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PRINCIPLES OF STRATIGRAPHY

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Stratigraphy is That branch of geology that deals with formation, composition, sequence, and correlation of stratified rocks. Since the whole Earth is stratified, at least in a broad sense, bodies of all the different types of rocks—igneous, sedimentary, metamorphic—are subject to stratigraphic study and analysis. In most cases however, stratigraphy focuses on the evaluation of sedimentary rock strata. Modern principles of stratigraphic analysis were worked out in the 18th and 19th centuries by geologists such as Niels Stensen, James Hutton, Georges Cuvier, William Smith and Charles Lyell. By 1900 all the intellectual tools needed to establish the description, sequence, and correlation of strata were in place. Shortly after 1900, the tools needed to establish the absolute age of minerals containing unstable radioisotopes also became available, giving stratigraphers a physical basis for making chronostratigraphic correlations, at least in certain, favourable stratigraphic situations. Since the 1950's effort has also been expended in establishing international standards for stratigraphic nomenclature, usage of stratigraphic terms, and the internationally agreed designation of 'type-sections' or stratotypes for various sorts of stratigraphic units, especially those relating to chronostratigraphy.

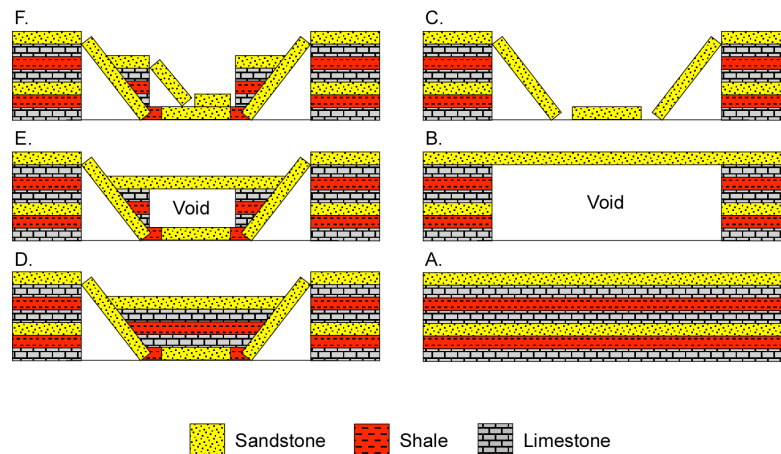


Figure 1. Steno's conceptual interpretation of the stratigraphic history of Tuscany. A. Flat-lying, continuous sediments were deposited beneath marine waters. B. lithified sediments are uplifted and subterranean voids or caverns develop through the erosive action of subsurface waters. C. When the subterranean voids grow sufficiently large collapse of the roofing layers takes place elevating the cavern walls, down-dropping flat-lying layers that remain intact, and causing the tilting of blocks adjacent to the elevated areas. D. submergence of the entire land surface, once again, causes flat-lying, continuous sediments be to deposited. E. These new sediments are lithified and uplifted, after which new, cavernous voids develop. F. A new round of erosional collapse further modifies the landscape. Note how Steno's model encompasses both the apparent directional and cyclic nature stratigraphic deposits and landscape formation. Redrawn from Steno's diagram in *De solido intra solidum naturaliter contento disseratiinis prodromus*.

First principles

The study of stratigraphy began with attempts to understand common observations such as what the rocks we call fossils are and how the rocks that comprise mountains came to be elevated above the land surface. Of course, both fossils and mountains were well known to ancient Greek natural historians such as Plato, Aristotle, Xenophanes, and Pliny. Although a variety of explanations for these phenomena were offered, no systematic investigations of modern aspect were carried out, according to the intellectual style of the time. The organic nature of fossils was recognized by a number of Renaissance scholars, including Leonardo de Vinci (1452–1519) and Conrad Gesner (1516–1565). Da Vinci's writings were particularly prescient in that he recognized fossil mollusc shells from the on the tops of mountains were similar to the shells of modern molluscs, and that this similarity implied that sediments occupying the mountain tops must have been deposited originally beneath marine waters. These were isolated musings, however.

The first modern treatment of a stratigraphic problem was published by Niels Stensen (1638–1686, also known by his anglicised literary name, Nicholas Steno) in 1669. Most scholars mark Steno's *De solido intra solidum naturaliter contento disseratiinis prodomus* as the first stratigraphic treatise. In this short work—which was presented to Steno's patron, the Grand Duke Ferdinand II of Tuscany—Steno establishes three cardinal principles of stratigraphic analysis and then uses these to reconstruct the geological history of Tuscany. Steno's principles are as follows.

1. *Original horizontality* – unconsolidated sediments deposited on a solid base must have originally formed horizontal layers since the sediment particles would have 'slithered' to the lowest point. Thus, consolidated strata inclined at some angle must have become tilted after consolidation.
2. *Original continuity* – layers of unconsolidated sediments deposited on a solid base would have formed continuous sheets of material. Thus, bands of consolidated sediments whose ends have been broken must have experienced this breakage and erosion after consolidation.
3. *Superposition* – Since each layer of unconsolidated sediment deposited on a solid base must form after the basal layer has been deposited, layers of sediment that overly other layers are younger than the other layers.

Using these principles Steno argued that Tuscan geology, and especially the stratified sediment layers forming its mountains, represented the remains of a series of subterranean erosion and land-surface collapse events (**Figure 1**). Not only did this model reconcile the cyclic and directional aspects of the Tuscan stratigraphic record, it also established the principal of stratigraphic correlation as the hypothetical matching of stratigraphic observations from distant outcrops in order to obtain a sense of a rock body's geometric structure (**Figure 2**).

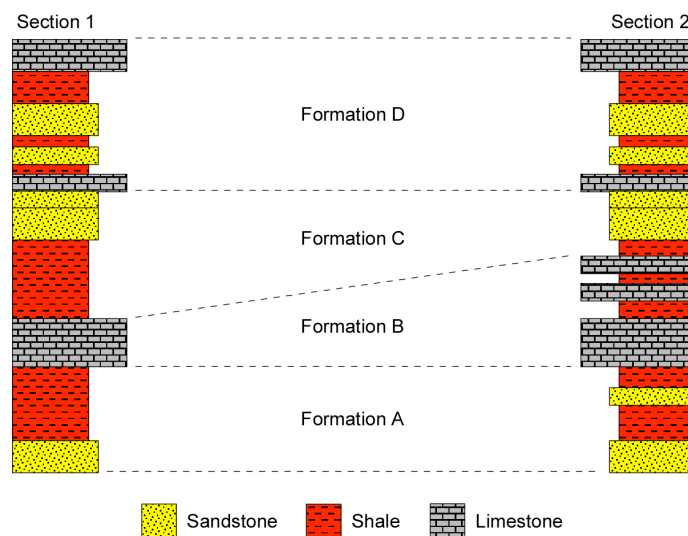


Figure 2. In addition to developing his theory landscape formation, Steno's model stressed the importance of stratigraphic correlation: the matching of stratigraphic sequences between outcrops. In this illustration two hypothetical outcrop sections have been correlated based on rock type and subdivided into lithologically unified packages of strata.

The next significant contribution to stratigraphic principles was made in 1785 by the Scottish lawyer-gentlemen farmer James Hutton (1726–1797), who stressed the cyclic aspects of the stratigraphic record in his doctrine of uniformitarianism. Citing evidence from the angular unconformities exposed at such Scottish localities as Jedburgh, and Siccar Point, Hutton reasoned that the originally horizontal marine sediments of the lower succession must have been consolidated, then tilted as they were raised up above the water's surface, planned off by erosion, submerged, buried by additional horizontally deposited sediments, which were then consolidated, and the entire sequence, and lifted again to become the rock bodies we see before us at these, and other, localities. To Hutton, these erosion-deposition-uplift cycles had been repeated endlessly in Earth history, implying that (1) the Earth itself is very old, (2) the

processes we see working today (e.g., erosion, deposition, gradual uplift) operated in the past, (3) that the power for uplift came from the heat generated by compaction, supplemented by heat at depth left over from the Earth's initial formation, and (4) the ultimate purpose of this system was to produce a self-renewing Earth that was 'adapted to the purposes of man.' In particular, Hutton denied that fossils provided any evidence for the directional passage of time because each uniformitarian cycle's biota was 'perfect'.

Writing slightly later (1812), the French Baron Gorges Cuvier (1769-1832) published a summary of his paleontological studies in the Paris Basin in his book *Recherches sur les Ossements Fossils*, the first chapter of which took issue with Hutton's uniformitarian approach to stratigraphic analysis. Cuvier argued that the abrupt disappearance of entire fossil marine faunas that characterize several horizons within this basin, and the equally abrupt appearance of new terrestrial faunas in strata lying just above these marine beds, was evidence for the repeated and sudden and, in ecological terms, catastrophic elevation of the land. In contrast to Hutton's endless cycles, Cuvier and his colleagues—who came to be known as 'catastrophists'—envisioned an Earth whose internal core was undergoing a constant thermal contraction. As this core pulled away from the hard crust gaps opened up. It was these gaps that were responsible for the catastrophes. In a manner analogous to Steno's model, crustal failure occurred when the subterranean gaps become too large to support the burden of the overlying crust. It was supposed that these failures happened suddenly, down-dropping entire regions, the surrounding parts of which would appear to be thrust up (in relative terms) as mountains. Unlike Hutton's endless uniformitarian cycles, Cuvier's hypothesis of Earth history was resolutely directional and finite. The Earth would eventually cool to the point where no more contraction would take place, thus bringing the catastrophes to an end. Also unlike Hutton, the catastrophists saw extinction as being a real phenomenon with new biotas responding to the changed environment in unique ways.

The next major contribution to stratigraphy was made by the English canal surveyor and geologist William Smith (1769-1839). Smith was the first to recognize the difference between lithostratigraphy (the characterization of rock strata by the kind and/or arrangement of their mineralogical constituents) and biostratigraphy (the characterization of rock strata by their biological constituents). Before Smith, the remains of once living creatures and the mineral particles of which sedimentary rocks are made were considered to be of equal value in recognizing strata. Smith made a conceptual distinction between lithological and palaeontological sources of stratigraphic information and, by careful analysis of the fossils contained in stratigraphic bodies, demonstrated that strata with very similar lithological constituents could be distinguished on the basis of their fossil content. Even more importantly, Smith showed that the successive biotas preserved in the sedimentary strata of the British midlands always occurred in the same sequence regardless of the character of local lithological sequences. This key stratigraphic principle later became known as the *Principle of Faunal Succession* (**Figure 3**). By applying the Principle of Faunal Succession to his biostratigraphical observations Smith was not only able to predict more accurately the types of rocks that would be encountered during canal construction, he was also able in 1815 to produce the first modern geological map.

While William Smith was not given to abstract theorizing, his commitment to field observations, willingness to accept those observations at face value, and use of fossil extinction events as a basis on which to recognize the directional passage of time was far more in line with the philosophical tenets of catastrophism than uniformitarianism. Uniformitarianism's champion was Charles Lyell (1797-1875). Lyell accepted the cyclic nature of Huttonian uniformitarianism to the extent that he denied the possibility of both extinction and evolution (though, to be fair it must be said that the latter was denied by Cuvier as well, albeit on different grounds). Lyell also emphasized and greatly developed Hutton's original commitment to a mechanistic uniformitarianism in which known natural laws and processes operating at rates comparable to those observed today were held to be responsible for all features of the geological record (though also to be fair Cuvier, Agassiz and the other scientific catastrophists also accepted the principles of mechanistic uniformitarianism). Lyell summarized these arguments, and supported them with examples drawn from his geological travels throughout Europe in a massive three-volume work *Principles of Geology* published in 1830-1833.

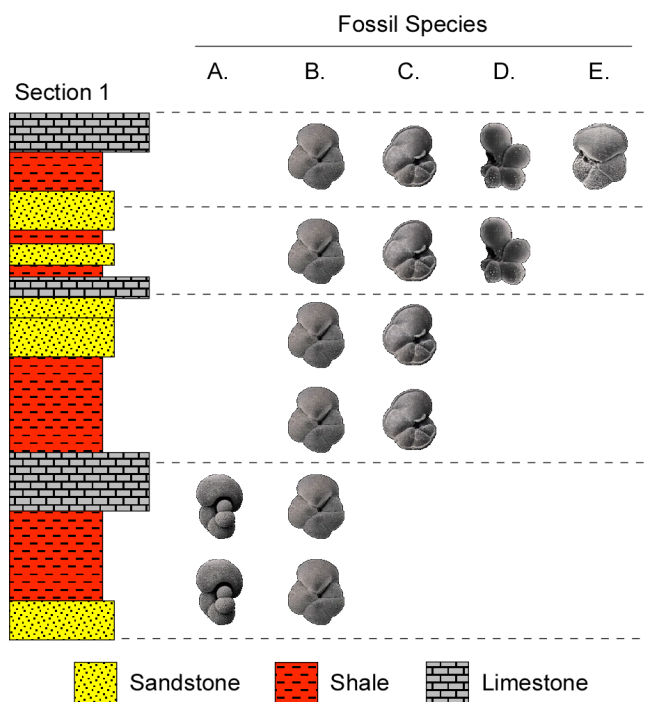


Figure 3. Organization of stratigraphic sequences into units based on their fossil content using the principle of faunal succession. In this illustration the distribution of five fossil planktonic foraminiferal species has been used to recognize stratigraphic units on the basis of unique associations of species. The principle of faunal succession works as a way or recognizing stratigraphic units because fossil species are individualized in the sense that they have a definite and unique starting point (the speciation event) and ending point (the global extinction event). Thus, the stratigraphic range of a fossil species encompasses a distinct time interval. Note also that palaeontologically-defined stratigraphic units differ in both number and kind from lithologically defined units (compare with **Figure 2**).

While the uniformitarian-catastrophist debate has often been portrayed as a triumph of dispassionate scientific reason over theologically-driven special pleading with the Lyell uniformitarians founding the sciences of stratigraphy and sedimentary geology as we know them today, a more faithful nuances of the historical record reveals a far more interesting story. Lyellian uniformitarianism did indeed triumph. But not so much over the scientific catastrophism of Cuvier, Brongniart, d'Orbigny, and Agassiz as over the theological catastrophism embraced by the school of Natural Theology (especially in England) and sheer scientific fantasy. Lyell's reasoned approach that emphasized modern processes working over long periods of time appealed to many, not the least of which was Charles Darwin who used Lyellian principles as a basis for his geological explorations on the *Beagle* voyage. Lyell's commitment to the basic uniformitarian doctrine of endless and ahistorical cyclicity, however, was not accepted even among Lyell's contemporaries. He was caricatured for this position by Henry de la Beche in a famous cartoon, and was forced to retract from by stages through the latter part of his life. Neither was Lyell's view of the value of fossils for achieving stratigraphic correlations—at least for higher taxonomic groups—employed, by Lyell's contemporaries, much less by contemporary stratigraphers. Modern uniformitarianism is a combination of Huttonian-Lyellian emphasis on modern, observable processes operating over long periods of time—that emphasizes their mechanistic conservatism, but nevertheless allows for the incorporation of processes that have no modern counterpart (e.g., Louis Agassiz's continental glaciations, enormous flood-basalt volcanic eruptions, asteroid impacts)—and a catastrophist emphasis on extinction and the directional nature of geological time.

Following Smith's demonstration of the power of biostratigraphy, the forefront of stratigraphic research turned to the identification of biostratigraphic zones that could be used to facilitate long-range stratigraphic correlations, (e.g., intrabasinal, interbasinal, and intercontinental). This immediately raised a further conceptual problem. Once the same biozone had been identified in different localities, did this mean that the resulting correlation located the two sections in terms of their position in the sequence of biotas preserved over geological time (homotaxis) or in terms of geological time itself (homochrony). These concepts are distinct because the same sequence of events could be persevered at different localities without the individual events having taken place at the same times.

Up to 1900 stratigraphers had been forced to couch their observations in terms of relative time (e.g., Event A took place before or after Event B) because there was no way to measure absolute time in stratigraphic successions. Attempts to estimate absolute time were made, usually based on modern sediment accumulation rates and estimates of compaction ratios for different sedimentary rock types. Nevertheless, since these rates and ratios vary widely, and since there was no way of confirming that any given estimate was correct, such calculations were approximate at best.

This situation changed in the early 1900's, however, with the discovery of natural radioactivity and unstable radioisotopes of naturally occurring elements. Radioisotopes have unstable nuclei that spontaneously decay through the emission of charged subatomic particle from the isotope's nucleus at a fixed and measurable rate. Daughter isotopes are produced as the products of this decay process, along with various types of radiation. If the amount of original radioisotopic material of a specific type is known for a particular mineral species, and the amount of daughter-product isotope is known, the absolute age of the of the mineral can be calculated, subject, of course to several assumptions (e.g., correct value for the decay constant, accurate measurements, no loss of daughter product isotope).

Unfortunately, accurate isotopic dating cannot usually be carried out on sediments directly. Most sedimentary rocks are composed of mineral grains whose own origin predates the origin of the sedimentary rock body by a substantial time interval. In some instances though, a layer of volcanic material (e.g., an ash-fall tuff) with newly formed mineral crystals can become interbedded within a suite of sedimentary rock. In such cases the age obtained from the volcanic deposit can be used to constrain the age of the immediately overlying and underlying sediments, subject, once again, to assumptions. By using isotopically dateable materials located stratigraphically near major biostratigraphically-defined boundaries in the stratigraphic record (see below) it is possible to estimate absolute ages for these boundaries.

Stratigraphic Classification

As stratigraphers combined the principles of stratigraphic analysis set down by Steno, Hutton, Cuvier, Smith, Lyell, and others with lithostratigraphic, biostratigraphic, and geochronologic observations during the first half of the 20th Century, the true geometric relation between observed lithostratigraphic and biostratigraphic units emerged, along with their mutual relation to an entirely conceptual 'chronostratigraphy' (the characterization of rock strata by their temporal relations). These concepts are illustrated in **Figure 4**, and are usually discussed in terms of the distinction between rock-stratigraphic units (that are distinguished by physical or biotic criteria that can be observed at the outcrop, core, well-log, etc.) from time-stratigraphic units (that are in all cases inferences based on stratigraphic observations, but have the advantage of being referable to a common geological time scale). There has been, and continues to be, much confusion over the use of these terms primarily stemming the genuine subtlety of the distinction, but also because of problems stemming from the definition of certain sorts of stratigraphic units (e.g., biostratigraphic Opper zones which are defined on rock-stratigraphic criteria chosen for their supposed ability to achieve time-stratigraphic correlations), and the fact that many stratigraphers prefer to report their rock-stratigraphic observations (e.g., position in a measured section or core) in terms of time-stratigraphic inferences.

In order to stabilize stratigraphic classification and nomenclature the International Subcommission on Stratigraphic Classification (ISSC)¹ was created in 1952 at the 19th International Geological Congress (Algiers). From 1952 to 1965 the ISSC operated as a standing committee under successive international geological congresses. In 1965 responsibility for the ISSC was transferred to the International Union of Geological Sciences (IUGS) where it remains. The ISSC maintains a WWW site at http://www.geocities.com/issc_arg/.

The ISSC has several purposes. Among these is to publish and maintain the International Stratigraphic Guide whose purpose is to promote international agreement on principles of stratigraphic classification and develop a common internationally acceptable stratigraphic terminology and rules of stratigraphic procedure. The various stratigraphic unit concepts and definitions recognized by the ISSC are summarized briefly below.

¹ Originally the International Subcommission on Stratigraphic Terminology (ISST).

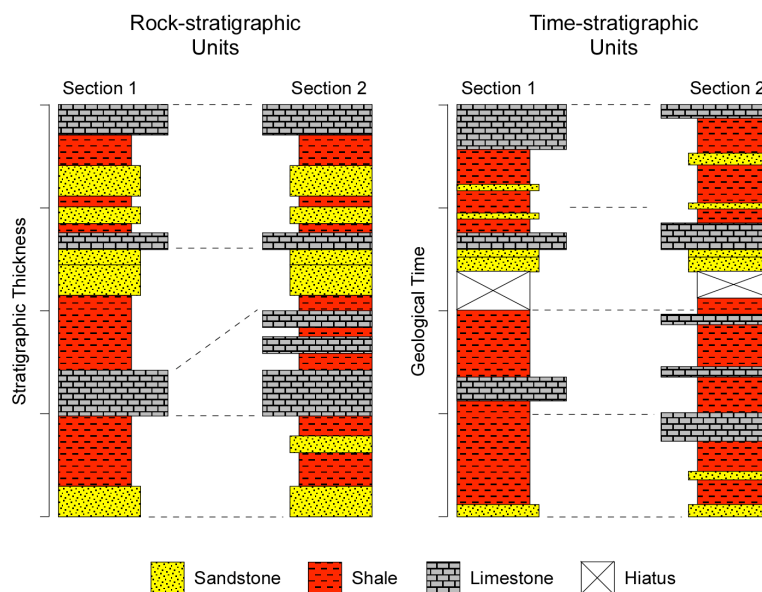


Figure 4. The difference between rock-stratigraphic units (left) and time-stratigraphic units (right). In this illustration the rock stratigraphic units, along with their lithostratigraphic correlation, are scaled to stratigraphic thickness, as they would be observed in a field study. When these same sections are portrayed as time-stratigraphic units (and organized according to the time intervals over which they were deposited), however, the character of their comparative relations (both inter-sectional and intra-sectional, as well as their inter-section correlations, change).

Lithostratigraphic units

The basic unit of lithostratigraphy is the formation, which is the smallest mappable unit possessing a suite of lithologic characteristics that allow the unit to be distinguished from other such units. Formations need not be lithologically homogeneous, but the entire interval of strata should be diagnosable. Moving up the lithostratigraphic hierarchy to more inclusive units, a set of contiguous formation may be combined to form a group (e.g. the Lias Group), membership in which is usually identified based on (1) common lithological characteristics (e.g., dominantly argillaceous facies) or (2) genetic characteristics (e.g., a suite of formations bounded by two basin-wide unconformities). Occasionally contiguous groups will themselves be placed into subgroups or supergroups (e.g., the Newark Supergroup, the Wealden Supergroup) based on genetic characteristics. Subgroups and supergroups may also include formations not previously assigned to a group. The most inclusive lithostratigraphic unit is a complex which is distinguished by its diverse lithological composition—including sedimentary metamorphic, and/or igneous rocks—and its complex structure.

Moving down the lithostratigraphic hierarchy to more exclusive units, a member is a subdivision of a formation recognized on lithologic criteria (e.g., the sandy member of a formation representing a suite of deltaic strata). Typically, members consist of more than a single bed, though some massive bodies with no internal stratification are recognized as members. The smallest formal lithostratigraphic unit is a bed which is a thin, lithostratigraphically monotonous sequence with some locally unique lithological character (e.g., the *Hypsilophodon* Bed). A hypothetical example of this lithostratigraphic hierarchy is presented in **Figure 5**.

Wealden Supergroup	Vectis Formation	Shepard's Chine Member
		Barnes High Sandstone Member
		Cowleze Chine Member
	Wessex Formation	<i>Hypsilophodon</i> Bed
		Sudmoor Point Sandstone Mbr.

Figure 5. An example of the use of lithostratigraphic units to subdivide a classic Lower Cretaceous suite of non-marine sediments in the Wessex Basin of Great Britain. See text for discussion.

Biostratigraphic units

The basic unit of biostratigraphy is the biozone, which is any unit of rock distinguished from other such units on the basis of its fossil content. Unlike formations, biozones do not need to be mappable units, and so can vary greatly in thickness and geographic extent. Biozones may be defined on a wide variety of criteria (see Biozones article in this volume). Intervals of strata between biozones that lack fossils are referred to as barren interzones while barren intervals within biozones may be termed barren intrazones. Moving up the biostratigraphic hierarchy, a set of contiguous biozones may be grouped into superbiozones. Superbiozones do not need to be genetically linked in any way, but some justification for the designation should be made at the time of the superbiozone's proposal. Biozones may also be subdivided into subbiozones in order to express finer levels of biostratigraphic detail or identify a biotically distinctive regional grouping of strata. The term zonule is used to refer to a biostratigraphically diagnosable unit that is subordinate to a subbiozone. Finally, individual stratigraphic surfaces characterized by a distinctive biotic component are referred to as biohorizons. A hypothetical example of this biostratigraphic hierarchy is presented in **Figure 6**.

Maastrichtian	<i>Rosita contusa</i> - <i>Globotruncanita stuartiformis</i> Assemblage Zone	<i>Abathomphalus</i> <i>mayaroensis</i> Subzone	
		<i>Gansserina</i> <i>gansseri</i> Subzone	<i>Racemiguembelina fructicosa</i> Zonule <i>Globotruncana aegyptiaca</i> Zonule
	<i>Rosita fornicata</i> - <i>Globotruncanita stuartiformis</i> Assemblage Zone	<i>Rugotruncana</i> <i>subcircumnodifer</i> Subzone	<i>Rugotruncana subpennyi</i> Zonule
			<i>Globotruncana lapparenti</i> s.s. Zonule

Figure 6. An example of the use of biostratigraphic units to zone a classic Upper Cretaceous suite of deep-marine sediments in north-central Texas on the basis of their planktonic foraminiferal content. Note chronostratigraphic series unit (Maastrichtian) and that not all subbiozones are divided into zonules. See text for discussion. (Species names modified from Pessagno and Smith, 1973, Cushman Foundation for Foraminiferal Research Special Publication No. 12, to reflect more recent nomenclatural changes.

Chronostratigraphic and geochronologic units

Chronostratigraphic units comprise groups of strata recognized as being formed during a specific interval of geological time. While chronostratigraphic terms are conceptual rock-stratigraphic units, their classification is mirrored by the geochronologic or time-stratigraphic classification scheme. To understand the difference between these two scales, consider an hourglass. Sand falling through the neck of the hourglass is deposited in the lower reservoir over a certain time interval (1 hour). A chronostratigraphic unit is equivalent to the sand deposit while the associated geochronologic unit is equivalent to the amount of time over which the sand deposit accumulated (1 hour). The chronostratigraphic unit accumulated over a the time interval and can be said to represent that interval in terms of the deposit's thickness and extent. But the sand deposit itself cannot be said to be time. **Table 1** lists the chronostratigraphic and geochronometric unit equivalents.

Application of chronostratigraphic unit classification may be illustrated by the chronozone (equivalent to a geochronologic chron). All stratigraphic intervals represent potential chronozones/chrons as do all lithostratigraphic and biostratigraphic units. For example, the *Exus alphas* biozone represents a chronozone that begins with the stratigraphic horizon time-equivalent with the speciation event of this (hypothetical) species and ends with the stratigraphic horizon that is time-equivalent its global extinction event (**Figure 7**). This chronozone corresponds to the chron which is defined as the time interval between this species' global speciation and extinction events. Both the chronozones and chrons are worldwide in extent, though it may not be possible to recognize either in localities remote from the geographic range of the species. The chronozones and chrons will also be estimates (at least for biostratigraphic zones) and subject to revision as outlined above.

Table 1. Chronostratigraphic and geochronologic unit equivalents with an example.

Chronostratigraphic Units	Geochronologic Units	Example
Eonathem	Eon	Phanerozoic
Erathem	Era	Mesozoic
System	Period	Cretaceous
Series	Epoch	Upper Cretaceous
Stage	Age	Maastrichtian
Chronozone	Chron	<i>Belemnella occidentalis</i> Zone

Stages (equivalent to a geochronologic age) are the most common chronostratigraphic unit and are usually defined on the basis of the chronozones of a series of biozones (e.g., the Maastrichtian Stage/Age). Note that biozone boundaries themselves cannot be used to achieve a true chronostratigraphic system because they are inherently diachronous (see **Figure 7**). Stages may be subdivided into substages. Systems (equivalent to a geochronologic period) are composed of a sequence of stages. For example, the Induan, Olenekian, Anisian, Laningian, Carnian, Norian, and Rhaetian stages/ages, all of which are defined on the basis of biochronozones, combine to form the Triassic System/Period. Similarly, Erathems (equivalent to a geochronologic era) are composed of a sequence of systems/periods. Three erathems/eras are currently recognized, the Palaeozoic, Mesozoic, and Cenozoic. Finally, Eonathems (equivalent to a geochronologic eon) are composed of a sequence of ears. Thus, the Palaeozoic, Mesozoic, and Cenozoic combine to form the Phanerozoic Eonathem/Eon. This was preceded in geological time successively by the Proterozoic and Archean eonathems/eons.

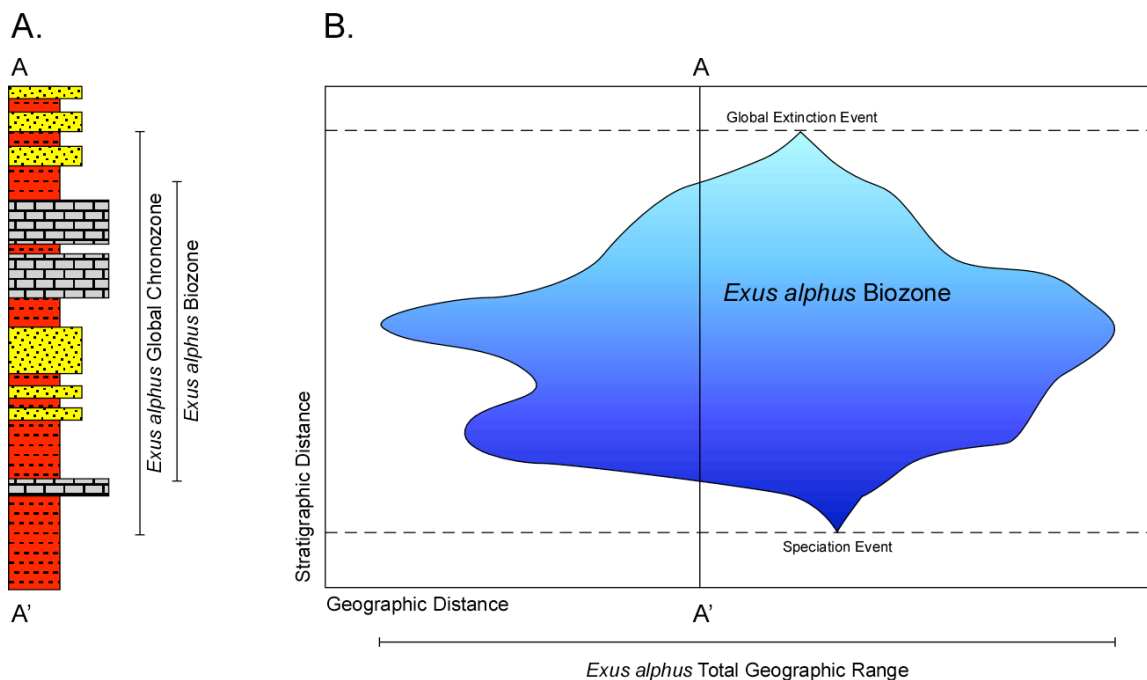


Figure 7. An example of the use of biostratigraphic units to zone a classic Upper Cretaceous suite of deep-marine sediments in north-central Texas on the basis of their planktonic foraminiferal content. Note chronostratigraphic series unit (Maastrichtian) and that not all subbiozones are divided into zonules. See text for discussion. (Species names modified from Pessagno and Smith, 1973, Cushman Foundation for Foraminiferal Research Special Publication No. 12, to reflect more recent nomenclatural changes.

Other types of stratigraphic units

With the advent of geophysical methods of analysis, several special types of other lithostratigraphic classifications have been developed to take advantage of the chronostratigraphic implications of such methods. Perhaps the best example of this is the study of rock magnetism which can be used in some lithologies to determine the ancient polarity of the Earth's magnetic field. Based on such observations, magnetostratigraphic units can be defined as an interval of strata possessing a characteristic magnetic polarity, either normal or reversed. These can then be

related to time through use of the chronostratigraphic equivalent of the magnetozone, the magnetochron. Magnetozones are particularly useful for chronostratigraphic analysis because the time interval over which the Earth's magnetic field changes polarity is short compared to the duration of the magnetozones, biozones, and formations. However, magnetozones are rarely able to be recognized based on their magnetic properties alone, necessitating the use of other types of stratigraphic analysis—usually biostratigraphy—to achieve the identifications. This increases the complexity of the analysis (and the corresponding chance of error) significantly. Nevertheless, combined magneto-bio-chronostratigraphic analysis has resulted in marked improvements in our understanding of the stratigraphic record. Other types of lithostratigraphic observations that have proven useful in this context include chemical stratigraphy, isotope stratigraphy, seismic stratigraphy, climate stratigraphy, cycle stratigraphy, and orbital stratigraphy.

Stratotypes

With the recognition of a distinction between rock-stratigraphic units and time-stratigraphic units, the ISSP recognized a need for the designation of 'type-sections' or stratotypes that would constitute standards of reference for various sorts of stratigraphic units. There are two primary kinds of stratotypes: (1) unit stratotypes, which serve as the standard of definition for a stratigraphic unit, and (2) boundary stratotypes, which serve as the standard of definition for a stratigraphic boundary. Unit stratotypes can be either single sections or suites of sections that, when taken together, form a composite unit stratotype. Of course, the primary requirement for a stratotype is that it adequately represent the concept of the stratigraphic unit or boundary in all essential particulars. This ideal, however, is rarely met in practice. All real stratigraphic sections exhibit a collection of generalized and idiosyncratic characteristics, and no stratigraphic section can be regarded as truly representative of all other sections and cores worldwide. In addition, disagreements among which section to select for designation as an official ISSP recognized stratotype have tended to incorporate appeals to historical precedent, priority, and even nationalism, as well as more objective, scientific criteria. There is also the danger that new discoveries might render a designated stratotype incorrect (e.g., the base of the Cambrian System boundary is taken as the level of the first occurrence of the trace fossil *Treptichnus pedum* which was thought to occur at 2.4 m above the base of Member 2 of the Chapel Island Formation at Fortune Head, Newfoundland, but which subsequent investigations have now shown to occur at least 4 m below that horizon in the same section, see the Cambrian article in this volume). Despite these practical deficiencies though, the stratotype concept has proven to be popular and has undoubtedly contributed to the goal of stabilizing the definitions of stratigraphic units.

One recent modification of the boundary stratotype concept that has proven to be particularly useful is the 'topless' mode stratotype designation for stage boundaries. Under this convention, a boundary stratotype designated to serve as the reference for the base of one stage is automatically regarded as definition the top of the underlying stage. This convention elegantly solves the problem of designating unit stratotypes for two successive stages and finding that the upper boundary of the lowermost unit, and the lower boundary of the uppermost unit were placed at different horizons leading to the artificial production of a stratigraphic gap or an overlap.

The principles of stratigraphic analysis were worked out during the 19th Century. During the 20th Century they were applied and an intercontinental scale and modified to accommodate technological developments that allowed more and different types of geological observations to be employed in achieving stratigraphic correlations. No doubt the former trend will be further refined, and the latter extended, during the 21st Century. The other current frontier in research principal-based stratigraphic research will lie in the creation of databases that summarize stratigraphic observations over the Earth's surface (and extending into its subsurface), the development of automated algorithms for comparing the data included in such databases and resolving conflicts between alternative information sources, and in the training of stratigraphers to appreciate the strengths and weaknesses of each type of stratigraphic information source so that they may apply the ago old principles of stratigraphy to optimal effect.

Acknowledgements

I would like to thank _____ for reading and commenting on a preliminary draft of this article and For current information on stratigraphic nomenclature and stratotypes see the relevant section of the International Stratigraphic Guide (abridged version available online at: <http://micropress.org/stratigraphy/guide.htm>).

See Also

Cambrian, Carboniferous, Cretaceous, End-Cretaceous Extinctions, Eocene, Devonian, Geochronometry, Jurassic, Miocene, Oligocene, Ordovician, Paleocene, Permian, Permian Extinctions, Pleistocene, Pliocene, Principles of Stratigraphy, Sequence Stratigraphy, Silurian, Time Scale, Triassic, Vendian-Ediacaran, Biozones, Magnetostratigraphy, Chemical Stratigraphy, Isotope Stratigraphy, Seismic Stratigraphy, Climate Stratigraphy, Cycle Stratigraphy, Orbital Stratigraphy

Further Reading

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Nomenclature, terms, and units

Angular unconformity: an surface of erosion in which the lower strata dip at a different angle than the younger strata.

Biostratigraphy: the characterization of rock strata by their biological constituents.

Biochronozone: the associated chronozone of a biozone.

Depositional hiatus: a horizon within a body of sedimentary rock that represents a gap in time due to the nondeposition of sediment, active erosion, or structural complications.

Diachrony: the condition of taking place at different times

Facies: a stratigraphic body distinguished from other such bodies by a difference in appearance or composition.

Chronostratigraphy: the characterization of rock strata by their temporal relations.

Geochronology: the geological study of absolute time.

Lithostratigraphy: the characterization of rock strata by the kind and/or arrangement of their mineralogical constituents.

Homochrony: the condition of taking place at the same time.

Homotaxis: the condition of occupying the same position in a sequence.

Isochrony: the condition of being created at the same time.

Radioisotopes: an isotope of an element capable of changing spontaneously into the isotope of another element by emitting a charged particle from its nucleus.

Stratotype: the original or subsequently designated type of a named stratigraphic unit (unit stratotype) or stratigraphic boundary (boundary stratotype).

Stratum (pl. strata): a tabular section of a rock body that consists throughout of the same type of rock material.