Discussion and reply: Notes on geochronologic and chronostratigraphic units

Discussion

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We welcome Walsh's contribution to the discussion of geologic time units and their relevance in regional and international stratigraphic codes. At this time, we do not want to engage in a debate of the merits of his proposals, but we do want to comment on some of the references made to various portions of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), hereafter referred to as the Code. There are two areas of concern. First, is the author proposing amendments to the Code, and if so, what are those amendments? Second, some of the specific examples of the Code cited by the author do not accurately reflect the meaning of the Code, and we would like to provide some clarification. This clarification is necessary because the Geological Society of America requires contributors to its publications to follow the procedures outlined within the Code.

AMENDING THE CODE

First, it is unclear as to whether Walsh's article is meant to be simply a discussion paper, or whether the author indeed wishes to make concrete suggestions with respect to modifying the Code. If it is simply a discussion paper, then the inclusion of (i) a set of proposed definitions for a variety of geologic time units, (ii) statements such as ''future revisions of the Code should correct the ambiguous wording of Article 66b,'' and (iii) the use of the term ''Notes'' at the beginning of the article may cause some readers to interpret this document as a proposal for amending the Code. Furthermore, some of the terms proposed in the article are terms that already exist in the Code, and we are concerned that confusion could occur regarding use of these terms, since they have somewhat different definitions than those existent in the Code. In particular, we are concerned with the redefinitions of ''geochronologic unit'' and ''geochronometric unit.'' In the Code, geochronologic units (Articles 66–79) and geochronometric units (Articles 96 and 97) are conceptually exclusive. Walsh would change this so that geochronometric units become a subset of geochronologic units. In addition, the proposed usage of the terms ''chron'' and ''chronozone'' as the basic units of Walsh's geochronologic and chronostratigraphic units could cause confusion, since they have different ranks in the Code than in Walsh's proposal.

Although we would be the first to point out that the Code is meant to be flexible and changed as the need arises, there is a specific procedure to be followed in amending the Code, as outlined in Article 21. The purpose of this article is to ensure that changes are made by the geologic community in accordance with the published rules of procedures of the commission. This article is also designed to ensure that the need for the change is clearly stated, and that the proposed rewording of the Code is clearly stated. All proposed amendments are presented to the North American Commission on Stratigraphic Nomenclature (NACSN). If accepted for consideration by a majority vote of the commission, the proposed amendment is published, and the geologic community is given a year to comment on the proposed amendment. After a year, depending on the comments received on the proposal, the amendment is either adopted or rejected. These procedures are designed to ensure the widest range of input from the geoscience community. By not following these procedures, it is difficult for the NACSN to consider Walsh's suggestions in any meaningful fashion.

MEANING OF THE CODE

It is worth bearing in mind that both the Code and the International Stratigraphic Guide (Salvador, 1994) encapsulate the history of the development of geology and stratigraphy, as a science. Well before the onset of abundant, precise isotopic age determinations, there existed a geologic time scale based on observations made throughout the world on rocks and their constituent materials (fossils, etc.). What is termed a ''chronostratigraphic unit,'' in both the Code and the International Stratigraphic Guide, represents this rock-based geological history. The definition of such units in both the Code and the International Stratigraphic Guide is an attempt to outline the stratigraphic practices that should be followed when creating or modifying such units.

An important aspect of the Code is that it is designed to be a self-consistent document. Failure to recognize this leads to some state-

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ments in Walsh's article that may be misleading to the average reader. For example, on page 706, Walsh (2001) suggests that Article 66 of the Code confuses the concept of ''unit stratotype'' with the concept of ''chronostratigraphic unit.'' However, Article 66 is only one of 14 articles (66–79) that deal with the definition and creation of chronostratigraphic units. Article 76 states that one of several requirements for establishing a formal chronostratigraphic unit includes ''designation and description of boundary type sections, stratotypes, or other kinds of units on which it is based.'' As a chronostratigraphic unit in the Code is a geologic time unit based on material referents (Articles 61 and 66), that is, rocks and their constituent materials, therefore there is no inconsistency in requesting designation of type sections or stratotypes. In fact, without their designation it is not possible for other researchers to establish the validity of the proposed unit, and eventually to establish golden spikes at the boundary of the unit. In fact, all material-based units within the Code require the designation of type or reference sections in their definition, and chronostratigraphic units are no exception.

Also on page 706, Walsh (2001) suggests that the use of the term ''represents'' in Article 66b of the Code is incorrect and should be replaced with the term ''comprises'' or ''consists of.'' However, as noted in Article 61 of the Code, geologic time units are conceptual in nature. In this context, use of the term ''represents'' in Article 66b is logically consistent. Conceptually, a ''chronostratigraphic unit'' is meant to serve as a reference or composite section of rocks that is representative of a specific time interval. As such, a formal chronostratigraphic unit does not contain all of the rocks on Earth formed during that particular time interval, but it does ''represent,'' or is ''representative of'' all of the rocks on Earth formed during that time interval. To replace ''represents'' with ''consists of'' fundamentally changes the purpose and significance of a chronostratigraphic unit as currently defined in the Code. Making such a change may be desirable, but to do so would require reexamination and redefinition of Articles 61 through 79 of the Code so that the Code is logically consistent throughout. It cannot be done with the replacement of a single word.

On page 708, in the discussion of synchronous boundaries, Walsh (2001) makes reference to page 849 of the Code. Here we repeat the key sentences from the Code: ''Although two rock bodies of very different ages may be formed during equal durations of time, the term isochronous is not applied to them in the Earth sciences. Rather, isochronous bodies are those bounded by synchronous surfaces and formed during the same span of time.'' Thus, users of chronostratigraphic units do not ask whether a fence is isometric, e.g., if it is a constant 2 m high throughout its lateral extent. Rather, they would ask if the base of the fence was at a constant 10 m above mean sea level, and the top of the fence was at a constant 12 m above sea level.

On page 710, Walsh (2001) suggests that inclusion of ''diachronic units'' in the Code is unnecessary. Although this may appear to be the case based on his arguments, these units exist in the Code because they serve a specific purpose, particularly for Quaternary geologists in North America. Suggestions that they be eliminated from the Code have resulted in a strong defense of both the need and utility of such units (not yet published NACSN minutes for 1998–2001 annual meetings). It is neither the philosophy nor the practice of the NACSN to remove any given category from the Code simply because a particular author does not find it useful.

In conclusion, we remind readers of the *Bulletin* that meetings of the NACSN are held each year in conjunction with the Geological Society of America Annual Meeting. These meetings are open to all.

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Reply

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My paper was intended to be a discussion relevant to the future revision of all stratigraphic codes and guides, with the goal of making them more logical. Although my paper was obviously not a formal proposal for amending the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), it did call attention to certain parts of the Code that should be modified. It is disappointing for Easton et al. to claim that ''By not following these procedures, it is difficult for the NACSN [North American Commission on Stratigraphic Nomenclature] to consider Walsh's suggestions in any meaningful form.'' But, of course they can. Any member of the NACSN, if they think that my suggestions have merit, can rewrite them into a technical format of their own choosing, acknowledge their source, and subject them to a majority vote of the commission. Why should this be so difficult?

Regarding the term ''geochronologic unit,'' etymologically this means ''geologic time unit.'' But a span of geologic time defined in terms of numerical ages as opposed to golden spikes (e.g., the Mesoproterozoic Era) is obviously a geologic time unit. So it is more

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logical to consider geochronometric units to be a subcategory of geochronologic units (along with aurichronologic and biochronologic units).

Easton et al. are not quite correct in claiming that chrons and chronozones ''have different ranks in the Code than in Walsh's proposal.'' Article 75 states [italics mine]: ''A chronozone is a nonhierarchical, but commonly small, formal chronostratigraphic unit, and its boundaries *may* be independent of those of ranked units.'' To me, ''nonhierarchical'' means having no *fixed* rank. As such, it is appropriate to consider chrons and chronozones to be very general concepts encompassing geochronologic and chronostratigraphic units of any rank, or of no rank. Just as the term ''biozone'' is simply an abbreviation of ''biostratigraphic unit'' (Salvador, 1994, p. 111), the term ''chronozone'' is logically just an abbreviation of ''chronostratigraphic unit,'' such that all chronostratigraphic units (ranked or unranked) are necessarily chronozones. I would only agree with Article 75b that chrons and chronozones should be *either* formal or informal, as the need arises. The example of the ''biochronozone of the ammonites'' given in Article 75b is certainly informal usage (as so stated), and so contradicts the first paragraph of Article 75, which indicates that chronozones are necessarily formal.

Easton et al. state: ''As a chronostratigraphic unit in the Code is a geologic time unit based on material referents (Articles 61 and 66), that is, rocks and their constituent materials, there is no inconsistency in requesting designation of type sections or stratotypes.'' First, Easton et al. are utterly incorrect in claiming that a chronostratigraphic unit is a geologic *time* unit. A chronostratigraphic unit is not a time unit—it is a *rock* unit, composed of material rock *formed* during a given span of time (North American Commission on Stratigraphic Nomenclature, 1983, Article 66b; Salvador, 1994, p. 77). That three past chairmen of the NACSN could commit such a fundamental error demonstrates the validity of my (Walsh, 2001, p. 706) observation that many workers are unclear on this subject. Second, the ''inconsistency'' referred to by Easton et al. in the above quote distorts the nature of the inconsistencies discussed in my paper. I am not at all opposed to the designation of *boundary* stratotypes for the formal global geochronologic and chronostratigraphic units of the Phanerozoic time scale, as any objective reader of my paper can plainly see. Along with Harland (1992, p. 1234), I am simply opposed to the presence of logically inconsistent definitions of key terms in a scientific document such as the North American Stratigraphic Code.

Recall that in Article 66, a chronostratigraphic unit is defined as ''a body of rock established to serve as the material reference for all rocks formed during the same span of time.'' This definition clearly but erroneously refers to the concept of a *unit stratotype* (''a well-described sequence of rock''; North American Commission on Stratigraphic Nomenclature, 1983, first paragraph on p. 849R), which is a very local section with a designated base and top (North American Commission on Stratigraphic Nomenclature, 1983, Article 8a; Salvador, 1994, p. 26–27, 88). This erroneous use of the term ''chronostratigraphic unit'' for the concept of ''unit stratotype'' is explicitly defended by Easton et al., who claim that ''Conceptually, a 'chronostratigraphic unit' is meant to serve as a reference or composite section of rocks that is representative of a specific time interval.'' In spite of the fact that we no longer use unit stratotypes to define geochronologic and chronostratigraphic units (North American Commission on Stratigraphic Nomenclature, 1983, Article 78; Salvador, 1994, p. 88; Remane et al., 1996, p. 78), let's humor Article 66 and Easton et al. and pretend that we do. Let's suppose that we establish the well-described, 10,000 m thick Grimy Gulch section as the unit stratotype of the new Grimygulchian System. The Grimygulchian System (a chronostratigraphic unit) would then *consist of* all existing material strata on Earth that were formed during the span of time subtended by the Grimy Gulch unit stratotype. This section would indeed then ''represent'' the rest of the Grimygulchian System. But would it be correct to say that the Grimy Gulch section *is* the Grimygulchian System, or that the Grimy Gulch section *is* a chronostratigraphic unit? Of course not. However, this is exactly what is implied by Easton et al., as well as by Articles 66 and 96 and the first and fourth paragraphs on p. 849R of the Code, which all erroneously state or imply that a chronostratigraphic unit *is* a stratotype or reference section. Suppose that Senator Smith represents all of the people of Texas. Would it then be correct to say that Senator Smith *is* the people of Texas? Of course not.

Let me further explain the second fundamental inconsistency in the Code. If a chronostratigraphic unit ''consists of a body of strata formed during a specific time span'' (North American Commission on Stratigraphic Nomenclature, 1983, Article 66b; Salvador, 1994, p. 77), then it is *logically necessary* to define that specific time span (geochronologic unit) *first* (Salvador, 1994, p. 88; Walsh, 2001, p. 706). Therefore, contrary to Article 66, a chronostratigraphic unit *cannot possibly* ''serve as the basis for defining the specific interval of time, or geochronologic unit . . . represented by the referent.'' This is an incoherent circular definition. To use another analogy, human generations must be defined in terms of a specific time span. For example, the Baby Boomer Generation may be defined as the set of all Americans born between 1946 and 1961. Would it make any sense to turn this around and say that the Baby Boomer Generation serves as the basis for defining the span of time between 1946 and 1961? Of course not, because this span of time must be defined *first,* before the exact content of the Baby Boomer Generation can even be conceptualized. Articles 80, 83a, 88, and 89 are incoherent for the same reason. To quote S.S. Buckman (1903, p. 96): ''Now I do begin to see how it is that people use terms incorrectly—they do not test them by expressions of every-day life. But that is their fault, not mine.'' Given the above, Easton et al. are quite correct that in order to make the Code logically consistent throughout, a ''reexamination and redefinition of Articles 61 through 79'' (and all other passages dealing with geochronologic and chronostratigraphic units) will be necessary. I obviously never believed that this task could be accomplished ''with the replacement of a single word.''

I do not quarrel with the rewording of my fence analogy by Easton et al., but their discussion ignores the main issue. Do they agree or disagree with my (Walsh, 2001) argument that, over any appreciable geographic area, chronostratigraphic units cannot be isochronous? Again, Article 66 maintains that a chronostratigraphic unit is a material unit, *and* that each of its boundaries is synchronous. But this combination of attributes is impossible, owing to the ubiquitous presence of unconformities in the stratigraphic record (Harland, 1992, p. 1232; Walsh, 2001, Fig. 1). Nevertheless, I would like to clarify my claim that the term ''isochronous'' cannot be meaningfully applied to (single) spans of time. It may be meaningful to ask about the isochrony of two temporal units defined by different sets of events. For example, one could say that mammal biochron M is isochronous with foraminiferal biochron F if both of these biochrons coincidentally began at 50 Ma and ended at 47 Ma. However, to call the single span of time from 50 Ma to 47 Ma ''isochronous'' would still be tautological, because there is no possible way in which that span of time could be anything other than 3 m.y. in duration.

Finally, I have never believed that a given

category should be removed from the Code ''simply because a particular author [e.g., me] does not find it useful.'' I believe that the category ''diachronic unit'' should be removed from the Code because it is based on a generally false dichotomy between chronostratigraphic and other stratigraphic units regarding the concept of isochronous bodies (Walsh, 2001, p. 710). Nevertheless, I look forward to the publication of the defense of this category alluded to by Easton et al. Ironically, while I disagree with most of the arguments made by Watson and Wright (1980; cited in Article 91a), the caption for Figure 1 in that paper describes the relationship between geochronologic and chronostratigraphic units in a manner virtually identical to my own. This general subject is discussed in more detail by Walsh (2003).

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