Ruminations on Sequence Terminology with Specific Reference to "Sequence" and Sequence Boundary Types

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As first noted by Udden (1912), most siliciclastic stratigraphic successions deposited in coastal and shelf environments tend to be characterized by repetition or cyclicity. Analysis of this cyclicity can provide significant insights regarding regional facies patterns and stratal architecture in a basin. Such cyclic sedimentation patterns commonly are observed at a range of scales, from a few meters or less to several hundreds or thousands of meters. Sequence stratigraphy is essentially based on analysis of cyclicity in the sediment record as a function of the fundamental parameters controlling sedimentation patterns, i.e., sediment supply, physiography, subsidence, sedimentary processes, etc. Modern sequence stratigraphic concepts can be traced to the work of the European stratigraphers who in the late 19th century subdivided sedimentary rocks into discrete units separated by surfaces representing abrupt changes or breaks in sedimentation. These rock successions were formally defined as unconformity-bounded stages. At about the same time, Suess (1904) introduced and expounded on the concepts of eustasy and global controls on unconformities. Subsequently, Wheeler (1958, 1959), Weller (1960), and Sloss (1962, 1963), recognized the significance and utility of correlating time-synchronous surfaces across geological sections and further refined these concepts. Sloss (1963) identified regional stratigraphic units, which he termed sequences, bounded by significant unconformity surfaces. Note that although the sequences Sloss described were bounded by unconformities corresponding to time breaks in the millions or tens of millions of years, his usage of the term sequence was not intended to be reserved for any particular temporal or spatial scale.

Building on these earlier concepts, Mitchum (1977) and Vail et al. (1977) applied the term *depositional sequence* to stratigraphic units comprising regressive–transgressive–regressive sedimentary successions; the surfaces that were chosen to define the boundaries of these sequences were unconformities or their correlative conformities. However, not all unconformities are "created equal". There are those that correspond to temporal breaks of short duration in the order of hours to days to years at one extreme, and others that correspond to temporal breaks of long duration in the order of millions or tens of millions of years at the other extreme. Presumably the temporal aspect of the unconformities would be qualitatively proportional to the time represented by the strata between the upper and lower bounding unconformities. It follows then, that a hierarchical arrangement of sequences exists wherein unconformities representing major time breaks, and by extension, associated sequences, could and should be differentiated from unconformities representing minor time breaks. In general, "nested" cycles of different scales are commonplace in cyclic phenomena, consequently "nested" sequences of different scales can be recognized as well. Vail et al. (1991) dealt with this phenomenon by referring to "orders of sequences".

In a genetic sense also, not all unconformities are "created equal" insofar as there are a wide variety of processes that can lead to formation of unconformities, ranging from fluvial erosion and sediment bypass to deep-sea erosion and non-deposition. In either instance, sedimentary deposits are bracketed by unconformity-related time breaks. And consequently, in either instance a sequence is defined.

Sequence terminology**—**Controversy has surrounded the issue of exactly what these unconformity-bounded stratigraphic units should be called. There are those who prefer a two parallel terms, wherein one is descriptive and the other interpretive as to unconformity genesis (see Berggren et al., this volume), whereas there are those who prefer a single term (see Salvador, this volume), wherein the sequence definition is descriptive and based simply on the presence of an unconformity or correlative conformity surface. This writer prefers the simpler approach of defining as sequences any and all stratigraphic units bounded by unconformities or their correlative conformities, regardless of temporal or spatial scale and regardless of unconformity genesis. Consequently, the term sequence would be applicable to all unconformity-bounded units, whether they comprise fluvial deposits bounded by unconformities associated with fluvial erosion linked to local or regional up-lift, shelf deposits bounded by unconformities associated with fluvial or shoreface erosion linked to relative sea-level change, or deep-marine deposits bounded by unconformities associated with deep-marine-current erosion. Should the geoscientist have insight as to the cause (i.e., process) of the formation of the bounding surface, all the better. This can and should be addressed in associated discussion. However, a new term describing this stratigraphic unit need not be introduced simply because the mode of unconformity formation might be known or inferred or interpreted. If the latter approach were to be taken to the extreme, numerous terms could be coined, each relevant to a particular style of erosion associated with the corresponding bounding surfaces. And, if the interpretation should prove incorrect, the term used to describe this stratigraphic unit would change, perhaps many times over.

***Type 1 vs. Type 2 sequence boundaries*—**There has been much confusion regarding the meaning of Type 1 vs. Type 2 sequence boundaries and hence, sequence types. Vail et al. (1984) and Posamentier and Vail (1988) originally intended that Type 1 sequence boundaries be restricted to those surfaces that formed in response to periods of relative sea-level fall at the shoreline. In contrast, Type 2 sequence boundaries described those surfaces that were associated with slowdowns of relative sea-level rise but no period of relative sea-level fall. Some authors have incorrectly taken Type 1 sequence boundaries to mean those sequence boundaries associated with significantly greater erosionally-related time breaks than those associated with Type 2 sequence boundaries. Others have incorrectly taken Type 1 sequence boundaries to be associated with relative sea-level falls that exposed the entire shelf, in contrast with Type 2 sequence boundaries, which were associated with incomplete exposure of the shelf.

Rather than a system with two sequence boundary and hence sequence types, replacement with a single sequence boundary and sequence type is proposed (Posamentier and Allen, 1999). This change will tend to simplify sequence terminology as well as correct earlier misconceptions. It is suggested that the distinction between Type 1 and Type 2 sequence boundaries, and hence between Type 1 and Type 2 sequences, is artificial and should be eliminated. Sequence boundaries, as has been noted in many studies, can have varied expression, ranging from unconformity to correlative conformity. Figure 1 illustrates the basis for a proposal to eliminate the Type 1 and Type 2 designation in favor of a single unconformity type (with the associated correlative conformity). The left side of the figure illustrates an area of relatively low subsidence rate and an unconformable sequence boundary. The right side of the figure illustrates an area of relatively high subsidence rate and a correlative conformity separating the sequences.

With only one type of sequence, the need for Type 1 and 2 terminology is eliminated. The basis of the suggestion to drop the distinction between Type 1 and 2 sequence boundaries is that *unconformities can grade into correlative conformities along depositional strike as well as they can along depositional dip*. Consequently an unconformable sequence boundary (which formerly had been referred to as a Type 1 sequence boundary) along one part of a coastline can grade along strike into a conformable sequence boundary (which formerly had been referred to as a Type 2 sequence boundary) (Fig. 1). In summary, if one accepts the notion that along a dip profile sequence boundaries can be expressed as unconformities or correlative conformities and still be referred to as the same type of sequence boundary, then the same rationale should be applied along strike. Clearly, the same rules that apply in a dip direction (i.e., unconformity grading to a correlative conformity) must apply also along strike. Consequently, one can conclude that there are no type 1's or type 2's, just *sequence boundaries* expressed as unconformities or their correlative conformities, consistent with the definitions of sequence boundaries proposed by Sloss (1963) and Mitchum (1977).

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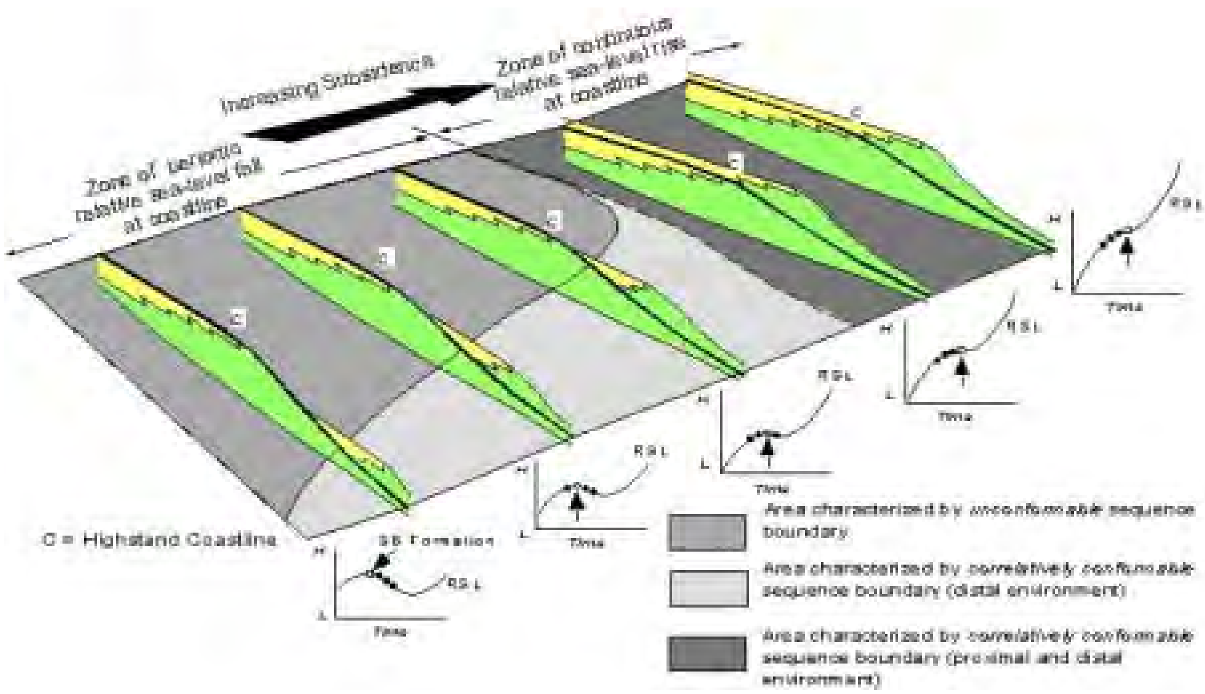

Figure 1. Schematic depiction of the relationship between unconformable sequence boundaries in areas of low subsidence (on the left side of the illustration) and correlative conformity sequence boundaries in areas of high subsidence (on the right side of the illustration). In this illustration, the rate of subsidence increases from lower left to upper right. The sequence boundary grades from an unconformity to a correlative conformity both along dip (note the profiles on the left side of the illustration) as well as along strike (from left to right across the illustration).