CONTRIBUTIONS to SCIENCE, **5** (1): 41–51 (2009)
Institut d'Estudis Catalans, Barcelona
DOI: 10.2436/20.7010.01.58 ISSN: 1575-6343
www.cat-science.cat

Geology as a "local" science

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Resum. Entendre i descriure la història de la Terra és un dels objectius finals de la geologia. La part de la geologia anomenada *estratigrafia* ha treballat sempre, i ho continua fent, buscant els llocs adients per a definir el millor coneixement que tenim de cada lapse de temps històric, tal com el podem «llegir» analitzant el registre rocós assequible als humans en superfície o per sondatges. La major part de successions estratigràfiques que s'han fet servir per a definir les unitats han estat publicades ja en el segle XIX (les més antigues aquí citades són del 1832). Per contra, les anàlisis més detallades de l'escala cronostratigràfica han portat a definir els anomenats «secció i punt d'estratotip de límit global» (*global boundary stratotype section and point*, GSSP), que s'estan estudiant actualment i la definició més antiga dels quals data del 1982. Possiblement no hi ha cap més ciència que necessiti tenir sempre en compte la localitat on un coneixement es fa més clar i on cal anar per a qualsevol revisió general de tota la història de la Terra. En aquest sentit, la geologia es pot definir com una ciència «local».

Paraules clau: història de la Terra · cronoestratigrafia · GSSP («secció i punt d'estratotip de límit global»)

Abstract. Understanding and describing Earth's history is one of geology's goals. Stratigraphy, the field of geology comprising our knowledge of the history of Earth and the life on the planet, has always searched for the places that best reveal the passing of historical time, such as it can be "read" by analyzing the rock record. In geology, such places establish a compulsory reference, as almost always reflected in the nomenclature employed. Most of the stratigraphic successions employed to define the units were described in the 19th century (the oldest ones cited here are from 1832). More detailed analyses of the chronostratigraphic scale have led to the establishment of the Global Boundary Stratotype Section and Point (GSSP), with the first definition dating from 1982. Geology is possibly the only science that must take into account the place where the knowledge was obtained and the place where it was further elucidated—as both have implications for any revision of the Earth's history. Thus, Geology can truly be defined as a "local" science.

Keywords: history of the Earth · chronostratigraphy · GSSP (Global Boundary Stratotype Section and Point)

Introduction

Legend has it that Newton discovered the law of gravity when an apple fell on top of him while he was resting under a tree. He understood that fruit falling was a different manifestation of the same law that made planets move around the sun, the law of universal gravitation. While taking a bath, the Greek philosopher Archimedes exclaimed "eureka!" (I have found it), when he noticed that the level of water rose as he got in, realizing that this effect could be used to determine volume (the water displaced by an object would be equal to its volume). Not long before, his relative, King Hero of Alexandria, had asked him to determine whether the crown given to him by a goldsmith was in fact made of pure gold. If Archimedes knew the volume of the gold crown, he could compare its weight with an equal volume of pure gold to know whether the crown had been made completely from this metal.

In both cases, to apply these discoveries we do not have to sit under a tree or take a bath. The principles of physics have been discovered in many different ways, but we do not need to "localize them" in order to understand and expand on them. The same applies to many other sciences, such as chemistry and engineering. However, for the "natural sciences" it is necessary to consider the place where a certain phenomenon was studied and described in order to understand and further investigate it, so that progress can be made. From this perspective, I would like to reflect on how this is particularly true for geology, which allows us understand the Earth's history. In geology, places are a compulsory reference and they are almost always reflected in the nomenclature employed. The importance of place is evident in the progress made in chronostratigraphic classification, i.e., the grid containing all geological phenomena described thus far and which is constantly being perfected.

Most of the information expounded upon and dealt with here has been published in Riba and Reguant [1], Riba [2], and

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Reguant [3]. It is also taken from several different sources, including the important work of Harland et al. [4] and documentation from the International Commission on Stratigraphy (ICS), which provides internationally accepted information that is accepted as the norm around the globe. This information, the product of the ICS' commissions and subcommissions dedicated to the different geological systems, has been published in specialized journals and is available on its web page.

Geology, the history of the Earth and chronostratigraphy

Understanding and describing Earth's history is one of geology's goals. Indeed, the word "geology" makes direct reference to the Earth, and not to its rocks, although they are the material by which we actually study it. Analysis of the rock record is not only useful for understanding the history of the Earth, but it also reveals the characteristics and properties of the many types of rocks as well as their possible uses. The contacts between different types of rocks are indicators of their chronological and spatial changes as well as records of those movements of the Earth that played a predominant role in their formation and distribution. Thus, in sedimentary rocks the order of deposition can be deciphered, even if, due to orogenic movements, they are not placed horizontally in the order in which they formed in sedimentary, marine, or continental basins. These basins usually contain fossils, fragments of signals of the presence of living beings, that existed at the time of the rocks' formation. Throughout the different geological periods, living beings were constantly changing, with the appearance of new groups or taxa derived from evolutionary processes. Consequently, their fossil remains certify the relative age of formation of a given sedimentary rock. Already in 1669, Nicolaus Steno understood that the succession of strata corresponds to the succession of time. William Smith, in charge of the construction of the Somerset Canal (England) at the end of the 18th century, realized that each stratum contained certain types of fossils and that they were not repeated in other segments of the succession.

These observations formed the basis of advances made throughout the 19th century and which gave rise to an appreciation of the temporal succession of the Earth's strata. The fact that most discoveries in geology came from those countries in which the sciences were well-developed, i.e., in Western Europe, is reflected in the names of the chronostratigraphic units. Today, at a time when Earth sciences are well-developed in a great number of countries, this reference system has remained valid, as evidenced in the stratigraphic tables that appear in journals, textbooks, and, especially, the successive editions of the International Stratigraphic Chart (ISC), which is published by the International Commission on Stratigraphy of the International Union of Geological Sciences, a body of the maximum authority in the field.

The stages and sites of the sedimentary successions

The Cenozoic Erathem. The Cenozoic Erathem is the most recent chronostratigraphic unit, spanning the time from 65.5 million years (my) ago until today. It is divided into three systems: Quaternary (0–1.8 my), Neogene (1.8–23 my), and Paleogene (23–65.5 my). Given the comparatively short length of the Quaternary system, it is sometimes included in the Neogene. Since the recent sediments found around the world have yet to be studied in a single place, for now, the Quaternary is further divided in two series: the Holocene, corresponding to the current interglacial period, which began approximately 12,000 years ago, and the Pleistocene, during which there was a series of glaciations interrupted by interglacial periods.

The Neogene. The sedimentary successions needed to define the different stages of the Neogene were found in different regions of Italy and southern France. Table 1 shows, by increasing antiquity, the names of the different stages as published in the ISC, including the name, the place from which this name was derived (i.e., where these successions are found), the author, and the years of its designation. All of the stage namesto locations in Italy, except the Burdigalian and the Aquitanian, which are named after French sites.

With the exception of the recently defined Gelasian, which addresses the upper Pliocene, the stage names reflect the birth of stratigraphy in Western Europe, as discussed above. An in-depth study of the upper Neogene inclined E. Perconig, in 1964, to create the Andalusian stage (Andalusia), since to many authors it was of better quality than the Messinian, which

Table 1. Series and stages of the Neogene: origin, author, and year of designation

Series	Stage	Origin	Author	Year of designation
Pliocene	Gelasian	Gela (Sicily)	Rio, Sprovieri & Di Stefano	1994
	Piacenzian	Piacenza	Mayer-Eymar	1858
	Zanclean	Zancla = Messina	Seguenza	1868
Miocene	Messinian	Messina	Mayer-Eymar	1867
	Tortonian	Tortona	Mayer-Eymar	1858
	Serravallian	Serravalle, Scrivia	Pareto	1865
	Langhian	The Langhe (Piedmont)	Pareto	1865
	Burdigalian	Burdigala (Bordeaux)	Depéret	1892
	Aquitanian	Aquitaine	Mayer-Eymar	1858

Table 2. Stages of the Parisian-Anglo-Belgian basin: origin, author, and year of designation

Basin	Stage	Origin	Author	Year of designation
Parisian	Stampian	Étampes	D'Orbigny	1852
	Ludian	Ludes	Munier Ch & Lapparent	1893
	Auversian	Auvers-sur-Oise	Dollfus	1905
	Lutetian	Lutetia (Paris)	Lapparent	1883
	Cuisian	Cuise-la Mothe	Dollfus	1877
	Sparnacian	Épernay (Sparnacum)	Dollfus	1877
English	Bartonian	Barton	Mayer Eymar	1857
	Thanetian	Thanet	Renevier	1873
Belgian	Rupelian	Rupel River	Dumont	1849
	Tongrian	Tongres	Dumont	1839
	Ledian	Lede	Mourlon	1887
	Bruxelian	Brussels	Dumont	1839
	Ypresian	Ypres	Dumont	1849
	Landenian	Landen	Dumont	1893
	Montian	Mons	Dewalque	1868

it would substitute. It was described around Carmona and to the north of Villanueva del Río, in the province of Seville, in the basin of the Guadalquivir River. Although it is sometimes used, the Messinian is the name listed in the ISC and is thus the most recognized one.

The Paleogene. The area where most of the Paleogene stages have been described is the Parisian-Anglo-Belgian basin. The name refers to the fact that during a great part of the upper Mesozoic and the lower Cenozoic a single basin existed. This great area shows a very continuous succession of strata whose main center is in Paris. The basin forms a cone-like structure, with the most modern terrains in the center and the most ancient ones progressively outwards. Thus, gypsums from the hills of Montmartre to Paris represent the last sedimentary deposits. Geologically, the United Kingdom is joined with the rest of the European continent since there is no oceanic crust rising to the surface in the English Channel; thus, it can only be considered a sea geographically. In this sense, there is no rupture between Great Britain and continental Europe.

Regarding the Paleogene, the stages in this basin, which are currently still referred to, are listed in Table 2. The names are sorted by increasing antiquity. The Bartonian, Lutetian, Ypresian and Thanetian are listed in the ISC. The others are frequently cited in the recent geological literature, particularly with respect to regional studies. Other names have not been included in the table because they are seldom used, such as the Marinesian of Paris and the Aaschià and Heersian of Belgium.

The order of the Paleogene stages, as accepted by the ISC, is shown in Table 3.

The tables show both that the Parisian-Anglo-Belgian basin does not consist of successions that can be applied universally and the Paleogene's upper and lower limits. In response, from the beginning and continuing throughout the 20th century, unit terms were created and integrated into a universal table. The lowest stage, the Danian (from Denmark), was designated by Desor in 1846. This term has been wrongly attributed to the upper Cretaceous, as found in some relatively recent maps. Above the Danian, the Selandian (from Seland, Denmark), designated by Rosenkrantz in 1924, was recently incorporated. In the Oligocene series, the Chattian is accepted above the Rupelian. The former was defined by Fuchs in 1894 in the Chattische Stufe of Doberg, close to Bünde (Westphalia, Germany). The name derives from a tribe that lived there, called the "Chatte or Katte". Priabonian (from Priabona, in the north of Italy) was added to the upper part of the upper Eocene, which had already been created by Munier and Lapparent in 1983.

The Mesozoic Erathem. The Mesozoic Erathem comprises three systems: Cretaceous, Jurassic, and Triassic. The stratigraphic successions used to establish the series and their stages are located in different places. In some cases, the definition and localization of these systems were more complex than was the case for the Cenozoic. They are discussed in the following.

The Cretaceous. The Parisian basin enabled the establishment of several Cretaceous stages. Moreover, by also taking into consideration southern France, Holland, and Switzerland, we have all the successions needed to define this large system, which is situated in the upper Mesozoic. Table 4 lists the names of all the stages; all of them have been accepted by the ISC.

The Jurassic. The name of the system is a local one, since it makes reference to a well-known area in Europe, the Jura. This

Table 3. Series and stages of the Paleogene as listed in the ISC

Series	Oligocene	Eocene	Paleocene
Stages	Chattian	Priabonian	Thanetian
	Rupelian	Bartonian	Selandian
		Lutetian	Danian
		Ypresian	

term was already used in the 17th century (1795) by A. von Humboldt, who was the first to refer to the "landscape of Jura." Later, L. Von Buch (1774–1853) and Quenstedt (1809–1899) divided Swabia's Jura into three series: the white Jura, the brown Jura, and the black Jura, terms that are still used locally. The long-accepted stages were defined in different places, as shown in Table 5.

The term Malm, designated by Oppel (1856), comes from an English term used by quarrymen and makes reference to the friable limestone that was used as a mill stone. Dogger, adopted by by C.F. Naumann (1854), is also a quarryman's term; it refers to the rounded sandstone concretions found in the English series in Yorkshire. The term Lias is widely used, sometimes as a system name; thus, we talk about the Liassic and the Jurassic. The term was created by W. Smith (1799), in Somerset (England), and has its etymological origin in the word for layer. Its origin is also probably its use by quarrymen. It is a harder stratum placed between loams. All these terms were created in England, one of the first places in which the Jurassic was studied and where it is well-developed.

Other areas where the Jurassic has been studied in detail and which have given names to the stages are in France and Germany. Both northern Italy and Switzerland also have been the object of particular attention, and some terms that are still used come from these places.

It is curious that the only stage name that does not make specific reference to any locality is the Tithonian, which derives from the Greek God Tithonus, who fell in love with Eos, the Greek Goddess of dawn (the Tithonian is positioned at the dawn of the Cretaceous). It is well-defined in Germany, where the type-area of the upper Tithonian is found, and in France, close to Bérrias, the type-area of the lower Tithonian.

*The Triassic.*The history of this system is somewhat unusual. The great abundance of outcrops in southwestern Germany, easily characterized in the field based on their petrographic characteristics, gave rise to the name Trias (which obviously means three). It refers to the three types of rocks, with the German names Keuper, Muschelkalk, and Bundsandstein.

F. von Alberti (1834) adopted the name Keuper, which was the dialectal name given by quarrymen in southern Germany to the region's iridescent clays. The same author proposed the other two names, which are easily translated: Muschelkalk, shelly limestone, and Buntsandstein (or *buntersandstein*), variegated earthenware/stoneware. This latter rock has been used as construction material in many places because of its reddish

Table 4. Series and stages of the Cretaceous: origin, author, and year of designation[a]

Series	Stage	Origin	Author	Year of designation
Upper Cretaceous	Maastrichtian	Maastricht (NL)	Dumont	1849
	Campanian	La Grande Campagne	Coquand	1871
	Santonian	Saintes	Coquand	1857
	Coniacian	Cognac	Mayer-Eymar	1881
	Turonian	Tours	D'Orbigny	1842
	Cenomanian	Le Mans	D'Orbigny	1847
Lower Cretaceous	Albian	Aube	D'Orbigny	1842
	Aptian	Apt	D'Orbigny	1840
	Barremian	Barrême	Coquand	1862
	Hauterivian	Hauterive (CH)	Renevier	1873
	Valanginian	Valangin (CH)	Degold	1853
	Berriasian	Bérrias	Coquand	1871

[a] All the terms are taken from French towns, except for those indicated with NL (Netherlands) and CH (Switzerland).

Table 5. Series and stages of the Jurassic: origin, author, and year of designation[a]

Series	Stage	Origin	Author	Year of designation
Upper Jurassic (Malm)	Tithonian	from the god Tithonus	Oppel	1865
	Kimmeridgian	Kimmeridge Bay (E)	Thurmann	1832
	Oxfordian	Oxford (E)	O. d'Halloy	1843
Middle Jurassic (Dogger)	Callovian	Kellaways (E)	D'Orbigny	1849
	Bathonian	Bath (E)	O. d'Halloy	1843
	Bajocian	Bayeux (F)	D'Orbigny	1859
	Aalenian	Aalen (D)	Mayer-Eymar	1864
Lower Jurassic (Lias)	Toarcian	Thouars (F)	D'Orbigny	1849
	Pliensbachian	Pliensbach (D)	Oppel	1858
	Sinemurian	Semur (F)	D'Orbigny	1842
	Hettangian	Hettange (F)	Renevier	1864

[a] E (England), F (France), D (Germany).

color. In Germany and in most of the Rhine area, it is common to see buildings and monuments made of Buntsandstein, e.g., the Strasbourg Cathedral, and many buildings in Basel and Heidelberg.

These three series are fundamentally formed by continental sediments, and therefore it has been difficult to establish global correlations. Thus, other places, with marine sediments, have been searched in order to establish the stages. The first alternative was the alpine zone, the source of the reference to the alpine Trias rather than to the Germanic Trias. Research also has been carried out in other places. Table 6 lists the stages as stated in the ISC.

The Paleozoic Erathem. For the Paleozoic Erathem it has been particularly difficult to establish a list of stage-type localities. In addition, while many systems were defined a long time ago, others remain undefined. To establish the Permian—which is the Paleozoic's most modern system—several rather, at least for that time, extraordinary journeys were required, since no clear elements were found in Western Europe. Permian derives from the name of the Russian part of the Urals. It was thought to refer to the city of Perm, but modern revisions have shown that the name actually comes from the ancient kingdom of Permya. The definition of the Permian was the result of the convictions of some European geologists, who felt that between the Carboniferous, well-known for its abundance of carbon, and the Triassic there was a system of time that was not well-represented in Western Europe. Accordingly, a team of geologists led by Roderick Impey Murchison and Edouard de Verneuil visited the Urals in 1840, where Russian geologists told them about layers that were abundant in fossils. Consequently, already in 1841, this system was given the name Permian, as explained in detail by Murchinson in a letter to Tsar Nicolau I, who had granted the scientists permission to visit Russia.

The other systems, in descending order, are: the Carboniferous, the Devonian, the Siluarian, the Ordovician, and the Cambrian. The Cambrian is the first system of the Phanerozoic Eon. It takes its name from Cambria, the classical name for Wales. The Cambrian is well-known for its abundance in fossils, and many localized stages have been defined. The most ancient eon, which ranges from 542 million years ago to the birth of a solid Earth, is called Cryptozoic, because it was very difficult to see fossils in the rocks and it has not been possible to establish a detailed scale of the chronostratigraphic units that form it. In fact, it was not until that 1950s that we had any idea of its antiquity or of the types of life that were present, or the formation of the continents, atmosphere, or hydrosphere. The subsequent evolution in our knowledge is described in detail in Reguant [3].

The Permian. In Germany, the Permian is divided in two series, Zechstein and Rothliegendes. The former comes from an ancient German word that means hard stone, and the latter from "rothes Todtliegendes", which means red substratum of the Kupferschiefer (copper shales). These two terms had already been used by Lehmann (1756) in his study of the eastern part of the Harz. Analogous to the three series of the Trias, the Permian is divided in two, which led Marcou (1859) and Geinitz (1861–1862) to give it the name Dyas. However, this name has not been very well-accepted, since in Western Europe the Permian is considered to be formed by three series, the Thuringian, Saxonian, and Autunian, which are also the names of the places where the corresponding stratigraphic successions were found. Thuringian was adopted by Renevier in 1874 to denominate the schists and limestones of Thuringia (Germany). Saxonian comes from Saxony (Germany) and was used by Lapparent and Munier-Chalmas (1892) to designate the red stoneware found in this area and which is of continental facies. Autunian (Autun, Saone-et Loire), was adopted by Mayer-Eymar and Laparent (1892); it refers to an area in France that is noteworthy for its bituminous schists.

The divisions of the Permian, as established recently by the Permian Commission of the IUGS and accepted by the ISC, are listed in Table 7.

The names of the series are also local: Lopingian was designated by Huang in 1932, in China; the Guadalupian received its name from Guadalupe (Mexico) and was adopted by Richardson (1907) and Girty (1908); Cisuralian (the western part of the Urals) was the designation of Waterhouse, in 1982. The Lopingian and its subdivisions are the result of stratigraphic research in China, the Guadalupian in the United States, and the Cisuralian in Russia; those regions that can be considered type-areas for the Permian. It is evident that the successions chosen as being the most appropriate were established in the indicated places. As discussed at the beginning of this article, this marked the entry of other countries to the field of geology during the 20th century, which in turn made it possible to find

Table 6. Series and stages of the Triassic: origin, author, and the year of designation[a]

Series	Stage	Origin	Author	Year of designation
Upper Triassic (Keuper)	Rhaetian	Rhaetian Alps (CH)	Gümbel	1859
	Norian	Noric Alps (Ö)	von Mojsisovics	1873
	Carnian	Carnic Alps (I)	von Mojsisovics	1873
Middle Triassic (Muschelkalk)	Ladinian	People of Ladini (CH and I)	Bittner	1892
	Asinian	Enns River (Anisius) (Ö)	von Mojsisovics	1895
Lower Triassic (Buntsandstein)	Olenekian	Olenek River (Siberia)	Kiparisova & Popov	1956-61
	Induan	Indus River (Salt Range)	Kiparisova & Popov	1956-61

[a]CH (Switzerland), Ö (Austria), I (Italy).

Table 7. Series and stages of the Permian: origin, author, and year of designation

Series	Stage	Origin	Author	Year of designation
Lopingian	Changhsingian	Changhsing (China)	Sheng	1963
	Wuchiapingian	Wuchiaping (China)	Sheng	1963
Guadalupian	Capitanian	Capitan Peak (USA)	Richardson	1904
	Wordian	Word Formation (USA)	Udden et al.	1916
	Roadian	Road Canyon (USA)	Furnish	1966
Cisuralian	Kungurian	Kungur (Russia)	Stuckenberg	1890
	Artinskian	Artinsk (Russia)	Karpinsky	1874
	Sakmarian	Sakmara River (Russia)	Karpinsky & Rujentzev	1874–1936
	Asselian	Assel (Russia)	Rujentzev	1937

successions more adequate than those previously identified in Germany and elsewhere in Western Europe.

The Carboniferous. As the word itself indicates, this system is characterized by carbon. For reasons not easily explained, it marks a time during which great quantities of carbon were formed (anthracite and coal) around the world, in a way practically unique to the Earth's history—although important quantities of lignite were formed during the Mesozoic and the Cenozoic, while during the Quaternary, pea—an initial stage in carbon formation—is being produced. Enormous coalfields are found in the Upper Carboniferous in Europe, giving rise to the system name, and in North America. Also, in the former USSR, China, and the ancient continent of Gondwana, which included important parts of what is now the Southern Hemisphere, carbon was formed in the Permian. That is why the name Anthracolithic (coal stone in Greek) has been used to refer to the Permocarboniferous.

Carboniferous (Conybeare 1822), refers to the abundance of carbon, since this energy-rich material allowed for the growth of industry in England, and in Europe as a whole. Geologically, the carbon-carrying sediments are not of marine facies, a fact that has prevented a world-wide stratigraphical correlation and that has led to the creation of two divisions in this system. Moreover, for the Upper Carboniferous, the interest this system has aroused historically has resulted in a remarkable number of different names for the systems and stages.

Two chronostratigraphic scales (Tables 8 and 9) provide information on the experts' current view of the situation. One scale makes reference to Western Europe, in which the local terms are derived from the names of important carbonous basins in England, France, and the Cantabrian mountain range (Asturias and León); this scale coincides with the one published in the ISC only in its inferior part, where there is no carbon. The marine facies useful for international correlation are located in Western Europe, in Belgium in particular. Wagner and Winkler Prins, geologists who also worked extensively in the Cantabrian mountain range, published the succession in Western Europe in 1993 [5].

The stages of the upper and productive Carboniferous acquired their names from sedimentary successions in France, Spain, and Germany, while the Namurian is basically found in England. The authors did not feel that it was useful to divide the Viséan and Tournaisian series, which, as shown in Table 9, are considered as stages by the ISC.

Except for two stages, known for a long time and described in Belgium (B), all of the stages have been described outside Western Europe, i.e., in Russia (R), around Moscow and the Urals, and the Bashkirian. Two series names derive from places in the United States: the coal-rich state of Pennsylvania and the Mississippi River. The Mississippian was created by Winchell, in 1870, and the Pennsylvanian by Martin J.S. Rudwick, in 1985.

The Devonian. The name comes from the county of Devon, in England, although initially the layers below the Carboniferous were named Old Red Sandstone. This was due to the fact that, except for southern England, where the successions of marine facies were found, other places in the country had continental facies, making comparisons with the underlying Paleozoic difficult. The discovery of these materials in Devonshire by a commissioner of the British government, Herny de la Beche, did not bode well with English geologists, leading to a long-raging controversy about the Devonian time, as Martin J.S. Rudwick (1985) recounted in great detail.

Subsequent studies showed that the Devonian was best represented not in England, but in continental Europe, and the names of the stages were subsequently taken from places in Belgium, France, and Germany. Recently, as a result of intense work carried out by the Subcommission on Devonian Stratigraphy, the earliest part of the system was determined to be best-represented in the Czech Republic (Table 10).

The Silurian. The name of this system is also indirectly "local," since Roderick Murchinson (1835) took the name of the Celtic tribe, the Silures, who lived in what is known as the Welsh Borderland, where the type areas of two of the series in which the system is divided, the Wenlock and the Ludlow, are found. As in the case of the lower Devonian, the upper Silurian is characterized by the successions found in the Czech Republic. The series division of this system has been modified very little since its creation by Murchison, as seen in Table 11, which is taken from the ISC.

Pridoli comes from Pridoli, an area of the Daleje Valley on the outskirts of Prague, Czech Republic [6]. Ludlow was named after a place with the same name in England (Murchison 1854); as is the case for Wenlock (Murchinson 1834). Llandovery was

Table 8. Series and stages of the Carboniferous in Western Europe: origin, author, and year of designation[a]

Series	Stage	Origin	Author	Year of designation
Stephanian	Stephanian C	Saint-Etiénne (F)	Munier Ch & de Lapparent	1834
	Stephanian B	Saint-Etiénne (F)	Munier Ch & de Lapparent	1834
	Barruelian	Barruelo de Santillán (S)	Wagner & Winkler Prins	1985
	Cantabrian	Cantabrian Mountains (S)	Wagner	1965
Westphalian	Westphalian D	Westphalia (D)	de Lapparent & Munier Ch	1892
	Bolsovian		Engel	1989
	Druckmantian		Engel	1989
	Langsetian		Engel	1989
	Yeadonian	Yeadon (E)	Hudson	1945
	Marsdenian	Marsden (E)	Bizat	1928
	Kinderscoutian	Kinderscout (E)	Bizat	1928
	Alportian	Alport (E)	Hudson & Cotton	1943
	Chokerian	Chokier (B)	Hodson	1957
	Arnsbergian	Arnsberg (D)	Hudson & Cotton	1943
Namurian	Pendleian	Pendle (E)	Hudson & Cotton	1943
Visean		Visé (B)	Dupont	1883
Tournaisian		Tournai (B)	Koninck	1872

[a] (F) France, (S) Spain, (D) Germany, (E) England, (B) Belgium.

Table 9. Series and stages of the Carboniferous according to the ISC: origin, author, and year of designation

Series	Stages	Origin	Author	Year of designation
Pennsylvanian	Gshelian	Gshel (R)	Nikitin	1890
	Kasimovian	Kasimov (R)	Dan'shin	1947
	Moscovian	Moscow (R)	Nikitin	1890
	Bashkirian	Baixkiria (R)	Semikhatova	1934
Mississipian	Serpukhovian	Serpukhov (R)	Nikitin	1890
	Visean	Visé (B)	Dupont	1883
	Tournaisian	Tournai (B)	Konink	1872

Table 10. Series and stages of the Devonian: origin, author, and year of designation[a]

Series	Stage	Origin	Author	Year of designation
Upper	Famennian	Famenne (B)	Dumont	1848
	Frasnian	Frasnes (B)	of Homalius d'Halloy	1862
Middle	Givetian	Givet (F)	of Homalius d'Halloy	1862
	Eifelian	Eifel (D)	Dumont	1848
Lower	Emsian	Ems (D)	Dorlodot	
	Pragian	Prague (CZ)	Ziegler & Klapper	
	Lochkovian	Lochkov (CZ)		1900–1985

[a] B (Belgium), F (France), D (Germany), CZ (Czech Republic).

named after the district of Llandovery, in Wales (Murchinson 1839).

The Ordovician. Like the Silurian, the name Ordovician comes from the Ordovices, the last Welsh tribe to be subdued by the Romans. There is still no agreement on the names of the stages that should be used, since those used until recently—shown in the following list—have not been accepted into the ISC, which makes use of only a few recently defined names (Table 12).

The stages, taken as series by many authors and accepted for many years, are (in ascending antiquity):

- Ashgillian: Ashgill (England), Marr (1905)
- Caradocian: Caradoc (England), Murchison (1835)
- Llandeilian: Llandeilo (Wales), Murchison (1835)
- Llanvirnian: Llanvirn (Wales), Hicks (1875)
- Arenigian: Arenig (Wales), Sedgwick (1852)
- Tremadocian: Tremadoc (Wales), Sedgwick (1852)

Table 11. Series and stages of the Silurian: origin of the name, author, and year of designation[a]

Series	Stage	Origin	Author	Year of creation
Pridoli				
Ludlow	Ludfordian Gorstian			
Wenlock	Homerian Scheinwoodian	Homer		
Llandovery	Telychian Aeronian Rhuddanian	Telych (W) Aeron (W) Ruddan (W)	Cfr. Basset 1985 Cfr. Basset 1985 Cfr. Basset 1985	Approved by the Int Sub Sil Str 1984

[a] (W) Wales.

Table 12. Series and stages of the Ordovician: origin, author, and year of designation

Series	Stage	Origin	Author	Year of designation
Upper Ordovician	Hirnantian Katyan Sandbyan	Hirnant (Wales) Katy Lake (USA) S.Sandby (Sweden)	Bancroft Bergström et al.	1933 2006
Middle Ordovician	Darrivilian X	(Australia)		1996
Lower Ordovician	Floian Tremadocian	Flo (Sweden) Tremadoc (Wales)	Bergstrom et al. Sedgwick	2006 1852

Table 13. Series and stages of the Cambrian: origin, author, and year of designation[a]

Series	Stages	Origin	Author	Year of designation
Furongian	X Paibian	 Paibi, Hunan, China	 Shanchi et al.	 2002
Middle Cambrian	X X			
Lower Cambrian	X X			

[a] According to current information.

Cambrian. It has been very difficult to study the most ancient system because of the poor condition of the relevant outcrops. For this reason, except for certain regions where the subdivisions have been given names, we generally refer to three series without place names: the Lower, Middle, and Upper Cambrian. Recent revisions have started to provide more specific names, as shown in Table 13.

The name Furongian, accepted to designate the Upper Cambrian, is currently the only specific name given to a Cambrian series. It comes from Furong, which means lotus, since it refers to the province of Hunan, in the state of Lotus (China).

The definition of the limits between units and their location

The different subcommissions dedicated to the study of each of the systems have been working very hard to find places where the limit between chronostratigraphic units can be defined. According to international agreements made thus far, the place where the inferior limit of a certain unit is situated is called the GSSP (global boundary stratotype section and point).

The information available until now is provided in the following list, starting from the most modern times and going back towards more ancient ones.

- GSSP base of the Pleistocene Series (Quaternary): section in Vrica, Italy [7]
- GSSP base of the Gelasian Stage, Pliocene (Neogene): section in Gela, Italy [8]
- GSSP base of the Piacenzian Stage, Pliocene (Neogene): section in Punta Piccola, Italy [9]
- GSSP base of the Zanclean Stage, Pliocene (Neogene): section in Eraclea Minoa, Sicily, Italy [10]
- GSSP base of the Pliocene Series (Neogene): section in Eraclea Minoa, Sicily, Italy [10]

- GSSP base of the Messinian Stage, Miocene (Neogene): section in Oued Akrech, Rabat, Morocco [11]
- GSSP base of the Tortonian Stage, Miocene (Neogene): section in Monte dei Corvi, Ancona, Italy [12]
- GSSP base of the Aquitanian Stage, Miocene (Neogene): section in Lemme-Carrosio, Italy [13]
- GSSP base of the Neogene Period: section in Lemme-Carrosio, Italy [13]
- GSSP base of the Rupelian Stage, Oligocene (Paleogene): section in Massignano, Italy [14]
- GSSP base of the Oligocene Series (Paleogene): section in Massignano, Italy [14]
- GSSP base of the Ypresian Stage, Eocene (Paleogen): section in Dababiya, Luxor, Egypt [15]
- GSSP base of the Eocene Series (Paleogene): section in Dababiya, Luxor, Egypt [15]
- GSSP base of the Danian Stage (Paleogene): section in The Kef, Tunis [16]
- GSSP base of the Series Paleocè (Paleogene): section in The Kef, Tunis [16]
- GSSP base of the Paleogene Period: section in The Kef, Tunis [16]
- GSSP base of the Cenozoic Era: section in The Kef, Tunis [16]
- GSSP base of the Maastrichtian Stage (Cretaceous): section in Dax, Tercis le Bains, France [17]
- GSSP base of the Turonian Stage (Cretaceous): section in Rock Canyon, Pueblo, Colorado, USA [18]
- GSSP base of the Cenomanian Stage (Cretaceous): section in Mont Risou, Hautes Alpes, France [19]
- GSSP base of the Bajocian Stage (Jurassic): section in Cabo Mondego, Portugal [20]
- GSSP base of the Aalenian Stage (Jurassic): section in Fuentelsalz, Spain [21]
- GSSP base of the Pliensbachian Stage (Jurassic): section in Wine Haven, Yorkshire, England [22]
- GSSP base of the Sinemurian Stage (Jurassic): section in East Quantoxhead, Watchet, W Somerset, England [23]
- GSSP base of the Ladinian Stage (Triassic): section in Bagolino, Italy [24]
- GSSP base of the Induan Stage (Triassic): section in Meishan, Zhejiang, China [25]
- GSSP base of the Triassic Period: section in Meishan, Zhejiang, China [25]
- GSSP base of the Changhsingian Stage (Permian): section in Changxing County, Zhejiang, China [26]
- GSSP base of the Wuachiapingian Stage (Permian): section in Guangxi Province, S. Xina [27]
- GSSP base of the Asselian Stage (Permian): section in Aidaralash Creek, Kazakhstan [28]
- GSSP base of the Cisuralian Series (Permian): section in Aidaralash Creek, Kazakhstan [28]
- GSSP base of the Permian Period: section in Aidaralash Creek, Kazakhstan [28]
- GSSP base of the Bashkirian Stage (Carboniferous): section in Fm. Battleship, Arrow Canyon, Nevada, USA [29]
- GSSP base of the Pennsylvanian Subperiod (Carboniferous). Section in Fm. Battleship, Arrow Canyon, Nevada, USA [29]
- GSSP base of the Tournaisian Stage (Carboniferous): section in La Serre, Montagne Noire, France [30]
- GSSP base of the Mississipian Subperiod (Carboniferous): section in La Serre, Montagne Noire, France [32]
- GSSP base of the Carboniferous Period: section in La Serre, Montagne Noire, France [30]
- GSSP base of the Famennian Stage (Devonian): section in Comiac, Montagne Noire, France [31]
- GSSP base of the Frasnian Stage (Devonian): section in Col du Puech de la Suque, Montagne Noire, France [32]
- GSSP base of the Givetian Stage (Devonian): section in Jebel Mech Indane, Tafilalt, Morocco [33]
- GSSP base of the Eifelian Stage (Devonian): section in Wetteldorf Richschnitt, Schönecken-Weteldorf, Germany [34]
- GSSP base of the Emsian Stage (Devonian): section in the Zinzilban Gorge, Samarkanda, Uzbekistan [35]
- GSSP base of the Pragian Stage (Devonian): section in Velka Chuchle, Prague, Czech Republic [36]
- GSSP base of the Lockovian Stage (Devonian): section in Klonck, Prague, Czech Republic [37]
- GSSP base of the Devonian Period: section in Klonk, Prague, Czech Republic [37]
- GSSP base of the Pridoli Series (Silurian): section in Pozáry, Prague, Czech Republic [38]
- GSSP base of the Ludfordian Stage (Silurian): section in Ludlow, Shropshire, England [38]
- GSSP base of the Gorstian Stage (Silurian): section in Ludlow, Shropshire, England [38]
- GSSP base of the Ludlow Series (Silurian): section in Ludlow, Shropshire, England [38]
- GSSP base of the Homerian Stage (Silurian): section in Ludlow, Shropshire, England [38]
- GSSP base of the Sheinwoodian Stage (Silurian): section in Apedale, Shropshire, England [38]
- GSSP base of the Wenlock Series (Silurian): section in Apedale, Shropshire, England [38]
- GSSP base of the Telychian Stage (Silurian): section in the area of Llandovery, Wales [38]
- GSSP base of the Aeronian Stage (Silurian): section in the area of Llandovery, Wales [38]
- GSSP base of the Ruddanian Stage (Silurian): section in Dob's Linn, Moffat, Scotland [39]
- GSSP base of the Silurian System: section in Dob's Linn, Scotland [39]
- GSSP base of the Hirnantian Stage (Ordovician): section in Wangjiawa, Yichang, China [40]
- GSSP base of the Sandbian Stage (Ordovician): section in Fagelsang Scane, Sweden [41]
- GSSP base of the Darriwilian Stage (Ordovician): section in Huangnitang, Changshan, China [42]
- GSSP base of the Floian Stage (Ordovician): section in Västergötland, Sweden [43]
- GSSP base of the Tremadocian Stage (Ordovician): section in Green Point, Newfoundland, Canada [44]

– GSSP base of the Ordovician Period: section in Green Point, Newfoundland, Canada [44]
– GSSP base of the Paibian Stage (Cambrian): section in Paibi, NW Hunan, China [45]
– GSSP base of the Furongian Series (Cambrian): section in Paibi, NW Hunan, China [45]
– GSSP base of the Cambrian Period: section in Fortune Head, peninsula of Burin, Newfoundland, Canada [46]

Final reflections

Stratigraphy, the field of geology comprising our knowledge of the history of Earth and the life on the planet, has always searched for suitable places, i.e., those that best represent the knowledge accumulated thus far regarding the passing of historical time, such as it can be "read" by analyzing the rock record, which is accessible to us on the surface or through borehole cores. Most of the stratigraphic successions employed to define the units were published in the 19th century (the oldest ones cited here are from 1832). More detailed analyses of the chronostratigraphic scale have led to the establishment of the GSSP, with the first definition dating from 1982.

Geology is possibly the only science that must take into account the place where the knowledge was obtained and the place that allowed it to be further elucidated—as both have implications for any revision of the Earth's history. Thus, Geology can truly be defined as a "local" science.

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