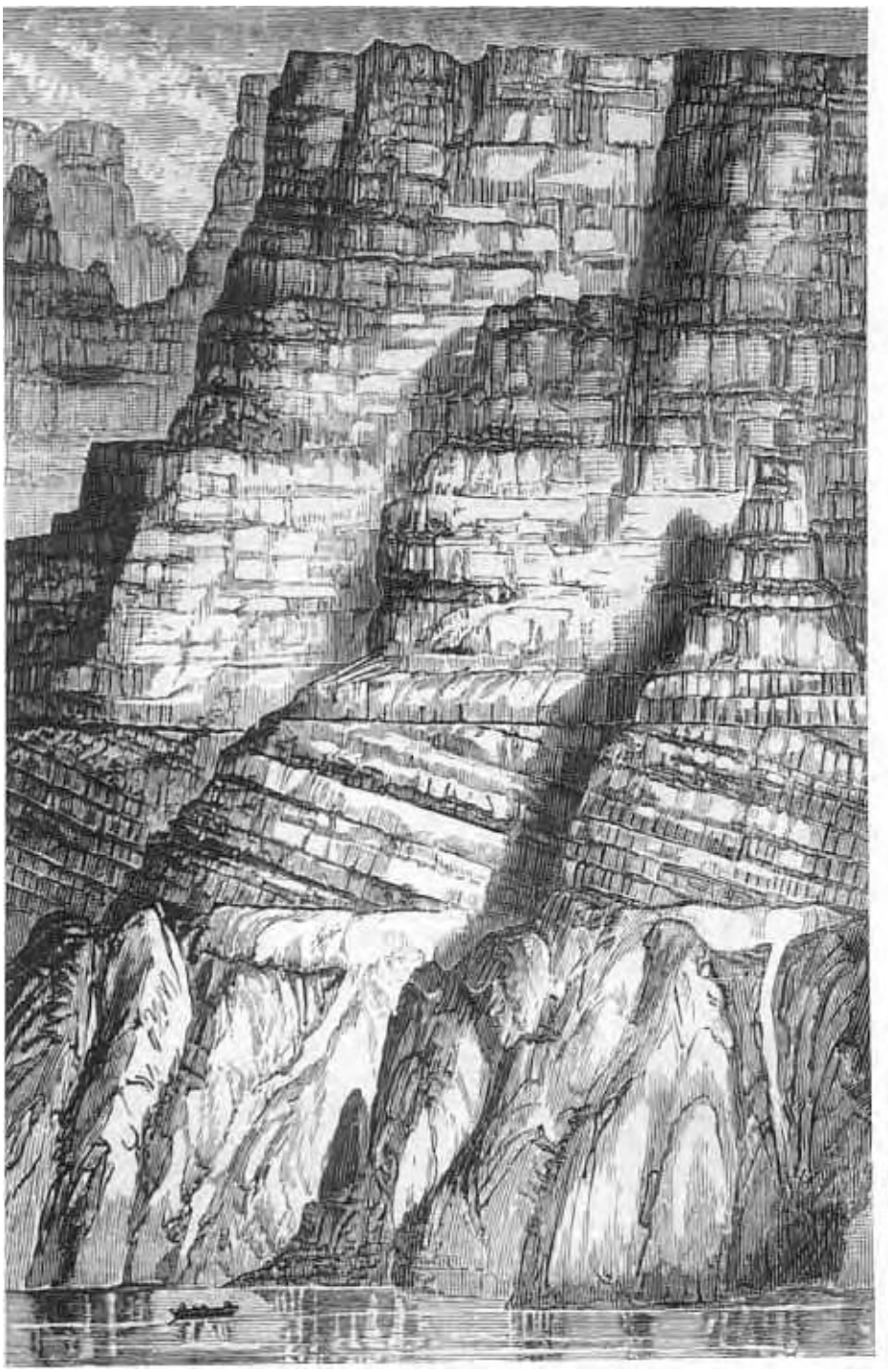


STRATIGRAPHIC NOMENCLATURE AND DESCRIPTION

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

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

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

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

GEOLOGIC NAMES UNITS AND THE GEOLOGIC NAMES COMMITTEE

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

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

The Geologic Names Committee defines and recommends policy and rules governing stratigraphic nomenclature and classification in all manuscripts and

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

The basis of the committee's action is the North American Stratigraphic Code (the code) and its predecessors. The North American Commission on Stratigraphic Nomenclature currently has more than 20 members chosen from 8 geological societies and State and Federal surveys in North America: American Association of Petroleum Geologists, Geological Society of America, Geological Survey of Canada, Geological Association of Canada, Canadian Society of Petroleum Geologists, U.S. Geological Survey, Association of American State Geologists, Asociación Méxicana de Geólogos Petroleros, Sociedad Geólogica Méxicana, and Instituto de Geología de la Universidad Nacionál Autónoma de México. Several editions of the code have been printed since the first one was prepared in 1933; the most recent edition, published in 1983, is for sale by the American Association of Petroleum Geologists, Box 979, Tulsa, OK 7410l. Survey authors can get copies from one of the GNU offices. Amendments and additions to the code are proposed from time to time. They are published as Notes or Reports, usually in the American Association of Petroleum Geologists Bulletin. Before proposed changes are adopted by the commission for inclusion in the code, comments and discussions are invited from the geologic profession.

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

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

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

Conformance to the Code and Modification to Stratigraphic Units

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

units). Pedostratigraphic units replace the classification termed "soil-stratigraphic units" in the 1961 and 1970 codes. The term "lithostratigraphic unit" replaces the term "rock-stratigraphic unit" of the 1961 and 1970 codes.

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

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

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

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

TEMPORAL AND RELATED UNITS

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

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

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

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

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

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

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

MATERIAL UNITS

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

FORMAL NAMES

The 1983 code carefully lists the requirements for a formal geologic unit name (article 3) and states that

the first letter in all words used in the formal geologic unit name is capitalized (arts. 3–16, 22–47, 55–60 of the code).

New Names

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

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

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

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

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

Previously Defined Names

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

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

Modification of Existing Names

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

Abandoned names (art. 20 of the code)

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

applied to the name of a unit that is being areally restricted. An abandoned name is understood to be abandoned everywhere, including its type section, locality, or area.

Areal limits (art. 12 of the code)

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

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

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

Change in age assignment

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

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

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

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

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

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

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

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

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

Informal Names

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

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

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

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

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

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

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

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

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

Summary of Formal Versus Informal Usage

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

Examples of Informal Nomenclature

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

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

STRATIGRAPHIC UNIT DESCRIPTIONS

TEXT MATTER

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

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

EXPLANATIONS FOR GEOLOGIC MAPS

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

Correlation or Sequence of Map Units

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

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

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

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

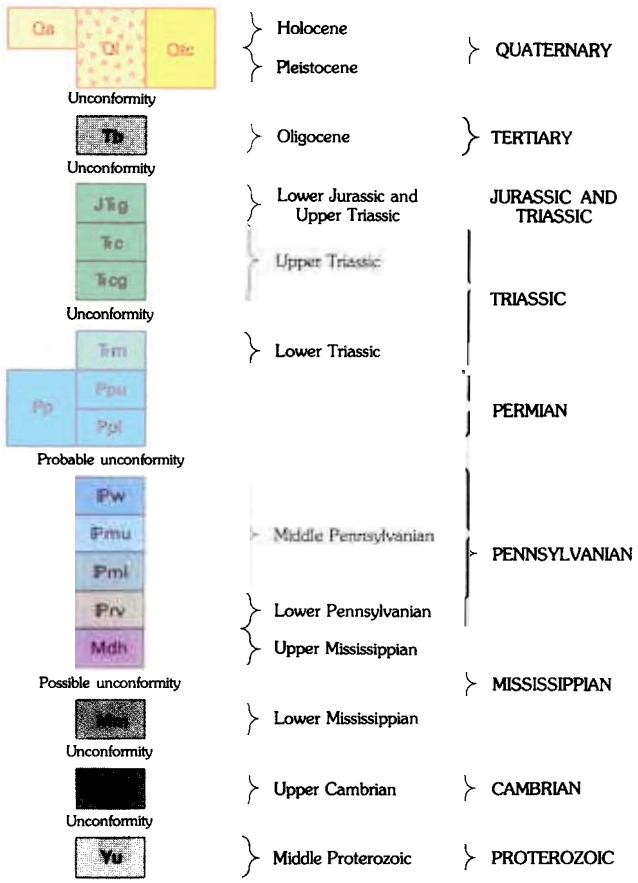
Description of Map Units

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

Kr **Raritan Formation (Upper Cretaceous)**

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

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

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

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

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

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

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

Trc **Chinle Formation (Upper Triassic)**

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

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

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

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

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

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

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

Morgan Formation (Middle Pennsylvanian)

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

Pml Lower member—Shown in cross section only

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

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

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

Cl **Lodore Formation (Upper Cambrian)**—Shown in cross section only

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

Contact—Dashed where approximately located

Fault—Approximately located. Arrows indicate relative movement. Shown in cross sections only

Fold—Showing trace of axial surface. Dashed where approximately located; dotted where concealed

Anticline, showing crestline

Asymmetrical anticline—Shorter arrow indicates steeper limb

Syncline, showing troughline and direction of plunge

Asymmetrical syncline—Shorter arrow indicates steeper limb

Synclinal bend of monocline

Anticlinal bend of monocline

Strike and dip of beds

Strike of vertical beds

Trace of master joints

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

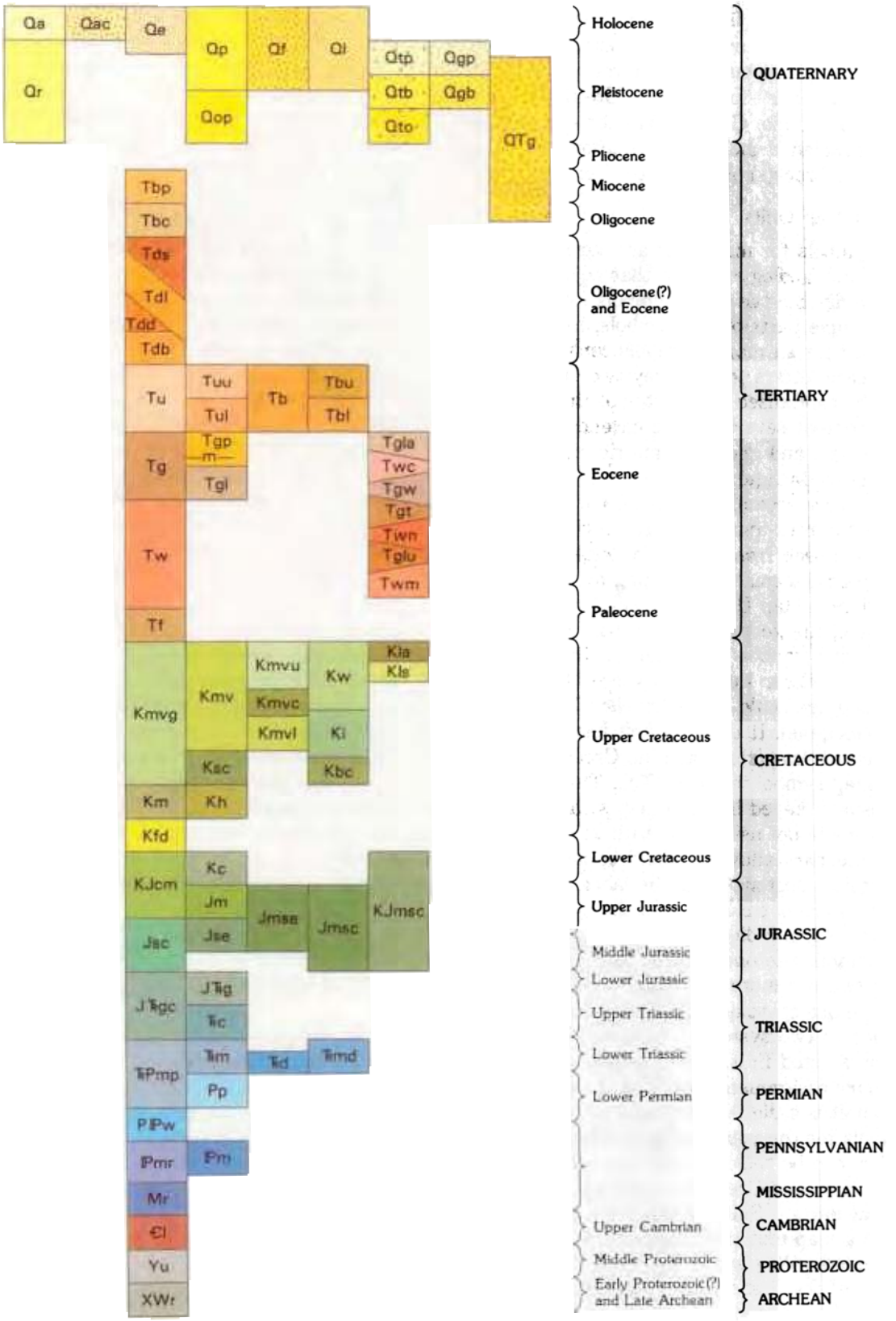


Figure 8. A moderately complex correlation diagram from the explanation of a 1-degree × 2-degree geologic map.

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

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

Symbols for Map Units

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

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

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

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

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

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

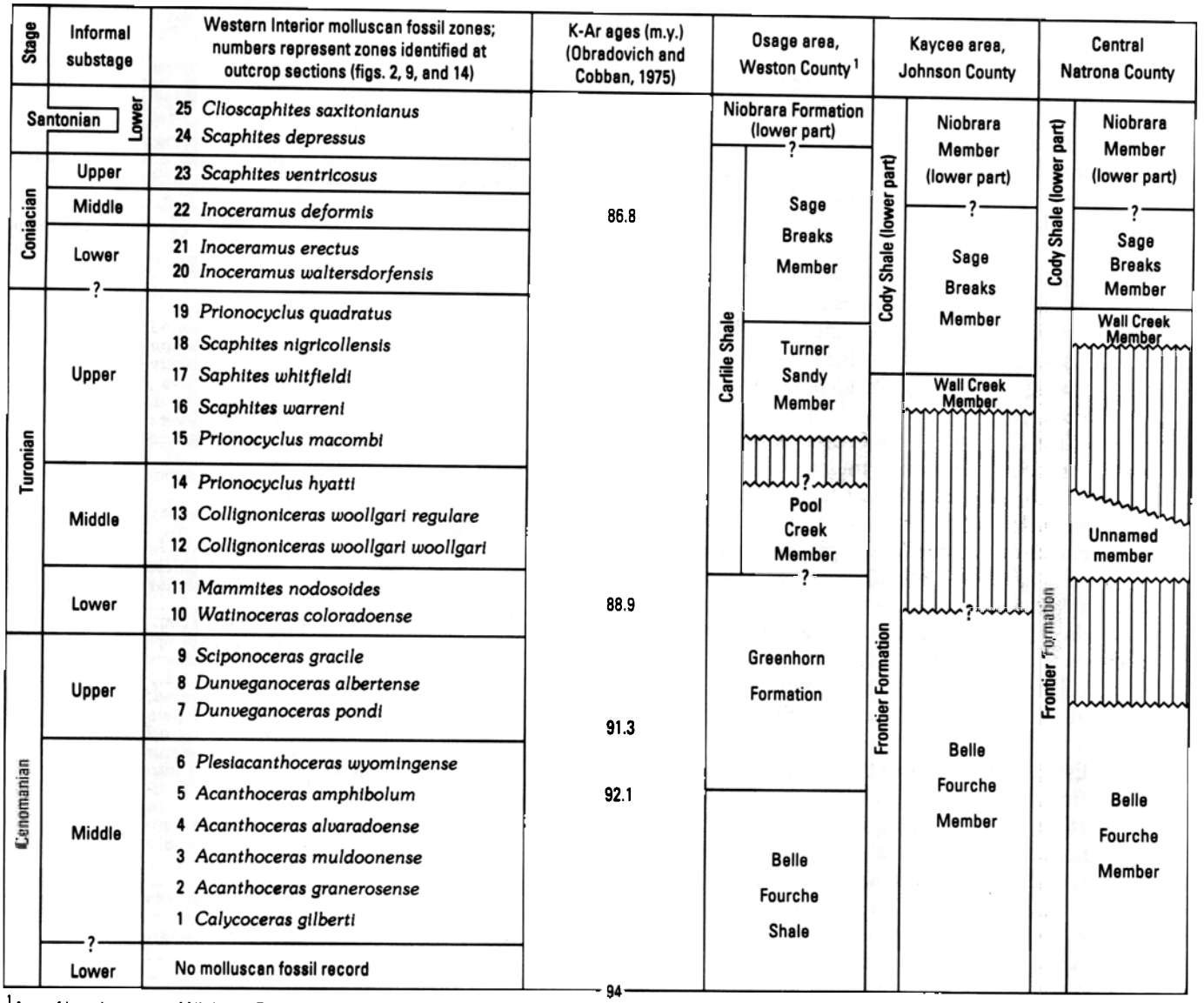
Superscripts. Superscript letters and numbers are used in some map symbols, especially for Tertiary and Quaternary terrace deposits. The youngest and lowest terrace deposit is assigned number 1. Older and higher terrace deposits are assigned numbers 2, 3, and so forth in order of increasing age.

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

CORRELATION CHARTS AND STRATIGRAPHIC TABLES

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

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



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

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

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

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

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

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

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

MEASURED SECTIONS

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

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

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

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

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

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

CROSS SECTIONS AND STRATIGRAPHIC COLUMNAR SECTIONS

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

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

STRATIGRAPHIC STYLE AND EXPRESSION

ABBREVIATIONS

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

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

SECTIONS OF THE STURGIS FORMATION

Upper part of the section

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

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

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

CAPITALIZATION OF STRATIGRAPHIC UNIT NAMES

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

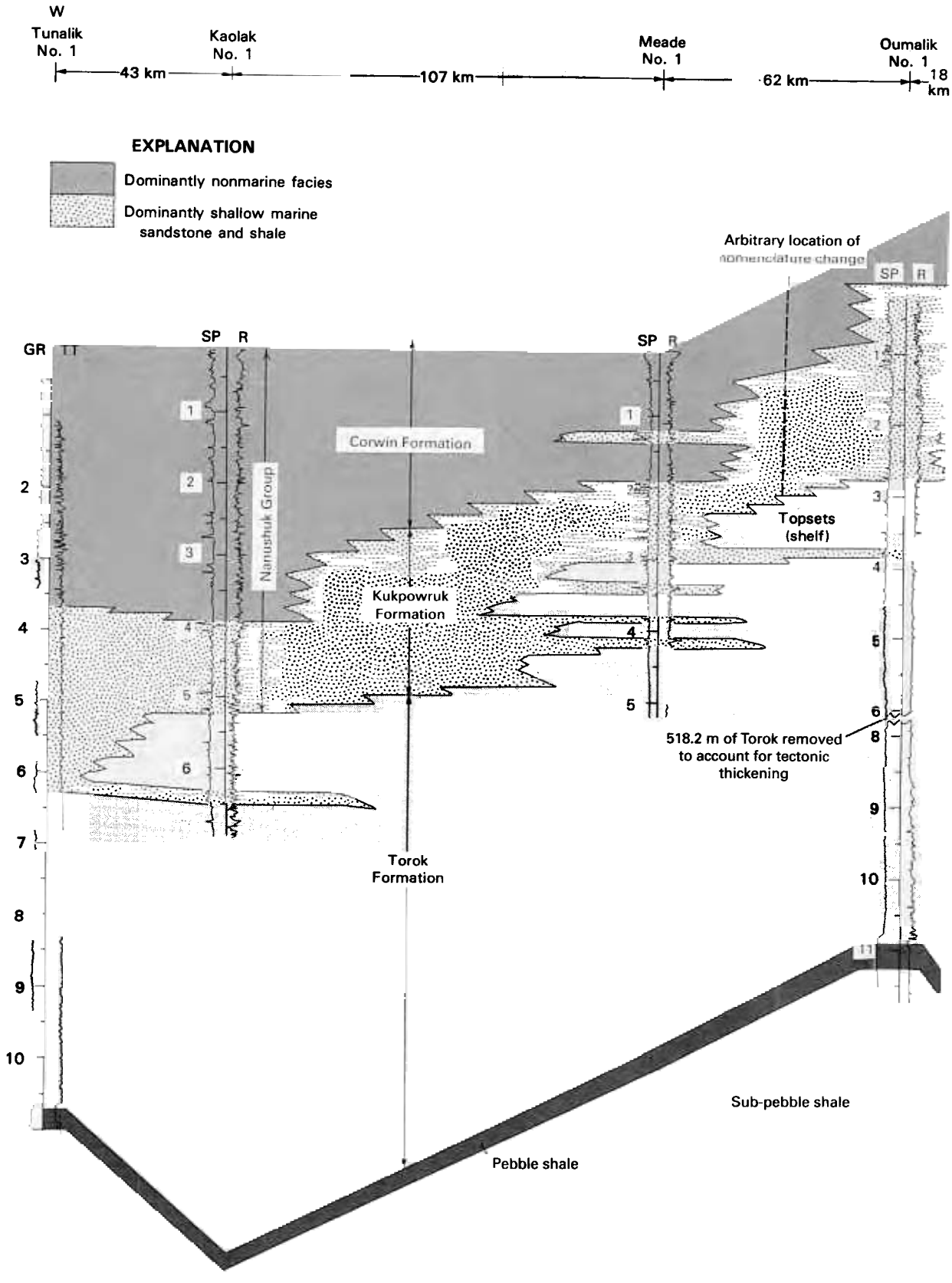
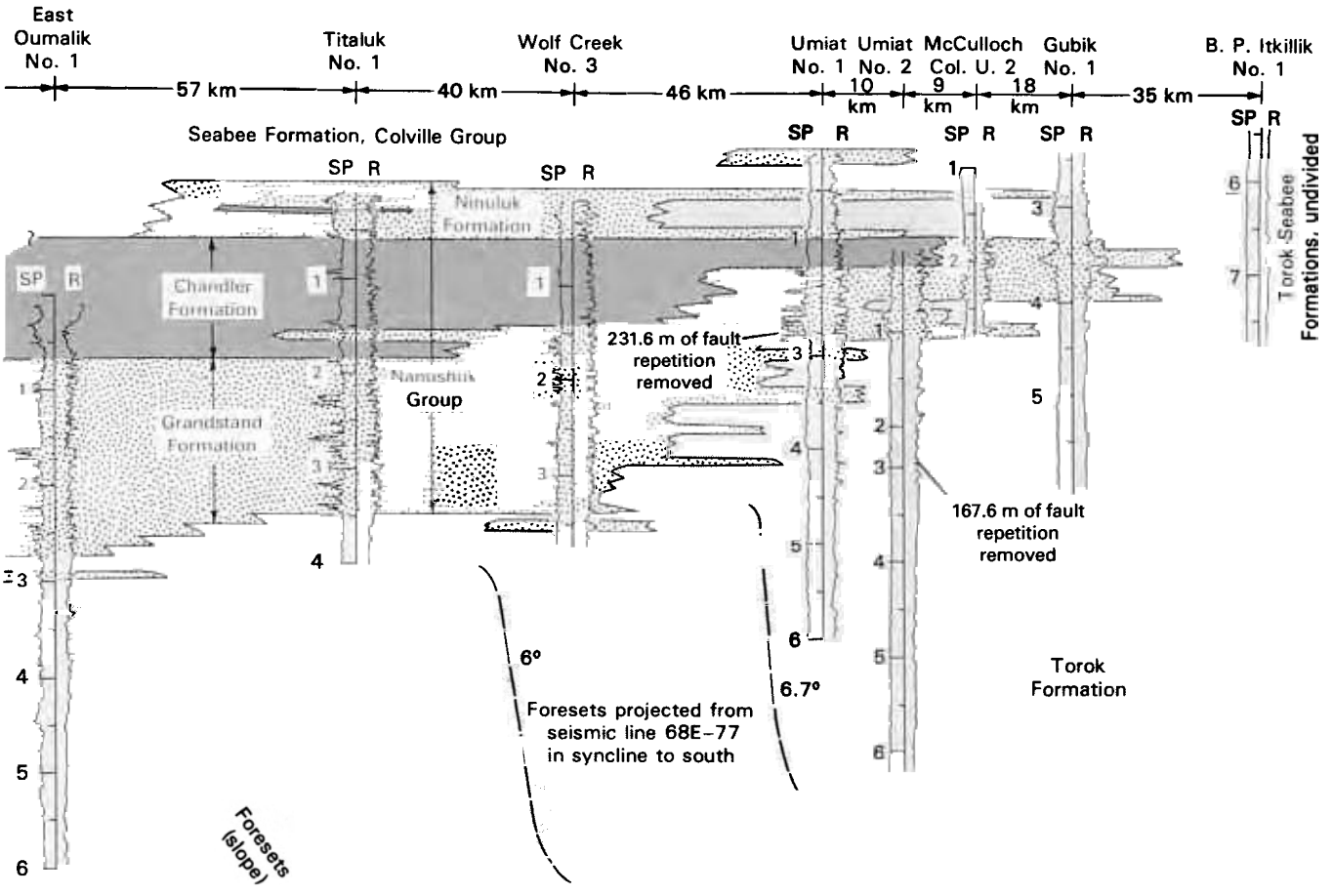
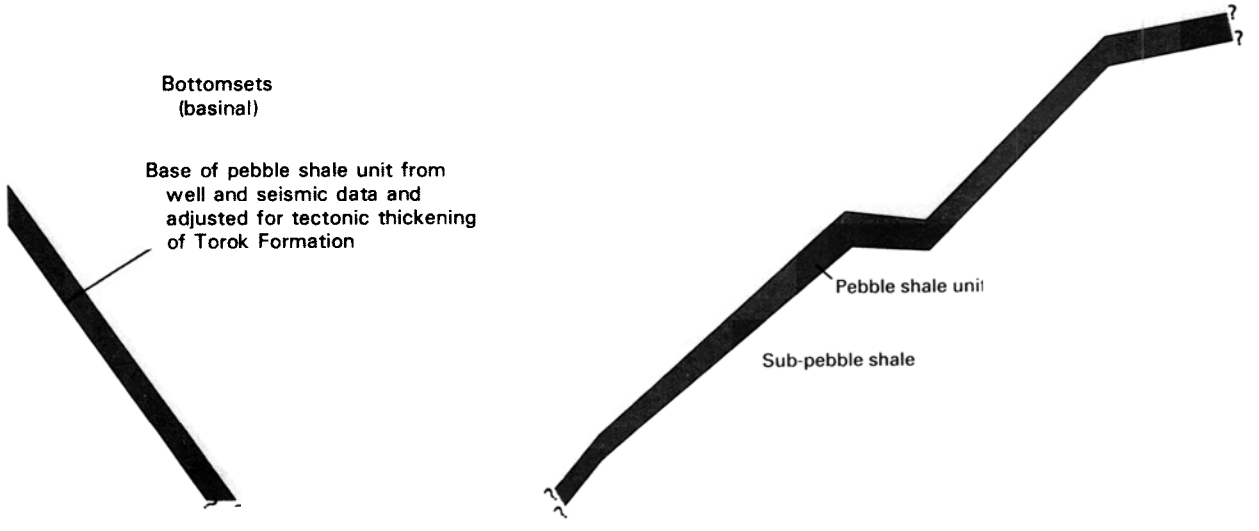


Figure 13. A stratigraphic cross section showing complex intertonguing.



Bottomsets of westerly derived Torok deposited on bottomset turbidite facies of southerly derived Torok and Fortress Mountain Formations at some horizon below



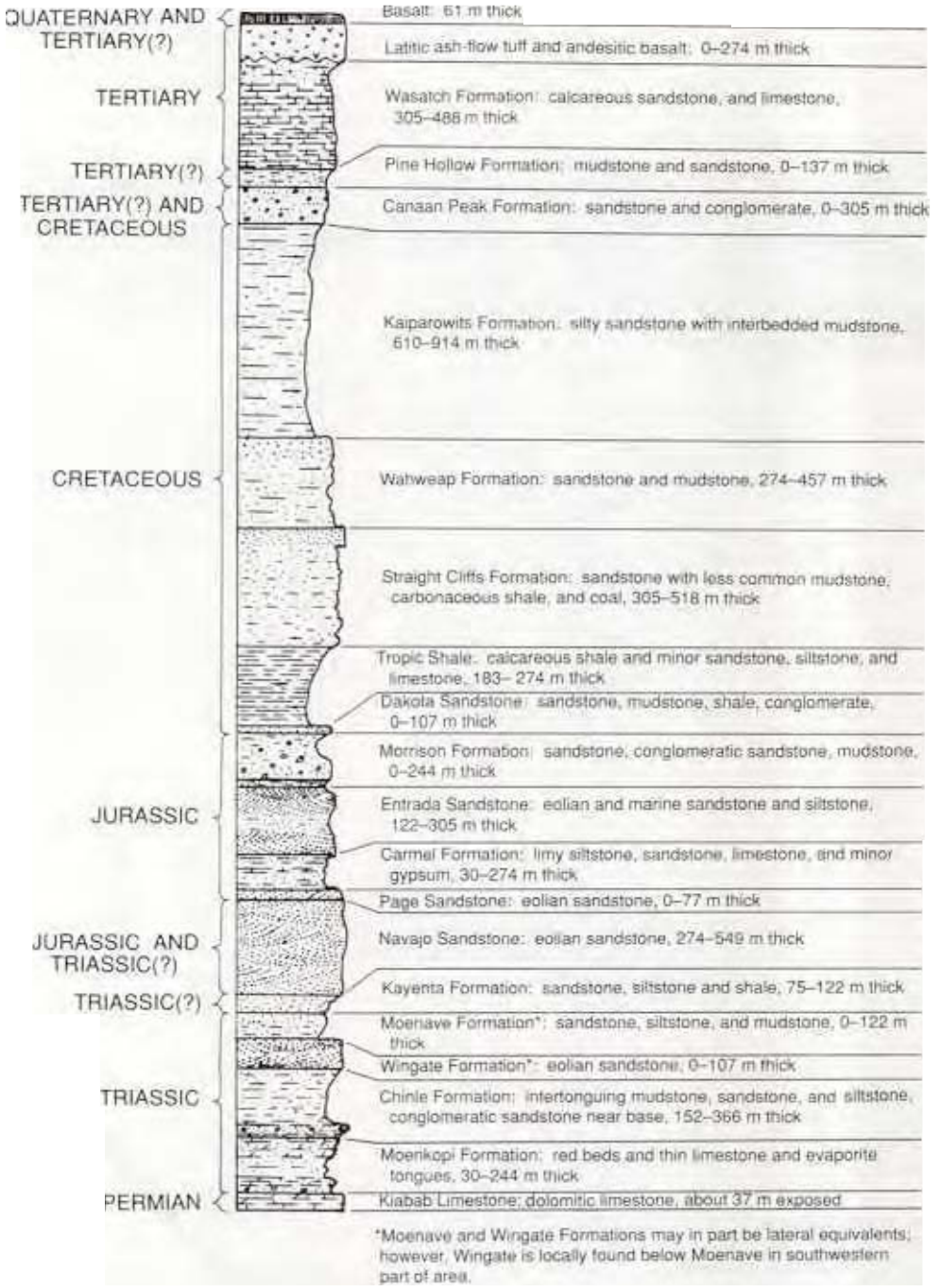


Figure 14. A stratigraphic columnar section.

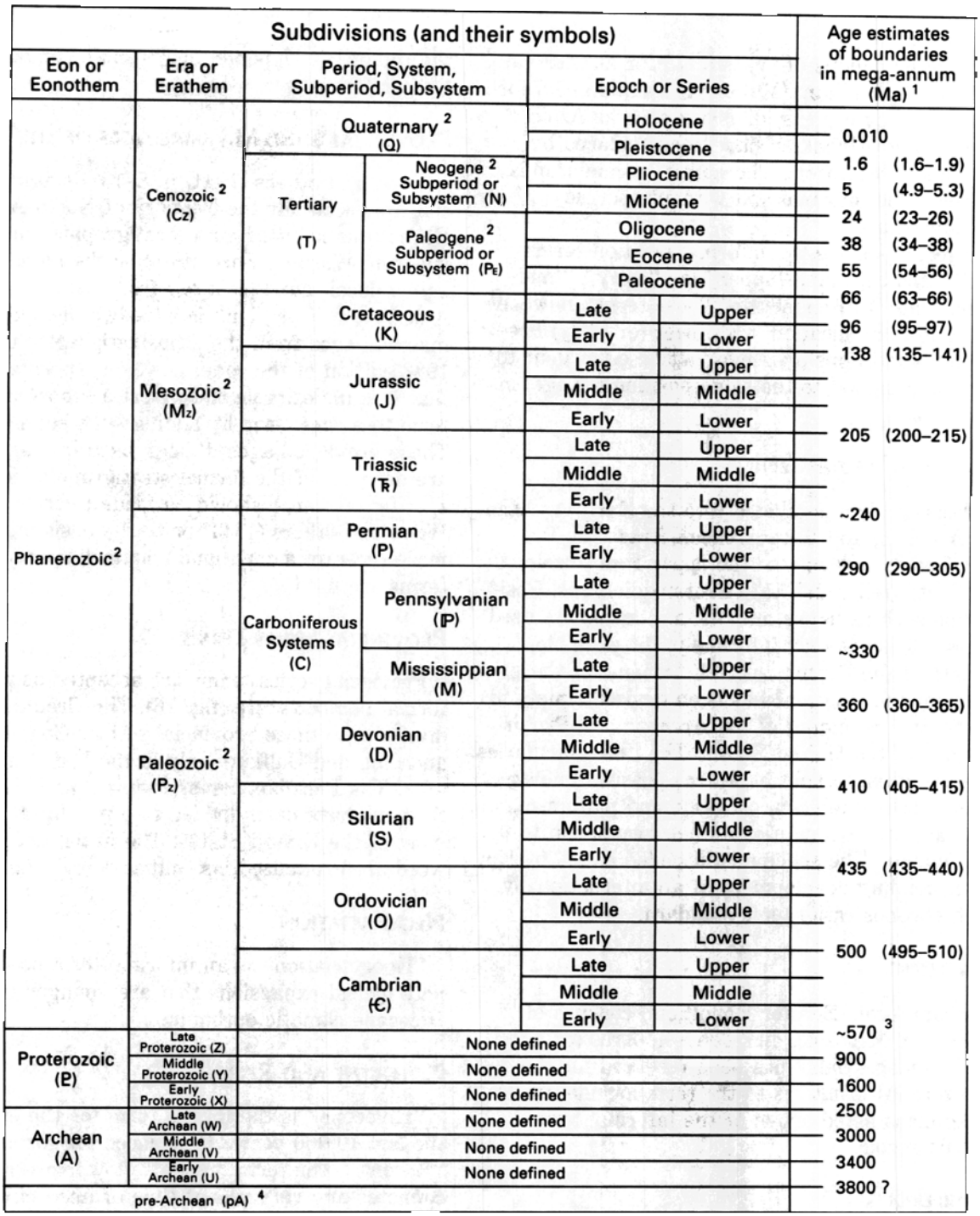
Shale, though correct, could be listed simply as Twin Creek, Morrison, Dakota, and Mancos Formations. Such a listing enhances readability. Note that "Formations" is capitalized.

DIVISIONS OF GEOLOGIC TIME

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

PRECAMBRIAN

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



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

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

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

[4] Informal time term without specific rank.

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

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

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

Archean and Proterozoic

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

Phanerozoic

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

Carboniferous

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

Provincial Land-Mammal Ages of the Tertiary

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

Provincial Series Terms

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

Neoglaciation

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

Holocene and Recent

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

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

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

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

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

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

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

[4] Informal time term without specific rank.

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

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

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

Archean and Proterozoic

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

Phanerozoic

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

Carboniferous

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

Provincial Land-Mammal Ages of the Tertiary

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

Provincial Series Terms

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

Neoglaciation

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

Holocene and Recent

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

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

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

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

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

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

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

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

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

European Stage Terms

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

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

Expressions for Degrees of Doubt

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

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

Quotation Marks

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

Undesirable Expressions

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

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

Units of Economic, Local, Subsurface, or Regional Interest

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

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

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

Publication of Stratigraphic Data

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

Publication Restrictions

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

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

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

U.S. Geological Survey Publications

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

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

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

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