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Sequence stratigraphy using well logs and cores, a systematic approach

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Summary

Sequence stratigraphy, in its most general sense, involves correlation of facies successions, bounded by key surfaces that violate Walther's Law. Construction of a sub-regional sequence stratigraphic framework, especially using well logs and core involves 10 key steps outlined below. Examples of each step will be given with an emphasis on fluvio-deltaic systems in the Cretaceous Interior Seaway of North America. This talk emphasizes that correlating well logs may require some model-driven assumptions (e.g., deltas clinoform). The key is to use multiple-working models. Correct correlations may be very difficult to achieve without making some *a priori* assumptions about the correlation style, but such assumptions are best based on good stratigraphic facies models that respect the rocks and take their lead from seismic stratigraphy. Robust well log cross sections commonly look like high-resolution seismic lines (Bhattacharya and Abreu, 2016). The general approach and discussion of this talk has been published by Bhattacharya et al. (2016).

Workflow

1. Compile previous work such as regional seismic lines or general paleogeographic maps to establish the gross basin-scale paleogeography (e.g., proximal-distal relationships), age, and structure. Detailed cross sections can then be oriented with respect to broadly defined depositional strike and dip.
2. Establish the nature of depositional facies, preferably calibrated to core or outcrop data, which may yield important *a priori* information about correlation styles. For example, shoreline-related strata will clinoform and pinch out in a distal, seaward direction, whereas fluvial strata may comprise layer-cake floodplain mudstones incised by sandy channels.
3. Identity Walther's Law breaks by dislocations in a facies succession, such as may mark flooding surfaces, sequence boundaries, or other key bounding discontinuities (Bhattacharya, 1993). Log trends such as coarsening-fining trends maybe used to identify key boundaries, in the absence of core data, and the key surface commonly is marked by a change in depositional trend.
4. Pick a stratigraphic datum to hang cross sections on, or use several datums. The proviso is that all stratigraphic datums distort the stratigraphy. High-resolution seismic data show that although bed geometries in shallow marine systems may be smooth they are never flat. Moreover, because choosing a marker bed, such as a bentonite or condensed section, as a datum can distort the actual stratigraphic relationships, several datums may be needed to illustrate stratigraphic geometries accurately. There are distortions with both top and bottom datums (Bhattacharya et al., 2016).

5. Establish correlation lengths by examining closely spaced data, such as twinned wells, wells in producing fields, or laterally continuous analog outcrops. Correlation of closely spaced well data should precede expansion to a more regional scale, although the process is iterative.
6. Focus on correlations of log markers in mudstones, as these tend to record the most amount of time and provide key facies information such as trace fossils, microfauna, and paleosols.
7. Loop-tie correlations. This can be challenging in units that exhibit clinoforms. Beware of aliasing and be aware of probable *a priori* correlation lengths and clinoform dip magnitudes! Strike-sections are commonly harder to correlate than dip sections.
8. Identify lapout and stratal truncation. Stratal terminations are commonly used to identify sequence boundaries, however, unlike in analysis of seismic-data, in well log analysis, lapout cannot be seen directly. It must be interpolated between wells. Such interpolation requires correlating as many key markers as possible.
9. Fit the sandstones within a framework of mudstones, especially in shallow marine settings. Sandstones should be correlated last, in contrast to what happens in many lithostratigraphic studies (Gani and Bhattacharya, 2009).
10. Make your maps. Map anomalies may require revision of correlations. Sandstone body stacking patterns are best seen in maps on which the relative position of successive sandstone bodies can be shown, as opposed to a single well log or cross section.
11. Finally, Wheeler diagrams (time stratigraphic charts) make assigning facies to specific systems tracts easier and may highlight anomalous correlations.

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