Status of Divisions of the International Geologic Time Scale

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Each chronostratigraphic unit of the International Geologic Time Scale will be defined at its base by a Global Stratotype Section and Point (GSSP) or Global Standard Stratigraphic Age (GSSA). Nearly 50 GSSPs and 10 GSSAs have now been ratified. Ideally, the GSSP coincides with events having a global correlation potential. The international stage divisions of some systems, such as the Jurassic or Neogene, are similar to traditional usage in European geology. However, in order to utilize global correlation horizons, the international stage divisions of other systems, such as the Ordovician or Permian, have required assembling new stage nomenclatures or hybrids of different regional stages. A reference table by the International Commission on Stratigraphy itemizes the current or potential GSSP and GSSA definitions of all international geologic time units. □ *Cenozoic, chronostratigraphy, GSSP, Mesozoic, Paleozoic, Precambrian.*

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Standardization of the International Geologic Time Scale

A major role of the International Commission on Stratigraphy (ICS) is the establishment and publication of a standard global stratigraphic time scale. Each formal unit of the Phanerozoic Era (542 Ma to Present) and latest Proterozoic (Ediacaran System/Period) will be defined by a Global Stratotype Section and Point (GSSP) at its base. The Archean and Proterozoic eons of the Precambrian interval are subdivided by absolute age (Global Standard Stratigraphic Age, or GSSA). Names, ranks and GSSPs of the global scale proposed by its subcommissions are approved by the International Commission on Stratigraphy and ratified by the International Union of Geological Sciences (IUGS). Each GSSP defines the initiation of a geochronologic interval (geologic time units of 'period', 'epoch', etc.) and its corresponding chronostratigraphic interval (time-rock units of 'system', 'series', 'stage', etc.). Even though a GSSP is a point within the rock record at a specific locality, its placement generally coincides with primary correlation criteria based on important faunal, magnetic, cycle and/or isotopic events that can be globally correlated. The origin, philosophy and implications of the GSSP concept are explored in a companion paper by Walsh *et al.* (2004, this issue). The ICS has the mandate to complete all GSSPs for global divisions of Earth history by 2008. When all Phanerozoic units are defined by GSSPs, then geo-history will have a universal language of a 'Standard' Geologic Time Scale.

Prominent regional lithologic characteristics in marginal marine facies were utilized for assigning many of the historic stratotypes for system, series and stage units, but their boundaries were often demarked by hiatuses. These facies shifts were commonly the local manifestation of a global environmental change, which was also accompanied by evolution or extinction of biologic species, sea-level excursions, and redistributions in the carbon cycle. The GSSP concept of high-precision correlation requires that the stage boundaries be assigned within continuous successions, but very few of the historical stratotypes qualify in this regard. Therefore, the GSSPs are commonly selected in deeper marine facies in which evolutionary events of semi-cosmopolitan pelagic fauna (conodonts, ammonoids, graptolites, planktonic foraminifers, certain types of trilobites, etc.) and/or carbon-isotope excursions serve as primary correlation markers. Stable isotope excursions and magnetic reversals are preferred secondary correlation markers, because these events are globally synchronous and can be utilized in deep marine to terrestrial sections.

The great majority of ratified or potential GSSPs are in western Europe (Fig. 1). This distribution mostly reflects that the stratigraphic studies developed in western Europe, but is also due to tectonic processes that kept western Europe in low-latitude shallow-sea environments for much of the Phanerozoic eon and have subsequently exposed the richly fossiliferous

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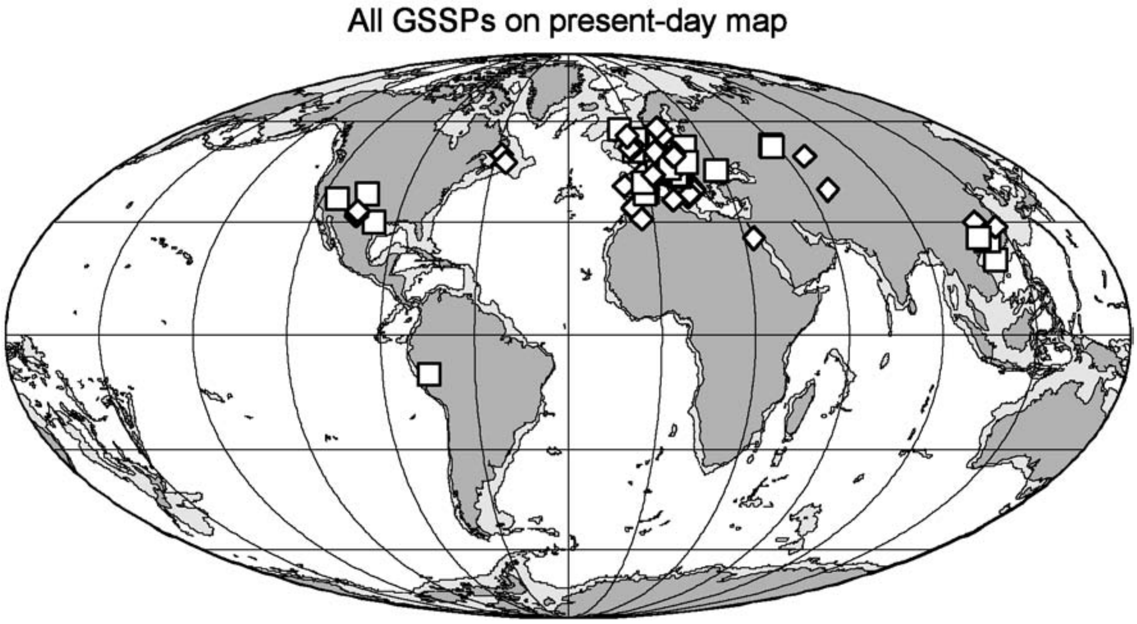

Fig. 1. Geographic distribution of ratified (diamonds) and candidate (squares) GSSPs on a present-day (0 Ma) map (status in Jan., 2004; see Table 1). Most of the GSSPs are in western Europe, where the clustering has overlapped many additional GSSPs. [This figure is modified from a compilation by Alan Smith for *Geologic Time Scale 2004*]

sections that were the basis of the historical compilations of the chronostratigraphic scale. Many of these GSSP levels are partially consistent with historical usage of stage terminology (e.g. the base-Cenomanian GSSP defining the base of the Upper Cretaceous has not departed significantly from the beginning of the Cenomanian Stage as assigned by Alcide d'Orbigny in 1847. Other GSSP levels defining stages have necessitated a revision of the historical usage (e.g. the base-Triassic GSSP is significantly younger than the major mass extinction and geochemical anomalies that were formerly grouped as the 'Permian/Triassic boundary events').

Even though the international geologic scale is defined with global events (when possible), numerous regional scales of traditional usage are built from local significant changes in sediment, paleoenvironment or fossil characteristics. For example, the 'Cincinnatian' is an upper Ordovician unit that has been used for over a century in the central part of USA. One must be able to easily and confidently convert from these traditional regional scales to the international standard as defined by GSSPs, and to correlation among different regional scales. Indeed, this is the heart of compiling a global Earth history – how to relate the well-documented successions of events in each region to the other regions of the planet. Only in this way can geoscientists understand the intricate workings of evolution, of environmental cause-effect, of tectonics and of geochemical cycling. This is one of the main goals of the different subcommissions of the International Commission on Stratigraphy.

As of March 2004, approximately two-thirds of the ~90 stage-level Phanerozoic divisions of the international geologic scale are defined by GSSPs at their boundaries, and primary correlation criteria have been decided for GSSPs of most other stages. An itemized summary of these GSSP placements and associated nomenclature for the chronostratigraphic units are provided in Tables 1 and 2, and are schematically shown in Figure 2. The current listing, including a standardized description, map and stratigraphic column for each GSSP, is maintained at the ICS website (www.stratigraphy.org). The estimated absolute age (Ma) for each stage boundary is from *A Geologic Time Scale 2004* (Gradstein, *et al.* in press) and is summarized in a companion paper by Gradstein & Ogg (2004, this issue). In general, the age for each GSSP horizon is extrapolated after calibrating a primary scale (e.g. biostratigraphic zonation, marine magnetic anomaly pattern) to selected radiometric ages. There is direct radiometric dating of only a few GSSPs (e.g. base-Triassic, base-Turonian) or their primary correlation horizons (e.g. base-Cambrian, base-Jurassic, Cretaceous/Palaeogene boundary). However, orbital-climate 'Milankovitch' cycles enable direct age assignments to several of the Neogene GSSP levels.

These brief summaries of the GSSP placements for

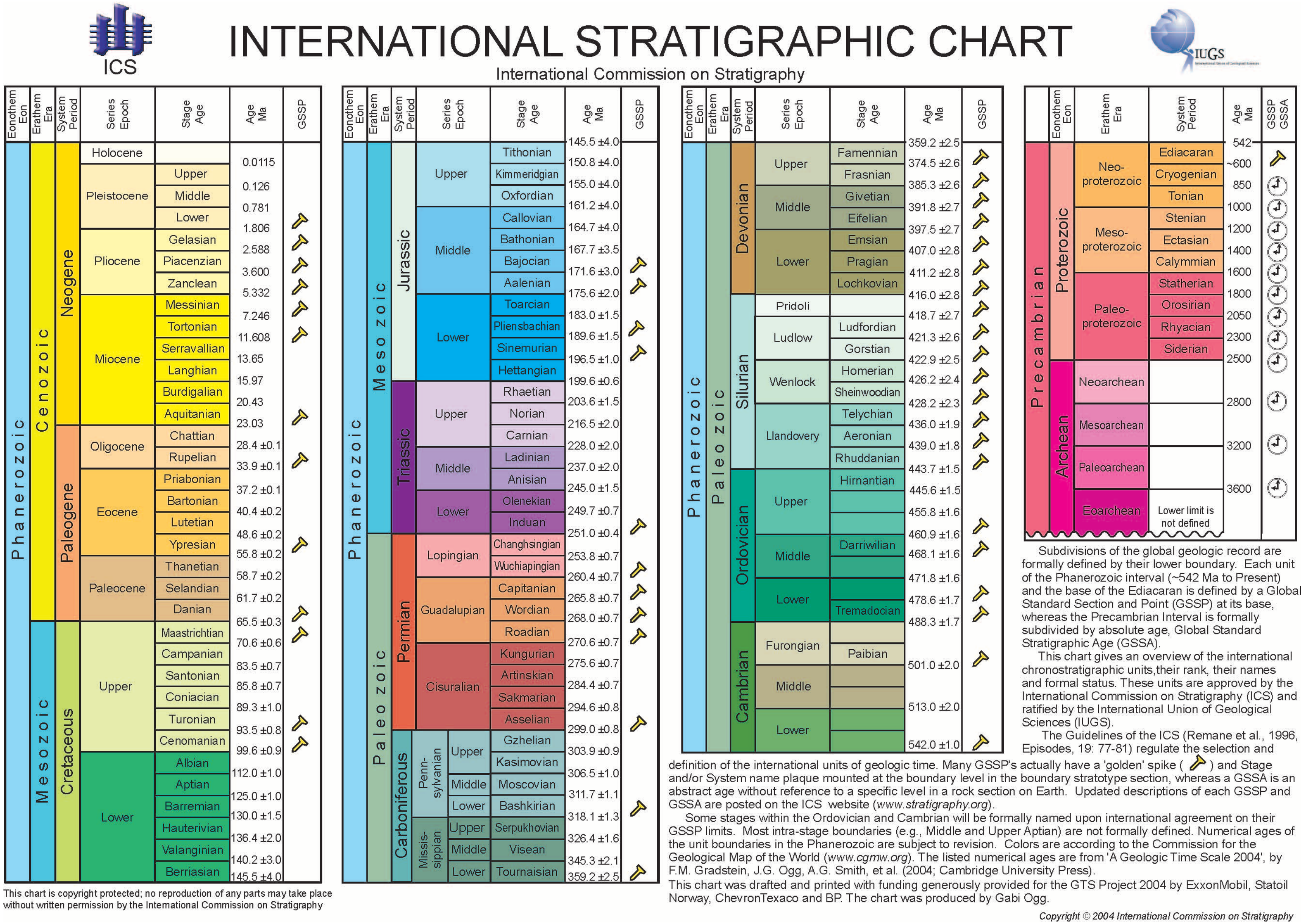

Fig. 2. The International Stratigraphic Chart for the Precambrian and Phanerozoic with ratified GSSPs (status in March 2004). The colours are the standard suite of the Commission for the Geologic Map of the World (UNESCO). Updated versions of this figure can be downloaded from the website (*www.stratigraphy.org*) of the International Commission on Stratigraphy of IUGS.

Table 1. Status as of March 2004 of GSSP and GSSA definitions for lower boundaries of international geologic stages, periods and eras. The background shading is the standard colour scale of the US Geologic Survey. Updates of this compilation can be obtained from the website (*www.stratigraphy.org*) of the International Commission on Stratigraphy of IUGS.

Global Boundary Stratotype Sections and Points (GSSPs)
Status in March 2004; see ICS website (www.stratigraphy.org) for updates

EON, Era, System, ***Series***, Stage	Age (Ma) GTS2004	Est. ± myr	Derivation of Age	Principal correlative events	GSSP and location	Status	Publication
PHANEROZOIC							
Cenozoic Era							
Neogene System				The ***"Quaternary"*** is traditionally considered to be the interval of oscillating climatic extremes (glacial and interglacial episodes) that was initiated at about 2.6 Ma, therefore encompasses the Holocene, Pleistocene and uppermost Pliocene. It is not a formal chronostratigraphic unit.			
Holocene Series							
base Holocene	11.5 ka	0.00	Carbon-14 dating calibration	exactly 10,000 Carbon-14 years (= 11.5 ka calendar years BP) at the end of the Younger Dryas cold spell		Informal working definition	
Pleistocene Series							
base Upper Pleistocene subseries	0.126	0.00	Astronomical cycles in sediments	base of the Eemian interglacial stage (= base of marine isotope stage 5e) before final glacial episode of Pleistocene	Potentially, within sediment core under the Netherlands (Eemian type area)	Informal working definition	
base Middle Pleistocene subseries	0.781	0.00	Astronomical cycles in sediments	Brunhes-Matuyama magnetic reversal		Informal working definition	
base Pleistocene Series	1.806	0.00	Astronomical cycles in sediments	Just above top of magnetic polarity chronozone C2n (Olduvai) and the extinction level of calcareous nannofossil *Discoaster brouweri* (base Zone CN13). Above are lowest occurrence of calcareous nannofossil medium *Gephyrocapsa* spp. and extinction level of planktonic foraminifer *Globigerinoides extremus.*	Top of sapropel layer 'e', Vrica section, Calabria, Italy	Ratified 1985	Episodes 8 (2), p.116–120, 1985
Pliocene Series							
base Gelasian Stage	2.588	0.00	Astronomical cycles in sediments	Isotopic stage 103, base of magnetic polarity chronozone C2r (Matuyama). Above are extinction levels of calcareous nannofossil *Discoaster pentaradiatus* and *D. surculus* (base Zone CN12c).	Midpoint of sapropelic Nicola Bed ("A5"), Monte San Nicola, Gela, Sicily, Italy	Ratified 1996	Episodes 21 (2), p.82–87, 1998
base Piacenzian Stage	3.600	0.00	Astronomical cycles in sediments	Base of magnetic polarity chronozone C2An (Gauss); extinction levels of planktonic foraminifers *Globorotalia margaritae* (base Zone PL3) and *Pulleniatina primalis.*	Base of beige layer of carbonate cycle 77, Punta Piccola, Sicily, Italy	Ratified 1997	Episodes 21 (2), p.88–93, 1998
base Zanclean Stage, base Pliocene Series	5.332	0.00	Astronomical cycles in sediments	Top of magnetic polarity chronozone C3r, ~100 kyr before Thvera normal-polarity subchronozone (C3n.4n). Calcareous nannofossils – near extinction level of *Triquetrorhabdulus rugosus* (base Zone CN10b) and the lowest occurrence of *Ceratolithus acutus.*	Base of Trubi Fm (base of carbonate cycle 1), Eraclea Minoa, Sicily, Italy	Ratified 2000	Episodes 23 (3), p.179–187, 2000
Miocene Series							
base Messinian Stage	7.246	0.00	Astronomical cycles in sediments	Astrochronology age of 7.246 Ma; middle of magnetic polarity chronozone C3Br.1r; lowest regular occurrence of the *Globorotalia conomiozea* planktonic foraminifer group.	Base of red layer of carbonate cycle 15, Oued Akrech, Rabat, Morocco	Ratified 2000	Episodes 23 (3), p.172–178, 2000

base Tortonian Stage	11.608	0.00	Astronomical cycles in sediments	Last Common Occurrences of the calcareous nannofossil *Discoaster kugleri* and the planktonic foraminifer *Globigerinoides subquadratus*. Associated with the short normal-polarity subchron C5r.2n.	Midpoint of sapropel 76, Monte dei Corvi beach section, Ancona, Italy	Ratified 2003	*Episodes article in preparation*
base Serravallian Stage	13.65	0.00	Astronomical cycles in sediments	Near lowest occurrence of nannofossil *Sphenolithus heteromorphus*, and within magnetic polarity chronozone C5ABr.		GSSP anticipated in 2004	
base Langhian Stage	15.97	0.0	Calibrated magnetic anomaly scale	Near first occurrence of planktonic foraminifer *Praeorbulina glomerosa* and top of magnetic polarity chronozone C5Cn.1n		GSSP anticipated in 2004	
base Burdigalian Stage	20.43	0.0	Calibrated magnetic anomaly scale	Near lowest occurrence of planktonic foraminifer *Globigerinoides altiaperturus* or near top of magnetic polarity chronozone C6An		*Guide event is undecided*	
base Aquitanian Stage, base Miocene Series, base Neogene System	23.03	0.0	Astronomical cycles in sediments	Base of magnetic polarity chronozone C6Cn.2n; lowest occurrence of planktonic foraminifer *Paragloborotalia kugleri*; near extinction of calcareous nannofossil *Reticulofenestra bisecta* (base Zone NN1).	35 m from top of Lemme-Carrosio section, Carrosio village, north of Genoa, Italy	Ratified 1996	Episodes 20 (1), p.23–28, 1997
Paleogene System							
Oligocene Series							
base Chattian Stage	28.4	0.1	Calibrated magnetic anomaly scale relative to base-Miocene and C24n. Arbitrary 100 kyr uncertainty assigned.	Planktonic foraminifer, extinction of *Chiloguembelina* (base Zone P21b)	Probably in Umbria-Marche region of Italy	GSSP anticipated in 2004	
base Rupelian Stage, base Oligocene Series	33.9	0.1	Calibrated magnetic anomaly scale relative to base-Miocene and C24n.	Planktonic foraminifer, extinction of *Hantkenina*	Base of marl bed at 19 m above base of Massignano quarry, Ancona, Italy	Ratified 1992	Episodes 16 (3), p.379–382, 1993
Eocene Series							
base Priabonian Stage	37.2	0.1	Calibrated magnetic anomaly scale relative to base-Miocene and C24n.	Near lowest occurrence of calcareous nannofossil *Chiasmolithus oamaruensis* (base Zone NP18)	Probably in Umbria-Marche region of Italy		
base Bartonian Stage	40.4	0.2	Calibrated magnetic anomaly scale relative to base-Miocene and C24n.	Near extinction of calcareous nannofossil *Reticulofenestra reticulata*			
base Lutetian Stage	48.6	0.2	Calibrated magnetic anomaly scale relative to base-Miocene and C24n.	Planktonic foraminifer, lowest occurrence of *Hantkenina*	Leading candidate is Fortuna section, Murcia province, Betic Cordilleras, Spain	GSSP anticipated in 2004	
base Ypresian Stage, base Eocene Series	55.8	0.2	Astronomical cycles in sediments scaled from base-Paleocene	Base of negative carbon-isotope excursion	Dababiya section near Luxor, Egypt	Ratified 2003	Micropaleontology v.49 (Suppl. 1), 2003. *Episodes article in preparation*
Paleocene Series							
base Thanetian Stage	58.7	0.2	Astronomical cycles in sediments scaled from base Paleocene, using base of magnetic polarity chronozone C26n. Arbitrary 0.1 (2 precession cycles, plus the base-Paleogene radiometric) uncertainty assigned to all estimates.	Magnetic polarity chronozone, base of C26n, is a temporary assignment	Leading candidate is Zumaya section, northern Spain	*Guide event is undecided*	

Continues.

Table 1. continued.

Global Boundary Stratotype Sections and Points (GSSPs) *Status in March 2004; see ICS website (www.stratigraphy.org) for updates*							
EON, Era, System, ***Series,*** Stage	Age (Ma) GTS2004	Est. ± myr	Derivation of Age	Principal correlative events	GSSP and location	Status	Publication
base Selandian Stage	61.7	0.2	Astronomical cycles in sediments scaled from base Paleocene, using magnetic polarity chronozone placement of C27n.9	Boundary task group is considering a higher level – base of calcareous nannofossil zone NP5 – which would be ~1 myr younger.	Leading candidate is Zumaya section, northern Spain	*Guide event is undecided*	
base Danian Stage, base Paleogene System, base Cenozoic	65.5	0.3	Ar-Ar and U-Pb age agreement	Iridium geochemical anomaly. Associated with a major extinction horizon (foraminifers, calcareous nannofossils, dinosaurs, etc.);	Base of boundary clay, El Kef, Tunisia *(but deterioration may require assigning a replacement section)*	Ratified 1991	
Mesozoic Era Cretaceous System				*Most substages of Cretaceous also have recommended GSSP criteria*			
Upper							
base Maastrichtian Stage	70.6	0.6	Estimated placement relative to Ar-Ar calibrated Sr-curve	Mean of 12 biostratigraphic criteria of equal importance. Closely above is lowest occurrence of ammonite *Pachydiscus neubergicus*. Boreal proxy is lowest occurrence of belemnite *Belemnella lanceolata*.	115.2 m level in Grande Carrière quarry, Tercis-les-Bains, Landes province, SW France	Ratified 2001	Episodes 24 (4), p.229–238, 2001; Odin (ed.) IUGS Spec. Publ. Series, v.36, Elsevier, 910pp.
base Campanian Stage	83.5	0.7	Spline fit of Ar-Ar ages and ammonite zones.	Crinoid, extinction of *Marsupites testudinarius*	Leading candidates are in southern England and in Texas		
base Santonian Stage	85.8	0.7	Spline fit of Ar-Ar ages and ammonite zones.	Inoceramid bivalve, lowest occurrence of *Cladoceramus undulatoplicatus*	Leading candidates are in Spain, England and Texas		
base Coniacian Stage	89.3	1.0	Spline fit of Ar-Ar ages and ammonite zones.	Inoceramid bivalve, lowest occurrence of *Cremnoceramus rotundatus* (*sensu* Tröger *non* Fiege)	Base of Bed MK47, Salzgitter-Salder Quarry, SW of Hannover, Lower Saxony, northern Germany	GSSP anticipated in 2004	
base Turonian Stage	93.5	0.8	Spline fit of Ar-Ar ages and ammonite zones.	Ammonite, lowest occurrence of *Watinoceras devonense*	Base of Bed 86, Rock Canyon Anticline, east of Pueblo, Colorado, west-central USA	Ratified 2003	*Episodes article in preparation*
base Cenomanian Stage	99.6	0.9	Spline fit of Ar-Ar ages and ammonite zones, plus monitor standard correction. Then cycle stratigraphy to place foraminifer datum relative to ammonite zonation.	Planktonic foraminifer, lowest occurrence of *Rotalipora globotruncanoides*	36 m below top of Marnes Bleues Formation, Mont Risou, Rosans, Haute-Alpes, SE France	Ratified 2002	*Episodes 27 (1), p.21–32, 2004*
Lower							
base Albian Stage	112.0	1.0	Estimated placement relative to bases of Cenomanian and Aptian, with large uncertainty due to lack of GSSP criteria. Ar-Ar age of 114.6 +/− 0.7 Ma from *Parahoplites nutfieldensis* below.	Calcareous nannofossil, lowest occurrence of *Praediscosphaera columnata* (= *P. cretacea* of some earlier studies), is one potential marker.		*Guide event is undecided*	
base Aptian Stage	125.0	1.0	Base of M0r, as recomputed from Ar-Ar age from MIT guyot	Magnetic polarity chronozone, base of M0r	Leading candidate is Gorgo a Cerbara, Piobbico, Umbria-Marche, central Italy		
base Barremian Stage	130.0	1.5	Pacific spreading model for magnetic anomaly ages (variable rate), using placement at M5n.8.	Ammonite, lowest occurrence of *Spitidiscus hugii – Spitidiscus vandeckii* group	Leading candidate is Río Argos near Caravaca, Murcia province, Spain		

base Hauterivian Stage	136.4	2.0	Pacific spreading model for magnetic anomaly ages (variable rate), using placement at base M11n.	Ammonite, lowest occurrence of genus *Acanthodiscus* (especially *A. radiatus*)	Leading candidate is La Charce village, Drôme province, southeast France		
base Valanginian Stage	140.2	3.0	Pacific spreading model for magnetic anomaly ages (variable rate), using placement at M14r.3 (base *T. pertransiens*).	Calpionellid, lowest occurrence of *Calpionellites darderi* (base of Calpionellid Zone E); followed by the lowest occurrence of ammonite *"Thurmanniceras" pertransiens*	Leading candidate is near Montbrun-les-Bains, Drôme province, southeast France		
base Berriasian Stage, base Cretaceous System	145.5	4.0	Pacific spreading model for magnetic anomaly ages (variable rate), assigning to base of *Berriasella jacobi* zone (M19n.2n.55)	Maybe near lowest occurrence of ammonite *Berriasella jacobi*		*Guide event is undecided*	
Jurassic System							
Upper							
base Tithonian Stage	150.8	4.0	Pacific spreading model for magnetic anomaly ages (variable rate), assigning to base M22An	Near base of *Hybonoticeras hybonotum* ammonite zone and lowest occurrence of *Gravesia* genus, and the base of magnetic polarity chronozone M22An		*Guide event is undecided*	
base Kimmeridgian Stage	155.7	4.0	Pacific spreading model for magnetic anomaly ages (variable rate), age is assigned as base M26r.2, using the Boreal ammonite definition	Ammonite, near base of *Pictonia baylei* ammonite zone of Boreal realm	Leading candidates are In Scotland, SE France and Poland	GSSP anticipated in 2004	
base Oxfordian Stage	161.2	4.0	Pacific spreading model for magnetic anomaly ages (variable rate), assigning to base M36An	Ammonite, *Brightia thuouxensis* Horizon at base of the *Cardioceras scarburgense* Subzone (*Quenstedtoceras mariae* Zone)	Leading candidates are in SE France and southern England	GSSP anticipated in 2004	
Middle							
base Callovian Stage	164.7	4.0	Equal subzones scale Bajo-Bath-Callov	Ammonite, lowest occurrence of the genus *Kepplerites (Kosmoceratidae)* (defines base of *Macrocephalites herveyi* Zone in sub-Boreal province of Great Britain to southwest Germany)	Leading candidate is Pfeffingen, Swabian Alb, SW Germany	GSSP anticipated in 2004	
base Bathonian Stage	167.7	3.5	Equal subzones scale Bajo-Bath-Callov	Ammonite, lowest occurrence of *Parkinsonia (G.) convergens* (defines base of *Zigzagiceras zigzag* Zone)			
base Bajocian Stage	171.6	3.0	Equal subzones scale Bajo-Bath-Callov	Ammonite, lowest occurrence of the genus *Hyperlioceras* (defines base of the *Hyperlioceras discites* Zone)	Base of Bed AB11, 77.8 m above base of Murtinheira section, Cabo Mondego, western Portugal	Ratified 1996	Episodes 20 (1), p.16–22, 1997
base Aalenian Stage	175.6	2.0	Duration of Aalenian-Toarcian from cycle stratigraphy	Ammonite, lowest occurrence of *Leioceras* genus	base of Bed FZ107, Fuentelsalz, central Spain	Ratified 2000	Episodes 24 (3), p.166–175, 2001
Lower							
base Toarcian Stage	183.0	1.5	Duration of Aalenian-Toarcian from cycle stratigraphy	Ammonite, near lowest occurrence of a diversified *Eodactylites* ammonite fauna; correlates with the NW European *Paltus* horizon.		*Guide event is undecided*	
base Pliensbachian Stage	189.6	1.5	Cycle-scaled linear Sr trend	Ammonite, lowest occurrences of *Bifericeras donovani* and of genera *Apoderoceras* and *Gleviceras*.	Wine Haven section, Robin Hood's Bay, Yorkshire, England, UK	GSSP anticipated in 2003	
base Sinemurian Stage	196.5	1.0	Cycle-scaled linear Sr trend	Ammonite, lowest occurrence of arietitid genera *Vermiceras* and *Metophioceras*	0.9 m above base of Bed 145, East Quantoxhead, Watchet, West Somerset, SW England, UK	Ratified 2000	Episodes 25 (1), p.22–26, 2002
base Hettangian Stage, base Jurassic System	199.6	0.6	U-Pb age just below proposed GSSP for base-Jurassic	Near lowest occurrence of smooth *Psiloceras planorbis* ammonite group		*Guide event is undecided*	

Continues.

Table 1. continued.

Global Boundary Stratotype Sections and Points (GSSPs)
Status in March 2004; see ICS website (www.stratigraphy.org) for updates

EON, Era, System, ***Series,*** Stage	Age (Ma) GTS2004	Est. ± myr	Derivation of Age	Principal correlative events	GSSP and location	Status	Publication
Triassic System							
Upper							
base Rhaetian Stage	203.6	1.5	Magnetostratigraphic correlation to cycle-scaled Newark magnetic polarity pattern	Near lowest occurrence of ammonite *Cochlocera,* conodonts *Misikella* spp. and *Epigondolella mosheri,* and radiolarian *Proparvicingula moniliformis.*	Key sections in Austria, British Columbia (Canada), and Turkey	*Guide event is undecided*	
base Norian Stage	216.5	2.0	Magnetostratigraphic correlation to cycle-scaled Newark magnetic polarity pattern	Base of *Klamathites macrolobatus* or *Stikinoceras kerri* ammonoid zones and the *Metapolygnathus communisti* or *M. primitius* conodont zones.	Leading candidates are in British Columbia (Canada), Sicily (Italy), and possibly Slovakia, Turkey (Antalya Taurus) and Oman.	*Guide event is undecided*	
base Carnian Stage	228.0	2.0	Magnetostratigraphic correlation to cycle-scaled Newark magnetic polarity pattern	Near first occurrence of the ammonoids *Daxatina* or *Trachyceras,* and of the conodont *Metapolygnathus polygnathiformis*	Candidate section at Prati di Stuores, Dolomites, northern Italy. Important reference sections in Spiti (India) and New Pass, Nevada (USA).	*Guide event is undecided*	
Middle							
base Ladinian Stage	237.0	2.0	U-Pb array by Mundil et al. on levels near *Nevadites* (= *Secedensis*) ammonite zone in Dolomites, plus placement relative to magnetostratigraphy correlations to cycle-scaled Newark magnetic polarity pattern	Alternate levels are near base of *Reitzi, Secedensis,* or *Curionii* ammonite zone; near first occurrence of the conodont genus *Budurovignathus.*	Leading candidates are Bagolino (Italy) and Felsoons (Hungary). Important reference sections in the Humboldt Range, Nevada (USA).	*Guide event is undecided*	
base Anisian Stage	245.0	1.5	Proportional subzonal scaling	Ammonite, near lowest occurrences of genera *Japonites, Paradanubites, and Paracrochordiceras;* and of the conodont *Chiosella timorensis*	Candidate section probable at Desli Caira, Dobrogea, Romania; significant sections in Guizhou Province (China).	GSSP anticipated in 2004	
Lower							
base Olenekian Stage	249.7	0.7	Composite standard from conodonts scaled to base-Anisian and base-Triassic	Near lowest occurrence of *Hedenstroemia* or *Meekoceras gracilitatis* ammonites, and of the conodont *Neospathodus waageni.*	Candidate sections in Siberia (Russia) and probably Chaohu, Anhui Province, China. Important sections also in Spiti.	*Guide event is undecided*	
base Induan Stage, base Triassic System, base Mesozoic	251.0	0.4	U-Pb ages bracket GSSP (Bowring et al., 1998)	Conodont, lowest occurrence of *Hindeodus parvus*; termination of major negative carbon-isotope excursion. About 1 myr after peak of Late Permian extinctions.	Base of Bed 27c, Meishan, Zhejiang, China	Ratified 2001	Episodes 24 (2), p.102–114, 2001
Paleozoic Era							
Permian System			Permian-Carboniferous time scale is derived from calibrating a master composite section to selected radiometric ages				
Lopingian Series							
base Changhsingian Stage	253.8	0.7	”	Conodont, near lowest occurrence of conodont *Clarkina wangi*	Leading candidates are in China		
base Wuchiapingian Stage	260.4	0.7	”	Conodont, near lowest occurrence of conodont *Clarkina postbitteri*	Candidate section is Tieqiao rail-bridge section, Laibin Syncline, Guangxi Province, China	Ratification pending (Feb'04)	

Guadalupian Series							
base Capitanian Stage	265.8	0.7	”	Conodont, lowest occurrence of *Jinogondolella postserrata*	4.5 m above base of Pinery Limestone Member, Nipple Hill, SE Guadalupe Mountains, Texas, USA	Ratified 2001	*Episodes article in preparation*
base Wordian Stage	268.0	0.7	”	Conodont, lowest occurrence of *Jinogondolella aserrata*	7.6 m above base of Getaway Ledge outcrop, Guadalupe Pass, SE Guadalupe Mountains, Texas, USA	Ratified 2001	*Episodes article in preparation*
base Roadian Stage	270.6	0.7		Conodont, lowest occurrence of *Jinogondolella nanginkensis*	42.7 m above base of Cutoff Formation, Stratotype Canyon, southern Guadalupe Mountains, Texas, USA	Ratified 2001	*Episodes article in preparation*
Cisuralian Series							
base Kungurian Stage	275.6	0.7		Conodont, near lowest occurrence of conodont *Neostreptognathus pnevi-N. exculptus*	Leading candidates are in southern Ural Mtns.		
base Artinskian Stage	284.4	0.7	”	Conodont, lowest occurrence of conodont *Sweetognathus whitei*	Leading candidates are in southern Ural Mtns.		
base Sakmarian Stage	294.6	0.8	”	Conodont, near lowest occurrence of conodont *Sweetognathus merrelli*	Leading candidate is at Kondurovsky, Orenburg Province, Russia.		
base Asselian Stage, base Permian System	299.0	0.8	”	Conodont, lowest occurrence of *Streptognathodus isolatus* within the *S. "wabaunsensis"* conodont chronocline. 6 m higher is lowest fusilinid foraminifer *Sphaeroschwagerina vulgaris aktiubensis.*	27 m above base of Bed 19, Aidaralash Creek, Aktöbe, southern Ural Mountains, northern Kazakhstan	Ratified 1996	Episodes 21 (1), p.11–18, 1998
Carboniferous System							
Pennsylvanian Subsystem				*Series classification approved in 2004*			
Upper							
base Gzhelian Stage	303.9	0.9	”	Near lowest occurrences of the fusulinids *Daixina, Jigulites* and *Rugosofusulina, or* lowest occurrence of *Idiognathodus simulator* (s.str.). Close to lowest occurrence of ammonoid *Shumardites.*		*Guide event is undecided*	
base Kasimovian Stage, base Upper Pennsylvanian Series	306.5	1.0	”	Near base of *Obsoletes obsoletes* and *Protriticites pseudomontiparus* fusulinid zone, or lowest occurrence of conodont *Streptognathodus subexcelsus* or ammonoid *Parashumardites*		*Guide event is undecided*	
Middle							
base Moscovian Stage, base Middle Pennsylvanian Series	311.7	1.1	”	Near lowest occurrences of conodonts *Declinognathodus donetzianus* and/or *Idiognathoides postsulcatus*, and of fusulinid *Aliutovella aliutovica*.		*Guide event is undecided*	
Lower							
base Bashkirian Stage, base Pennsylvanian Subsystem	318.1	1.3	”	Conodont, lowest occurrence of *Declinognathodus nodiliferus* s.l.	82.9 m above top of Battleship Wash Fm., Arrow Canyon, southern Nevada, USA	GSSP ratified 1996. Subsystem rank of Mississippian and Pennsylvanian names ratified 2000.	Episodes 22 (4), p.272–283, 1999
Mississippian Subsystem				*Series classification approved in 2004*			
Upper							
base Serpukhovian, base Upper Mississippian Series	326.4	1.6	”	Near lowest occurrence of conodont, *Lochriea ziegleri*		*Guide event is undecided*	

Continues.

Table 1. continued.

Global Boundary Stratotype Sections and Points (GSSPs)
Status in March 2004; see ICS website (www.stratigraphy.org) for updates

EON, Era, System, ***Series,*** Stage	Age (Ma) GTS2004	Est. ± myr	Derivation of Age	Principal correlative events	GSSP and location	Status	Publication
Middle base Visean, base Middle Mississippian Series	345.3	2.1	"	Foraminifer, lineage *Eoparastaffella simplex* morphotype 1/morphotype 2	Leading candidate is Pengchong, south China		
Lower base Tournaisian, base Mississippian Subsystem, base Carboniferous System	359.2	2.5	"	Conodont, above lowest occurrence of *Siphonodella sulcata*	Base of Bed 89, La Serre, Montagne Noir, Cabrières, southern France	Ratified 1990	Episodes 14 (4), p.331–336, 1991
Devonian System			Devonian time scale is a statistical fit of a composite biostratigraphic zonation (based on Figure 8 of Williams et al., 2000) to selected radiometric ages				
Upper base Famennian Stage	374.5	2.6	"	Just above major extinction horizon (Upper Kellwasser Event), including conodonts *Ancyrodella* and *Ozarkodina and goniatites of Gephuroceratidae and Beloceratidae*	base of Bed 32a, upper Coumiac quarry, Cessenon, Montagne Noir, southern France	Ratified 1993	Episodes 16 (4), p.433–441, 1993
base Frasnian Stage	385.3	2.6	"	Conodont, lowest occurrence of *Ancyrodella rotundiloba* (defines base of Lower *Polygnathus asymmetricus* conodont Zone)	Base of Bed 42a', Col du Puech de la Suque section, St. Nazaire-de-Ladarez, SE Montagne Noir, southern France	Ratified 1986	Episodes 10 (2), p.97–101, 1987
Middle base Givetian Stage	391.8	2.7	"	Conodont, lowest occurrence of Polygnathus hemiansatus, near base of goniatite Maenioceras Stufe	Base of Bed 123, Jebel Mech Irdane ridge, Tafilalt, Morocco	Ratified 1994	Episodes 18 (3), p.107–115, 1995
base Eifelian Stage	397.5	2.7	"	Conodont, lowest occurrence of *Polygnathus costatus partitus*; major faunal turnover	Base unit WP30, trench at Wetteldorf Richtschnitt, Schönecken-Wetteldorf, Eifel Hills, western Germany	Ratified 1985	Episodes 8 (2), p.104–109, 1985
Lower base Emsian Stage	407.0	2.8	"	Conodont, lowest occurrence of *Polygnathus kitabicus* (= *Po. dehiscens*)	Base of Bed 9/5, Zinzil'ban Gorge, SE of Samarkand, Uzbekistan	Ratified 1995	Episodes 20 (4), p.235–240, 1997
base Pragian Stage	411.2	2.8	"	Conodont, lowest occurrence of *Eognathodus sulcatus*	Base of Bed 12, Velká Chuchle quarry, southwest part of Prague city, Czech Republic	Ratified 1989	Episodes 12 (2), p.109–113, 1989
base Lochkovian Stage, base Devonian System	416.0	2.8	base-Devonian from scale in Cooper (this volume), which is 1 myr younger than Tucker et al (1998) estimate.	Graptolite, lowest occurrence of *Monograptus uniformis*	Within Bed 20, Klonk, Barrandian area, southwest of Prague, Czech Republic	Ratified 1972	Martinsson (ed.), The Silurian-Devonian Boundary, IUGS Series A, no.5, 349 pp., 1977
Silurian System			Silurian and Ordovician time scales are from calibrating a CONOP composite graptolite zonation to selecte radiometric ages				Holland and Bassett (eds), *A Global Standard for the Silurian System*, Nat. Mus. Wales, Geol. Series No.10, Cardiff, 325 pp., 1989

Pridoli Series							
base Prídolí Series *(not subdivided in stages)*	418.7	2.7	”	Graptolite, lowest occurrence of *Monograptus parultimus*	Within Bed 96, Pozáry section near Reporje, Barrandian area, Prague, Czech Republic	Ratified 1984	Episodes 8 (2), p.101–103, 1985
Ludlow Series		2.6					
base Ludfordian Stage	421.3	2.6	”	*Imprecise.* May be near base of *Saetograptus leintwardinensis* graptolite zone.	Base of lithologic unit C, Sunnyhill Quarry, Ludlow, Shropshire, southwest England, UK	Ratified 1980	Lethaia 14, p.168, 1981; Episodes 5 (3), p.21–23, 1982
base Gorstian Stage	422.9	2.5	”	*Imprecise.* Just below base of local acritarch *Leptobrachion longhopense* range zone. May be near base of *Neodiversograptus nilssoni* graptolite zone.	Base of lithologic unit F, Pitch Coppice quarry, Ludlow, Shropshire, southwest England, UK	Ratified 1980	Lethaia 14, p.168, 1981; Episodes 5 (3), p.21–23, 1982
Wenlock Series							
base Homerian Stage	426.2	2.4	”	Graptolite, lowest occurrence of *Cyrtograptus lundgreni* (defines base of *C. lundgreni* graptolite zone)	Graptolite biozone intersection in stream section in Whitwell Coppice, Homer, Shropshire, southwest England, UK	Ratified 1980	Lethaia 14, p.168, 1981; Episodes 5 (3), p.21–23, 1982
base Sheinwoodian Stage	428.2	2.3	”	*Imprecise.* Between the base of acritarch biozone 5 and extinction of conodont *Pterospathodus amorphognathoides.* May be near base of *Cyrtograptus centrifugus* graptolite zone.	Base of lithologic unit G, Hughley Brook, Apedale, Shropshire, southwest England, UK	Ratified 1980	Lethaia 14, p.168, 1981; Episodes 5 (3), p.21–23, 1982
Llandovery Series							
base Telychian Stage	436.0	1.9	”	Brachiopods, just above extinction of *Eocoelia intermedia* and below lowest succeeding species *Eocoelia curtisi.* Near base of *Monograptus turriculatus* graptolite zone.	Locality 162 in transect d, Cefn Cerig road, Llandovery area, south-central Wales, UK	Ratified 1984	Episodes 8 (2), p.101–103, 1985
base Aeronian Stage	439.0	1.8	”	Graptolite, lowest occurrence of *Monograptus austerus sequens* (defines base of *Monograptus triangulatus* graptolite zone)	Base of locality 72 in transect h, Trefawr forestry road, north of Cwm-coed-Aeron Farm, Llandovery area, south-central Wales, UK	Ratified 1984	Episodes 8 (2), p.101–103, 1985
base Rhuddanian Stage, base Silurian System	443.7	1.5	”	Graptolites, lowest occurrences of *Parakidograptus acuminatus* and *Akidograptus ascensus*	1.6 m above base of Birkhill Shale Fm., Dob's Linn, Moffat, Scotland, UK	Ratified 1984	Episodes 8 (2), p.98–100, 1985
Ordovician System							
Upper							
base Hirnantian Stage	445.6	1.5	”	Potentially at base of the *Normalograptus extraordinarius-N. ojsuensis* graptolite biozone	Candidate section is Wangjiawan, China		
base of sixth stage *(not yet named)*	455.8	1.6	”	Potentially near first appearance of the graptolite *Diplacanthograptus caudatus*	Candidate sections ae Black Knob Ridge (Oklahoma, USA) and Hartfell Spa (S. Scotland, UK)		
base of fifth stage *(not yet named)*	460.9	1.6	”	Graptolite, lowest occurrence of *Nemagraptus gracilis*	1.4 m below phosphorite in E14a outcrop, Fågelsång, Scane, southern Sweden	Ratified 2002	Episodes 23 (2), p.102–109, 2000 *(proposal; formal GSSP publication in preparation).*

Continues.

Table 1. continued.

Global Boundary Stratotype Sections and Points (GSSPs)
Status in March 2004; see ICS website (www.stratigraphy.org) for updates

EON, Era, System, ***Series,*** Stage	Age (Ma) GTS2004	Est. ± myr	Derivation of Age	Principal correlative events	GSSP and location	Status	Publication
Middle							
base Darriwilian Stage	468.1	1.6	"	Graptolite, lowest occurrence of *Undulograptus austrodentatus*	Base of Bed AEP184, 22 m below top of Ningkuo Fm., Huangnitang, Changshan, Zhejiang province, southeast China	Ratified 1997	Episodes 20 (3), p.158–166, 1997
base of third stage *(not yet named)*	471.8	1.6	"	Conodont, potentially lowest occurrence of *Protoprioniodus aranda* or of *Baltoniodus triangularis*	Candidate sections at Niquivil (Argentina) and Huanghuachang (China)		
Lower							
base of second stage *(not yet named)*	478.6	1.7	"	Graptolite, lowest occurrence of *Tetragraptus approximatus*	Just above E bed, Diabasbrottet quarry, Västergötland, southern Sweden	Ratified 2002	*Episodes article in preparation*
base of Tremadocian Stage, base Ordovician System	488.3	1.7	"	Conodont, lowest occurrence of *Iapetognathus fluctivagus;* just above base of *Cordylodus lindstromi* conodont Zone. Just below lowest occurrence of planktonic graptolites. Currently dated around 489 Ma.	Within Bed 23 at the 101.8 m level, Green Point, western Newfoundland, Canada	Ratified 2000	Episodes 24 (1), p.19–28, 2001
Cambrian System				Potential GSSP correlation levels include *Cordylodus proavus, Glyptagnostus reticulatus, Ptychagnostus punctuosus, Acidusus atavus,* and *Oryctocephalus indicus.*		Overview of potential subdivisions in Episodes 23 (3), p. 188-195, 2000.	
Upper ("Furongian") Series							
upper stage(s) in Furongian				*Potential GSSP levels in upper Cambrian are based on trilobites and conodonts*			
base Paibian Stage, base Furongian Series	501.0	2.0	Radiometric ages near primary marker level. Estimated age and uncertainty only.	Trilobite, lowest occurrence of agnostoid *Glyptagnostus reticulatus.* Coincides with base of large positive carbon-isotope excursion.	369.06 m above base of Huaqiao Fm, Paibi section, NW Hunan province, south China	Ratified 2003	*Episodes article in preparation*
Middle	513.0	2.0	Radiometric ages near primary marker level. Estimated age and uncertainty only.	*Potential GSSP levels in Middle Cambrian are based mainly on trilobites*			
Lower				*Potential GSSP levels in Lower Cambrian are based on archaeocyatha, small shelly fossils, and to a lesser extent, trilobites*			
base Cambrian System, base Paleozoic, base PHANEROZOIC	542.0	1.0	U-Pb age from Oman coinciding with the negative carbon excursion.	Trace fossil, lowest occurrence of *Treptichnus (Phycodes) pedum.* Near base of negative carbon-isotope excursion.	2.4 m above base of Member 2 of Chapel Island Fm., Fortune Head, Burin Peninsula, southeast Newfoundland, Canada	Ratified 1992	Episodes 17 (1&2), p.3–8, 1994.
PROTEROZOIC				*Pre-Cambrian eras and systems below Ediacaran are defined by absolute ages, rather than stratigraphic points.*			
Neoproterozoic Era							
base **Ediacaran System**	630		Age as suggested by Ediacaran Subcomm: bracketed by radiometric ages of 600 and 635 Ma	Termination of Marinoan (or Varanger) glaciation, and distinctive C-13 change.	Base of the Marinoan cap carbonate (Nuccaleena Formation), immediately above the Elatina diamictite in the Enorama Creek section, Flinders Ranges, South Australia.	Age-definition (650 Ma) for "Neoproterozoic III" ratified 1990, and replaced by Ediacaran GSSP in Feb 2004	

Cryogenian System	850	Defined chronometrically	Base = 850 Ma		
Tonian System	1000	Defined chronometrically	Base = 1000 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
Mesoproterozoic Era					
Stenian System	1200	Defined chronometrically	Base = 1200 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
Ectasian System	1400	Defined chronometrically	Base = 1400 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
Calymmian System	1600	Defined chronometrically	Base = 1600 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
Paleoproterozoic Era					
Statherian System	1800	Defined chronometrically	Base = 1800 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
Orosirian System	2050	Defined chronometrically	Base = 2050 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
Rhyacian System	2300	Defined chronometrically	Base = 2300 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
Siderian System	2500	Defined chronometrically	Base = 2500 Ma	Ratified 1990	Episodes 14 (2), p.139–140, 1991
ARCHEAN					
Neoarchean Era	2800	Defined chronometrically	Base = 2800 Ma	Subcomm. decision 1996, but not submitted to ICS	Informally in Episodes 15(2), p.122–123, 1992.
Mesoarchean Era	3200	Defined chronometrically	Base = 3200 Ma	Subcomm. decision 1996, but not submitted to ICS	Informally in Episodes 15(2), p.122–123, 1992.
Paleoarchean Era	3600	Defined chronometrically	Base = 3600 Ma	Subcomm. decision 1996, but not submitted to ICS	Informally in Episodes 15(2), p.122–123, 1992.
Eoarchean Era		Base is not defined		Subcomm. decision 1996, but not submitted to ICS	Informally in Episodes 15(2), p.122–123, 1992.

each period/system are primarily extracted from detailed discussions in the corresponding chapters of *A Geologic Time Scale 2004*.

Archean and Proterozoic Eons of the 'Precambrian'

Subdivisions and correlation of the Phanerozoic Eon are traditionally based on the evolution of metazoan life – the fossil record. In contrast, the Precambrian generally lacks well-documented precise global correlation horizons, and correlation of regional Precambrian stratigraphies generally utilizes comparison of radiometric ages. Therefore, the current Precambrian time scale is divided into the chronometric subdivisions, in which time boundaries (GSSAs) have been selected to demarcate the estimated ages of principal cycles of sedimentation, mountain building and volcanism. These GSSA definitions were subsequently formalized in Plumb (1991).

The 'Precambrian' is not a formal stratigraphic term and simply refers to all rocks that formed prior to the Cambrian Period. The Precambrian is formally divided into an older Archean Eon and a younger Proterozoic Eon. The informal Archean divisions of Eo-, Paleo-, Meso- and Neo-Archean eras were approved by the Precambrian subcommission in 1996, but were never formally submitted to and ratified by ICS/IUGS. No base was defined to the Archean, but the term 'Hadean' (after Hades, hence forever unknown) has been suggested to span the time from the moon-forming catastrophic impact to the end of heavy bombardment. The Archean would begin with the preserved rock record.

The Proterozoic Eon begins at 2500 Ma. The Paleo-, Meso- and Neo-Proterozoic eras are poetically divided into periods named after their typical tectonic, sedimentary or environmental characteristics (Table 2). The final Neoproterozoic period, which had been temporarily called 'Neoproterozoic III', was formally named as the Ediacaran period/system in early 2004. The Ediacaran period begins at the termination of 'Snowball Earth' glacial episodes of the Cryogenian Period, and is defined by a GSSP in the Flinders Range of Australia.

Potentially, some of the current schematic divisions of the Precambrian based on absolute ages (GSSAs) may be suitable for high-resolution GSSP definitions and global correlation levels. Some possibilities for 'natural' Precambrian subdivisions that utilize important correlative geologic events are presented by Bleeker (2004, this issue).

Table 2. Origin of nomenclature for periods of the Proterozoic Eon. [This figure is modified from a table in the Precambrian chapter of *Geologic Time Scale 2004*].

PERIOD NAME	base	DERIVATION	GEOLOGICAL PROCESS
EDIACARAN	GSSP, ~630 Ma	Ediacara = from Australian Aboriginal term for place near water	*"Evolution of first megascopic marine animals"*
Oldest record of megascopic marine life. GSSP in Australia coincides with termination of glaciations and a pronounced carbon-isotope excursion			
CRYOGENIAN	−850 Ma	Cryos = ice; Genesis = birth	*"Global glaciation"*
Glacial deposits, which typify the late Proterozoic, are most abundant during this interval			
TONIAN	−1000 Ma	Tonas = stretch	
Further major platform cover expansion (e.g., Upper Riphean, Russia.; Qingbaikou, China; basins of Northwest Africa), following final cratonization of polymetamorphic mobile belts, below.			
STENIAN	−1200 Ma	Stenos = narrow	*"Narrow belts of intense metamorphism & deformation"*
Narrow polymetamorphic belts, characteristic of the mid-Proterozoic, separated the abundant platforms and were orogenically active at about this time (e.g., Grenville, Central Australia)			
ECTASIAN	−1400 Ma	Ectsis = extension	*"Continued expansion of platform covers"*
Platforms continue to be prominent components of most shields			
CALYMMIAN	−1600 Ma	Calymma = cover	*"'Platform covers"*
Characterised by expansion of existing platform covers, or by new platforms on recently cratonized basement (e.g. Riphean of Russia)			
STATHERIAN	−1800 Ma	Statheros = stable, firm	*"Stabilisation of cratons; Cratonization"*
This period is characterized on most continents by either new platforms (e.g. North China, North Australia) or final cratonization of fold belts (e.g. Baltic Shield, North America)			
OROSIRIAN	−2050 Ma	Orosira = mountain range	*"Global orogenic period"*
The interval between about 1900 Ma and 1850 Ma was an episode of orogeny on virtually all continents;			
RHYACIAN	−2300 Ma	Rhyax = stream of lava	*"Injection of layered complexes"*
The Bushveld Complex (and similar layered intrusions) is an outstanding event of this time; the age of the Bushveld seems unlikely to change dramatically			
SIDERIAN	−2500 Ma	Sideros = iron	*"Banded iron formations"*
The earliest Proterozoic is widely recognised for an abundance of BIF, which peaked just after the Archaean-Proterozoic boundary			

Paleozoic era

The Cambrian system/period has undergone radical changes in its definition and subdivisions during the past decade, but it will require another few years until an international set of stages are pinned by GSSPs. Once regarded as beginning with the earliest preserved shells of animals, the base of the Cambrian is now defined at a GSSP associated with the first occurrence of the activity of complex metazoans in the form of widespread characteristic feeding traces (ichnofossil *Tricophycus pedum*). This level is approximately coincident with a brief but pronounced negative excursion in carbon isotopes. The Cambrian interval has numerous regional subdivisions based on facies patterns and endemic fauna, but most of these are not conducive for global usage. However, in the Middle and the Late Cambrian, global biostratigraphic markers, such as those based on pandemic and pelagic agnostoid trilobites, are present (Geyer and Shergold 2000), and the future global subdivision of these epochs of the Cambrian will have GSSPs coinciding with a subset of these levels. At present, only the base of the upper Cambrian 'Furongian' epoch/series (base of Paibian stage) is defined by a GSSP.

Existing regional suites of series and stages for the Ordovician were also found to be unsatisfactory for global division. The Ordovician subcommission has identified a set of widespread biostratigraphic datums using graptolites and conodonts and then used these events for assigning GSSPs for global subdivision. The resulting international stages are being named according to their approximate correspondence to the extent of regional stages (e.g. Tremadocian and Hirnantian stages of British regional succession, Darriwilian of Australian succession).

The Silurian subdivisions were mainly fixed in 1980 and 1984 by assigning GSSPs to a combination of graptolite datums and classical lithology-based stages (and nomenclature) within southwest England and Wales (Holland & Bassett 1989). However, some of these levels have either lacked a precise correlation horizon or proved challenging to achieve a global correlation (e.g. bases of Wenlock and Ludlow series). Therefore, the Silurian subcommission is reviewing some of these GSSP assignments.

Devonian, Carboniferous and Permian subdivisions have mainly utilized conodonts for global correlation horizons associated with ratified or potential GSSPs. The Devonian stages are fully delimited by GSSPs distributed in Czech Republic, France, Germany, Uzbekistan and Morocco.

Even through the Carboniferous was one of the first established geological periods; it is one of the most complicated and confusing in terms of stratigraphic classification and correlation. The well established, but independent, regional subdivisions in Europe, Russia, North America, and elsewhere are difficult to correlate. For the international standard series and stages, the Carboniferous subcommission decided to abandon the western Europe system of Stephanian–Westphalian–Namurian, and adopt a Russian-based nomenclature for the Carboniferous stages within each series. The potential GSSP for each stage will be coincident with widespread conodont or fusulinid appearance. Currently, only the major division of the Carboniferous into the Mississippian and Pennsylvanian 'sub-systems/sub-periods' has been defined by a GSSP.

The Permian has a tripartite division – the lower Cisuralian series/epoch will have four GSSPs in Russia and Kazakhstan, the middle Guadalupian series/epoch has placed three stage GSSPs in Texas, and the upper Lopingian series has assigned two stage GSSPs in China. All GSSPs are coincident with conodont appearances.

Mesozoic era

Most of the traditional stages of the Triassic (Anisian, Ladinian, Carnian, Norian, Rhaetian) were named from ammonoid-rich successions of the Northern Calcareous Alps of Austria. However, the stratigraphy of these Austrian tectonic slices proved unsuitable for establishing formal boundary stratotypes, or even deducing the sequential order of the stages (Tozer 1984). The general lack of unambiguous historical precedents for placement of Triassic stage boundaries, coupled with difficulties in achieving consensus on global correlation horizons, have retarded establishment of formal GSSPs. The base of the Triassic (and Mesozoic) at the GSSP in China coincides with the recovery from the end-Permian mass extinctions as indicated by the near-global occurrence of a conodont and the termination of a major negative carbon-isotope excursion. These basal-Triassic events occur significantly after the peak of Late Permian extinctions. The Triassic stages will retain the Alpine nomenclature, but await decisions on the primary correlation horizons using a combination of conodont and ammonoid criteria.

Ammonites have provided a high-resolution correlation and subdivision of Jurassic strata throughout the globe (e.g. Arkell 1956). The bases of nearly all Jurassic stages and substages are traditionally assigned to the base of ammonite zones in marginal-marine sections in western Europe (e.g. Oppel 1856–1858), and the current or potential GSSPs have retained this close tie to European ammonite markers. The identification of GSSPs within the upper Jurassic has been hindered by a pronounced latitudinal segregation into Tethyan, Boreal and other faunal realms, which have frustrated global correlation for over a century.

This faunal provincialism, especially for ammonites, continued through the Early Cretaceous, thereby complicating decisions on GSSPs for the base-Cretaceous (Berriasian) and the other five Lower Cretaceous stages. As a result, a calpionellid (microfossil) marker is suggested for base-Valanginian, and magnetic reversal horizons have been suggested as primary correlation criteria for GSSPs for base-Cretaceous (Chron M19n) and base-Aptian (Chron M0r). GSSPs for the Late Cretaceous have included a diverse set of palaeontological groups, including planktonic foraminifers, pelagic crinoids, inoceramid bivalves, ammonites and belemnites.

Cenozoic era

The division of the Cenozoic into the Paleogene and Neogene periods/systems abandons the formal use of 'Tertiary' and 'Quaternary', which were residual concepts from when all Earth history consisted of only four major divisions. However, the 'Quaternary' is retained as a valuable climate-stratigraphic term for the past 2.6 myr that was dominated by major glacial oscillations, and therefore encompasses the Holocene, Pleistocene and latest Pliocene epochs.

The epoch/series divisions of the Paleogene period/system are defined by GSSPs associated with an iridium anomaly caused by the end-Cretaceous impact (base-Paleocene), a brief negative carbon-isotope excursion (base-Eocene), and the extinction of a planktonic foraminifer (base-Oligocene). Stages within each of these epochs/series have not yet been formally defined by GSSPs, nor have primary correlation criteria been selected. However, these GSSPs will potentially utilize calcareous nannofossil and/or planktonic foraminifer datums and magnetic reversals.

Each GSSP within the Neogene period/system has been calibrated to multiple correlation horizons (microfossil, magnetic, stable isotope or astronomical cycle). In addition, the GSSPs have been chosen to allow direct calibration to the astronomical 'Milankovitch' cyclicity, hence directly to absolute age. The base of the Pleistocene epoch/series through the base of the upper Miocene have these calibrated GSSPs. The Pleistocene has a high-resolution oxygen-isotope 'stage' nomenclature; therefore, to avoid confusion, a new set of chronostratigraphic 'stages' defined by GSSPs will be avoided. Instead, the Pleistocene will be subdivided into 'sub-series/sub-epoch' units, with the base of the Middle Pleistocene tentatively assigned as the base of a magnetic reversal, and the base of the Upper Pleistocene to coincide with the inter-glacial climate interval at about 126 ka. The base of the Holocene epoch/series will probably be chronometrically defined by a GSSA (not GSSP) at the termination of the Younger Dryas cold interval at 10,000 'C-14 years' or 11,500 calendar years before 'Present', where 'Present' is fixed as 1950 AD.

Conclusion

It was not until the establishment of the International Commission on Stratigraphy (ICS) by the International Union of Geological Sciences (IUGS) that the goal of establishing an international chronostratigraphic scale had a means of fulfilment. The GSSP concept of defining the base of each successive unit at a level that coincided with potential markers for global correlation has required the concerted efforts of paleontologists, geochemists, paleomagnetists, cycle stratigraphers and other specialists, combined with international consensus. The goal of the resulting stratigraphic divisions of the International Geologic Time Scale is a global language for Earth history. The international standard developed by ICS is formally published in conjunction with the International Geological Congress every four years; but current updated tables and charts (PDF format) are freely available from the ICS website, *www.stratigraphy.org*. The complete suite of GSSP-defined units will be in place by 2008.

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