

## **Appendix 2-A**

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Geologic Time Scale

# Divisions of Geologic Time— Major Chronostratigraphic and Geochronologic Units

*Introduction.*—Effective communication in the geosciences requires consistent uses of stratigraphic nomenclature, especially divisions of geologic time. A geologic time scale is composed of standard stratigraphic divisions based on rock sequences and calibrated in years (Harland and others, 1982). Over the years, the development of new dating methods and 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 to be used in communicating ages of geologic units in the United States. Many international debates have occurred over names and boundaries of units, and various time scales have been used by the geoscience community.

*New time scale.*—Since the publication by the USGS of the 7th edition of “Suggestions to Authors” (STA7; Hansen, 1991), no other time scale has been officially endorsed by the USGS. For consistency purposes, the USGS Geologic Names Committee (GNC; see box for members) and the Association of American State Geologists (AASG) developed **Divisions of Geologic Time** (fig. 1). The **Divisions of Geologic Time** is based on the time scale in STA7 (Hansen, 1991, p. 59) and updates it with the unit names and boundary age estimates ratified by the International Commission on Stratigraphy (ICS). Scientists should note that other published time scales may be used, provided that these are specified and referenced (for example, Palmer, 1983; Harland and others, 1990; Haq and Eysinga, 1998; Gradstein and others, 2004). Advances in stratigraphy and geochronology require that any time scale be periodically updated. Therefore, the **Divisions of Geologic Time** is dynamic and will be modified as needed to include accepted changes of unit names and boundary age estimates.

The **Divisions of Geologic Time** shows the major chronostratigraphic (position) and geochronologic (time) units; that is, eonothem/eon to series/epoch divisions. Workers should refer to the ICS time scale (Ogg, 2004) for stage/age terms. Most systems of the Paleozoic and Mesozoic are subdivided into series utilizing the terms “Lower,” “Middle,” and “Upper.” The geochronologic counterpart terms for subdivisions of periods are “Early,” “Middle,” and “Late.” The international geoscience community is applying names to these subdivisions based on stratigraphic sections at specific localities worldwide. All series/epochs of the Silurian and Permian have been named. Although the usage of these names is preferred, “lower/early,” “middle,” and “upper/late” are still acceptable as informal units (lowercase) for these two systems/periods. Also the Upper Cambrian has been named “Furongian” in the ICS time scale. However, the GNC will not recognize this name and include it in the **Divisions of Geologic Time** until all series/epochs of the Cambrian are named.

*Cenozoic.*—There has been much controversy related to subdivisions of the Cenozoic, particularly regarding retention or

rank of the terms “Tertiary” and “Quaternary.” Although some stratigraphers have suggested that these terms be abandoned, the issue remains unresolved. If the terms are retained, there will need to be agreement on the status of the Quaternary as a system/period or subsystem/subperiod. Another controversial issue is the position of the base of the Quaternary; is it at the base of the Pleistocene or within the upper Pliocene? These positions have age estimates of 1.8 Ma and 2.6 Ma, respectively (see box for age terms). Until a decision is made on the subdivisions of the Cenozoic, the **Divisions of Geologic Time** will follow the general structure of the time scale in STA7 (Hansen, 1991) in accepting the use of the terms “Tertiary” and “Quaternary” and the equivalence of the bases of the Quaternary and Pleistocene. The map symbols “T” (Tertiary) and “Q” (Quaternary) have been used on geologic maps for more than a century and are widely used today.

*Precambrian.*—For many years, the term “Precambrian” was used for the division of time older than the Phanerozoic. For consistency with the time scale in STA7 (Hansen, 1991), the term “Precambrian” is considered to be informal and without specific stratigraphic rank (although it is capitalized).

*Map colors.*—Geologic maps utilize color schemes based on standards that are related to the time scale. Two different schemes are used, one by the Commission for the Geologic Map of the World (CGMW) and another by the USGS. Colors typically shown on USGS geologic maps have been used in a standard fashion since the late 1800s and recently have been published in the digital cartographic standard for geologic map symbolization (Federal Geographic Data Committee, Geologic Data Subcommittee, 2006). The GNC decided in 2006 that the USGS colors should be used for large-scale and regional geologic maps of the United States. For international maps or small-scale maps (for instance, 1:5 million) of the United States or North America, the GNC recommends the use of the international colors. Specifications for the USGS colors are in Federal Geographic Data Committee, Geologic Data Subcommittee (2006), and those for the CGMW colors are in Gradstein and others (2004).

*Acknowledgments.*—This Fact Sheet benefited from thoughtful reviews by John Repetski (USGS) and Donald E. Owen (Lamar University, Beaumont, Tex., and North American Commission on Stratigraphic Nomenclature).

By U.S. Geological Survey Geologic Names Committee

## Members of the Geologic Names Committee of the U.S. Geological Survey, 2006

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## Age Terms

The age of a stratigraphic unit or the time of a geologic event may be expressed in years before present (before A.D. 1950). The "North American Stratigraphic Code" (North American Commission on Stratigraphic Nomenclature, 2005) recommends abbreviations for ages in SI (International System of Units) prefixes coupled with "a" for annum: ka for kilo-annum, 10<sup>3</sup> years; Ma for mega-annum, 10<sup>6</sup> years; and Ga for giga-annum, 10<sup>9</sup> years. Duration of time should be expressed in millions of years (m.y.). For example, deposition began at 85 Ma and continued for 2 m.y.

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EONOTHEM / EON	ERATHM / ERA	SYSTEM/SUBSYSTEM / PERIOD/SUBPERIOD	SERIES / EPOCH	Age estimates of boundaries in mega-annum (Ma) unless otherwise noted	
Phanerozoic	Cenozoic (Cz)	Quaternary (Q)	Holocene	11,477 ±85 yr	
			Pleistocene	1.806 ±0.005	
		Tertiary (T)	Neogene (N)	Pliocene	5.332 ±0.005
				Miocene	23.03 ±0.05
			Paleogene (Pg)	Oligocene	33.9 ±0.1
		Eocene		55.8 ±0.2	
		Paleocene		65.5 ±0.3	
		Mesozoic (Mz)	Cretaceous (K)	Upper / Late	99.6 ±0.9
				Lower / Early	145.5 ±4.0
			Jurassic (J)	Upper / Late	161.2 ±4.0
	Middle			175.6 ±2.0	
	Lower / Early			199.6 ±0.6	
	Triassic (Tr)		Upper / Late	228.0 ±2.0	
			Middle	245.0 ±1.5	
			Lower / Early	251.0 ±0.4	
	Paleozoic (Pz)		Permian (P)	Lopingian	260.4 ±0.7
				Guadalupian	270.6 ±0.7
		Cisuralian		299.0 ±0.8	
		Carboniferous (C)	Pennsylvanian (P)	Upper / Late	306.5 ±1.0
				Middle	311.7 ±1.1
	Mississippian (M)	Lower / Early	318.1 ±1.3		
		Upper / Late	326.4 ±1.6		
		Middle	345.3 ±2.1		
	Devonian (D)	Lower / Early	Upper / Late	359.2 ±2.5	
			Middle	385.3 ±2.6	
			Lower / Early	397.5 ±2.7	
	Silurian (S)	Lower / Early	Pridoli	416.0 ±2.8	
Ludlow			418.7 ±2.7		
Wenlock			422.9 ±2.5		
Wenlock			428.2 ±2.3		
Llandovery			443.7 ±1.5		
Ordovician (O)	Lower / Early	Upper / Late	460.9 ±1.6		
		Middle	471.8 ±1.6		
		Lower / Early	488.3 ±1.7		
Cambrian (C)	Lower / Early	Upper / Late	501.0 ±2.0		
		Middle	513.0 ±2.0		
		Lower / Early	542.0 ±1.0		

EONOTHEM / EON	ERATHM / ERA	SYSTEM / PERIOD	Age estimates of boundaries in mega-annum (Ma) unless otherwise noted
Proterozoic (P)	Neoproterozoic (Z)	Ediacaran	630
		Cryogenian	850
		Tonian	1000
	Mesoproterozoic (Y)	Stenian	1200
		Ectasian	1400
		Calymmian	1600
	Paleoproterozoic (X)	Statherian	1800
		Orosirian	2050
		Rhyacian	2300
		Siderian	2500
Archean (A)	Neoaarchean		2800
			3200
	Mesoarchean		3600
			~4000
	Hadean (pA)		

**Figure 1. Divisions of Geologic Time** approved by the U.S. Geological Survey Geologic Names Committee, 2006. The chart shows major chronostratigraphic and geochronologic units. It reflects ratified unit names and boundary age estimates from the International Commission on Stratigraphy (Ogg, 2004). Map symbols are in parentheses.