Eons and geons - a simple planetary time scale

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Abstract

A widely used dictionary defines a time scale as "an arrangement of events used as a measure of the relative or absolute duration or antiquity of a period of history or geologic or cosmic time..." (Gove,1986, p. 2395). Different types of scales exist: in increasing order of information content, these are binary, nominal, ordinal, interval, and ratio scales. The Phanerozoic time scale has divisions based on characteristic fossil content and has nominal and ordinal attributes; its chronostratigraphic units are defined at stratotypes, and they are of relative short duration and most have been calibrated radiometrically. The divisions of the Proterozoic time scale proposed by the International Commission on Stratigraphy (Cowie et al., 1989) are of relatively long duration, and are named after geohistorical content and thus viewed as corresponding to chronostratigraphic units; yet, contrary to rules of stratigraphic nomenclature, they are not based on designated stratotypes, but on arbitrary ages with large round numbers.

For overview and integrative studies of planetary evolution during the longest part of Earth history (the Cryptozoic or Precambrian), a universal calendar system with numerical units of appropriately long duration to encompass major geological developments (basin formation, orogenic belts, etc.) is more suitable. A convenient measure of such a geochronometric scale is a unit of 100 million years (geon). Such a simple, numerical, equal-interval scale, coupled with a corresponding simple nomenclature (Hofmann, 1990, 1992, 1999), is preferable and more efficient in conveying long-term evolutionary trends than a system of complex nomenclature (Cowie et al., 1989; Plumb, 1991, 1992). The geon concept has been applied to document the geotectonic development of some regions, such as northwestern Canada, and the Grenville Province, and various authors have long used 100-m.y. bins in compilations illustrating various aspects of geospheric evolution.

In addition to geon unit maps, the geon concept can also be used in the preparation of geon gap maps, which emphasize the time values of contacts or discontinuities between major rock units, by visually and quantitatively portraying their relative magnitude. Such maps may be useful, for example, in the exploration for unconformity-related ore deposits.

A universal geon interval scale for numerically specified time periods of long duration (bins of 10^8 a) affords manifold advantages; in essence, such a scale has the benefits of being:
1) numerical, direct, and simple, with intervals of equal duration;
2) easy to learn, to remember, and to apply, because the numeral part also provides the nominal and ordinal functions - only 1 word needs to be assimilated, instead of necessitating the learning of a multitude of names whose additional requirement is that relative positions also need to be remembered;
3) geopolitically neutral by transcending language barriers and jurisdictional boundaries;
4) a logical extension of the calendar system;
5) versatile, and facilitating quantitative studies by providing 46 suitable time slices of equal duration in the preparation of certain maps, sections, and graphs tracking the evolution of the geospheres for all of geologic history;
6) applicable beyond Earth; and
7) helpful in enhancing communication with non-geologists by obviating a series of complex names of units, and by taking advantage of the early-acquired ability to count.

Precambrian chronologic data span most of geologic time and are dominantly numeric, so why not also utilize a numerical classification and a matching ordinal nomenclature? Astronomers already employ light-year and parsec units for large distances, so it is entirely appropriate to adopt a scale for correspondingly long geologic and astronomic time intervals.

References:

Cowie, J.W., Ziegler, W., and Remane, J., 1989, Stratigraphic Commission accelerates progress, 1984 to 1989. Episodes, v. 12 (2), p. 79-83.
Gove, P.B. (Editor-in-chief), 1986, Webster's third new international dictionary of the English language, unabridged. Springfield, MA, Merriam-Webster Inc., 2663 p.
Hofmann, H.J., 1990, Precambrian time units and nomenclature - the geon concept: Geology, v. 18, p. 340-341.
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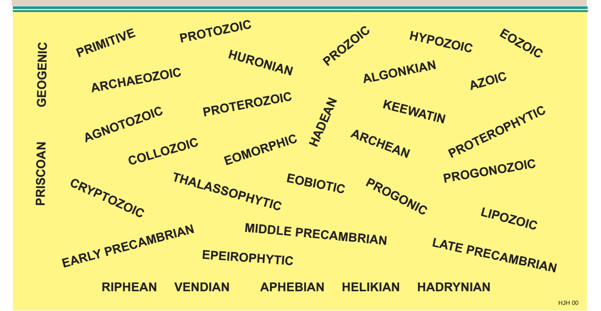
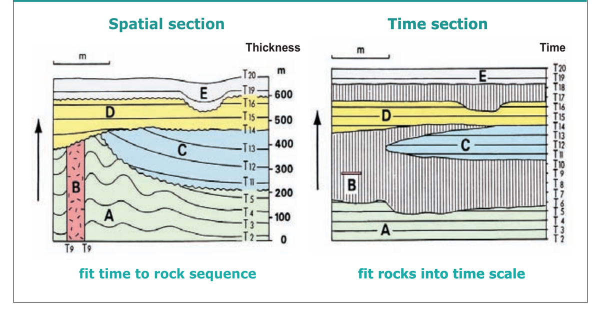
Hofmann, H.J., 1999, Geons and geons. Geology, v. 27, p. 855-856.
Plumb, K.A., 1991, New Precambrian time scale. Episodes, v. 14, p. 139-140.
Plumb, K.A., 1992, New Precambrian time scale: reply. Episodes, v. 15 (2), p. 124-125.

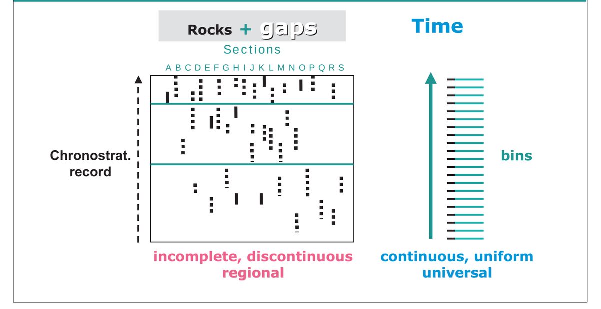
Terminology jungle
(after Hofmann, 1972, Int. Geol. Cong., 24th Sess., Proc. Sect. 1, p. 20-30)



Graphic representation of record



Concepts



Time

Concepts of time

- Point, occasion, event
- Period, duration
- Tempo
- Irreversibility

Clocks

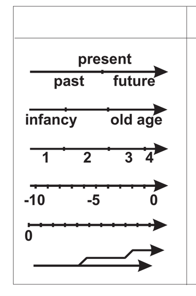
Universal time (UT):
Earth's rotation with respect to Sun
solar (synodic) day = 24h = 86,400s

Ephemeris time:
Motion with respect to distant star
sidereal day = 23h 56.1m = 86,164s

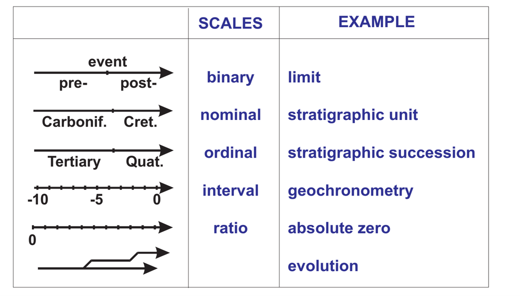
Atomic time:
emission frequency of ^{133}Cs 9,192,631,770/s

Types of time scales

Time



Time + rocks



Geochronometric scales

Use a universal calendar system with numerical units appropriately large to encompass major geological developments (basin formation, orogenic belts, evolution, etc.). A convenient measure is a unit of 100 million years.

Numerical nomenclature

Units of 10^8 years previously considered

100 my, Ma	-	current geological literature
亿年 (i nien)	-	Chinese geological literature
megacentury	-	A.F. Trendall, 1966
becquerel	-	P.F. Hoffman, unpublished
geocentury	-	P.E. Cloud, 1988
geon	-	H.J. Hofmann, 1990

Comparisons

10^0 a	= 1 a	= 1 year
10^1 a		= 1 decade
10^2 a		= 1 century
10^3 a	= 1 ka	= 1 milennium
10^6 a	= 1 Ma	= 1 megennium
10^8 a		= 1 geon
10^9 a	= 1 Ga	= 1 gigennium

Complex nomenclature

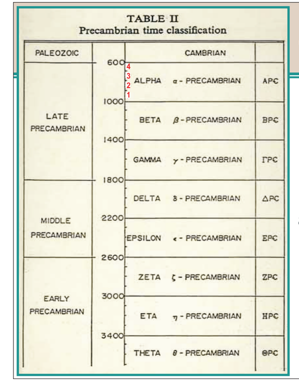


TABLE II
Precambrian time classification

PALEOZOIC		CAMBRIAN	
LATE PRECAMBRIAN	600	ALPHA α - PRECAMBRIAN	APC
	1000	BETA β - PRECAMBRIAN	BPC
	1400	GAMMA γ - PRECAMBRIAN	ΓPC
MIDDLE PRECAMBRIAN	1800	DELTA δ - PRECAMBRIAN	ΔPC
	2200	EPSILON ε - PRECAMBRIAN	EPC
	2600	ZETA ζ - PRECAMBRIAN	ZPC
EARLY PRECAMBRIAN	3000	ETA η - PRECAMBRIAN	HPC
	3400	THETA θ - PRECAMBRIAN	ΘPC

GOLDICH, 1968
(Can. J. Earth Sci. 5:715-724)

Scheme based on equal time intervals, but with complex alphanumeric nomenclature:

Greek letter units ascending with increasing age; numbered units decreasing with increasing age

Complex nomenclature

JIN et al., 1991
(Jour. of Stratigraphy 15(4):313-315, 320)

Scheme based on equal time intervals, but with complex nomenclature and inconsistent divisions:

Units have 3 divisions for 300-my eras in Proterozoic, 2 divisions for 400-my eras in Archean

Geon (H.P. Woodward, 1929, Pan-Amer. Geol. 51:15-22)

A unit … "taken to represent either the span of the average geologic period, or the thickness of the average stratigraphic equivalent, a matter of 60,000,000 years, and 50,000 feet [~15 km] of clastic depositions"

Using 543 Ma for the base of the Cambrian, and 11 geologic periods, an updated value for Woodward's geon is ~49.4 my

Geon (geological eon) (Hofmann, 1990)

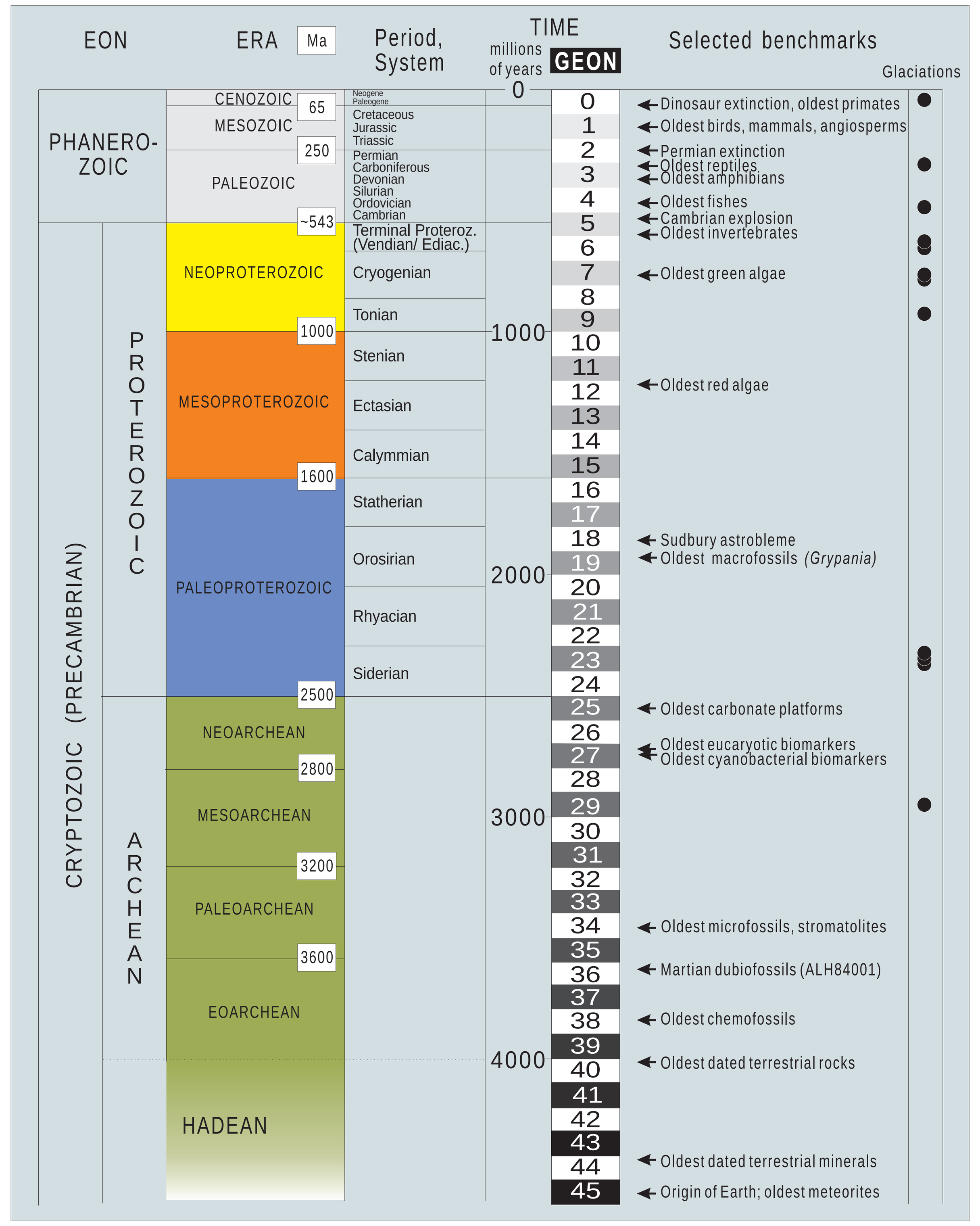
A specified 100-million-year interval of geologic time, counted backward from the present.

The geon is named for the leftmost part of the number representing age.

Ages such as 1851 Ma and 1800 Ma belong to Geon 18; the Cretaceous extinction (065 Ma) belongs to Geon 0

Geologic scale - geon scale

(after Hofmann, 1990, 1992; 2000 - Geolog, v. 29, pt. 1, p. 18)
www.eps.mcgill.ca/~hofmann/geonscale.html

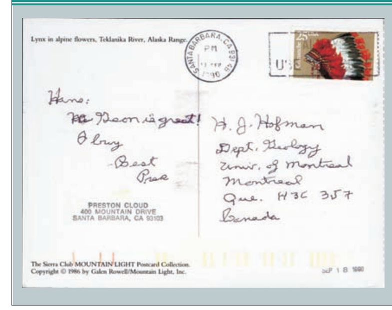


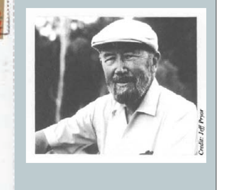
Perspectives

Partitioning time
Nominal and interval scales

Content	Events	Time
Albian	~ 105 Ma	0
Aalenian	~ 180 Ma	100
Artinskian	~ 260 Ma	200
Arenigian	~ 480 Ma	300
		400
Middle Ages	476 AD – 1453 AD	500
Han Dynasty	206 BC – 220 AD	600
Satavahana Dynasty	200 BC – 236 AD	700

Opinion





Preston E. Cloud, Jr.
1912-1991

Comparing Phanerozoic system and geon boundaries
* after Okulitch 1995, GSC Open File 3040

Period	Age*	Geon	δMa
	0 Ma		
Neogene, Paleogene; U. Cretaceous		0	
	98.9 Ma		1.1
L. Cretaceous; Jurassic		1	
	205.7 Ma		5.7
Triassic; Permian		2	
	300 Ma		0
Carboniferous; Devonian		3	
	410 Ma		10
Silurian; Ordovician		4	
	510 Ma		10
Cambrian; TPS (Ediacaran)		5	
	590 Ma		10

Implications

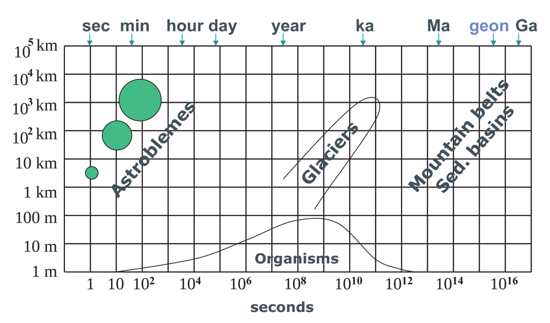
Parallel, complementary scales

Period/system boundaries approximate geon boundaries

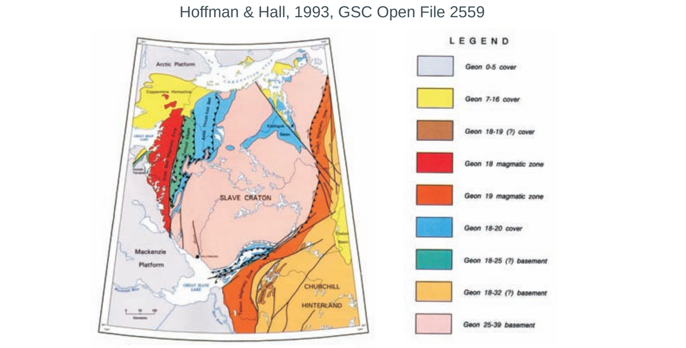
Era/erathem boundaries lie near middle of geons

Some applications

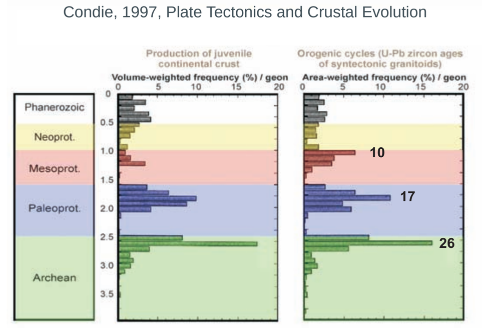
Scale of phenomena
(adapted from Carey 1962, J. Geol. Soc. India 3:97-105)



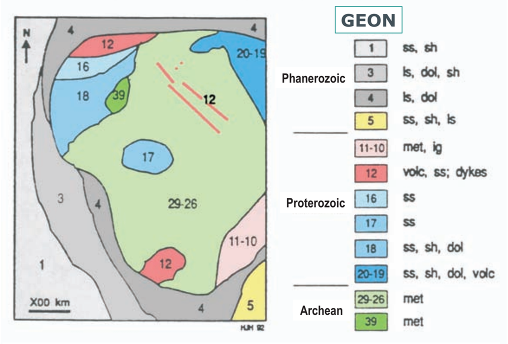
Geologic map using geon units
Temporal classification of principal tectonic elements adjacent to the Slave craton
Hoffman & Hall, 1993, GSC Open File 2559



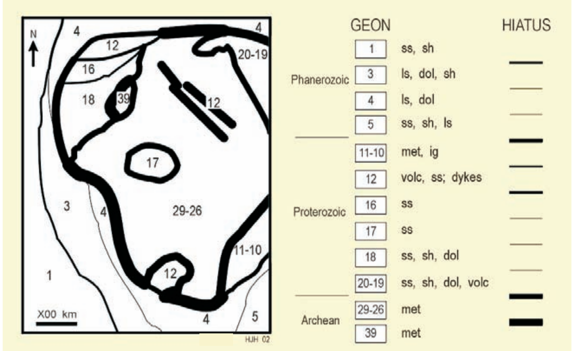
100-my bins (Geon units)
Age distribution of continental crust
Condie, 1997, Plate Tectonics and Crustal Evolution



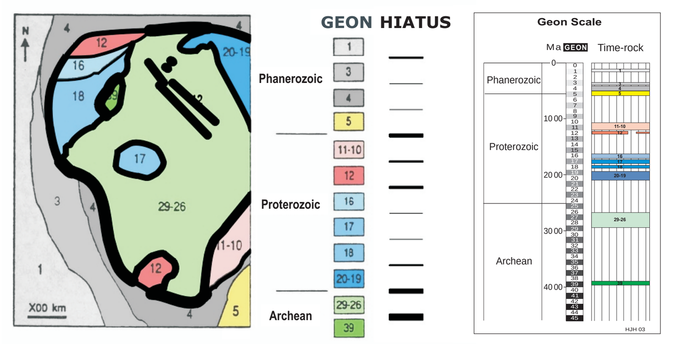
Geon map units
(after Hofmann, 1990, 1992)



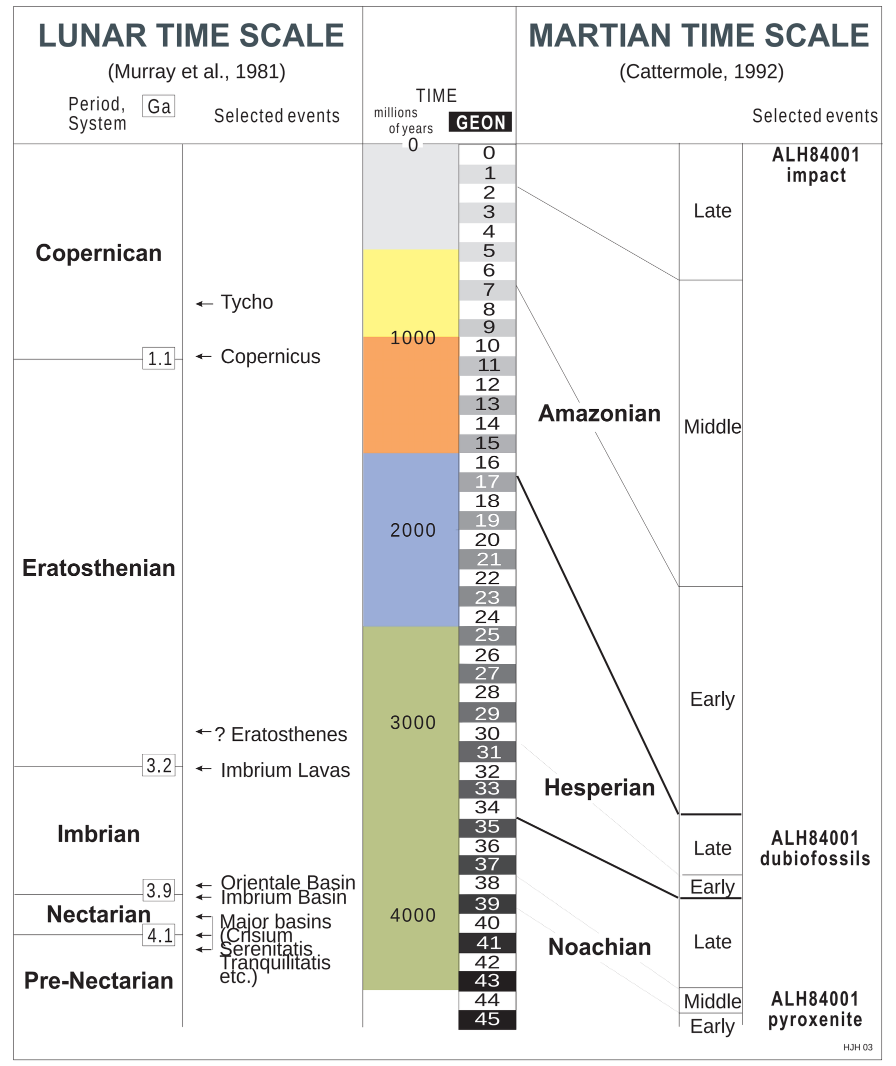
Geon gap map



Geon map units and gaps



Planetary histories and correlation



Conclusions

Why use the Geon concept?

It is numerical, direct, and simple
It is easy to learn, remember, and apply
It is necessary to learn only 1 word
It transcends language barriers
It is geopolitically neutral
It is a logical extension of the calendar system
It provides time slices of equal duration
It is versatile and facilitates quantitative studies
It is applicable beyond Earth
It is helpful in communicating with non-geologists

Geons for the Precambrian!

Precambrian chronologic data are dominantly numeric.

Then, why not utilize chronometric divisions with a corresponding numeric nomenclature?

Astronomers use light-year and parsec for large distances; it thus is appropriate to have a name for long time intervals

Time slice maps
Grenville Province
Rivers, 1997, Prec. Res. 86:117-154