarks. (*a*) *System names.*—The existing names that are generally accepted for systems have diverse origins, and they also have different sorts of endings; for example, Cambrian, Cretaceous, Jurassic, Tertiary.

(*b*) *Series names.*—Series are commonly known either by geographic names, for example, Waucoban Series, Niagaran Series, or by names of their encompassing systems modified by the capitalized adjectives Upper, Middle, Lower, for example, Lower Cretaceous Series, Middle Devonian Series. In general a geographic name is preferable because it may be tied to a type area. For names of geographic origin the adjectival endings *-an* or *-ian* have been widely used, for example, Cincinnatian Series, but it is permissible to use the geographic name without any special ending, for example, Cincinnati Series.

(*c*) *Stage names.*—The great majority of stage names already in use have been based on rock-stratigraphic units (groups, formations, members) and bear the names of these units, for example, Chemung Stage, Maestrichtian Stage, Claiborne Stage. Preferably a stage should have a geographic name not previously used in stratigraphic nomenclature, for example, Refugian Stage.

(*d*) *New names.*—Geographic names proposed for new time-stratigraphic units should not duplicate those used for rock-stratigraphic units. Moreover, two names should not be derived from the same place, for example, the stage names Bathonian and Bathian. The later variant should be regarded as a "stillborn homonym."

Article 33.—Doubt in the assignment of rocks to time-stratigraphic units should be made explicit if criteria of time equivalence are inconclusive or lacking. (See Article 28.)

Remark. (*a*) *Expression of doubt.*—Doubt can be expressed in several ways. (i) If the balance of evidence seems to favor one age assignment, the rock may be assigned to a specific time-stratigraphic unit with the doubt expressed by a question mark or by the words "probably" or "possibly." (ii) If the evidence suggests a position athwart a time-stratigraphic boundary, the doubt may be expressed (with or without question marks) by coupling the names of the two time-stratigraphic units with "or," "and," or a hyphen. (iii) If the evidence indicates only an upper or a lower limit, the assignment should be indicated by the prefix "pre-" or "post-," for example, pre-Cretaceous, post-Cambrian. (iv) It is not necessary to make formal time-stratigraphic assignments if evidence of age equivalence with established units is lacking.

PROCEDURE IN ESTABLISHING TIME-STRATIGRAPHIC UNITS

Article 34.—Requirements for establishing a time-stratigraphic unit include (i) statement of intention to designate such a unit; (ii) selection of name; (iii) definition of boundaries of the unit in the type area with specific reference to designated sections; (iv) distinguishing characteristics including fossils if present; (v) correlation and age relationships; and (vi) publication in a recognized scientific medium as specified in Article 13.

Remark. (*a*) *Invalid names.*—Naming a time-stratigraphic unit simply by adding "-an" or "-ian" to the name of a rock stratigraphic name is improper and does not constitute definition of a time-stratigraphic unit. A new name so proposed should be considered invalid.

REVISION OF TIME-STRATIGRAPHIC CLASSIFICATION AND NOMENCLATURE

Article 35.—Redefinition of a time-stratigraphic unit without changing its name is allowable but requires as much justification as the establishment of a new unit and demands con-

servatism. Redefinition of systems calls for international agreement.

Remark. (*a*) *Supplementary sections.*—If definition of a time-stratigraphic unit is inadequate, it may be redefined and revised by reference to supplementary sections. (See Article 34.)

Geologic-Time (Geochronologic) Units

NATURE OF GEOLOGIC-TIME UNITS

Article 36.—Geologic-time units are divisions of time distinguished on the basis of the rock record, particularly as expressed by time-stratigraphic units. They are not material units.

Remarks. (*a*) *Boundaries.*—Historically the definition of a period as a unit of geologic time depended on chosen sections in the type area of the system, which is the corresponding time-stratigraphic unit. The period comprised an interval of time defined by the beginning and ending of the deposition of the system. To define periods rigorously in this manner is to create unnamed time units between periods, in other words, gaps in formal geologic time. By later work supplementary sections largely or wholly filling the hiatuses have been found elsewhere in the world and their rocks, by common consent, have been assigned to one or another of the contiguous systems. Many of the gaps have thereby been essentially filled. Today it is probable that formal geologic time as referred to actual rocks is continuous or even (as now classified) duplicated. In practice, placement of boundaries of time units is imprecise because of imperfect correlation.

(*b*) *Validity of geologic-time units.*—The units of geologic time are no more valid than the time-stratigraphic units on which they are based. (See Articles 26, 27, and 28.)

RANKS OF GEOLOGIC-TIME UNITS

Article 37.—Ranks of geologic-time units in order of decreasing magnitude are eon, era, period, epoch, and age.

Remarks. (*a*) *Period, epoch, and age.*—A period is defined as the time during which the corresponding system was deposited. Epochs are similarly related to series, and ages (in the formal sense), to stages. Because some of these words, particularly "age," are often used informally, wherever they are used formally in conjunction with a proper name they should be capitalized as noted in Article 38a.

(*b*) *Era and eon.*—An era is defined as the time during which the corresponding erathem was deposited. The Paleozoic Era, Mesozoic Era, and Cenozoic Era are combined into a geologic time unit called the Phanerozoic Eon.

NOMENCLATURE OF GEOLOGIC-TIME UNITS

Article 38.—Geographic or other names used for period, epoch, and age are identical with those of the corresponding time-stratigraphic units; the names of eras and eons are independently formed.

Remarks. (*a*) *Capitalization.*—In naming a formal unit of geologic time the initial letter of each term is capitalized, as Devonian Period. (See Article 37a.)

(*b*) *Names of epochs.*—If a series name consists of the system name preceded by Lower, Middle, or Upper, the corresponding epoch name should consist of the period name preceded by Early, Middle, or Late; for example, Early Devonian Epoch.

(*c*) *Time intervals* represented by unconformities should not receive formal names. They should, in general, be referred to preceding or succeeding stratigraphic units by the prefixes *pre-* and *post-*; for example, post-Laramie interval. Where such convenient names for time intervals as "Laramide revolution" are used, they should have no part in formal stratigraphic nomenclature. Similarly, the naming of time intervals represented by cycles of erosion that are expressed in present-day land forms, for example, "Elk Valley erosion cycle" is permissible, but such physiographic names have no part in formal stratigraphic nomenclature. It is generally undesirable to use the same geographic name for an erosion cycle or erosion surface and for a rock unit; for example, "Fremont erosion cycle" in Wyoming and "Fremont Limestone" in Colorado.

Geologic-Climate Units (for Use in the Quaternary)

Article 39.—A geologic-climate unit is an inferred widespread climatic episode defined from a subdivision of Quaternary rocks.

Remarks. (*a*) *Definition.*—A geologic-climate unit is defined from its records, which are bodies of rock, soil, and organic material. At any single place the time boundaries of the geologic-climate unit are defined by the boundaries of some kind of stratigraphic unit. These local stratigraphic boundaries may be isochronous surfaces, but the different stratigraphic boundaries that define the limits of the geologic-climate unit in different latitudes are not likely to be isochronous. In this respect geologic-climate units differ from geologic-time units, which are based on time-stratigraphic units. The locality where the geologic-climate unit is first defined is its type locality.

(*b*) *Principal purposes.*—Geologic-climate units are used (i) in correlating episodes of deposition of Quaternary rocks in different areas, and (ii) in determining the historical sequence of events in the Quaternary Period.

(*c*) *Extent.*—Geologic-climate units may be extended geographically as far as the record of the geologic climate can be identified, regardless of changes of facies of the rocks, soils, or other materials that constitute the record.

Article 40.—Glaciation and interglaciation are fundamental units of geologic-climate classification; stade and interstade are subdivisions of a glaciation.

Remarks. (*a*) *Definitions.*—(i) A glaciation was a climatic episode during which extensive glaciers developed, attained a maximum extent, and receded. (ii) An interglaciation was an episode during which the climate was incompatible with the wide extent of glaciers that characterized a glaciation. (iii) A stade was a climatic episode within a glaciation during which a secondary advance of glaciers took place. (iv) An interstade was a

climatic episode within a glaciation during which a secondary recession or a stillstand of glaciers took place.

(*b*) *Nomenclature.*—Formal names of geologic-climate units should be chosen in accordance with the rules (see Article 13) that govern the naming of rock-stratigraphic units. A geologic-climate unit may be named after a rock-stratigraphic unit, a soil-stratigraphic unit, or some other geographically named stratigraphic unit. In the type locality of the geologic-climate unit the record of its major climatic characteristics should be plain, and the evidence of climatic change at the lower and upper limits should be manifest.

Procedure for Amendment

Article 41.—Additions or amendments to this code may be proposed to the Commission by any geologist in writing at any time. If accepted for consideration by a majority vote of the Commission, they may be adopted by a two-thirds vote of the Commission at an annual meeting not less than a year after publication of the proposal.

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Roman numbers refer to Articles; lower case letters in italics refer to Remarks. Thus 13 *e* refers to Article 13, Remark *e*. *fn* refers to footnote.

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