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The reality of GSSPs

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Summary

The proposal that chronostratigraphic and geochronologic units are un-necessary and confusing is based on a mistaken concept of GSSPs. Each GSSP does represent a specific point in time, and two successive GSSPs do mark the beginning and end of an interval of time that is a geochronologic unit. But the supposition that this unit in time then serves to define a corresponding chronostratigraphic unit is mistaken. First, there were chronostratigraphic units and geochronologic units more than 100 years before there were GSSPs. The historical chronostratigraphic units that are the basis for much of the Geological Time Scale were defined on distinctive stratigraphic successions, and the time during which it was deposited is the corresponding geochronologic unit. GSSPs were established to identify specific stratigraphic levels that define the bases of the chronostratigraphic units and to resolve the problems when gaps and overlaps between successive units were later discovered. Unfortunately, the GSSP for a specific boundary is too often presented only as the single stratigraphic signal at which the boundary is placed in the stratotype section. Yet, in reality it only has significance for chronostratigraphic correlation when compared to the distribution of other stratigraphic signals in the boundary interval.

***Keywords*:** GSSP, chronostratigraphy, geochronology

The International Commission on Stratigraphy (ICS) was founded with its primary objective being the establishment of a single, hierarchal set of global chronostratigraphic units (stages, series, and systems) with lower boundaries defined by GSSPs (Global Standard Stratotype Section and Point). With 63 of the 100 stages boundaries of the Phanerozoic now defined by GSSPs and with a single set of standard global units mostly identified, considerable progress has been made in developing the ICS Chronostratigraphic Chart. With the addition of well-calibrated numerical ages for many stage, as well as series and system, boundaries, the ICS Chart is now widely recognized as the global standard Geologic Time Scale. The ICS concept of GSSPs was first explained in the 1st edition of the *International Stratigraphic Guide* (Hedberg, 1976) and further elaborated in the 2nd edition (Salvador, 1994). However, GSSPs have come to mean something different to some stratigraphers and the correlation of GSSPs is too often misrepresented.

Zalasiewicz *et al.* (2004) proposed that the distinction between time-rock units and time units is no longer necessary because of the widespread adoption of GSSPs "in defining intervals of geologic time within rock strata." Because GSSPs are placed at stratigraphic horizons that also represent specific points in time, two successive GSSPs define an interval of time that is a geochronologic unit (period, epoch, age), and all strata interpreted as deposited during that interval of time would comprise the corresponding chronostratigraphic unit (system, series, stage). For this reason, Zalasiewicz *et al.* (2004) argue that the dual classification of chronostratigraphic and geochronologic units is not necessary and leads to confusion, and for these reasons proposed the exclusive use of geochronologic units. After a decade of discussions on the issue, Zalasiewicz *et al.*

(2013) accepted and further clarified the nature and use of the dual classification. Nevertheless, the concept that GSSPs define geochronologic units and that a chronostratigraphic unit is the strata deposited during the time defined by the geochronologic unit is still widely held (e.g., Gradstein *et al.*, 2004). The difference between this concept and that of the *International Stratigraphic Guide* (Hedberg, 1976; Salvador, 1994) – that chronostratigraphic units and their boundaries serve to define corresponding geochronologic units – is subtle, yet important.

Chronostratigraphic units and parallel geochronologic units were established long before the concept of GSSPs. Rocks and their spatial relationships (superposition, cross-cutting relations, unconformities) are the record of Earth's history and the passage of time. The character of stratigraphic successions, the varied stratigraphic signals within them, and superposition are the basis for characterizing distinctive stratigraphic intervals and for evaluating temporal relationships with stratigraphic intervals elsewhere. These stratigraphic intervals, being material units that can be sampled and mapped today, are chronostratigraphic units; the time in the past during which each one was deposited is the parallel geochronologic unit. It is important to note that the *International Stratigraphic Guide* provides specific guidelines for establishing chronostratigraphic units, but none what-so-ever for defining geochronologic units other than that each geochronologic unit represents the time during which the interval of strata comprising the chronostratigraphic unit was deposited. According to Gradstein *et al.* (2004) "*A geologic time unit (geochronologic unit) is an abstract concept measured from the rock record by radioactive decay, Milankovitch cycles, or other means*." Further, they define a chronostratigraphic unit as follows: "*A "rock-time" or chronostratigraphic unit consists of the total rocks formed globally during a specified interval of geologic time*". Nowhere do Gradstein *et al.* (2004) elucidate how the points in time are measured, and they ignore the fact that the time measured is subject to regular refinement or considerable revision. Some GSSPs have indeed been placed at a specific sedimentary cycle that has been astronomically tuned, but such boundary levels can only be recognized in stratigraphic successions elsewhere that preserve complete sets of astronomically tuned cycles that first must be temporally correlated with considerable precision by biostratigraphic and magnetostratigraphic correlations. The numerical ages of some GSSPs are constrained by high precision radiometric ages from ash beds within the stratotype section, but without other stratigraphic signals in the boundary interval the GSSP cannot be recognized in stratigraphic sections elsewhere that lack datable ash beds. Furthermore, temporal correlation is most often required for stratigraphic intervals within chronostratigraphic units, and effective correlation of these intervals requires application of chronostratigraphic methods (i.e., biostratigraphy, chemostratigraphy, paleomagnetostratigraphy, etc.).

Most of the systems, series and stages of the ICS Chart were first defined from type-sections or type areas in Europe, the historical home of stratigraphy. They served as the basis for temporally correlating stratified Phanerozoic rocks worldwide primarily on their paleontological content. But, rarely were boundaries between succession units precisely defined. With the study of stratigraphic successions away from the type sections (or areas), overlaps of and gaps between many successive chronostratigraphic units were discovered. Because of natural limits to the palaeoecological and palaeogeographical distributions of palaeontological content on which the units were recognized and because of the lack of specific boundaries, there were different interpretations of the stratigraphic extent accorded to the same unit from one region to another, and for many systems myriad sets of regional series and stages were established. It was in order to resolve these deficiencies and complexities that the concept of GSSPs was developed, and the goal of single set of global units with precisely defined boundaries that could be correlated as widely as possible was established.

Candidate GSSPs are evaluated by the ICS and its constituent working groups based on a long list of criteria (Hedberg, 1976; Cowie *et al.*, 1986; Salvador, 1994; Remane *et al.*, 1996). The most important of these is that the boundary at the candidate stratotype is defined at the level of a single stratigraphic signal within an interval of multiple, varied stratigraphic signals, that should allow for reliable, high-resolution correlation across the greatest possible palaeogeographical range of palaeoenvironmental settings. Chronostratigraphic correlation (chronocorrelation), i.e., evaluating temporal relationships between geographically widely separated stratigraphic successions, is an interpretative process whether it involves correlation of a GSSP, its boundary interval, or an interval within a chronostratigraphic unit. Accurate chronocorrelation requires the evaluation of multiple, varied stratigraphic signals rather than relying solely on a single signal, such as that on which the level of the GSSP was placed, e.g., the lowest occurrence of a specific taxon, a paleomagnetic reversal, an isotopic excursion, or a eustatically induced vertical facies change. Without a GSSP being chosen at horizon that not only is the level of a distinct stratigraphic signal and within a boundary level of many varied stratigraphic signals, the point in time at the GSSP is of little use for accurate, high-resolution correlation. Furthermore, the ICS Chart is composed of units that were originally defined on distinctive stratigraphic successions of variable duration, much like characteristic intervals of human history, such as the Renaissance. Defining the beginning or end of the Renaissance requires identifying human products (architecture, art, literature) on which that period of human history was identified as important and distinctive, and only then are numerical ages assigned. The same applies to chronostratigraphic units and geochronologic units. First, stratigraphic signals are selected to define a chronostratigraphic unit; they then, in turn, define a geochronologic unit. Numerical ages can be calibrated only after stratigraphic signals have been selected. It is the rock record, especially the multitude of varied stratigraphic signals within stratigraphic successions, on which the Geologic Time Scale is based and geochronologic units can only be defined once these stratigraphic signals are evaluated for correlation potential. The fallacy of the proposal that the distinction between time-rock units and time units is no longer necessary is illustrated by the GSSPs for several Silurian stages and series. Some were some at the bases of graptolite zones, yet graptolites do not occur in the sections. There the GSSPs do represent points in time, but because they were placed without regard to adequate stratigraphic signals for correlation, they have proved to be deficient and in need of re-definition.

It is unfortunate that too often the GSSP concept is illustrated only by reference to the single stratigraphic signal at which the boundary is defined (Ogg *et al.*, 2008). Whether it is the FAD of a single taxon, a paleomagnetic reversal, or an isotopic excursion, interpretation of accurate chronocorrelation of that signal into other stratigraphic successions requires that that signal maintains the same stratigraphic level relative to other stratigraphic signals in the boundary interval as it has in the stratotype section. A true characterization of a GSSP includes not only the stratigraphic level of the single signal on which it is placed but also on the levels of other stratigraphic signals through the boundary interval. Several GSSPs have been defined on single stratigraphic signals without adequate consideration of other signals to characterize the boundary interval, and some of these GSSPs have been found subsequently to be seriously deficient.

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