Geoheritage (2011) 3:83–88
DOI 10.1007/s12371-010-0028-3

ORIGINAL ARTICLE

GSSPs: The Case for a Third, Internationally Recognised, Geoconservation Network

Murray Gray

Received: 18 August 2010 / Accepted: 22 November 2010 / Published online: 14 December 2010

Abstract A network of over 100 Global Stratotype Sections and Points (GSSPs) is being established by the International Commission on Stratigraphy, a Commission of the International Union of Geological Sciences. This network of sites, about 60% of which are already ratified, relates to all the stage, system and series boundaries of the geological column and thus provides the fundamental basis for the geological timescale and the history of planet Earth. Given the importance of these sites and the work that has been ongoing by the international geological community since 1977 to select and ratify the sites, their long-term conservation is essential, yet in most cases, there is no legislative protection for them and no international recognition, beyond the geological community, of their importance. The two existing international conservation networks used to protect geological sites/areas (World Heritage Sites and Global Geoparks) are both unsuitable for the conservation of the GSSP network, and instead a case is made in this paper that UNESCO, in collaboration with other organisations, should establish a third internationally recognised geoconservation network for the complete GSSP site series.

Keywords GSSPs · Geological timescale · ICS · IUGS · UNESCO

Introduction

The general demise of the International Union of Geological Sciences' (IUGS) project to establish a Global Geosites network means that there are currently only two international site/area networks that recognise geoheritage values and encourage their geoconservation—World Heritage Sites and Global Geoparks.

World Heritage Sites are recognised under the World Heritage Convention, which is concerned with "protecting the world's cultural and natural heritage". The Convention was adopted by the General Conference of UNESCO in 1972, and to date, more than 185 countries have ratified it, making it an important international conservation instrument. A requirement for inscription on the World Heritage List is that the sites are appropriately managed by national and/or local governments and organisations so that their outstanding international heritage values are retained and maintained for future generations. As of November 2010, there are 911 sites on the List in 151 countries, but less than 100 are recognised for their earth science value (e.g. Dingwall et al. 2005). The vast majority are located in developed regions of the world, particularly in Europe, and there is also imbalance between the number of cultural (704) and natural (180) sites (there are also 27 mixed sites). As a result, in 1994, UNESCO launched a Global Strategy for a "representative, balanced and credible" World Heritage List. The aim was, and is, to identify and fill the major gaps, thematic and spatial, in the List. In relation to geological and geomorphological sites, the International Union for the Conservation of Nature (IUCN) carried out a study of existing sites (Dingwall et al. 2005). One of their analyses demonstrated some significant gaps in the representation of the geological column, particularly the absence of sites in the Silurian and Cenozoic, whilst another identified the low number of stratigraphic sites. One of the aims of this work was to assist the World Heritage Committee and its advisors to identify possible gaps in the coverage of the World Heritage List so as to encourage countries to nominate sites that might help fill these gaps.

M. Gray (✉)
Department of Geography, Queen Mary, University of London,
Mile End Road,
London E1 4NS, UK
e-mail: j.m.gray@qmul.ac.uk

Table 1 Summary of the GSSP table (from Subcommission for Stratigraphic Information)

System	Series	Stage	Age (Ma)	Location	Status	Reference
	Holocene	**Holocene**	**0.011784**	**North GRIP ice core, Greenland**	**Ratified 2008**	**Episodes 31/2**
		Tarantian	0.126	Amsterdam-Terminal borehole, Netherlands	Accepted by ICS (2008); on hold by IUGS	Episodes 31/2
		Ionian	0.781	Awaited		
		Calabrian	1.806	Vrica, Italy	Ratified 1985	Episodes 8/2
Quaternary	**Pleistocene**	**Gelasian**	**2.588**	**Monte San Nicola, Sicily, Italy**	**Ratified 1996/2009**	**Episodes 21/2**
		Piacenzian	3.6	Punta Piccolo, Sicily, Italy	Ratified 1997	Episodes 21/2
	Pliocene	**Zanclean**	**5.332**	**Eraclea Minoa, Sicily, Italy**	**Ratified 2000**	**Episodes 23/3**
		Messinian	7.246	Oued Akrech, Morocco	Ratified 2000	Episodes 23/3
		Tortonian	11.608	Mone dei Corvi Beach, Italy	Ratified 2003	Episodes 28/1
		Serravallian	13.82	Fromm Ir-Rih Bay, Malta	Ratified 2007	Episodes 32/3
		Langhian	15.97	Awaited		
		Burdigalian	20.43	Awaited		
Neogene	**Miocene**	**Aqitanian**	**23.03**	**Lemme-Carrioso, Italy**	**Ratified 1996**	**Episodes 20/1**
		Chattian	28.4+/-0.1	Awaited		
	Oligocene	**Rupelian**	**33.9+/-0.1**	**Massignano, Italy**	**Ratified 1992**	**Episodes 16/3**
		Priabonian	37.2+/-0.1	Awaited		
		Bartonian	40.4+/-0.2	Awaited		
		Lutetian	48.6+/-0.2	Awaited		
	Eocene	**Ypresian**	**55.8+/-0.2**	**Dababiya, Egypt**	**Ratified 2003**	**Episodes 30/4**
		Thanetian	58.7+/-0.2	Zumaia, Spain	Ratified 2008	
		Selandian	61.1+/-0.2	Zumaia, Spain	Ratified 2008	
Palaeogene	**Palaeocene**	**Danian**	**65.5+/-0.3**	**Oued Djerfane, Tunisia**	**Ratified 1991**	**Episodes 29/4**
		Maastrichtian	70.6+/-0.6	Tercis les Bains, France	Ratified 2001	Episodes 24/4
		Campanian	83.5+/-0.7	Awaited		
		Santonian	85.8+/-0.7	Awaited		
		Coniacian	89.3+/-1	Awaited		
		Turonian	93.6+/-0.8	Pueblo, Colorado, USA	Ratified 2003	Episodes 28/2
	Upper	Cenomanian	99.6+/-0.9	Mount Risou, France	Ratified 2002	Episodes 27/1
		Albian	112+/-1	Awaited		
		Aptian	125+/-1	Awaited		
		Barremian	130+/-1.5	Awaited		
		Hauterivian	133.9+/-2	Awaited		
		Valanginian	140.2+/-3	Awaited		
Cretaceous	**Lower**	**Berriasian**	**145.5+/-4**	**Awaited**		
		Tithonian	150.8+/-4	Awaited		
		Kimmeridgian	155.6+/-4	Awaited		
	Upper	Oxfordian	161.2+/-4	Awaited		
		Callovian	164.7+/-4	Awaited		
		Bathonian	167.7+/-3.5	Ravin du Bes, France	Ratified 2008	Episodes 32/4
		Bajocian	171.6+/-3	Cabo Mondego, Portugal	Ratified 1996	Episodes 20/1
	Middle	Aalenian	175.6+/-2	Fuentelsaz, Spain	Ratified 2000	Episodes 24/3
		Toarcian	183+/-1.5	Awaited		
		Pliensbachian	189.6+/-1.5	Robin Hood's Bay, UK	Ratified 2005	Episodes 29/2
		Sinemurian	196.5+/-1	East Quantoxhead, UK	Ratified 2000	Episodes 25/1
Jurassic	**Lower**	**Hettangian**	**199.6+/-0.6**	**Kuhjoch section, Tyrol, Austria**	**Ratified 2010**	
		Rhaetian	203.6+/-1.5	Awaited		
		Norian	216.5+/-2	Awaited		
	Upper	Carnian	228.7+/-2	Prati di Stuores, Italy	Ratified 2008	Albertiana 36
		Ladinian	237+/-2	Bagolino, Italy	Ratified 2005	Episodes 28/4
	Middle	Anisian	245+/-1.5	Awaited		Albertiana 36
		Olenekian	249.5+/-0.7	Awaited		Albertiana 36
Triassic	**Lower**	**Induan**	**251+/-0.4**	**Meishan, China**	**Ratified 2001**	**Episodes 24/2**
		Changhsingian	253.8+/-0.7	Meishan, China	Ratified 2005	Episodes 29/3
	Lopingian	Wuchiapingian	260.4+/-0.7	Penglaitan, China	Ratified 2004	Episodes 29/4
		Capitanian	265.8+/-0.7	Nipple Hill, Texas, USA	Ratified 2001	
		Wordian	268+/-0.7	Guadalupe Pass, Texas, USA	Ratified 2001	
	Guadalupian	Roadian	270.6+/-0.7	Stratotype Canyon, Texas, USA	Ratified 2001	

Table 1 (continued)

		Kungurian	275.6+/-0.7	Awaited		
		Artinskian	284.4+/-0.7	Awaited		
		Sakmarian	294.6+/-0.8	Awaited		
Permian	**Cisuralian**	**Asselian**	**299+/-0.8**	**Aidaralash Creek, Kazakhstan**	**Ratified 1996**	**Episodes 21/1**
	Upper Pennsylvanian	Gzhelian	303.4+/-0.9	Awaited		
		Kasimovian	307.2+/-1	Awaited		
	Middle Pennsylvanian	Moscovian	311.7+/-1.1	Awaited		
	Lower Pennsylvanian	Bashkirian	318.1+/-1.3	Arrow Canyon, Nevada, USA	Ratified 1996	Episodes 22/4
	Upper Mississippian	Serpukhovian	328.3+/-1.6	Awaited		
	Middle Mississippian	Visean	345.3+/-2.1	Pengchong, China	Ratified 2008	
Carboniferous	**Lower Mississippian**	**Tournaisian**	**359.2+/-2.5**	**La Serre, France**	**Ratified 1990**	**Episodes 14/4**
		Farmennian	374.5+/-2.6	Coumiac Quarry, France	Ratified 1993	Episodes 16/4
	Upper	Frasnian	385.3+/-2.6	Col du Puech de la Suque, France	Ratified 1986	Episodes 10/2
		Givetian	391.8+/-2.7	Jebel Mech Irdane, Morocco	Ratified 1994	Episodes 18/3
	Middle	Eifelian	397.5+/-2.7	Wetteldorf, Germany	Ratified 1985	Episodes 8/2
		Emsian	407+/-2.8	Zinzil'ban Gorge, Uzbekistan	Ratified 1995	Episodes 20/4
		Pragian	411.2+/-2.8	Velká Chuchle, Czech Republic	Ratified 1989	Episodes 12/2
Devonian	**Lower**	**Lochkovian**	**416+/-2.8**	**Klonk, Czech Republic**	**Ratified 1972**	**IUGS Series A, 5**
	Pridoli		418.7+/-2.7	Reporyje, Czech Republic	Ratified 1984	Episodes 8/2
		Ludfordian	421.3+/-2.6	Ludlow, UK	Ratified 1980	Episodes 5/3
	Ludlow	Gorstian	422.9+/-2.5	Ludlow, UK	Ratified 1980	Episodes 5/3
		Homerian	426.2+/-2.4	Sheinton Brook, UK	Ratified 1980	Episodes 5/3
	Wenlock	Sheinwoodian	428.2+/-2.3	Hughley Brook, UK	Ratified 1980	Episodes 5/3
		Telychian	436+/-1.9	Cefn-cerig Road Section, UK	Ratified 1984	Episodes 8/2
		Aeronian	439+/-1.8	Trefawr Track Section, UK	Ratified 1984	Episodes 8/2
Silurian	**Llandovery**	**Rhuddanian**	**443.7+/-1.5**	**Dobb's Linn, UK**	**Ratified 1984**	**Episodes 8/2**
		Hirnantian	445.6+/-1.5	Wangjiawan North Section, China	Ratified 2006	Episodes 29/3
		Katian	455.8+/-1.6	Black Knob Ridge, Oklahoma, USA	Ratified 2006	Episodes 30/4
	Upper	Sandbian	460.9+/-1.6	Sularp Brook, Sweden	Ratified 2002	Episodes 23/2
		Darriwilian	468.1+/-1.6	Huangnitang Section, China	Ratified 1987	Episodes 20/3
	Middle	Dapingian	471.8+/-1.6	Huanghuachang Section, China	Ratified 2007	Episodes 28/2; 32/2
		Floian	478.6+/-1.7	Diabasbrottet, Sweden	Ratified 2002	Episodes 27/4
Ordovician	**Lower**	**Tremadocian**	**488.3+/-1.7**	**Green Point, Newf'land, Canada**	**Ratified 2000**	**Episodes 24/1**
		10	492	Awaited		
		9	496	Awaited		
	Furongian	Paibian	499+/-2	Wuling Mts, China	Ratified 2003	Lethaia 37
		Guzhangian	503	Louyixi, China	Ratified 2008	Episodes 32/1
		Drmian	506.5	Drum Mts, Utah, USA	Ratified 2006	Episodes 30/2
	3	5	510	Awaited		
		4	517	Awaited		
	2	3	521	Awaited		
		2	528	Awaited		
	Terreneuvian			**Fortune Head,**		
Cambrian		**Fortunian**	**542+/-1**	**Newfoundland, Canada**	**Ratified 1992**	**Episodes 17/1 & 2**
Ediacaran			635	Enorama Creek, Australia	Ratified 1990	Lethaia 39
Cryogenian			850	Defined chronometrically at present. GSSP to follow.	Ratified 1990	Episodes 14/2
Tonian			1000	Defined chronometrically	Ratified 1990	Episodes 14/2
Stenian			1200	Defined chronometrically	Ratified 1990	Episodes 14/2
Ectasian			1400	Defined chronometrically	Ratified 1990	Episodes 14/2
Calymmian			1600	Defined chronometrically	Ratified 1990	Episodes 14/2
Statherian			1800	Defined chronometrically	Ratified 1990	Episodes 14/2
Orosirian			2050	Defined chronometrically	Ratified 1990	Episodes 14/2
Rhyacian			2300	Defined chronometrically	Ratified 1990	Episodes 14/2
Siderian			2500	Defined chronometrically at present. GSSP to follow.	Ratified 1990	Episodes 14/2

Table 1 (continued)

Era						
Neoarchean			2800	Defined chronometrically	Subcomm. decision (1996) not submitted to ICS	Infomally in Episodes 15/2
Mesoarchean			3200	Defined chronometrically	Subcomm. Decision 1996 not submitted to ICS	Infomally in Episodes 15/2
Palaeoarchean			3600	Defined chronometrically	Subcomm. Decision 1996 not submitted to ICS	Infomally in Episodes 15/2
Eoarchean			4000	Defined chronometrically	Subcomm. Decision 1996 not submitted to ICS	Infomally in Episodes 15/2
Eon						
Hadean			4600	Formation of planet. Informal term.		

The Global Network of National Geoparks (Global Geoparks) was established in 2004 and is a rapidly growing international network of areas recognised for their geoheritage values. The network is supported by UNESCO but is not yet a fully recognised UNESCO programme. The three aims of Global Geoparks are conservation of the geopark's geoheritage, geological education and sustainable economic development mainly through geotourism. There are currently (November 2010) 77 members of the network in 24 countries, but most are in China (24) and Europe (42).

This paper draws attention to a third important, but less well known, geoheritage site network where international recognition and action is urgently required in order to try to secure its conservation—Global Stratotype Sections and Points (GSSPs).

Global Stratotype Sections and Points

The International Commission on Stratigraphy (ICS), a commission of the IUGS, has a programme to reach international agreement and definition of all the main stratigraphic boundaries within the geological timescale. The result will be a global network of over 100 GSSPs. The history, philosophy and application of the concept of GSSPs was reviewed by Walsh et al. (2004). The programme commenced in 1977 and is still ongoing with full documentation of ratified sites being published, mainly in the IUGS journal *Episodes*.

The requirements for GSSP status were outlined by Remane et al. (1996) and have subsequently been amended by the ICS. They include:

- stratigraphic completeness across the GSSP level;
- adequate thickness of section above and below;
- continuous sedimentation;
- absence of synsedimentary, tectonic or metamorphic disturbance;
- abundance and diversity of well-preserved fossils;
- support from magnetostratigraphy, chemostratigraphy and dating to increase the possibilities of global correlatability;
- accessibility, including logistics, national politics and property rights; and
- provisions for conservation and protection.

This last point is discussed below.

Table 1 gives a full list of the 115 stratigraphic boundaries in the geological column. Twelve of these in the Precambrian are defined chronometrically (Plumb 1991) and will remain so, and thus have no terrestrial rock record that may be lost or damaged. That leaves 103 GSSPs to be defined on the basis of lithostratigraphy, but this includes the Pleistocene/Holocene boundary as identified in the North GRIP ice core from Greenland (Walker et al. 2008) archived in the University of Copenhagen, Denmark, and possibly some others defined in cores. Thus, there is a maximum of 102 GSSPs that are, or will be, defined on the basis of field outcrops. Of these, 61 had been ratified up to 17 September 2010 (Subcommission for Stratigraphic Information web site: https://engineering.purdue.edu/Stratigraphy/gssp/). Of the remaining 41, two have ratified temporary chronostratigraphic boundaries that will be replaced eventually by GSSPs. For the other 39, agreement has yet to be reached, though in most cases, there are shortlists of one or more candidate GSSPs. For example,

there are three candidate GSSPs (in Poland, USA and Germany) for the base of the Coniacian. The most important sites (Series boundaries in the Cenozoic, System boundaries in the Mesozoic and Palaeozoic) are highlighted in Table 1.

Clearly, these sites are of crucial importance to international stratigraphy and ought to be retained for the future and thus need to be protected from loss or damage (though not from natural processes that retain exposure of the outcrops). Whilst inclusion on the GSSP list clearly identifies the scientific importance of these sites, it does not provide any legislative protection. This has to be the responsibility of the countries or regional/local authorities in which the sites are located. Some GSSPs do have protection through national legislative programmes. For example, Dobb's Linn in Scotland, the GSSP marking the Ordovician/Silurian boundary, is a Site of Special Scientific Interest with protection through the UK's *Countryside & Rights of Way Act* (2000). Similarly, the Precambrian/Cambrian boundary at Fortune Head, Newfoundland, Canada, was designated as an Ecological Reserve in 1992. Also on Newfoundland, the GSSP marking the Cambrian/Ordovician boundary (Cooper et al. 2001) at Green Point (Fig. 1) lies within Gros Morne National Park and is therefore protected by the Parks Canada legislation and the Gros Morne National Park Management Plan. On the other hand, most of the GSSPs in the developing world and even several in the developed world are currently unprotected. For example, of the nine GSSPs currently ratified in Italy, only two are protected, including the Eocene/Oligocene boundary at Massignano (Ancona) located within the Regional Park of Monte Conero. All the others are not protected and some are in a poor condition. Similarly, the GSSP for the base of the Middle Jurassic Series and Aalenian Stage at Fuentelsaz, Guadalajara, Spain, has no legal protection (Carcavilla et al. 2009) other than the Spanish laws requiring permissions from the regional government before any palaeontological sampling can be carried out (Page et al. 2008).

Remane et al. (1996), in their revised guidelines for the establishment of GSSPs, recommended (p. 80) that:

> When making a formal submission to ICS, the concerned Subcommission should try to obtain guarantees from the respective authority concerning… permanent protection of the site.…ICS should attempt to finalise, within 3 years after IUGS ratification, any remaining official steps for the protection of the site with the authorities of the country in which the GSSP is located.

There are two points to be made about these statements. First, several GSSPs were ratified prior to these 1996 recommendations for geoconservation. Secondly, the reports on most GSSPs ratified after 1996 give little or no information about the geoconservation status of the sites. But as Page (2004) points out, the establishment of GSSPs is a conservation-driven activity in itself since the intention is to select key sites that will exist into the future as stratigraphic reference points. It follows from the above discussion that not enough attention has been given to the crucial need for conservation of GSSPs. But how should this be achieved?

Fig. 1 GSSP for the Cambrian/Ordovician boundary at Green Point, Newfoundland, Canada

Conservation of GSSPs: the way forward?

The lack of effective protection for most GSSPs is a serious matter given their scientific importance to geology and the time and effort expended by the ICS and IUGS to identify, agree and ratify the sites since 1977. Without adequate protection, GSSPs will remain vulnerable to activities that may damage or even destroy them (Page 2004). Whilst it must remain the responsibility of nation states to protect sites within their territories, international recognition of their standing and importance would help bring the importance of the GSSP network to the attention of national

governments and other authorities. However, the two existing international site programmes aimed at geoconservation are unsuitable to be applied to the GSSP network for the reasons outlined below.

One possibility that has been suggested is that the GSSP site network could be established as a serial World Heritage Site. Serial sites are those where a number of individual sites with a common theme are linked together as one serial World Heritage site. An example is the Cornwall & West Devon Mining Landscape in the UK that comprises ten individual mining areas as one serial World Heritage Site. However, it should be noted that these are within the same region of a single country. Given the number and widespread global distribution of GSSPs and the requirement for their management, a single serial GSSP World Heritage Site seems an unlikely and unworkable outcome. Another possibility is that groups of sites could be proposed as serial World Heritage Sites, and this has indeed been suggested by Page et al. (2008) for the 11 Jurassic GSSPs. Not all of these have yet been agreed and ratified, and there would again be the need for coordination between several countries. Page et al. (2008) point out that most of these are in Europe and this project may yet become the ultimate goal for the International Subcommission on Jurassic Stratigraphy. However, not all the other Subcommissions are likely to be able to follow suit, and thus, this approach is unlikely to provide the full consistency and impact that global recognition for the whole network would bring.

On the other hand, the Global Geopark programme is certainly unsuitable as geoparks normally comprise substantial territorial areas within which there may be several geosites rather than the individual sites of limited extent represented in the GSSP network.

Consequently, it is proposed here that the best approach would be for the ICS, IUGS, IUCN and UNESCO to work together to establish a third geoconservation site network, namely a separate GSSP network to sit alongside the World Heritage and Geopark programmes. This would have several benefits. For example, it would create a strong, unified and consistent network recognised by UNESCO that would publicise the importance of these sites to national governments and encourage them to provide legislative and/or other protective/management methods for the sites. It would avoid individual Subcommissions of the ICS from the considerable effort involved in achieving World Heritage status for their site groups. It would also assist UNESCO and the IUCN in their efforts to achieve a series of sites representative of the geological column. Here is a network of sites that has already been subject to rigorous selection processes and comprehensive international scrutiny by geological experts and finally to ratification by the IUGS, an organisation that already advises UNESCO on applications for World Heritage and Global Geopark status. Thus, there can be no question about the integrity of the network already established and there would be only very limited resource implications for UNESCO. But in recognising this third site network, UNESCO would achieve immense benefits in bringing international attention to the set of sites that define the fundamental basis of the geological history of the planet.

However, this proposal is unlikely to be quickly adopted by UNESCO which has still to fully commit to adopting Global Geoparks as a full UNESCO programme. Nonetheless, when and if that adoption takes place, the next step for international geological and geoconservation community should be to vigorously promote the GSSP network as a new UNESCO programme. In the meantime, pressure should be exerted by national geological communities supported if possible by the ICS, IUGS, IUCN and UNESCO to persuade governments or regional/local authorities to give legal protection to individual GSSPs within their territories.

References

Carcavilla L, Durán JJ, Garcia-Cortés Á, López-Martinez J (2009) Geological heritage and geoconservation in Spain: past, present, and future. Geoheritage 1:75–91

Cooper RA, Nowlan GS, Williams SH (2001) Global stratotype section and point for the base of the Ordovician system. Episodes 24(1):19–28

Dingwall P, Weighell T, Badman T (2005) Geological World Heritage: a global framework. A contribution to the global theme study of World Heritage natural sites, Protected Area Programme. IUCN, Gland, Switzerland, p 51

Page KN (2004) The protection of Jurassic sites and fossils: challenges for global Jurassic science (including a proposed statement on the conservation of palaeontological heritage and statotypes). Revista Italiana di Palaeontologia e Stratigrafia 110:373–379

Page KN, Meléndez G, Henriques M-H (2008) Jurassic Global Stratotype Section and Points (GSSPs)—a potential serial World Heritage Site? Volumina Jurassica 6:155–162

Plumb KA (1991) New Precambrian time scale. Episodes 14:139–140

Remane J, Bassett MG, Cowie JW, Gohrbandt KH, Lane RH, Michelsen O, Naiwen W (1996) Revised guidelines for the establishment of global chronostratigraphic standards by the International Commission on Stratigraphy. Episodes 19:77–81

Walker M et al (2008) The Global Stratotype Section and Point (GSSP) for the base of the Holocene Series/Epoch (Quaternary System/Period) in the NGRIP ice core. Episodes 31(2):264–267

Walsh SL, Gradstein FM, Ogg JG (2004) History, philosophy, and application of the global stratotype section and point (GSSP). Lethaia 37:201–218