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On the Ordovician Period and Quaternary Sub-Era

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INTRODUCTION

Since the publication of 'A Geologic Time Scale 2004' by Gradstein, Ogg, Smith et al. (2004, Cambridge University Press) and sponsored by the International Commission on Stratigraphy (ICS), two stratigraphic science issues have generated some interesting debates:

1. The status of the Tertiary and Quaternary
2. The standard international subdivision of the Ordovician.

Below, ICS outlines its long-standing and persistent strategy to improve the knowledge and understanding of these historically complex stratigraphic subjects, ultimately leading to consensus-stratigraphic decisions and uniform usage in international geoscience.

GLOBAL SERIES AND STAGES FOR THE ORDOVICIAN SYSTEM

Until recently, there was no global standard set of stratigraphic subdivisions for the Ordovician System/Period. British series/epochs have often been used as *de facto* nomenclature on stratigraphic correlation charts and geologic time scales. However, these regional subdivisions are not widely adopted outside of the British Isles and related paleobiogeographic regions (e.g. northwestern Gondwana) because the high degree of biogeographic provincialism and paleoecologic differentiation of Ordovician faunas prevent the British series from being correlated with precision and high resolution.

As a result, several independent and very different sets of series and constituent stages were established for the Ordovician System, with each generally applicable to a different paleoplate or modern continent. Of course, this has greatly confused Ordovician stratigraphy, and often results in imprecise correlations of Ordovician stratigraphic successions. An example is the Argentine Precordillera where British series are traditionally used to correlate Ordovician strata that contain faunas of predominantly Laurentian affinity.

The Subcommission on Ordovician Stratigraphy of ICS has addressed this problem by developing a standard set of Global Series and Stages for the Ordovician System (Figure 1). This task has taken more than 20 years and is nearing completion with only one boundary stratotype, that of the base of the Third Stage and Middle Ordovician Series, still to be approved. The process and the rationale are described in Finney (2005). The new global standard is being accepted rapidly and is facilitating reliable global correlations. It provides a common language for discussing Ordovician strata, fossils and geologic events. It is of fundamental importance in advancing research on Ordovician rocks worldwide.

Some workers on Ordovician geology may lament the loss of the familiar regional classification (e.g. British series, Australian stages, North American series and stages) that they have long used. However, the establishment of the new global classification allows Ordovician geologists to have the best of "both worlds". The regional classifications remains unchanged, are not lost, and can continue to be used where they work best in describing regional geology. At the same time, the global units, based on cosmopolitan index species, allow for precise, reliable global correlation.

TOWARDS A CONSENSUS FOR THE NEOGENE AND QUATERNARY

Tertiary, Quaternary, Neogene, Pliocene and Pleistocene units of the stratigraphic column have seen divergent meanings and *ad hoc* definitions, both scientifically and politically inspired. Whatever the outcome of any scientific debate, it has to be presented and discussed in an organizationally correct way, well-documented, following the existing ICS rules. Hence, let us review the facts.

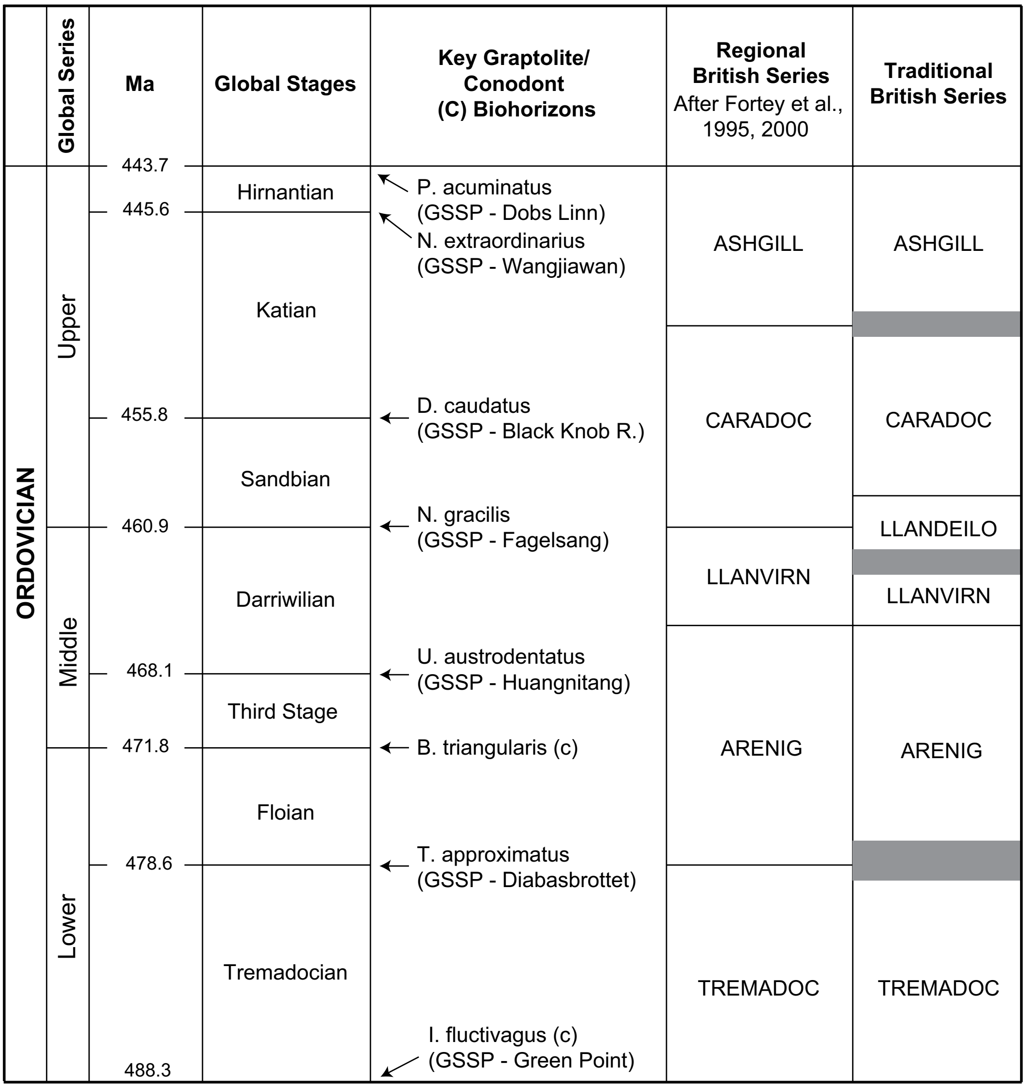


Figure 1: Ordovician chronostratigraphic chart showing global Series and Stages, both those defined and those proposed; GSSPs that have been defined and biohorizons under consideration for boundaries still to be defined; and correlation to global Series and Stages of regional British series, as redefined by Fortey et al. (1995, 2000), and of traditional British Series.

Pleistocene Epoch/Series

In 1985, a joint working group of the International Commision on Stratigraphy (ICS) and INQUA (now the International Union for Quaternary Research) formally proposed the base of the Pleistocene. The basal boundary level is the top of sapropel layer 'e' in the Vrica section, Calabria, Italy, just above top of magnetic polarity chronozone C2n (Olduvai) and the extinction level of the calcareous nannofossil *Discoaster brouweri* (base Zone CN13). Above are the lowest occurrences of medium-sized species of the calcareous nannofossil *Gephyrocapsa* and the extinction level of the planktonic foraminifer *Globigerinoides extremus*. Based on the orbitally tuned sedimentary cycles in the Vrica section, the age of the boundary is 1.806 Ma. The formal definition was ratified in 1985, and published in the journal *Episodes* (1985, vol. 8, no. 2, p. 116–120).

The base-Pleistocene proposal and ratification explicitly stated that the boundary decision was "isolated from other more or less related problems, such as … the status of the Quaternary within the chronostratigraphic scale".

The Pleistocene is an Epoch/Series unit in the International Stratigraphic Chart (see www.stratigraphy.org), with a lower rank than Neogene, Quaternary and Cenozoic.

Cenozoic Periods/Systems

The Cenozoic currently has two ratified Period/System-level divisions: (1) the Paleogene (Danian through Chattian) had its base ratified in 1991, and (2) the Neogene (Aquitanian through Recent) had its base ratified in 1996.

Neogene Period/System

The Neogene in Italy, which originally included the regional Calabrian stage, had no well-defined "top". Renevier (the first chair of what has become now ICS) and some others at the end of the 1800s had the Neogene extending to the Recent. This usage is shown in old textbooks by Krumbein and Sloss.

From the literature, the Neogene extending to the Present, has a long history, and is not in any way a novelty, as outlined clearly in *Episodes* (2005, vol. 28, no. 2, p. 118-120). Hence, *Geologic Time Scale 2004* adopted this usage to strengthen late Cenozoic stratigraphic subdivisions, and included a potential definition of the Quaternary.

Tertiary and Quaternary

The Tertiary and Quaternary have been consistently recognized by International Geological Congresses of the past century. However, there has been no clarification of their rank. This uncertain status of the former Quaternary and Tertiary eras within the chronostratigraphic scale was indicated in the 1985 base-Pleistocene ratification.

The joint INQUA-ICS Task Force on the base of the Quaternary in 2005 unanimously recommended moving Quaternary down to 2.6 May at base Gelasian. The official position of INQUA (March 2006) is that "The base of the Quaternary should be placed at the current base of GSSP Gelasian Stage (currently in the Pliocene) at MIS 103." The official voting of ICS was also 100% for placing the base of the Quaternary at this level. Therefore, both ICS and INQUA are in total agreement on the definition of the span of Quaternary.

The joint INQUA-ICS Task Force was evenly divided on whether the Quaternary, as defined above, should be given the rank of period or of sub-era. The INQUA Executive decided in May 2005 that "the Quaternary and Tertiary should have the status of sub-eras", then in March 2006 changed its mind and took the position that "the Quaternary must be a full formal chronostratigraphic unit, the appropriate status for which is the Period (or System)." However, the official voting of ICS on this recommendation generated a 70% majority vote in favor of sub-era.

At present, the Quaternary is a formal sub-era of the Cenozoic time scale. It is the interval of oscillating climatic extremes (glacial and interglacial episodes) that was initiated at about 2.6 Ma (set equal to base of Gelasian stage), therefore it encompasses the Holocene and Pleistocene epochs and the late Pliocene. Its base is equivalent to the formally ratified base of the Gelasian Stage at Monte San Nicola, Gela, Sicily, Italy; it correlates with Marine Isotopic stage 103, and base of magnetic polarity chronozone C2r (Matuyama). See also *Episodes* vol. 28, no. 2, p.118-120, 2005.

The ICS charts, database and website now indicate this status and duration of the Quaternary (Figure 2).

QUO VADIS

In September 2006, the ICS appointed a three-person late Cenozoic task force to highlight and summarize the past confused definitions of the Quaternary, and the possible path for ICS to follow to improve international stratigraphic clarity. The task force consists of Dr. Brad Pillans (Chair of the INQUA Commission on Stratigraphy), Dr. Phil Heckel (Chair of the Subcommision on Carboniferous of ICS) and Dr. Alexey S. Tesakov (Late Cenozoic stratigraphy specialist, Geology Department, Russian Academy of Sciences, Moscow). A dozen formal steps are to be considered, including the definitions of:

- Pleistocene and its base and rank;
- Quaternary and its base and rank;

ICS

INTERNATIONAL STRAT

International Commission on

Eonothem Eon	Erathem Era	Sub-Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP
Phanerozoic	Cenozoic	Quaternary *	Neogene	Holocene		0.0118	
				Pleistocene	Upper	0.126	
					Middle	0.781	
					Lower	1.806	GSSP
				Pliocene	Gelasian	2.588	GSSP
		Tertiary*			Piacenzian	3.600	GSSP
					Zanclean	5.332	GSSP
				Miocene	Messinian	7.246	GSSP
					Tortonian	11.608	GSSP
					Serravallian	13.82	GSSP
					Langhian	15.97	
					Burdigalian	20.43	
					Aquitanian	23.03	GSSP
			Paleogene	Oligocene	Chattian	28.4 ±0.1	
					Rupelian	33.9 ±0.1	GSSP
				Eocene	Priabonian	37.2 ±0.1	
					Bartonian	40.4 ±0.2	
					Lutetian	48.6 ±0.2	
					Ypresian	55.8 ±0.2	GSSP
				Paleocene	Thanetian	58.7 ±0.2	
					Selandian	61.7 ±0.2	
					Danian	65.5 ±0.3	GSSP
	Mesozoic		Cretaceous	Upper	Maastrichtian	70.6 ±0.6	GSSP
					Campanian	83.5 ±0.7	
					Santonian	85.8 ±0.7	
					Coniacian	89.3 ±1.0	
					Turonian	93.5 ±0.8	GSSP
					Cenomanian	99.6 ±0.9	GSSP
				Lower	Albian	112.0 ±1.0	
					Aptian	125.0 ±1.0	
					Barremian	130.0 ±1.5	
					Hauterivian	136.4 ±2.0	
					Valanginian	140.2 ±3.0	
					Berriasian	145.5 ±4.0	

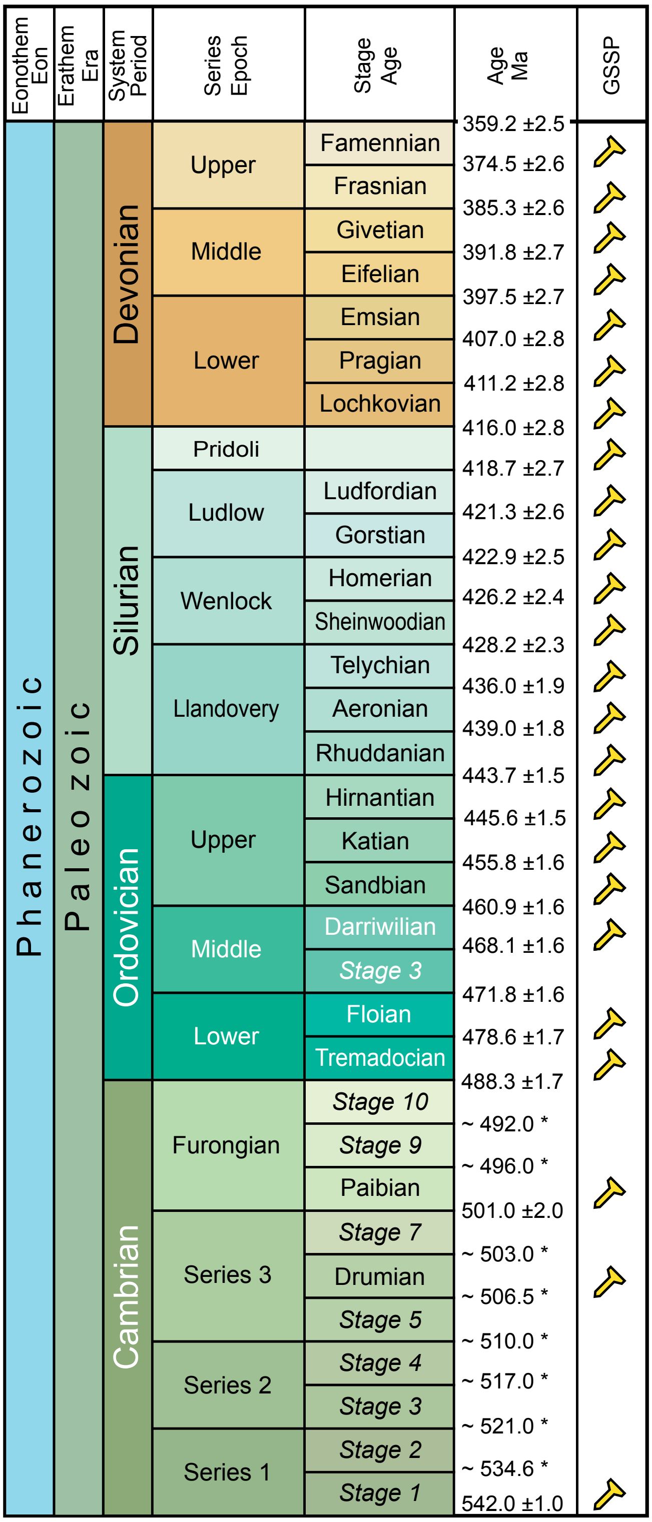
Eonothem Eon	Erathem Era	System Period		Series Epoch	Stage Age	Age Ma	GSSP
						145.5 ±4.0	
Phanerozoic	Mesozoic	Jurassic		Upper	Tithonian	150.8 ±4.0	
					Kimmeridgian	155.7 ±4.0	
					Oxfordian	161.2 ±4.0	
				Middle	Callovian	164.7 ±4.0	
					Bathonian	167.7 ±3.5	
					Bajocian	171.6 ±3.0	GSSP
					Aalenian	175.6 ±2.0	GSSP
				Lower	Toarcian	183.0 ±1.5	
					Pliensbachian	189.6 ±1.5	GSSP
					Sinemurian	196.5 ±1.0	GSSP
					Hettangian	199.6 ±0.6	
		Triassic		Upper	Rhaetian	203.6 ±1.5	
					Norian	216.5 ±2.0	
					Carnian	228.0 ±2.0	
				Middle	Ladinian	237.0 ±2.0	GSSP
					Anisian	245.0 ±1.5	
				Lower	Olenekian	249.7 ±0.7	
					Induan	251.0 ±0.4	GSSP
	Paleozoic	Permian		Lopingian	Changhsingian	253.8 ±0.7	GSSP
					Wuchiapingian	260.4 ±0.7	GSSP
				Guadalupian	Capitanian	265.8 ±0.7	GSSP
					Wordian	268.0 ±0.7	GSSP
					Roadian	270.6 ±0.7	GSSP
				Cisuralian	Kungurian	275.6 ±0.7	
					Artinskian	284.4 ±0.7	
					Sakmarian	294.6 ±0.8	
					Asselian	299.0 ±0.8	GSSP
		Carboniferous	Penn-sylvanian	Upper	Gzhelian	303.9 ±0.9	
					Kasimovian	306.5 ±1.0	
				Middle	Moscovian	311.7 ±1.1	
				Lower	Bashkirian	318.1 ±1.3	GSSP
			Missis-sippian	Upper	Serpukhovian	326.4 ±1.6	
				Middle	Visean	345.3 ±2.1	
				Lower	Tournaisian	359.2 ±2.5	GSSP

Quaternary*: Formal chronostratigraphic unit sensu joint ICS-INQUA taskforce (2005) and ICS.

Tertiary*: Informal chronostratigraphic unit sensu Aubry et al. (2005, Episodes 28/2).

IGRAPHIC CHART

Stratigraphy



This chart was drafted by Gabi Ogg. Intra Cambrian unit ages with * are informal, and awaiting ratified definitions.

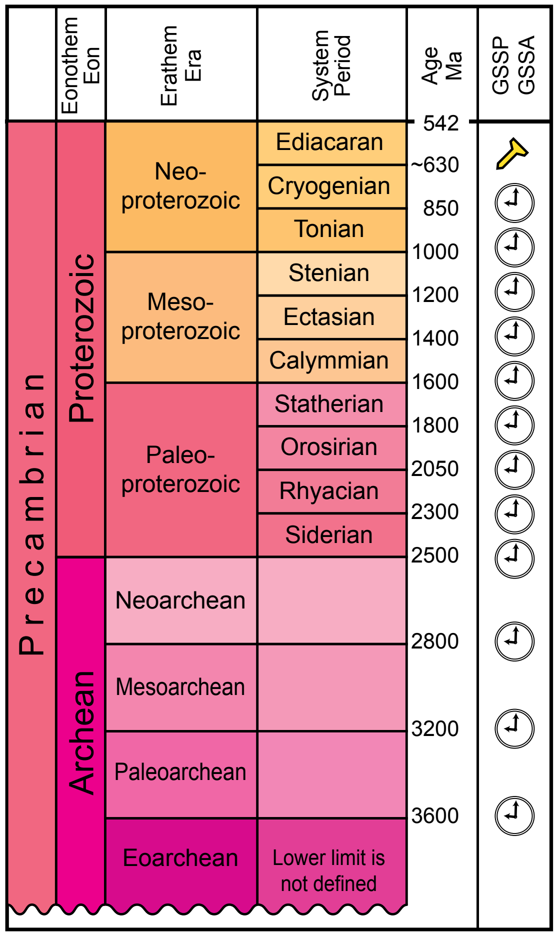


Figure 2: Subdivisions of the global geologic recordare formally defined by their lower boundary. Each unit of the Phanerozoic (~542 Ma to Present) and the base of Ediacaran are defined by a basal Global Standard Section and Point (GSSP), whereas Precambrian units are formally subdivided by absolute age (Global Standard Stratigraphic Age, GSSA). Details of each GSSP are posted on the ICS website (*www.stratigraphy.org*).

International chronostratigraphic units, rank, names and formal status are approved by the International Commission on Stratigraphy (ICS) and ratified by the International Union of Geological Sciences (IUGS).

Numerical ages of the unit boundaries in the Phanerozoic are subject to revision. Some stages within the Ordovician and Cambrian will be formally named upon international agreement on their GSSP limits. Most sub-Series boundaries (e.g., Middle and Upper Aptian) are not formally defined.

Colors are according to the Commission for the Geological Map of the World (*www.cgmw.org*).

The listed numerical ages are from 'A Geologic Time Scale 2004', by F.M. Gradstein, J.G. Ogg, A.G. Smith, et al. (2004; Cambridge University Press).

- Neogene and its top and rank;
- Paleogene rank;
- Pliocene and the placement of its stages. The use and position of Gelasian, and re-examination of its definition;
- Tertiary and its use and rank.

The task force also may want to advise on a realistic correlation web for the last 5 Ma underlying rational, global subdivisions and hierarchy. The findings of this task force will be presented at the 33th International Geologic Congress in Oslo, Norway in 2008.

Until further notice, geoscientists are advised to follow the ICS stratigraphic scheme outlined in Figure 2.

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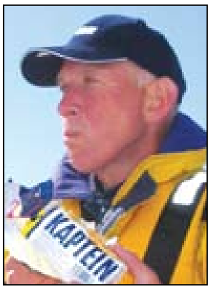
ABOUT THE AUTHORS



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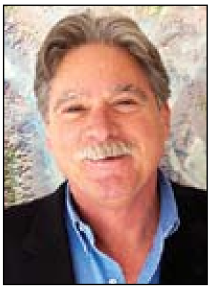

Stan Finney *is Chair and Professor of Geological Sciences at California State University at Long Beach. He has served as Chair of the International Subcommission on Ordovician Stratigraphy (1996-2004) and presently serves as Vice Chair of the International Commission on Stratigraphy (2000-2008). He is a specialist on Ordovician graptolite biostratigraphy and has published on graptolite taxonomy, paleoecology and paleobiogeography, the Late Ordovician mass extinction, and the stratigraphy and structure of the Roberts Mountains allochthon of north-central Nevada. His recent research utilizes U-Pb geochronology of detrital zircons to interpret the paleogeographic and geotectonic history of the Precordillera terrane of western Argentina.*

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