Divisions of Geologic Time—Major Chronostratigraphic and Geochronologic Units

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Abbreviations

b.y.	billion years
C.E.	Common Era
CGMW	Commission for the Geologic Map of the World
FGDC	Federal Geographic Data Committee
Ga	giga-annum (or billion [10^9] years ago)
GNC	Geologic Names Committee
ICS	International Commission on Stratigraphy
ka	kilo-annum (or thousand [10^3] years ago)
k.y.	thousand years
Ma	mega-annum (or million [10^6] years ago)
m.y.	million years
Q	Quaternary
SI units	International System of Units
STA7	Suggestions to Authors of the Reports of the U.S. Geological Survey—Seventh Edition
T	Tertiary
USGS	U.S. Geological Survey

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Chapter C

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

Introduction

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

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

Time Scales

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

Formal Chronostratigraphic (Position) and Geochronologic (Time) Units

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

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

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

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

[1]U.S. Geological Survey.

[2]Geological Survey of Alabama.

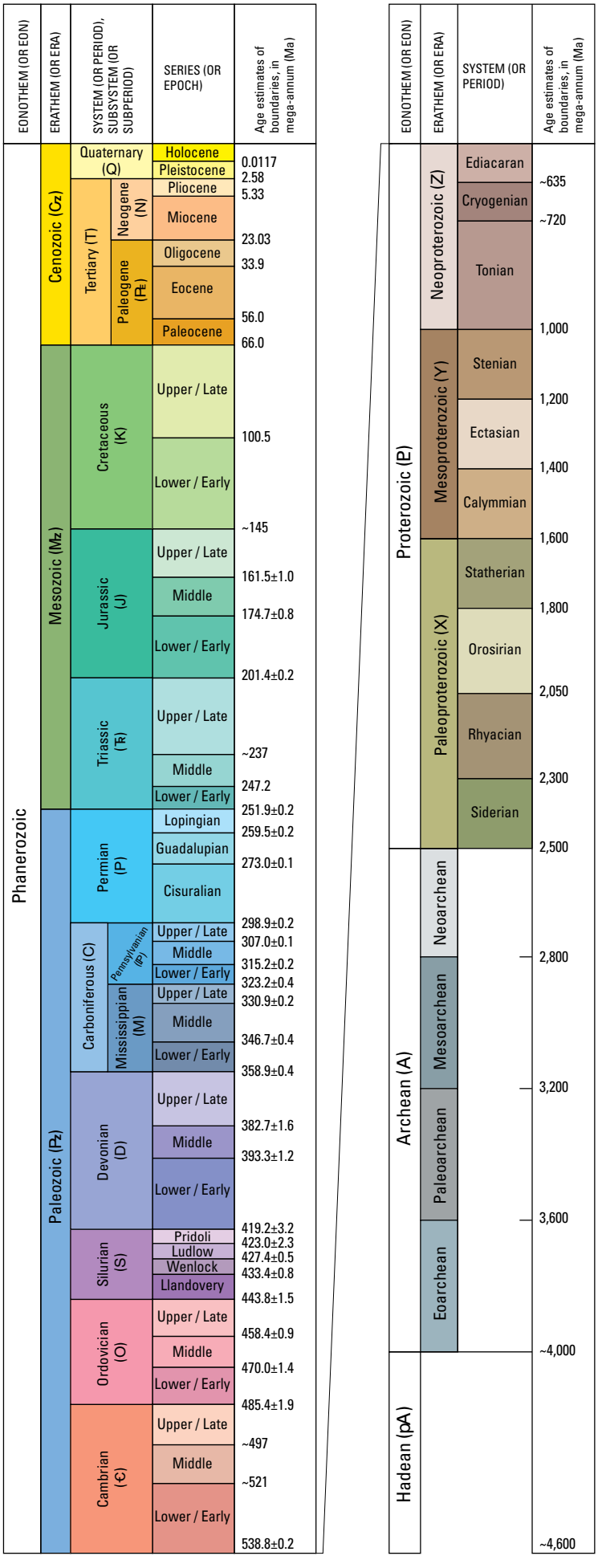

Figure 1. Chart showing updated divisions of geologic time, modified from U.S. Geological Survey Geologic Names Committee (2018). Chart shows major chronostratigraphic and geochronologic unit names as approved by U.S. Geological Survey (USGS) Geologic Names Committee (GNC), as well as updates to their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

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

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

Precambrian

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

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

Cenozoic

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

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

Anthropocene

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

Age Terms

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

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

Stratigraphic-Age Symbols

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

Map-Unit Colors

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

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

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

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

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