NORTH AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE
Note 68 – Application for Addition of Submembers to the North American Stratigraphic Code: A Case for Formalizing Lithostratigraphic units of Intermediate Rank

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ABSTRACT: The existing hierarchy of formal lithostratigraphic units of the North American Stratigraphic Code (NACSN 2005) recognizes "Bed" or "Beds" (Flow in the case of volcanic rocks) as the only formal subdivision of members. Beds, in a geological context, are discrete depositional/accumulation units bounded by bedding planes and the formal term Bed should not be applied to thicker subdivisions of members composed of several discrete and distinguishable beds, especially of differing lithology. In such cases, thicker divisions of members that may contain one or more formally named Beds, would be usefully assigned to the division termed "Submember". In this paper we review the issue, discuss the justification of formalizing submembers, and propose a formal amendment to the North American Stratigraphic Code

There are several advantages to formalizing this additional division. First, submembers are already being used informally in many units. Formalization of the concept would require that these divisions meet the same standards as other stratigraphic units, e.g., designated type sections and careful specification of boundaries. Second, the formal use of Submembers would avoid the confusing issue of having a formally named "Bed" within an interval termed "Beds". Third, the addition of an intermediate rank permits accurate communication and precise correlation of complex sedimentary successions. The insertion of the rank of submember would allow retention of existing formal members and beds, rather than promoting the addition of new members to replace overly thick intervals formally named beds.

INTRODUCTION: STATEMENT OF PROBLEM

The rise of high-resolution stratigraphy requires a precise terminology for effective communication among stratigraphers, paleontologists, and sedimentary geochemists. There is an increasing realization that stratigraphic units can and should be defined on the basis of objective, regionally recognized bounding beds as opposed to arbitrary cutoffs at gradational lithofacies transitions. This change in emphasis reflects the empirical patterns of the stratigraphic record and the recognition that widespread discontinuities and condensed intervals provide natural boundaries for formally defined rock units. In many successions, these boundaries also permit a high-resolution allostratigraphic framework. In both litho- and sequence-stratigraphic approaches, there is a desire for ever finer scales of subdivision and consequent increased resolution of the timing and correlation of stratigraphic events and history.

In many successions, there is a need for precisely defined stratigraphic units at a variety of scales. The present stratigraphic classification includes six basic formal ranks for sedimentary rocks: bed(s), member, formation and group (International Stratigraphic Guide [hereafter, "the Guide"; Salvador, 1994: Chapter 5.C.1–7]; North American Stratigraphic Code [hereafter, "the Code"; NACSN, 2005: Articles 24–28]), along with supergroup (NACSN, 2005: Article 29) and subgroup (Salvador, 1994: Chapter 5.C.7). We argue that these six basic ranks are not quite adequate to capture the hierarchical pattern of the stratigraphic record. Furthermore, our proposal brings the current Code into agreement with the Guide, which allows the prefixes "Sub" and "Super" where appropriate.

The term "bed", as currently used for any division of a named stratigraphic member, is, in some cases, awkward and confusing. As defined sedimentologically, a bed is a unified body of sediment or sedimentary rock of relatively distinct composition that is bounded above and below by bedding planes, and is equivalent to a stratum. A bed is therefore an objectively recognizable and measurable entity that commonly records an episode (or episodes) of sediment deposition, accumulation, and/or diagenesis in the case of some nodule or concretion beds, bounded by discontinuities or changes in sedimentary process. Some intervals termed "beds" are composite or amalgamated units that record two or more episodes of deposition and final accumulation with possible intervening hiatuses; for these beds, recognition as formally

named Beds may be appropriate. Certain beds in this strict sense are regionally continuous and provide important physical and temporal markers in stratigraphic sections. As such, a formally named Bed has utility as a stratigraphic unit, and its recognition and tracing provide a valuable approach to correlation.

The current Code states that: "The designation of a bed or a unit of beds as a formally named lithostratigraphic unit generally should be limited to certain distinctive beds whose recognition is particularly useful" (NACSN, 2005: Article 26). Following this approach, formally recognized beds include not only the discrete bounded entities termed "Bed" s.s., but may also include intervals, up to many meters thick (e.g., certain debris flows and mudflows). In some cases, a Bed may consist of multiple sedimentological beds of strongly varying lithology that are potentially as thick as or thicker than some members and even formations in other parts of the stratigraphic record. In fact, considering beds as subdivisions of members may result in the confusing situation that some formally named beds actually contain, within them, distinctive marker horizons that represent individual beds worthy of being singled out and formally named as a "Bed".

At present, thicker subdivisions of members cannot have formal names in the Code and have merely been folded into an overly broad definition of Bed. An instructive example is the Mississippian Henley Bed of the lower Borden Formation, as used in Kentucky (originally defined as the Henley member of the Cuyahoga formation in Ohio; Hyde, 1915). The Henley Bed in eastern Kentucky (redefined as a bed of the Farmers Member of the Borden Formation by Peck, 1969) is 10–90 ft (3–30 m) thick (Matchen and Kammer, 1994) and contains a series of regionally traceable marker beds representing multiple lithofacies that include dark-gray shale, red mudstone, pale-gray, marly limestone, and sandstone beds. Under older versions of the Code, the term "Bed" was allowable for such intervals; under the current Code (NACSN, 2005), this would become Henley Beds.

POSSIBLE SOLUTIONS

There is clearly a need to recognize thicker, multi-bed divisions of members as formal units of higher rank than the constituent physically differentiable beds. There are several possible solutions to this issue. First, the units presently defined as Beds could be raised to the rank of members by elevating the member in which they occur to formation status and the encompassing formation to group status. However, this is clearly problematic as, in some cases, a member promoted to formational rank may be of insufficient thickness to form a mappable unit. More importantly, this elevation of ranks leads to instability and inconsistencies in terminology. In most cases, it is desirable to keep the existing stratigraphic definitions and nomenclature intact, and to preserve a terminology that is as close as possible to the original definitions (NACSN, 2005: Article 19).

A second possible solution, used in the 1983 and 2005 versions of the Code, is to pluralize the term, i.e., Beds, to recognize that the intervals are actually bedsets and to distinguish them from a true bed. Thus, for example, the term Taughannock Falls Bed (of the middle part of the Tully Formation; Heckel, 1973) would become Taughannock Falls Beds, as a formal term. However, this could be easily confused if the "s" is dropped, especially in cases where, for example, one or more discrete and geographically extensive true beds are present within the formally named interval, e.g., the "A Bed" of the Taughannock Falls Beds.

The third solution, which builds upon the presently accepted framework, as outlined in the second alternative, is to add a formal lithostratigraphic rank of Submember that occupies a hierarchical rank between that of Bed(s) and Member. Submembers would constitute portions of existing members. They would be defined and named according to the same rules of lithostratigraphic nomenclature and procedure as those that apply to the designation of formally named members and formations. In general, formally named and defined members would not require changes of existing stratigraphic frameworks with one exception. A previously recognized and named Bed would continue to be termed the "X Bed", if it fits the geologic definition of a bed; whereas one that is comprised of several beds, or bedsets, could be elevated to the rank of Submember. This would permit inclusion of individual beds into formally defined Submembers.

Furthermore, there may also be cases in which it may be useful to recognize a genetically related grouping of beds that is a part of a Submember and call this grouping Beds. A good case in point of the potential utility of both Submembers and Beds (plural) is provided by the detailed sedimentological studies of the Falher Member of the Spirit River Formation (Caddel and Moslow, 2004) in Alberta and British Columbia. Zonneveld and Moslow (2004) subdivided the Fahler Member into A through G units representing conglomeratic shoreface gas reservoirs. Caddel and Moslow (2004) termed the third unit the Fahler C sub-Member, dividing it into C1 and C2 "stratal units". Although not formally named, these units are lithologically defined divisions of a submember, several meters in thickness, that constitute bedsets. If formally named, these divisions of the Fahler-C submember could be termed "Beds" and indeed if distinct marker units exist within them, these could be given Bed designation. Such hierarchical terminology, whether formal or informal can be highly useful in thick intervals that show complex internal architectures.

Overall, we favor flexibility and inclusivity in terminology that suits varying purposes without undermining the stability of existing lithostratigraphic frameworks.

ADVANTAGES TO FORMALIZED SUBMEMBERS

There are a number of advantages to the formalization of Submembers:

a) It would permit and encourage increased precision in lithostratigraphic correlation and synthesis and discussion of high-resolution stratigraphy. It would bring into formal lithostratigraphy many readily recognizable field units that would enhance the ease of recognition of regional patterns.

b) It would require application of the rules of stratigraphic nomenclature and thus sharpen the definitions of otherwise informal and sometimes vaguely defined submember- and bed-level units. For example, each formally defined and named Submember would have to conform to the rules of having a specified type locality, a measured and described type section, and a formal definition in terms of diagnostic features, stacking patterns, etc., and incorporate these lithologically distinguishable units (submembers) into a succession of presently informally and formally defined beds and formally or informally defined members.

c) It would permit improvement of hierarchical frameworks by encouraging the recognition and definition of distinguishable, albeit currently informally named, beds as lithologically distinct units within Submembers. The present practice of using Bed or Beds as any formal subdivision of a Member presents an awkward situation in communication, which would be eliminated. The current stratigraphic literature includes a number of reports in which the concept of named beds and submembers has been applied to depositional and lithostratigraphic analysis (for examples, e.g., Brett et al. [1990, 1999] for the Silurian; Brett and Baird [1994, 1996] for the Middle Devonian; McLaughlin et al. [2008] for the Upper Ordovician; Caddel and Moslow [2004] for the middle Cretaceous; Campisano and Feibel [2008] for Neogene hominin-bearing srata).

d) It would enable retention of established stratigraphic frameworks and nomenclature, as existing member-level units would remain unmodified in their definition and nomenclature, except for their division into submembers. It would not encourage elevation of members to formations to accommodate these lower-rank units. Those stratigraphers who chose not to use the increased precision in correlation and depositional analysis allowed by the new submember unit would be free to utilize Member and Bed(s) without any change in their definition. However, a more detailed subdivision would be available and unambiguously defined for those who chose to utilize these terms.

PROPOSED REVISION

The proposal of formal Submembers requires changes in the Code (2005), particularly in Articles 25–27, Article 30, and Table 2. The proposed changes are given below with italics and red text used to highlight proposed changes. In order to minimize the renumbering of articles in the Code, old Articles 26 [Bed(s)] and 27 [Flow] have been combined into new Article 27 [Bed(s) and Flow(s)] and new Article 26 [Submember] has been inserted.

Recommended Changes (New wording highlighted in red and italics)

Article 25. — **Member**. A member is the formal lithostratigraphic unit next in rank below a formation and is always a part of some formation. It is recognized as a named entity within a formation because it possesses characteristics distinguishing it from adjacent parts of the formation. A formation need not be divided into members unless a useful purpose is served by doing so. Some formations may be divided completely into members; others may have only certain parts designated as members; still others may have no members. A member may extend laterally from one formation to another.

Remarks. (a) **Mapping of members**. — A member is established when it is advantageous to recognize a particular part of a heterogeneous formation. A member, whether formally or informally designated, need not be mappable at the scale required for formations. Even if all members of a formation are locally mappable, it does not follow that they should be raised to formational rank, because proliferation of formation names may obscure rather than clarify relations with other areas.

(b) **Lens and tongue**. — A geographically restricted member that terminates on all sides within a formation may be called a lens (lentil). A wedging member that extends outward beyond a formation or wedges (“pinches”) out within another formation may be called a tongue.

(c) **Organic reefs and carbonate mounds**. — Organic reefs and carbonate mounds may be distinguished formally, if desirable, as members within a formation. For the requirements of formalization, see Article 30f.

(d) **Division of members**. — A formally or informally recognized division of a member *composed of multiple beds* is called a *submember. Members and submembers may be formally or informally divided into* bed or beds, except for volcanic flow rocks, for which the smallest formal unit is a flow. Members may contain beds or flows, but may never contain other members. *Distinctive marker beds may be recognized within members without the need to subdivide into submembers.*

(e) **Laterally equivalent members.** — Although members normally are in vertical sequence, laterally equivalent parts of a formation that differ recognizably may also be considered members.

Article 26. — **Submember**. *A submember is the lithostratigraphic unit next in rank below a member and is always a part of some member. It is recognized as a named entity within a member because it possesses characteristics distinguishing it from adjacent parts of the member. A member need not be divided into submembers unless a useful purpose is served by doing so. Some members may be divided completely into submembers; others may have only certain parts designated as submembers; still others may have no submembers. A submember may extend laterally from one member to another.*

Remarks. (a) **Mapping of submembers**. — *A submember is established when it is advantageous to recognize a particular part of a heterogeneous member. A submember, whether formally or informally designated, need not be mappable at the scale required for formations. Even if all submembers of a member are locally mappable, it does not follow that they should be raised to member rank, because proliferation of names may obscure rather than clarify relations with other areas.*

(b) **Division of submembers**. — *A formally or informally recognized division of a submember is called a bed or beds, except for volcanic flow rocks, for which the smallest formal unit is a flow. Submembers may contain beds or flows, but may not contain other submembers. A member need not be divided into submembers in order to be divided into beds or flows.*

(c) **Laterally equivalent submembers.** — *Although submembers normally are in vertical sequence, laterally equivalent parts of a member that differ lithologically from one another may also be considered submembers.*

Article 27. — **Bed(s) and Flow(s)**. A bed, or beds, is the smallest formal lithostratigraphic unit of sedimentary rocks. *A flow is the smallest formal lithostratigraphic unit of volcanic flow rocks. A flow is a discrete, extrusive, volcanic rock body distinguishable by texture, composition, order of superposition, paleomagnetism, or other objective criteria. It is part of a member and thus is equivalent in rank to a bed or beds of sedimentary-rock classification.*

Remarks. (a) **Limitations**. — The designation of a bed or a unit of beds as a formally named lithostratigraphic unit generally should be limited to certain distinctive beds whose recognition is particularly useful. Coal beds, oil sands, and other beds of eco-

Table 2. Categories and Ranks of Units Defined in This Code*

I. MATERIAL CATEGORIES BASED ON CONTENT OR PHYSICAL LIMITS

LITHOSTRATIGRAPHIC	LITHODEMIC	MAGNETOPOLARITY	BIOSTRATIGRAPHIC	PEDOSTRATIGRAPHIC	ALLOSTRATIGRAPHIC
Supergroup	Supersuite (Complex)				
Group	Suite	Polarity Superzone			Allogroup
Formation	*Lithodeme*	*Polarity Zone*	*Biozone* (Interval, Assemblage or Abundance)	*Geosol*	*Alloformation*
Member (or Lens, or Tongue)		Polarity Subzone	Subbiozone		Allomember
Submember					
Bed(s) or Flow(s)					

IIA. MATERIAL CATEGORIES USED TO DEFINE TEMPORAL SPANS

CHRONO-STRATIGRAPHIC	POLARITY CHRONO-STRATIGRAPHIC
Eonothem	Polarity Superchronozone
Erathem (Supersystem)	
System (Subsystem)	*Polarity Chronozone*
Series	
Stage (Substage)	Polarity Subchronozone
Chronozone	

IIB. NON-MATERIAL CATEGORIES RELATED TO GEOLOGIC AGE

GEOCHRONOLOGIC	POLARITY CHRONOLOGIC	DIACHRONIC (Diachron)	GEOCHRONOMETRIC
Eon	Polarity Superchron		Eon
Era (Superperiod)			Era (Superperiod)
Period (Subperiod)	*Polarity Chron*	*Episode*	*Period* (Subperiod)
Epoch		Phase	Epoch
Age (Subage)	Polarity Subchron	Span	Age (Subage)
Chron		Cline	Chron

*Fundamental units are italicized.

TEXT-FIGURE 1
A copy of Table 2 of the 2005 North American Stratigraphic Code, showing changes that would be required if the rank of "Submember" is formally adopted. Note the insertion of Submember between the rank of Member and Bed(s).

nomic importance commonly are named, but such units and their names usually are not a part of formal stratigraphic nomenclature (Articles 22g and 30g). *The designation and naming of flows as formal rock-stratigraphic units should be limited to those that are distinctive and widespread. Many flows are informal units.*

(b) **Key or marker beds**. — A key or marker bed is a thin bed of distinctive rock that is widely distributed. Such beds may be named, but usually are considered informal units. Individual key beds and *individual flows* may be traced beyond the lateral limits of a particular formal unit (Article 23c).

~~Article 27. — **Flow.** A flow is the smallest formal lithostratigraphic unit of volcanic flow rocks. A flow is a discrete, extrusive, volcanic rock body distinguishable by texture, composition, order of superposition, paleomagnetism, or other objective criteria. It is part of a member and thus is equivalent in rank to a bed or beds of sedimentary-rock classification. The designation and naming of flows as formal rock-stratigraphic units should be limited to those that are distinctive and widespread.~~

The proposal of formal submembers also requires changes to Article 30, specifically remark (e).

Bed and flow names. — The names of beds or flows combine a geographic term, a lithic term, and the term "bed" or "flow;" for example, Knee Hills Tuff Bed, Ardmore Bentonite Beds, Negus Variolitic Flows.

(e) Member *and submember* names. — All member *and submember* names include a geographic term and the word "*member*~~;~~" *or* "*submember*;" some have an intervening lithic designation, if useful; for example, Wedington Sandstone Member of the Fayetteville Shale. Members *and submembers* designated solely by lithic character (for example, siliceous shale member), by position (upper, lower), or by letter or number, are informal.

The following changes to the Code will also be required:

First, there is a need to make changes to the **Contents** section on p. 1550:

Article 26. Submember 1569

Remarks: a. Mapping of submembers 1569

b. Division of submembers 1569

c. Laterally equivalent submembers 1569

Article 27. Bed(s) and Flow (s) 1569*

Remarks: a. Limitations 1569*

b. Key or marker beds 1569*

*Note: that the addition of new sections on Submembers will probably alter the page numbering from this point forward in the code. This will need to be changed once the changes are incorporated.

Second, p. 1567, Article 23c has two references to Article 26b. These will need to be changed to Article 27b. As an aside, there is a mistake in a sentence on p. 1556 that refers to "lithodemic units (Article 27)", which should be Article 31. Note that this is a mistake in the 1983 Code that was not corrected in the 2005 Code.

Third, the proposal of submembers requires a change to Table 2 of the Code (text-fig. 1).

SUMMARY

The hierarchy of formal lithostratigraphic units recognized by the North American Stratigraphic Code is not fully adequate to characterize all subdivisions of members. Herein we review the issue, consider alternatives, discuss the justification of formalizing the rank of Submember and propose an amendment to the Code to that end. We reach the following conclusions

A) The only rank smaller than Member in the existing code is Bed(s). However, geologically, beds represent discrete depositional units bounded by bedding planes; many units presently designated as "Bed" do not fit this definition.

B) The term Bed should not be applied to thicker, especially heterolithic subdivisions of members. Thicker subdivisions of members may instead be assigned to the formal rank of Submember; Submembers may encompass one or more formally named Beds.

C) Submembers are already being used informally in many units.

D) Formalization of the concept of Submembers would require that these divisions meet the same standards as other stratigraphic units, e.g., designated, measured, and lithologically described type sections and careful specification of boundaries.

E) The use of the rank Submember would provide for more refined correlation and communication and would avoid confusing and ambiguous terminology.

F) The insertion of submembers also promotes nomenclatural stability in allowing retention of existing formal members and beds.

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