The Global Standard Stratotype-section and Point (GSSP) concept is the modern standard for defining chronostratigraphic units in the geological time scale, and over the past decade the working groups involved in locating and characterizing GSSPs have rekindled appreciation for stratigraphy within the profession. The rules adopted by the ICS for establishing the GSSP are, however, less restrictive than, and to some extent in conflict with, the principles set forth by the International Subcommission on Stratigraphic Classification (ISSC) under the leadership of Hollis Hedberg (1976). Under the ICS rules, global boundaries may be established ad hoc for units at any level without regard for the constraints of nested chronostratigraphic hierarchy, even while acknowledging that the stage supposedly holds the critical place. Furthermore, the ICS rules, in advocating that GSSPs be located strictly according to their correlatability, have the effect of requiring preconceived boundaries that correspond to global geohistorical events. These apparently practical shortcuts have serious consequences against which the Hedberg guidelines specifically warned. Not only does the disregard of stage unit- and boundary-stratotypes do more or less violence to the existing literature, but event-based definitions are inherently unstable in stratigraphic space. We review here the problems associated with the declaration of a GSSP, using the controversy over the Paleocene/Eocene boundary as a case history.

Introduction

The adoption by the International Commission on Stratigraphy (ICS) of the concept of formally defining chronostratigraphic boundaries in terms of GSSPs (Cowie et al., 1986; Remane et al., 1996) has fostered a renewed interest in stratigraphy. Numerous working groups have focused on specific boundaries under the umbrella of UNESCO-IUGS, either in the form of IGCP projects or as initiatives of its stratigraphic subcommissions, with overall highly beneficial results. For instance, a wealth of data has been accumulated over the last decade regarding the complex evolution of the planet during Chron C24r (~55.9 to 53.3 Ma), as the byproduct of IGCP Project 308 on “Paleocene/Eocene boundary events in space and time”. Similarly, attention to the Permo-Triassic boundary by the Subcommission on Triassic Stratigraphy has sponsored intensive research, reported in the pages of Albertiana. While the resulting improvements in global standard chronostratigraphy can only be applauded, there are concerns about some aspects of the procedures regulated by this body and by the role played by the GSSP itself (Naidin, 1998; Aubry et al., 1999). At the invitation of Dr. J. Remane, President of the ICS, we review these concerns below.

The Global Stratigraphic Scale (GSS) versus the Standard (or International) Global Chronostratigraphic Scale (SGCS)

Stratigraphy is the most fundamental endeavour in geology, inasmuch as it is the only means by which we can place a geological document into a comprehensive temporal context. Stratigraphy and geological time have been forever intertwined, ever since Lyell (1830–1833) demonstrated the methodologic approach to relative chronology that would propel geology to the forefront among the natural sciences. The relationship between the stratigraphic record and geological time has, however, changed more than once since Lyell’s time, in at least three major episodes or “dynasties” (see Aubry et al., 1999 for details). The first dynasty was launched by Lyell’s Principles themselves and lasted well into the 20th century. It was devoted to the definition of time spans in the rock based on paleontologic data. The second episode, that began at the instigation of Hollis Hedberg (1937), culminated with the publication of the International Stratigraphic Guide (Hedberg, ed., 1976), that established the principles of modern chronostratigraphy and its terminology. The Guide was the product of an international cooperative effort of the International Subcommission of Stratigraphic Classification (ISSC, a subcommission of the ICS) and was offered as “a recommended approach to stratigraphic classification, terminology, and procedure—not as a “code.” (ibid., p. 4).

The third episode may be said to have begun in 1986, when the ICS introduced more formal definitions in chronostratigraphy (Cowie et al., 1986), later followed by “a formal and mandatory document regulating the procedure to be followed in the definition of chronostratigraphic boundaries” (Remane et al., 1996, p. 77). A date of 1986 is, of course, notably artificial because of the long-standing opposition of the English school to the philosophical approach of the ISSC (e.g., Ager, 1973). In the discussion that follows, we are concerned only with the second and third episodes in the history of chronostratigraphy.
The Standard Global Chronostratigraphic Scale (SGCS)

The SGCS in Hedberg (ed., 1976) consists of “a complete and systematically arranged hierarchy of named and defined chronostratigraphic units […] in a hierarchy [that] serves as a standard framework for expressing the age of all rock strata and for relating all Earth strata to Earth history” (ibid, p. 66). In this hierarchy the stage, defined by its unit- and boundary-stratotypes, is the basic unit of chronostratigraphy, upon which chronostratigraphic units of higher rank are constructed. For this reason, series and systems have no unit-stratotypes, and their boundary definitions are simply the boundary-stratotypes of their component lower stages. This hierarchy ensures that no gap or overlap occurs in the SGCS. More importantly, it ensures that series and systems are strictly chronostratigraphic units in content and format, cleared of the biostratigraphic character upon which most were originally defined.

The Global Stratigraphic Scale (GSS)

The ICS does not appear to have given a definition of the GSS, but we can safely quote Harland et al. (1990, p. 1): “A chronostratigraphic scale (CSS) is now conceived as a scale of rock sequences with standardized reference points selected in subsections, each particularly complete at and near the boundary and known as a boundary stratotype. […] Regional chronostratigraphic scales (RCSS) have gradually given rise […] to the single global traditional stratigraphic scale (TCSS) [the SGCS above]. This is being refined and standardized at global stratotype sections and points (GSSP) to give definition to the standard global chronostratigraphic scale.” As noted by Naidin (1998), the ICS from 1986 to the present has not outlined the basic principles that underlie its philosophy of stratigraphy, and the required procedures therefore stand with little explanatory background. However, it is an easy matter to trace the current philosophy of the ICS to its source, and the statement in Remane et al. (1996) that “Chronostratigraphic units of the Phanerzoic Global Standard can only be defined through boundary stratotypes” reads directly from Harland (1992). Even if, in principle, the stage remains the chronostratigraphic unit of lowest rank in the GSS, with its lower boundary defining the lower boundary of units of higher rank (Remane et al., 1996), in practice (and in agreement with Harland, 1992), the lower boundary of the chronostratigraphic unit of higher rank is defined ab initio, and this then defines the lower boundary of the units of lower rank (see documentation in Aubry et al., 1999).

The obvious implications are that (1) the GSSP of higher units is defined independently of existing stage stratotypes (“There is no formal priority rule in stratigraphy”, Remane et al., 1996, p. 78) and (2) the historic and established definitions of stages can be and are adjusted so as to fit the arbitrary boundary definition of units of higher rank (see examples of such procedures in Aubry et al., 1999).

Establishing chronostratigraphic units

Hedberg (ed., 1976, p. 86) stated that “Only after the type limits (boundary stratotypes) of a chronostratigraphic unit have been established can the limits be extended geographically beyond the type section”. In sharp contrast, the ICS rules (Remane et al., 1996, p. 78) state “Correlation precedes definition […] To define a boundary first and then evaluate its long-range correlation (as has been proposed in some cases) will mostly lead to boundary definitions of limited practical value”. Inasmuch as the Guide recommends that the boundary between two stages be chosen in such a way as to allow the best possible correlation, the procedures recommended by the ISSC and the ICS do not necessarily conflict for practical purposes. However, when conflict between definition and correlation arises, the mandatory regulations of the ICS are such that even well-documented and widely-used stages must be summarily modified. According to the ICS, “if the interregional correlation potential of a traditional boundary does not correspond to the needs of modern stratigraphy, its position has to be changed” (Remane et al., 1996, p. 77).

Different GSSP working groups have dealt with such problematic procedures in different ways (see Aubry et al., 1999). The Paleocene/Eocene (P/E) boundary is an example of a difficult and as yet unresolved case (Aubry et al., 1999; Aubry, 2000; Aubry and Berggren, 2000a, b) which we summarize here to show how the two approaches are contrasted.

When the Working Group (WG) on the P/E boundary was formed at the 28th International Geological Congress, the boundary was understood to be defined as the boundary between the upper Paleocene Thanetian and the lower Eocene Ypresian Stages, in agreement with the principles of hierarchical chronostratography (the Guide), with respect to currently accepted usage (e.g., Berggren et al., 1985a, b; Haq et al., 1988) and according to a regional tradition that goes back to Von Koenen (1885). These two stages have their unit-stratotypes in NW Europe, where the base of the Ypresian Stage corresponds to a well-defined lithostratigraphic unit, the Mont Héribu Member at the base of the Ieper Clay of the Ieper Group in Belgium, correlative with the Walton Member at the base of the London Clay Formation in southeastern England, on the opposite side of the English Channel. Although well defined lithostratigraphically, the base of the Ypresian Stage was only tentatively correlated outside the region for lack, in previous years, of definitive means of correlation (see discussion in Berggren et al., 1985a). The WG thus set out to relocate the base of the Ypresian Stage at a lithostratigraphic level associated with adequate correlation criteria but in such a way that the new location would not conflict with the accepted concepts of Thanetian and Ypresian Stages.

With the activity of the IGCP Project 308 Working Group, under the umbrella of UNESCO-IUGS, correlations between the deep sea record and the shallow marine Thanetian-Ypresian succession in NW Europe improved. Most significantly, recognition of the First Appearance Datum [FAD] of the calcareous nanofossil species Tribirachius digitalis allowed (1) the approximate dating of the base of the stratotypic Ypresian Stage, (2) the long distance correlation of this level in marine sediments, and (3) the association of the well-known Ypresian transgression with the end of intensive compressional tectonism in the North Atlantic (Figure 1; Aubry, 1996, Aubry et al., 1996 and references therein).

At about the same time, documentation of the close relationship of a series of previously unknown or poorly correlated events made it clear that biotic evolution in the marine as well as in the terrestrial realm had been dramatically affected over a short (~1.5 my) interval of Chron C24r. The most important feature of this interval was a carbon isotope excursion (CIE) with an amplitude of 3 to 4‰, which was first detected in oceanic deposits of the Southern Ocean (ODP Hole 690; Kennett and Stott, 1991), and then in the continental record of North America and Europe (Koch et al., 1992; Stott et al., 1996). The carbon isotope excursion tied together a newly-observed extinction event in deep-ocean microfauna termed the Benthic Foraminiferal Event (BFE; Thomas, 1992) and the long recognized Mammal Dispersal Event (MDE) among the terrestrial faunas of North America at the Clarforkian/Wasatchian Land Mammal Age boundary (Gingerich, 1989). The numerical chronology of these features within Chron C24r is still being debated, but it was immediately apparent that the CIE, BFE and MDE are >1 my older than the FAD of T. digitalis, i.e., they predate by over 1 my the base of the regional stratotypic Ypresian Stage (Berggren and Aubry, 1996, 1998) and consequently the Ypresian transgression (Figure 1). Unfortunately, the Paleocene/Eocene boundary WG in identifying global correlation tools for the base of the Ypresian Stage came many years after stratigraphers outside of western Europe had already estimated locations for the base of the Eocene in regional
Figure 1  The case of the Paleocene/Eocene boundary. The base of the unit stratotype of the Ypresian Stage was defined in Belgium (Mont Herin Member at the base of the Ieper Clay). Sequence stratigraphy has permitted firm correlation of the lithostratigraphic succession in Belgium with that of the London Basin. The latter is more amenable to correlation with the deep sea than the former. The lowest occurrence of the calcareous nannofossil species Tribrachiotus digitalis has permitted the dating of the base of the Ypresian Stage in its stratotypic area and its correlation in almost all marine records. The use of this criterion to define a GSSP for the P/E boundary satisfies the requirement of the ICS at the same time as it respects the integrity of chronostatigraphy as a scientific discipline (solution 1). The carbon isotope excursion (CIE) falls within a lithostratigraphic unit that has always been assigned to the Thanetian and is >1 my older than the base of the stratotypic Ypresian Stage. The current ICS rules would require that the base of the Ypresian Stage be adjusted to the base of the Eocene Series, which is depriving the stage of any true stratigraphic significance, and implies a complete disrespect for earlier scientific studies. The use of this criterion for a GSSP for the P/E boundary is rationally acceptable only if a new stage is first defined based on the CIE as a means of correlation. References that have contributed to the construction of the framework of correlation shown here can be found in Aubry (2000) and Aubry et al. (in press). The lithostratigraphic frameworks have been slightly simplified for clarity.
sequences. The marked paleontological changes, subsequently found to be associated with the global paleoclimatic crisis of the CIE, had previously caused workers in epicontinental section of NW Europe, as well as those in the North American continental sequences, to take this level as a working approximation of the boundary (e.g., Pomerol, 1969, 1977; Wood et al., 1941). Naturally enough, the “estimate” soon became the accepted fact in the regions where it was used, and in the years prior to the recent determinations the two “definitions” of the Paleocene/Eocene boundary unknowingly coexisted in the world literature (Aubry, 2000). Since the discrepancy was recognized, however, the fact that the CIE offers an excellent means of global correlation, on isotopic as well as paleontological grounds, has been cited as a perfectly sufficient reason for characterizing the P/E on this basis (e.g., Molina et al., Schmitz et al.).

Application of the ICS regulations, it would seem, would require that the CIE be defined on the best criterion for correlation—the CIE—and that the base of the IUGS-ratified Ypresian Stage would be derived to fit this definition of the base of the Eocene (Figure 1, solution 2). This would also mean that marine levels which have been assigned to the Thanetian Stage and the Paleocene Series, not only in NW Europe but in many parts of the world, would now be transferred to the Ypresian and the Eocene.

In fact, the “new” approach of the ICS merely ratifies an old, and discredited, tendency among stratigraphers to defend the local against the global. At least twice before, in our personal experience, widespread miscorrelation of a chronostratigraphic boundary has been vigorously defended, after the mistake has been exposed, by those who had become accustomed to the error—most notably on the grounds that the miscorrelation reflects some “natural” or “better” criterion. These controversies, over the Plio/Pleistocene boundary (Van Couvering and Berggren, 1976; Van Couvering, 1997) and before that the global miscorrelation of the Pliocene based on the “Hipparion datum” (Van Couvering and Miller, 1971; Berggren and Van Couvering, 1979), were only settled by figuratively returning to the outcrop and examining the original evidence according to Hedbergian principles. These examples, vivid in memory, include numerous demonstrations of the fact that most “natural” boundaries are not so much natural as habitual, and that allowing expediency to supersede rigor is a sure recipe for unending appeals to other versions of what is expedient.

We are therefore concerned that the present rules governing the erection of GSSPs will affect the stability of the Cenozoic chron stratigraphic scale. For example, chronostratigraphic units of long standing usage will be subject to redefinition each time a more powerful element of correlation is discovered. We consider these problems are not simply matters of priority, and contrary to Remane (2000, p. 137), we do not believe that the P/E WG is “lost in a struggle with false problems”. Instead, in agreement with Naidin (1998) we view the concept of GSSP to be unsatisfactory and the procedures of the ICS to be dangerously simplistic.

The Global Standard Stratotype-section and Point (GSSP)

At first glance, “global standard stratotype-section and point” would appear to be a new name for the old concept of boundary stratotype. The requirements by the ICS for the erection of a GSSP—documentation, ratification, and so on—are the same as those described in the International Stratigraphic Guide for a boundary stratotype. However, further scrutiny shows that in fact a GSSP has little to do with the boundary stratotype (a boundary stratotype “with a twist” in Aubry et al., 1999). In contrast, the concept of GSSP is clearly described as independent of the rock record by Harland et al. (1990, p. 3), who stated: “Before the standardisation [through GSSP definition] just described, the intervals were conceived as being the time equivalent of a rock unit that was already defined. Thus systems (series, stages or chronozones) were first described and the geological periods (epochs, ages, chron) were derived as the corresponding interval. [...] The new procedure effectively reverses the derivation. The time division (period, etc.) is now defined precisely by selecting initial and terminal points, while the corresponding rock formed in the interval (system, etc.) cannot be identified with certainty at its boundaries other than the GSSP depending, as it does, on estimate of relative age by correlation.”

The boundary stratotype in the Guide, on the other hand, represents a non pre-selected moment in time, so that chronostratigraphy is an expanding endeavour in which a network of correlation tools are used in unison to recognize this specific horizon all over the world. With a fixed reference point, the procedure is limitless, and precision is increasingly gained towards refining the age of the boundary stratotype and the means of correlation (Van Couvering, 2000). In contrast, the claim is made that the GSSP is “the only place where we actually know (by definition) that time and rock coincide within our classification” (Holland, 1984, p. 149; see also Cowie et al., 1986, p. 5). This makes sense, however, only if the age of the GSSP is predetermined, and if the means of correlation is preselected. The GSSP is “a defined point in rock [which] represents precisely a defined point in time” (Holland, 1986, p. 11), because it is supposed to be located with reference to a specific event—e.g., evolutionary (appearance or extinction), geophysical (a reversal of the earth’s magnetic field), disruption in the earth’s carbon budget (a δ13C excursion)—whose imprint is assumed to be recorded in the stratotype-section-to-be. Whereas correlation is a radiating/diverging process in the SGCS, it is an inescapably convergent one in the GSS.

It appears that GSSPs are, in essence, no more than pegs meant to validate our time scales. “As a result, the stratigraphic time scale [the SGCS] transforms into a ruler with rather formal grades for measuring time” (Lazarev, 1995, quoted in Naidin, 1998); “the GSSP is in fact a mere tool for geochronometry” (Aubry et al., 1999, p. 130). Stages become “conventional units like the units of measure in physics” (Remane, 2000, p. 137). We quote from Naidin’s excellent summary (1998, p. 1023): “The leaders of ICS have shown lately a tendency toward simplistic approach to problems of stratigraphy. This tendency is expressed not only in arguing for the primitive ideas of points, which turn ISS [the SGCS] into an idealistic measuring ruler.” Indeed, chronostratigraphy is becoming a mandatory deadlock grid to which willingly or unwillingly all earth scientists are committed.

Do GSSPs meet the needs of modern stratigraphy?

We do not intend to examine thoroughly this multifaceted question in the context of this paper, but wish to consider a number of critical points. They are successively concerned with historical priority, correlation versus definition, and best sections.

Historical priority

At the same time as it sets out “to develop precise boundary definitions for traditional boundaries”, the ICS claims that “there is no formal priority regulation in stratigraphy”, and that “priority can be given to the level with the best correlation potential” (Remane et al., 1996, p. 78). Given that GSSPs as well as boundary-stratotypes are preferentially located in continuous sections, chronostratigraphic boundaries are often, by necessity, moved out of the area where they were originally conceived. This is because many stage unit-stratotypes are either unconformity-bounded, or because they are transgressive tongues expressed in shallow-water facies that are not readily correlated outside of the type area. For instance, the base of the formally defined Rupelian Stage is defined in the Tethys realm...
although the stage was defined in the boreal domain; similarly, the Eifelian/Givetian boundary has been defined in a deep-water section in Morocco, whereas both stages were described from shallow water facies of Germany and Belgium, respectively. There would be no difficulty in relating pre- and post-GSSP studies if the means to correlate the formally defined chronostratigraphic units with their historical counterparts where described as formal definition is established. Unfortunately, this is generally not done. For instance, when the GSSP for the Eocene/Oligocene boundary was proposed and accepted, we did not know where the unit-stratotype of the Rupelian Stage stood with regard to the Priabonian/Rupelian GSSP definition, nor do we know even today the relation of the Givetian unit-stratotype to the Eifelian/Givetian GSSP definition. This should clearly be a basic procedure required by the ICS in the establishment of GSSPs, but unfortunately it is routinely ignored, and not simply through carelessness. On the contrary we read: "The original systems, series and stages were initially described as bodies of rock, and in many cases this usage persists explicitly. It is easier to proceed logically outside Europe where named rock units cannot be confused with named divisions of the [GSS]" (Harland et al., 1990, p. 5).

It is our concern that the chronostratigraphic scale, as it adds GSSP definition, is simultaneously being disconnected from its roots (see Naidin, 1998; Aubry and Berggren, 2000b) and also from the wealth of data that were collected and interpreted based on the SGCS. How are we going to effectuate cross correlations between regional chronostratigraphic units (regional stages) when formally defined stages have no unit-stratotypes, and when their base is no longer relevant to anything but an ideal event? that of the standard stage? Should we ignore the essential role of unit-stratotypes of stages in the integration of deep sea zonal and event stratigraphy with chronostratigraphy, i.e., as a starting point for delineating the magneto-biochonostratigraphic content of series and systems (e.g., Berggren et al., 1985a, b for the Cenozoic). Unit-stratotypes, as archives of original meaning and as a reference source, cannot be simply dismissed!

**Correlation precedes definition**

Following Egoyan (1983), Naidin (1998) justly observed that stratigraphy has changed from being a science of strata to being a science of boundaries. This change, that occurred as biozonal schemes were becoming alternative means to stages for describing the stratigraphic record, is well reflected in the evolution of chronostratigraphy. In the Guide (Hedberg, ed., 1976) chronostratigraphy was based on the succession of stage unit-stratotypes, whereas in the Guide (Hedberg, ed., 1994, see also Murphy and Salvador, 1999), chronostratigraphic units are defined solely by their boundary stratotypes.

Boundaries are the bread and butter of most stratigraphers today. Magnetostratigraphy, isotope stratigraphy, much of biosstratigraphy, i. al., rely upon boundaries for correlation. Somehow, the means of correlation that serve to preselect and subsequently denote a chronostratigraphic boundary is also a boundary of some kind. For instance, "the Lower/Middle Devonian (Givetian/Eifelian) boundary divisions of the [GSS]" (Harland et al., 1990, p. 5) level through the first occurrence of the conodont *P. costatus partitus* and "the Middle/Upper Devonian boundary level had been guided by the first appearance of the conodont Ancistrodella rotundiloba [...], which is coincident with the Lower asymmetricus Zone in the conodont standard zonation" (Cowie et al., 1989, p. 81). This makes the Middle Devonian Series a chronostratigraphic unit. In a similar vein, "the GSSP [for the Mid-Carboniferous boundary] is at 82.90 m above the top of the Battleship Wash Formation in the lower Bird Spring Formation at the first evolutionary appearance of the conodont Declinognathodus noduliferus i.e. (Lane et al., 1999, p. 272). This makes the chronostratigraphic boundary a (close) biosstratigraphic boundary as well.

The emphasis placed on boundaries reflects the fact that, defined by events, they are believed to have temporal significance, a *sine qua non* condition for quantification. Stratigraphy, indeed, has become, for many, event stratigraphy. Boundaries between magnetozones are equated with earth magnetic reversals and biozonal boundaries are assigned the age of biochronal boundaries. Events are used to fine-tune stratigraphic records. By associating a chronostratigraphic boundary with a means of correlation, it is believed that the stratigraphic horizon that serves as chronostratigraphic boundary has the age of the event used to select it. Yet, we have learned to mistrust boundaries and events, not because of diachrony in the case of biozonal boundaries but because of unconformities. Many boundaries are no more than unconformable contacts, and we have debunked the fallacious methodology that consists in indiscriminately fine-tuning records based on event stratigraphy (Aubry, 1995, 1998). We have shown that proper correlation between sections—deep sea as well as shallow water sections—is more than the simple joining of boundaries in what we call "stratigraphic correlations". These must be replaced by *temporal correlations* that involve a test for determining the completeness of stratigraphic sections, not merely by comparing sections with one another (as recommended by the ICS) but by comparing a record of stratigraphic events to an essentially independently derived chronology. Thanks to the Global Polarity Time Scale (GPTS; e.g., Cande and Kent, 1992) and the Integrated Magnetostratigraphic Scale (e.g., Berggren et al., 1995) this test is possible for the Cenozoic stratigraphic record. Full geochronologic analysis has not been performed, as yet, on most of the Cenozoic GSSPs that have been proposed to date, and no adequate test is yet available for the Mesozoic and Paleozoic stratigraphic record (although advances in applications of the orbital time scale may be anticipated). Without independent time control, the only protection against constant shifts as biostratigraphic evidence is refined, and as gaps in the record are recognized, is to define boundaries originally under Hedbergian principles. At the same time as any stratigraphic boundary must be considered suspect until proven time significant, we must allow for eventual reinterpretation of geological events. As seductive as they are most evolutionary appearances are a matter of conceptual interpretation and their appearance in the rock is always a matter of constant reevaluation. As useful as it might be, magnetostratigraphy must be submitted to careful scrutiny or it can be strongly misleading (e.g., Ali et al., 2000). As for isotopic events, a comparison of various upper Paleocene-lower Eocene records illustrate the potential for reinterpretation (see discussion in Aubry et al., 1996; compare also Pak and Miller, 1992 with Aubry, 1998). When events occurred at time of major disruption of the earth system, as during Chron C24r, what are the chances for events to be completely recorded in many sections?

We reiterate that for chronostratigraphy to be stable, a chronostratigraphic unit must be independent from any other form of stratigraphic unit, and that definition must necessarily precede correlation. The horizon to correlate must be independent of the means of correlation. The boundary stratotypes of the SGCS satisfactorily fulfilled this requirement; GSSPs, as presently conceived, do not.

**The best section**

There is more to stratigraphy than boundaries and event stratigraphy. The stratigraphic record is not only a medium that provides elements (e.g., paleontologic/biostratigraphic/paleobiologic, isotopic/paleoceanographic/paleobiologic/paleoclimatic) to reconstitute earth history. The stratigraphic record has an architecture that we are beginning to understand and decipher. For all the attention given to boundaries nowadays, stratigraphy, in particular Cenozoic stratigraphy, is evolving towards becoming once again a science of strata. This is because attention is increasingly given to a very special kind of boundary that—unlike those that are used for correlation, a product of intellectual exercise—is inherent to the stratigraphic record. These boundaries are unconformities, with little or no immediate temporal significance (we use here the term ‘unconformity’ in its broad sense, not just angular unconformities). Sequence stratigraphy
and allostratigraphy are mostly concerned with the correlation of bodies of strata, not with that of boundaries. The future of stratigraphy lies in these two disciplines that describe the architecture of the stratigraphic record, and which will greatly help resolve the broad mechanism(s) that controls the tuning of the earth system. Unconformities and stratigraphic gaps are being recognized as full components of the stratigraphic record. The methodologies (e.g., graphic correlation methods, temporal interpretation of stratigraphic sections) are in place to measure hiatuses and date unconformable surfaces. Surprisingly enough, these surfaces have the same age over large areas. There is little if any diachrony involved in many instances (see Poag, 1993; Aubry, 1995; Aurisano et al., 1995). For this reason, since base defines chronostratigraphic units, an unconformable surface may constitute an horizon of reference. The base of the marine Trubi marls that represents the base of the formally defined Zanclean Stage is an horizon that rests unconformably over the upper Messinian alluvial/lacustrine Arrenazollo Formation (Van Couvering et al., 1999). The base of the Ypresian Stage could very well be defined by the base of the London Clay Formation. If continuous boundary sections are deemed more suitable, however, we know how to correlate these horizons in more continuous stratigraphic sections.

Stratigraphy is not about the best section. Stratigraphy is concerned with all sections, for it is the matching of these sections, in the form of composite sections, that will provide ultimately the best documentation of earth history. To match these sections, we need a few horizons and stratigraphic units to serve as references. The units of the SGCS served well this purpose. Unit stratotypes of stages are more fundamental to chronostratigraphy than the ICS seems to realise.

Discussion

When difficult situations arise, various solutions—more appropriately stratagems—can be proposed to reconcile the ICS rules with the basic principles of chronostratigraphy that Hedberg recommended and that we defend here, realizing that the association of events with rocks can never be taken for granted. The objectives of chronostratigraphy, after all, are not to assist in arranging strata according to “hot” moments in geological history, nor even to provide a framework of correlations, but to provide lithostratigraphic types, but also by moving whenever the “true” level of the correlation precedes definition”. The consequence of this concept is that a boundary has no inherent integrity, but must migrate to the most “natural” (i.e., conspicuous) break in the record anywhere close to the traditional level. This is required, no matter how it violates precedent—not only by ignoring historical stratotypes, but also by moving whenever the “true” level of the correlation event is revised, and most of all when a previously determined “natural” boundary must be abandoned in favor of a better one. What may seem convenient and easy at first, in the end amounts to mandated uncertainty.

We conclude with the observation that, as in any other science, stratigraphy has evolved through a constant flow of improvements, and for this reason it carries with it a heavy historical baggage. It is this baggage that, rather than weighing us down, helps us envision the future. In this view, it is irresponsible of the ICS to deprive chronostratigraphy of its roots, by insisting that historical priority has no ground in setting its subdivisions.

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References


Conclusion

Stratigraphy is not about events; stratigraphy deals with lithostratigraphic horizons and units that it aims at correlating via the use of evidence for events. Although recorded in stratigraphic horizons, events do not belong to the stratigraphic record, but to time. It has become customary to equate stratigraphic correlations with the correlation of events, particular in deep sea stratigraphy, but also in vertebrate stratigraphy, because we naturally want to get beyond stratigraphy to get a grasp on geological time. The purpose, however, of rigorous procedures in this case, as in other scientific disciplines, is to keep wishful thinking from clouding our perceptions.

The assumption of a desired outcome results in endless controversies, because, as Gould (1996, p. 136) states “logic and sensibility do not coincide”. Ordinarily, rigid principles do not allow “common sense” (i.e., preconceptions) to dominate scientific research. But there are breakdowns, and we believe that this has happened in the discipline of chronostratigraphy. The lack of rigor in the current ICS rules does, in fact, allow decisions to be made based on preconceptions rather than on scientific principles. Returning to the case of the Paleocene/Eocene boundary, rigor dictates that the base of the Ieper Clay should constitute the base of the Eocene, because historic stages and their boundaries define objective and relative intervals of geological time without the need (or risk) of claiming prior knowledge of their duration, age or significance. On the other hand, to define the Paleocene/Eocene boundary according to a priori declarations that it is associated with a conspicuous event such as the CIE, is an example of “correlation precedes definition”. The consequence of this concept is that a boundary has no inherent integrity, but must migrate to the most “natural” (i.e., conspicuous) break in the record anywhere close to the traditional level. This is required, no matter how it violates precedent—not only by ignoring historical stratotypes, but also by moving whenever the “true” level of the correlation event is revised, and most of all when a previously determined “natural” boundary must be abandoned in favor of a better one. What may seem convenient and easy at first, in the end amounts to mandated uncertainty.
ety of Economic Geologists and Mineralogists, Tulsa, spec. vol. 54, pp. 213-274.


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History of Geology Conference
‘Geological Resources and History: Rocks and Dinosaurs’
Portugal, 24 June–1 July, 2001

The International Commission on the History of Geological Sciences (INHIGEO) is organising a meeting in Portugal in 2001. The three themes will be:

1. The use of stone through the ages
2. Dinosaurs and other megafauna in the history of geology
3. History of mining, metallurgy, and economic geology.

The meeting will involve oral and poster presentations, field excursions related to the conference themes, three talks by distinguished guest speakers, and a round-table discussion on ‘Why study the history of the geosciences?’. The conference will take place partly in Lisbon and partly in Aveiro, with visits to other towns such as Coimbra and Porto.

The provisional cost estimate is US$375 for accommodation and $100 for conference fee. Food will be additional.

Offers of papers are requested by the Conference President, Professor Manuel Pinto, by October 31, 2000, and abstracts should be submitted to him by January 1, 2001.

The conference languages will be English and French.

For further information, or for booking your attendance, please contact Professor Pinto at:
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