Aspects of the Relationship between Sequence Stratigraphy and Allostratigraphy: A Fluvial Perspective

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Sequence stratigraphy has enjoyed widespread usage, especially since its elaboration in the late 1970's (i.e., Payton, 1977). Allostratigraphy has not seen such prolific application. Various authors have commented on the virtues of allostratigraphy over sequence stratigraphy, noting that allostratigraphy is non-genetic, scale independent, more versatile, and formally recognized (Walker, 1990; Bhattacharya, 1993; Miall, 1997; Holbrook, in press). Sequence stratigraphy has the advantages, however, of offering more predictive power and a less cumbersome terminology. This paper evaluates elements in the relationships between allostratigraphy and sequence stratigraphy as they pertain to fluvial strata. The paper builds on two example studies, one ancient (Cretaceous) and one recent (Holocene), in the usage of allostratigraphy and sequence stratigraphy in fluvial-dominate strata. It is implicit that the points made in this paper likely have applicability in non-fluvial strata.

Cretaceous Huerfano Canyon Example

Middle Cretaceous Muddy Sandstone in the Huerfano Canyon comprise dominantly fluvial strata, with lesser amounts of paralic deposits. Three surfaces correlate throughout these Muddy exposures. The lower surface separates Muddy Sandstone from underlying marine Glencairn Shale and correlates to the widespread surface elsewhere dubbed SB3 (Holbrook and Ethridge, 1996). The second surface (SB4) subdivides the Muddy Sandstone into upper and lower sections (Holbrook and Ethridge, 1996). A third surface exists as a sharp, continuous contact at the base of the Muddy upper transitional member. The Cucharus Canyon Alloformation is defined as all the strata between surfaces SB3 and SB4. The Huerfano Canyon Alloformation encompasses all strata above SB4 and below the sharp, continuous contact at the base of the Muddy upper transitional member. The Cucharas Canyon and Huerfano Canyon alloformations each represent the basal strata of sequences deposited during separate transgressive/regressive events. SB3 and SB4 are both sequence boundaries. The upper discontinuity of the Huerfano Canyon Alloformation is a transgressive surface of erosion, that separates fluvial from overlying shoreface deposits.

Architectural-element analysis was used to informally define allomembers in Cucharas Canyon and Huerfano Canyon alloformations. Letters denoting alloformation (i.e., Kc and Kh) are assigned an additional descriptive letter to specify an allomember and, optionally, a number designating the order of the allomember in relative succession. Allosubmembers are accounted for by adding hyphenated labels (e.g., Kcv1-nv1 would be the oldest submember (nv1) of the oldest allomember (v1) of the Cretaceous Cucharus Canyon Alloformation (Kc)). Allosubmembers are not forally recognized in the North American Stratigraphic Code (NACSN, 1983) and are applied here only as an informal vehicle to reference specific allomember components. Allomembers record individual valleys. Two allosubmembers are also recorded, and are interpreted to record amalgamation of nested valleys and channel belts, respectively. Channel belt allosubmembers are composed of channel-fill and lateral-accretion elements. Allomembers and allosubmembers are amalgamated to form an extensive basal fluvial sheet sandstone bed within each alloformation.

Holocene Mississippi Valley Example

Holocene strata of the meandering Mississippi River are divided into informal allounits by Saucier (1994) throughout the Lower Mississippi Valley and are mapped in detail in the New Madrid seismic zone. Saucier (1994) recognized six channel belts bound by scour discontinuities from ariel photographs and placed them in chronological order using crosscutting relationships and absolute dating techniques (allounits Hpm1 – Hpm6). Three belts are mapped in the New Madrid seismic zone that roughly equate to Saucier's (1994) meander belts one, three, and six. Each of these belts consists of two distinct members (e.g., Hpm1a and Hpm1b), recording two distinct phases of meander development. Each of these members comprise lateral-accretion and channel-fill elements that could also be considered allomembers. These elements record point-bar development and channel abandonment, respectively. In the lower part of the valley, Aslan and Autin (2000) recognize an additional Holocene allounit that records a complex of stacked splay, lake, and minor-channel strata, and interpret this to record episodes of more rapid floodplain aggradation.

Allostratigraphy and Sequence Stratigraphy Comparisons

These two studies illustrate three points regarding the relative relationship of sequence stratigraphy and allostratigraphy. First, allounits may be defined objectively without genetic bias at any scale, using any type of discontinuity and distinction method. Such allounits are defined by architectural-element analysis in the Cretaceous example, and by ariel photographs and crosscutting relationships in the Mississippi Valley Holocene. Allounits may be interpreted independently after distinction by any of several objective criteria. Sequence stratigraphy demands that specific criteria be set forth that identify unique surfaces and units based on genetic criteria (e.g., flooding surfaces define parasequences, etc.). A search for sequence-stratigraphic units may mean guided misinterpretation of strata and/or oversight of other, more enlightening, allostratigraphic subdivisions. Traditional sequence-stratigraphic units may not even be present in many strata.

This leads to the second point. Allostratigraphy is effective at incorporating those aspects of sequence stratigraphy that apply in fluvial strata, but the reverse is not true. A sequence is defined by its bounding unconformities. As such, a sequence would be defined by bounding discontinuities and, by default, be an allounit. Allounits that are also sequences may, thus, be defined in fluvial-dominate strata. Such is the case of the Cucharas Canyon Alloformation. The parasequence is defined between marine flooding surfaces and does not have a clear analogy in purely fluvial strata. The systems tract, however, is often extended to fluvial successions. Systems tracts may be characterized as genetically related facies associations and their boundaries mapped based on architectural distinctions. They are traditionally used to distinguish changes in sediment accommodation modes. Allounits that record discontinuities in sediment architecture related to fluvial accommodation space, such as those discussed above by Aslan and Autin (2000), would be consistent with systems-tract principles. Martinsen, et al (1999), however, point out that such allounits do not always need to record sea level fluctuation to fall under the rubric of systems tracts, and that the discontinuities that bind them are not always discrete surfaces.

Fluvial systems are replete with discontinuities, each of which could be used to define allounits. Such allounits are not all encompassed by the sequence-stratigraphic paradigm or best defined by the lapping and facies relationships that traditionally used to distinguish sequence stratigraphic units. In the case of the Muddy, several allomembers were defined below the sequence level using architectural-element analysis. Likewise, channel belts and elements within in the Mississippi valley deposits are largely defined based on relative elevation, crosscutting relationships, and soil maturity, in addition to lithofacies characteristics. Both these studies illustrate that many allounits may be mapped in fluvial strata without invoking sequence-stratigraphic techniques.

Third and lastly, allostratigraphy needs modification if it is to equal the utility and popularity of sequence stratigraphy. Allostratigraphy is cumbersome. Lengthy terms such as “alloformation” and “allomember” become awkward with repeated usage compared to simpler terms such as “formation,” “bed,” and “sequence.” Little can be done to improve this without adversely affecting existing publications. It does seem reasonable, however, to allow the most used term “alloformation” to be abbreviated simply to “allo” at the author’s discretion. Likewise, the master sequence-stratigraphic term “sequence” could be substituted for “alloformation” for those specific alloformations that are bound entirely by prominent unconformities. For instance, the Cucharus Canyon Alloformation could be alternatively referred to formally as the Cucharus Canyon Sequence. This would be similar to the currently permitted substitution of “Limestone” for “Formation” to distinguish a lithostratigraphic unit that is dominantly formed of limestone. It would also serve as a vehicle to selectively integrate sequence-stratigraphic usage into the codified lexicon.

In addition, allostratigraphy lacks a hierarchy that adequately encompasses the breadth of nested units definable in fluvial strata. At present, no unit exists below “allomember.” In the case of the Cretaceous example, two distinct allounits and two architectural elements are defined beneath the level of valley-fill allomembers. This highlights the potential breath in scale for surfaces and allounits inherent to fluvial deposits. At least one more subdivision beneath allomember is in order. Miall (1996) suggested “allosubmember,” but a simpler term such as “component” would be preferable for reasons stated above. Likewise, formal adoption of the term “elements” (after Miall, 1996) could be explored as well.

Conclusions

In conclusion, allostratigraphy is the generic stratigraphy based on mappable discontinuities. Several techniques may be used to define these discontinuities, including: sequence stratigraphic techniques, soil-surface correlation, terrace elevation analysis, and architectural-element analysis. Each of these techniques, however, should be viewed as “approaches” to allostratigraphy, rather than separate, codified stratigraphys. Allostratigraphy will need to be less cumbersome and provide a better hierarchy, however, if it is to exercise its potential.

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