ICS on Stage

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The most important issue pressing the International Commission on Stratigraphy (ICS) is the standardization of the 90+ Phanerozoic stages, 45 of which now have a formal definition. Special challenges exist with the definition of Lower Palaeozoic stratigraphic units. At the same time, there are ten Palaeozoic and Mesozoic stages that are over 10 my in duration, but lack formal internal subdivision. A timetable is presented for the completion of the stratigraphic standardization process, scheduled for 2008. Scientific focus after 2008 should be more on geological processes across major boundaries and less so on stratigraphic ones.

A newly created ICS 'Subcommission on a Natural Time Scale for the Precambrian' replaces the previous 'Subcommission on Precambrian'. This new and enthusiastic group has given itself the important geologic task to put the Time Scale for 88% of Earth History (= Precambrian) on a natural footing, using geological events, not abstract time lines.

The official website of the ICS (*www.stratigraphy.org*) serves as a platform for ICS organization, news and discussions, and also links to other sites maintained by individual ICS units, by the IUGS and its major commissions, and by national stratigraphic commissions. It is now possible to find key stratigraphic information at one site, instead of in many different and scattered publications; PDF-type figures and outcrop pictures are constantly being added. The new website is dramatically increasing the relevance and awareness of ICS work in the field of educational and applied stratigraphy.

The ICS plays a leading organizational and scientific role in the CHRONOS initiative to create a global network of stratigraphic databases linked to the standard time scale. Through the network, geochemical, geophysical, geological and astrophysical databases with major stratigraphic content like time trends in geomagnetics, stable isotopes or biotic evolution, or the background of the current time scale itself can be probed and interrogated in a relational and intelligent manner. A wide variety of graphic tools will be on hand.

A key item for CHRONOS is the new Geological Time Scale (GTS2004) that is ready to replace the time scale presented by ICS in 2000 (Remane 2000). It will be documented in book format with colour figures on CD, and illustrated with large size time scale charts and a plasticized pocket card (Gradstein *et al*. in press); almost 40 co-authors are listed. A majority of stages will have geo-mathematically derived error estimates on both boundaries and on duration. Despite attempted rigour, both a lack of complete GSSP coverage, and disagreement on external error estimates of various types of radiometric dates require more research efforts and consensus agreements. Leading geochronologists, the CHRONOS Project and ICS jointly are pursuing more high-resolution radiometric dating at key boundaries and better radiometric data standardisation.

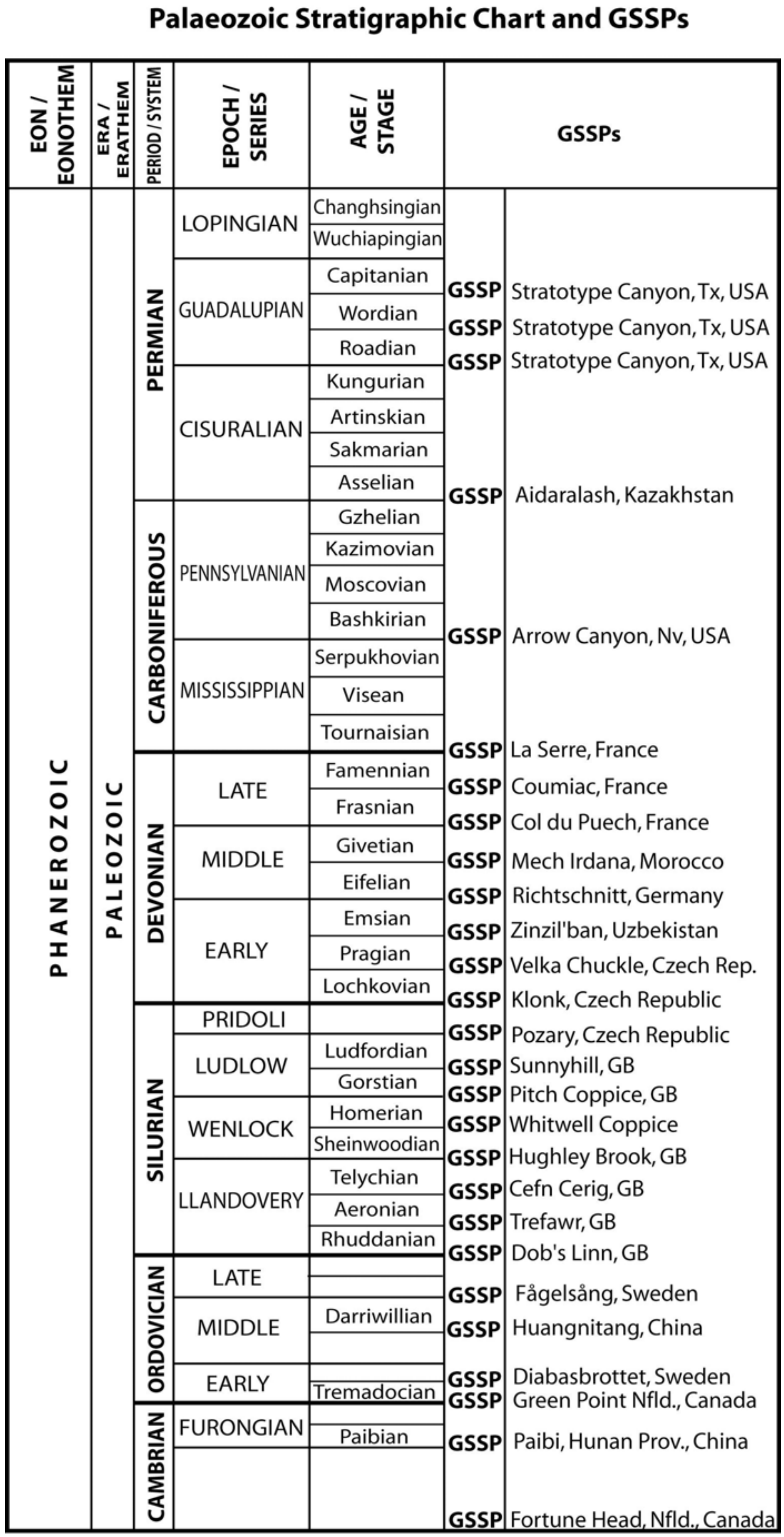
The ICS recently reached agreement with the fully peer reviewed international stratigraphy and paleontology journal '*Lethaia*' to be its formal publishing outlet for stratigraphic studies, discussions, new GSSP's, and organizational news. The journal has free online digital access to all subscribers under *www.tandf.no/leth*. Special stratigraphy issues are being planned for 2004 and beyond. ICS members are encouraged to actively consider the journal '*Lethaia*' for publication of their stratigraphic research results and news or discussion items.

The need for chronostratigraphic standardization

The statutes of the International Commission on Stratigraphy (ICS) under the International Union of Geological Sciences (IUGS) simply state that ICS is a body of expert stratigraphers founded for the purpose of promoting and coordinating long-term international cooperation and of establishing and maintaining standards in stratigraphy. ICS fosters much fundamental activity in the geosciences and maintains a highly active agenda with many new initiatives to support the global earth science community, be it professional or academic. Among its most tangible products, of course, are the Geologic Time Scale and the International Stratigraphic Guide. However, in the background of these more universal products much activity is ongoing to support these products that shape the image of ICS. One activity that requires most of the available ICS funding and is the focus for many of its most dedicated scientific participants, involves chronostratigraphic standardization.

Stage and Boundary Stratotype sections

The assignment of a local rock unit to a specific unit of relative geologic time is meaningless unless that unit can be correlated. Correlation is meaningless unless it takes place in an organized system of hierarchic relative time units anchored to type sections. This in short is the rationale for the Earth Science called stratigraphy.



Palaeozoic Stratigraphic Chart and GSSPs

EON / EONOTHEM	ERA / ERATHEM	PERIOD / SYSTEM	EPOCH / SERIES	AGE / STAGE	GSSPs	
PHANEROZOIC	PALEOZOIC	PERMIAN	LOPINGIAN	Changhsingian		
				Wuchiapingian		
			GUADALUPIAN	Capitanian	GSSP	Stratotype Canyon, Tx, USA
				Wordian	GSSP	Stratotype Canyon, Tx, USA
				Roadian	GSSP	Stratotype Canyon, Tx, USA
			CISURALIAN	Kungurian		
				Artinskian		
				Sakmarian		
				Asselian	GSSP	Aidaralash, Kazakhstan
		CARBONIFEROUS	PENNSYLVANIAN	Gzhelian		
				Kazimovian		
				Moscovian		
				Bashkirian	GSSP	Arrow Canyon, Nv, USA
			MISSISSIPPIAN	Serpukhovian		
				Visean		
				Tournaisian	GSSP	La Serre, France
		DEVONIAN	LATE	Famennian	GSSP	Coumiac, France
				Frasnian	GSSP	Col du Puech, France
			MIDDLE	Givetian	GSSP	Mech Irdana, Morocco
				Eifelian	GSSP	Richtschnitt, Germany
			EARLY	Emsian	GSSP	Zinzil'ban, Uzbekistan
				Pragian	GSSP	Velka Chuckle, Czech Rep.
				Lochkovian	GSSP	Klonk, Czech Republic
		SILURIAN	PRIDOLI		GSSP	Pozary, Czech Republic
			LUDLOW	Ludfordian	GSSP	Sunnyhill, GB
				Gorstian	GSSP	Pitch Coppice, GB
			WENLOCK	Homerian	GSSP	Whitwell Coppice
				Sheinwoodian	GSSP	Hughley Brook, GB
			LLANDOVERY	Telychian	GSSP	Cefn Cerig, GB
				Aeronian	GSSP	Trefawr, GB
				Rhuddanian	GSSP	Dob's Linn, GB
		ORDOVICIAN	LATE			
					GSSP	Fågelsång, Sweden
			MIDDLE	Darriwillian	GSSP	Huangnitang, China
			EARLY		GSSP	Diabasbrottet, Sweden
				Tremadocian	GSSP	Green Point Nfld., Canada
		CAMBRIAN	FURONGIAN			
				Paibian	GSSP	Paibi, Hunan Prov., China
					GSSP	Fortune Head, Nfld., Canada

Figure 1. Palaeozoic Stratigraphic Chart and boundary stratotypes

Mesozoic - Cenozoic Stratigraphic Chart and GSSPs

EON / EONOTHEM	ERA / ERATHEM	PERIOD / SYSTEM	EPOCH / SERIES	AGE / STAGE	GSSPs
PHANEROZOIC	CENOZOIC	QUATERNARY	HOLOCENE		
			PLEISTOCENE		GSSP Vrica, S. Italy
		NEOGENE	PLIOCENE	Gelasian	GSSP San Nicola, S. Italy
				Piacenzian	GSSP Punta Picola, S. Italy
				Zanclean	GSSP Eratea, S. Italy
			MIOCENE	Messinian	GSSP Oued Akrech, Morocco
				Tortonian	GSSP nearing final voting
				Serravallian	
				Langhian	
				Burdigalian	
				Aquitanian	GSSP Lemme Carrosio, N. Italy
		PALEOGENE	OLIGOCENE	Chattian	
				Rupelian	GSSP Massignano, N. Italy
			EOCENE	Priabonian	
				Bartonian	
				Lutetian	
				Ypresian	Dababyia, Egypt
			PALEOCENE	Thanetian	
				Selandian	
				Danian	GSSP El Kef, Tunisia
	PALEOZOIC	CRETACEOUS	LATE	Maastrichtian	GSSP Tercis, SW. France
				Campanian	
				Santonian	
				Coniacian	
				Turonian	GSSP nearing final voting
				Cenomanian	GSSP Mont Risou, France
			EARLY	Albian	
				Aptian	
				Barremian	
				Hauterivian	
				Valanginian	
				Berriasian	
		JURASSIC	LATE	Tithonian	
				Kimmeridgian	
				Oxfordian	
			MIDDLE	Callovian	
				Bathonian	
				Bajocian	GSSP Mondego, Portugal
				Aalenian	GSSP Fuentelsalz, Spain
			EARLY	Toarcian	
				Pliensbachian	GSSP nearing final voting
				Sinemurian	GSSP Quantox Head, GB
				Hettangian	
		TRIASSIC	LATE	Rhaetian	
				Norian	
				Carnian	
			MIDDLE	Ladinian	
				Anisian	
			EARLY	Olenekian	
				Induan	GSSP Meishan, Zhejiang, China

Figure 2. Mesozoic-Cenozoic Stratigraphic Chart and boundary stratotypes

The remarkable high resolution in relative time using modern micro and macrofossil zonations, and similar or better resolution in linear or semi linear time using stable isotope ratios like in $^{87}Sr/^{86}Sr$ and modern radiometric tools with argon and uranium isotopic systems are pressing the need for stability in the edifice of hierarchical stratigraphic units. The edifice of stratigraphic units with stages, series, systems etc. subdivides relative geologic time.

Modern stratigraphic classification has two means of anchoring the correlation between rock and time in a standardized manner. The first is through stages and the second through boundary stratotypes. Let us briefly consider both.

Rock and its varied content is the observed part of the scientific discipline of stratigraphy, and time is its abstract continuum in which the rock must be positioned. This is where the

time-rock unit called the stage comes in. The stage is the smallest and fundamental unit of chronostratigraphic classification and represents all rocks laid down or formed otherwise during the time span assigned to the stage. Here it is important to mention that the stage is the only chronostratigraphic unit supported by a type section. Higher units in the chronostratigraphic hierarchy like Series, Systems, Erathems and Eonothems do not have type sections.

A type section consists of one or more sections of sediment with typical attributes in a specific geographic area, generally with a base and a top. The type section of a stage does not generally or necessarily represent all sediments deposited in the time span covered by the stage, because many type sections consist of unconformity-bounded sedimentary units. Hence, there is no such thing as a standard stage, and boundaries of stages in a majority of cases fall outside the classical concept of the type section of a stage. The fact that type sections of stages are incomplete standards (in time) constitutes a principal practical problem in stratigraphy with regard to an objective definition of boundaries of stages.

The International Stratigraphic Guide (Salvador 1994) addresses this problem by introducing the Global Boundary Stratotype Section and Point (GSSP) that aims at the identification of a specific point in a continuous rock section that defines the base of a stage. The boundary stratotype places the emphasis on the boundary between stages in order to overcome the incomplete nature of stage type sections. It is important to mention that the boundary stratotype concept complements the stage stratotype concept, but does not replace it. Confusion exists on this fundamental issue that itself is simple enough, with opponents of boundary stratotypes insisting that its existence undermines the recognition of traditional stages, but no such trend is apparent in the literature. The two concepts clearly complement each other!

The International Commission on Stratigraphy (ICS) has laid down a set of rules and guidelines for the formal definition of boundary stratotypes (Table 1), with more details found on its website.

At present approximately 45 boundary stratotypes have been defined (Figures 1 and 2), but there are about 45 more Phanerozoic stratigraphic units without ratified base definition. Summaries of ratified GSSP's with locality maps and sections may be found in the ICS website *www.stratigraphy.org* . As may be seen from the listing in figures 1 and 2, the stratigraphic communities studying the Silurian, Devonian and Neogene have embraced the GSSP concept much more rapidly than stratigraphers studying the Mesozoic, where few stage boundaries have been formalized. The latter hampers construction of the standard geological time scale.

Under-rated, but equally important is the fact that over 10 Palaeozoic and Mesozoic stage units are over 10 my in duration, but lack formal guidelines for internal subdivision. These units are from old to young: Frasnian, Famennian, Viséan, Ladinian, Carnian, Norian, Aptian, Albian and Campanian; in addition, the Lower Cambrian lacks formal (global) subdivision. ICS Subcommissions are urged to start addressing the internal subdivision of these long stages, and at least come forward with recommendations for practical lower, middle and upper boundary definitions to assist geological research in general.

Klonk and the status of stratigraphic standardization

It is now 25 years since the first stratigraphic boundary was defined by a boundary stratotype or 'golden spike', inaugurating the concept of the Global Boundary Stratotype Section and Point (GSSP). This event of historic proportions for chronostratigraphy and geochronology involved the boundary between the Silurian and Devonian systems, or rather the lower limit of the Devonian (Martinsson 1977), at the locality called Klonk in the Czech Republic.

The problem of the Silurian-Devonian boundary and its consensus settlement in the Klonk section, hinged on a century old debate, known as the 'Hercynian Question' that touched many outstanding geoscientists of the previous century. The issue came to the foreground after 1877, when Kaiser stated that the youngest stages (étages) of Barrande's Silurian System in Bohemia, correspond to the Devonian System in the Harz Mountains of Germany and other regions. Kaiser's findings contrasted with the conventional 19th century wisdom that graptolites became extinct at the end of the Silurian. Eventually, it became clear that so-called Silurian graptolites in some sections occur together with so-called Devonian fossils in other sections, leading to the modern consensus that graptolites are not limited to Silurian strata.

Table 1. Information required for establishment of a Global Boundary Stratotype Section and Point (GSSP), (updated after Salvador ed., 1994; Remane *et al*., 1996).

Name of the boundary
GSSP definition
Stratigraphic rank and status of the boundary
Stratigraphic position of the defined unit
Type locality of the GSSP
Geologic setting and geographic location, incl. coordinates
Lithology/sedimentology/palaeobathymetry
Map and GPS (WGS-84) coordinates
Accessibility, incl. logistics, national politics and property rights
Conservation
Identification in the field
Stratigraphic completeness of the section
Global correlation, using where applicable biostratigraphy, magnetostratigraphy, stable isotope stratigraphy, and other stratigraphic tools and methods
References to historical background studies
Full publication in the journal 'Lethaia'; news summary in 'Episodes'

A bronze plaque in the Klonk outcrop shows the exact position of the modern Silurian - Devonian Boundary that also represents the base of the Lochkovian Stage, which is the lowest stage in the Devonian. The base of the Lochkovian Stage is defined by the first occurrence of the Devonian graptolite *Monograptus uniformis* in bed # 20 of the Klonk Section, NE of the village of Suchomasty. The lower Lochkovian index trilobites with representatives of the *Warburgella rugulosa* group occur in the next younger limestone bed # 21 of that section (Chlupác, 1993).

Boundary Stratotypes - Brief Background

The reasons that many stages lack boundary stratotypes vary, but three main factors play a role:

(a) For each stage boundary, many sections worldwide still need to be studied in detail,

(b) Many stratigraphers hope to find the criteria in the rock record for the perfect GSSP definition, rather an adequate and practical one

(c) Prejudices exist against selection of global physical events over (often more regional) fossil events, and

(d) Selection of a GSSP (as at Klonk) is to overcome regional or historical controversies.

Dogged discussions tend to forget or ignore the fact that (fortunately) there is no rule of historical priority in stratigraphy, and that all stratigraphy ultimately is guided by subjective consensus. There is an abundance of occasions where a set of zones traditionally associated with one stage eventually was re-assigned to the next underlying or overlying stage. Hence, beds assigned to such zones were re-assigned a younger or older age. Preference for stratigraphic priority is laudable when selecting a GSSP, but subsidiary to scientific and practical merit. The search for perfection also ignores the fact that emendations of a GSSP definition are feasible under ICS rules, using consensus voting on emended proposals.

It can be easily understood that it is important that a GSSP is selected in a continuous stratigraphic section, without obvious hiatuses. After a completed proposal is approved by a stratigraphic subcommission it is submitted to ICS for final approval; the final step is formal publication of the proposal in the journal '*Lethaia*'. A summary of the proposals also should be submitted to the news section of the web pages of ICS; this summary will than automatically also appear in the IUGS journal '*Episodes*'.

An interesting exception with a regional historical precedent for a basal disconformity in a GSSP is the lower limit of the Zanclean Stage and Pliocene Series, ratified in 2000 (see Episodes 23,3). Because the onset of the Pliocene in the Mediterranean traditionally is the marine transgression following the Messinian drying out of that region, the GSSP section for the Miocene/Pliocene boundary reflects this.

It may be desirable to add some documentation to a GSSP proposal about the historical significance of a new stage GSSP in the hierarchy of stratigraphic units of higher rank. Careful consideration needs to be given to the fact that, for example, the GSSP for the base of the Pleistocene Series in the Vrica Section in southern Italy automatically defines the boundary of the Pliocene/Pleistocene, and the base of the Calabrian Stage, the lowest Pleistocene stage. In the same vein, since the Induan is the lowest stage in the Triassic System, and the Triassic the lowest System in the Mesozoic Erathem, the base of the Indiuan Stage as defined in the Meishan Section, China also defines base Triassic and the Palaeozoic/Mesozoic boundary. It is along these lines of logical stratigraphic reasoning that definition of a GSSP should entail some historical background research, to ensure consensus stratigraphic hierarchy, built on scientific and practical merit.

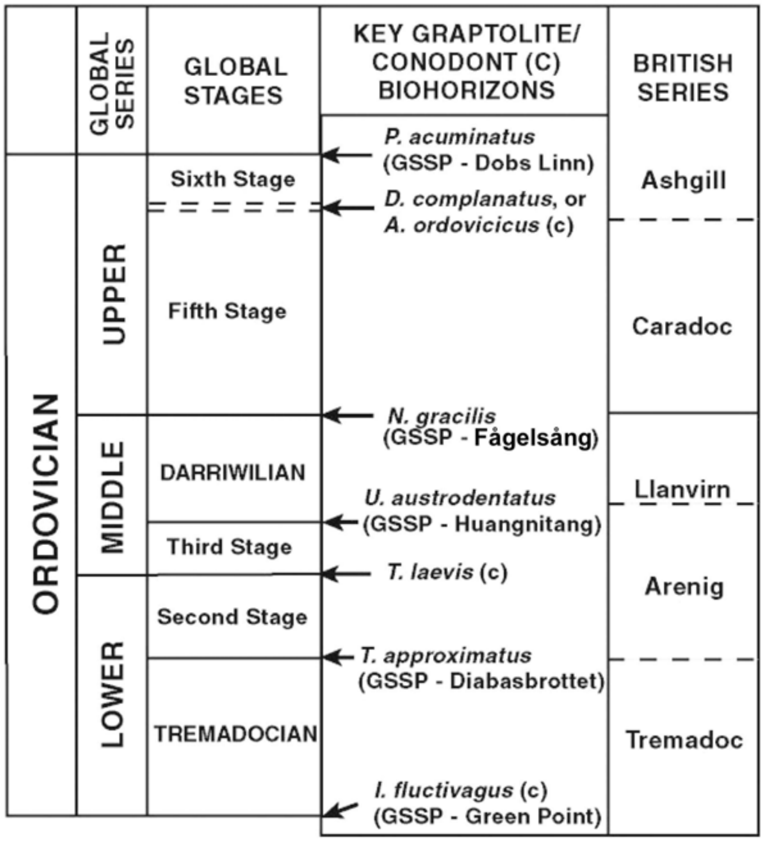


Figure 3. Status of formal definition of the global stages and their key biostratigraphic events for the Ordovician, with approximate correlation to local, redefined British Series.

Reconcile Precambrian rock record with abstract time

Due to the fact that most of the Proterozoic record lacks adequate fossils and physical event correlation in rock units across the globe is a vastly complex task, a different type of boundary stratotype was developed for that enormously long interval of time on Earth. The new boundary stratotype is called Global Standard Stratigraphic Age (GSSA), an abstract term for an abstract, non-geological concept. The definition of a boundary by its linear age is the consequence of the fact that the Proterozoic now includes units of global stratigraphic subdivision, where the boundaries are defined in terms of the age in millions of years. Summaries of ratified GSSA's may be found in the website of ICS.

Although there appears to be consensus that the subdivision of the Proterozoic in three Eras - Palaeoproterozoic, Mesoproterozoic and Neoproterozoic is excellent, the finer Period subdivisions often contain no datable rocks, which makes their use haphazard. Even more damaging, uncertainty in radiometric dates means that in the Precambrian, these abstract geochronologic time lines levels have error bars of 10 million years or more.

It is our opinion that abstract Period definitions that cannot be sustained by the Precambrian rock record on Earth should ultimately be reconciled with the latter. GSSA's must become GSSP's. In March 2003, Mike Villeneuve (Ottawa) organized a NUNA conference in Canada, co-sponsored by the ICS, to also tackle this complex issue at the heart of a Precambrian rock stratigraphy (NUNA, 2003). One outcome is the newly created ICS 'Subcommission on a Natural Time Scale for the Precambrian', under the leadership of W.Bleeker, (Canada) to replace the previous 'Subcommission on Precambrian'. The new and enthusiastic group has given itself the important geologic task to put the Time Scale for 88% of Earth History (= Precambrian) on a natural footing, using observable and correlative geological events.

The Ordovician overcomes historical controversies

The Ordovician Subcommission in recent years has found it necessary to establish a completely new set of series and stages, defined by GSSP's that offer the greatest potential for precise worldwide correlation (Figure 3). In its type area in Britain, the Ordovician System is divided into six series (Tremadoc, Arenig, Llanvirn, Llandeilo, Caradoc, Ashgill) that, because of historical priority, are used often as *de facto* global nomenclature on geological time scales. However, they were not unanimously adopted outside of the British

Isles because the high level of biogeographic and ecologic differentiation of Ordovician faunas made it difficult to correlate to the British series with precision and resolution. Instead, several independent and very different sets of series and constituent stages were established, each generally applicable to a different palaeoplate (Webby 1998).

British workers have actively promoted the Anglo-Welsh series for global chronostratigraphy to the extent of informally redefining them in terms of the graptolite zonation (Fortey *et al*. 1995, 2000). Doing so has demonstrated significant gaps and overlaps between successive series, as originally defined (Fortey *et al*. 1995). As a result, the biostratigraphic extent of the original series was been substantially modified, and the number of series was reduced to five by combining the Llanvirn and lower Llandeilo series into a single Llanvirn Series. Because graptolites are uncommon in some type areas of the British Series, correlation of series boundaries to the graptolite zonation is not always precise.

The base of the Llanvirn is defined on graptolites of the Atlantic province fauna that was restricted to high latitudes; thus it cannot be correlated with precision into graptolite successions elsewhere that contain Pacific province faunas. The base of the Arenig Series is defined on the graptolite *Tetragraptus approximatus*, which does not occur in Britain. And, on the basis of graptolites from the lower Rawtheyan Stage of the type Ashgill Series, Rickards (2002) recently demonstrated that a substantial part of the lower Ashgill Series is substantially older (two graptolite zones) than previously considered. In fact, it may correlate with the upper Caradoc Series.

Because no single set of regional Series and Stage divisions was acceptable for precise global correlation, the Subcommission on Ordovician Stratigraphy eventually chose a new course of action by resolving

1) To find the best biohorizons for precise global correlation using graptolites and/or conodonts,
2) To select global stratotype sections for these biohorizons, and
3) To define new global chronostratigraphic units with boundaries defined on these biohorizons.

The ICS subcommission decided to adopt a three-fold global Series subdivision with the names Lower, Middle, and Upper Ordovician and with each Series divided into two stages. This scheme required the selection of six GSSP's for defining Series and Stage boundaries, with the lower boundary of each Series serving also as the lower boundary of the lowest Stage in that Series. Six biohorizons were identified for evaluation, with one being the biohorizon that would also define the base of the Ordovician System. Although emended British Series names (e.g. "Caradocian") initially were attached to some of the proposed Stages, most Subcommission members are of the opinion that a name should be chosen only after the extent of the Stage has been determined by selection of GSSPs for both lower and upper boundaries. Until that time, the Stages are referred to by informal names (First, Second, Third in ascending order).

In 1996, the Darriwillian Stage was ratified as the upper Stage of the Middle Ordovician Series with the GSSP defined in the Huangnitang section in China at the first appearance datum (FAD) of the graptolite *Undulograptus austrodentatus*. Because the biohorizon proposed for the upper boundary of this Stage, the FAD of the graptolite *Nemagraptus gracilis*, was considered one of the best, most reliable biohorizons in the Ordovician System for global correlation, Subcommission members were of the opinion that the full extent of the Stage was known and, thus, it could be named. The name Darriwillian was taken from the Australian regional stage that spanned the same biostratigraphic interval as the global Stage.

In 2000, a GSSP was ratified for the base of the Ordovician System (the Cambrian/Ordovician boundary) at the Green Point section, Newfoundland, on the FAD of the conodont *Iapetognathus fluctivagus*. This GSSP also defines the lower boundary of the Lower Ordovician Series and of its lowest Stage. The name Tremadocian was subsequently approved for this first Stage of the Ordovician System, since selection of the GSSP for the lower boundary of the overlying Stage was nearing approval, and the biostratigraphic extent of the Stage seemed certain and was equivalent to that accorded to the British Tremadoc Series.

Two additional GSSPs were ratified in 2001 and ceremonially inaugurated in 2003. The FAD of the graptolite *Tetragraptus approximatus* in the Diabasbrottet section, Sweden is the GSSP for the base of the Second Stage and serves as the upper boundary of the Tremadocian Stage. The upper boundary of the Second Stage is the base of the Middle Ordovician Series and the Third Stage, but selection of a GSSP for this boundary has been delayed because of deficiences discovered in the primary biohorizon and stratotype section under consideration. Because the biostratigraphic extent of the Second Stage is not yet known, a formal name will not be chosen until its upper boundary has been determined. The FAD of the graptolite *Nemagraptus gracilis* in the Fågelsång section, Sweden is the GSSP for the base of the Upper Ordovician Series and the base of the Fifth Stage. And the Fifth Stage will not be formally named until the GSSP for the base of the Sixth Stage has been approved.

In a recent paper on the geology of the Appalachians (Ganis *et al*. 2001), the stratigraphy was described in terms of British series, Australian stages, and North American series. The target audience, Appalachian geologists, must be greatly confused by the complex mixture of stratigraphic nomenclature. This is but one example of the critical need for the Ordovician Subcommission to select the last two GSSPs (base of Middle Ordovician Series and Third Stage; base of Sixth Stage) and complete the set of formally named and defined global Series and Stages for the Ordovician System. To even begin to make progress, the Subcommission

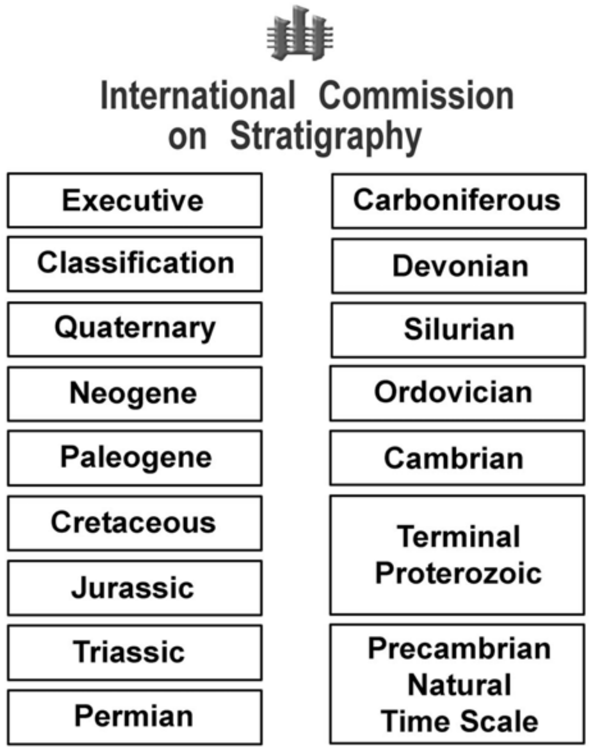


Figure 4. Organisational structure of ICS with 15 subcommissions that in turn lead numerous working groups

had to break away from the 'historical stage' approach, an action plan since followed by the Subcommission on Cambrian Stratigraphy.

Can Boundary Stratotypes simplify stratigraphic classification

The philosophy behind the boundary stratotype or GSSP is to define a level in an exposure where time and rock coincide, and thus to define successive stages with precisely defined criteria for their lower and upper limits in relative time. In contrast, stage stratotypes define a body of rock typical for the unit stage. If in the next few years all Phanerozoic stages have GSSP's for their lower limits, a stratigraphic continuum will have been defined that to the best of our knowledge is at the same time chronostratigraphic and geochronologic in nature. The direct outcome of this philosophy is the proposal, first advanced in Harland *et al.* (1990) and recently vocalized by a group around J.Zalaciewicz (ms *in prep*) to simplify stratigraphy. When stages are defined between successive GSSP's, the classical time-rock concept in stratigraphy tends to become redundant, which would lead to a redefinition of the term chronostratigraphy, and obsolescence of the terms upper and lower, in favour of early and late. Seemingly simplifying classification, this stratigraphic philosophy overlooks the conceptual importance of type sections with bodies of rocks that typify correlative units, like the classical stage. The ICS welcomes philosophical discussion on the challenging issue of a simplified stratigraphy.

The CHRONOS initiative

The ICS plays a leading organizational and scientific role in the CHRONOS initiative that is currently unfolding and taking shape in the USA to create a global network of stratigraphic databases linked to the standard time scale (Figure 5). Through the network geochemical, geophysical, geological and astrophysical databases with major stratigraphic content like time trends in geomagnetics, stable isotopes or biotic evolution, or the background of the current time scale itself can be probed and interrogated in a relational and intelligent manner. A wide variety of graphic tools will be on hand. To quote from the master proposal submitted on behalf of a large team of geoscientists led by Cinzia Cervato (USA) to the National Science Foundation (NSF) of the USA:

'The *Chronos* network system was conceived by scientists at two workshops (2001 and 2002) as an international network to assemble, integrate and distribute data relevant to earth history, a fundamental product being a dynamic time scale to frame and integrate Earth history events and processes for the benefit of science and society. The goal of *Chronos* is to create a new investigative environment for

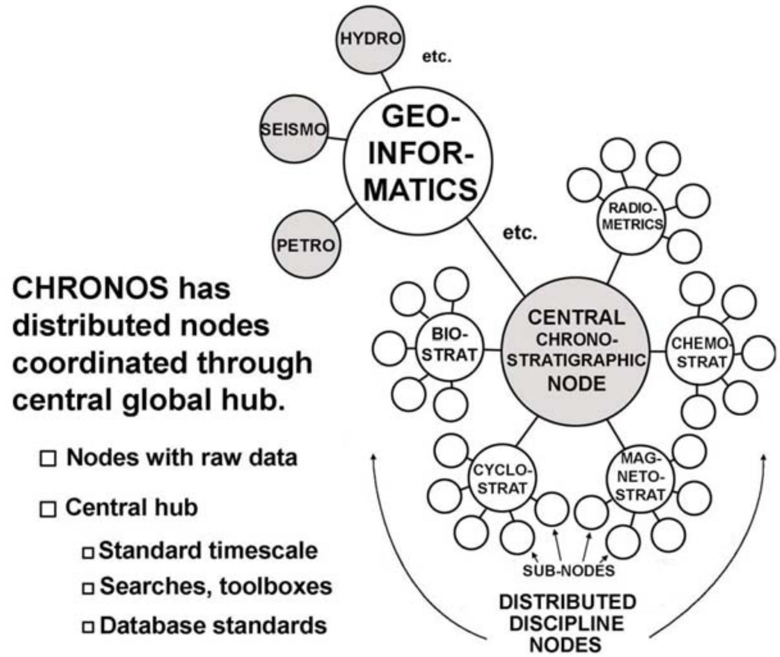


Figure 5. Schematic representation of the CHRONOS network with databases linked to the standard geological time scale. Once operational, this free-access stratigraphic computer network will contribute significantly to interdiciplinary stratigraphic and geochronologic standardisation

interdisciplinary Earth history research into the evolution and diversity of life, climate change, geochemical cycles, rapid geologic events, magnetic field fluctuations, and other major Earth system processes. In consolidating a wide range of Earth history data, the *CHRONOS* system will fulfill a basic necessity for modern, innovative Earth science research, and will empower the general public with new knowledge of Earth science facts and issues'.

A key item for CHRONOS is a new Geological Time Scale (GTS2004) that is slated to replace the time scale presented by ICS in 2000 (Remane 2000). It will be documented in great detail in book format to replace GTS89 by Harland *et al*.(1990), and also feature colour figures on CD and large size charts and a plastic pocket card (Gradstein *et al*., in press). Almost 40 co-authors are listed; a majority of stages will have geomathematically derived error estimates, (provided by F.P.Agterberg, Canada) on both boundaries and on duration. Despite attempted rigour, both the lack of complete GSSP coverage, and lack of consensus on external error estimates of various types of radiometric dates require extensive internationally coordinated research.

One of the good outcomes of the mentioned Nuna Conference in March 2003 on the Geological Time Scale (NUNA 2003) was extensive discussion among leading geochronologists to consider better cooperation, both with ICS and among themselves. Three issues are at stake and will be actively pursued:

- Establish protocols and practices to improve data exchange between geochronology laboratories
- Address better intercalibration of monitor standards in relative radiometric datings.
- Address improvements in the precision of decay constants of unstable isotope systems

The outcome of these important issues has direct and important bearings on the precision of the Geologic Time Scale.

Geoinformatics and stratigraphic information

Hand in hand with the CHRONOS and the NUNA initiatives wide ranging activities are currently underway to vastly improve the current manner in which geoscience information is being handled, stored and disseminated. ICS plans to soon address this issue in detail under its NEWS section on the official ICS website. One outcome will be that proponents of GSSP's will be required to submit detailed field section information and sample storage information as part of standard archiving policy. Several digital data centers and distributing nodes are actively being established to serve the international geoscience community; key physical data storage centres will be upgraded.

Formalization of Pleistocene Stratigraphy

After a period of dormancy, the ICS again has an active Pleistocene Subcommission, headed by Phil Gibbard (UK), tackling the formalization of Pleistocene/Holocene stratigraphic units. Pre-eminent among its tasks are:

a. Formalization of GSSPs for the Lower/Middle and for the Middle/Upper subseries/subepoch boundaries of the Pleistocene Series/Epoch. The formal nomenclature for the subseries/subepoch divisions of the Pleistocene will be Lower/Early, Middle/Mid, and Upper/Late.
b. Formalization of a GSSA for the base of the Holocene Series/Epoch.
c. An international correlation chart for the most commonly used regional stratigraphic units and isotope stages. No international stage-level subdivisions for the Pleistocene or Holocene will be formalized.
d. The group will strive to provide a uniform coverage of terrestrial and marine settings with global coverage.
e. Progress and discussions within the Subcommission will be summarized through the ICS website and through INQUA.

ICS - Quo Vadis?

Although creating a standardized chronostratigraphy/geochronology with GSSPs in the Phanerozoic and Precambrian is an important task at hand, it should not occupy ICS to the point where the role of stratigraphy as modellers of earth history at all possible scales suffers or is neglected. To say it with an analogy: Standardizing the meter, units of mass and other physical units with the atomic second using the most modern tools certainly is a major task, it should not become a goal in itself, and remain unapplied.

Hence, the ICS has set as challenge and goal to get the GSSP's in first instance completed by the year 2008, and is currently organising meetings to address and formulate its future after 2008. One such meeting took place in Urbino, Italy in June 2002, and brought together a majority of chairs of ICS subcommissions (see Report under *www.stratigraphy.org*). A follow-up meeting will be held during the 32th International Geological Congress in Florence in 2004.

During the Urbino meeting the plan was formulated that high-resolution global change, as seen through the eyes of dynamic stratigraphy, i.e. geological process oriented stratigraphy, would be an exciting and socially responsible challenge. In this human era global change and global environmental challenges are ever more pressing issues. Stratigraphy plays an exciting role in this since its fossilized record can often be unravelled to a level of detail and accuracy in correlation that allows great insight into the dynamic forces that drive global changes. It is this geological process oriented stratigraphy that we consider the most exciting and meaningful as a new mandate. Only through active rejuvenation of its goals and manner of operation and communication will stratigraphy and ICS serve the global geoscience community.

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