Strategies for Well Log Correlation within a Sequence Stratigraphic Framework: Is the Gain Worth the Pain?

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Summary

In many basins, interpretation of well log data is the primary method for development of a stratigraphic framework which can be used for mapping and prediction of reservoir intervals. Basins like the Williston and Alberta have abundant well data and seismic imaging thin reservoir intervals like the Bakken is a challenge. Correlation of well logs for thin reservoir intervals is a fundamental part of exploration and development programs, but strategies for this task are not always clearly defined. Unlike correlation of beds in outcrop where surfaces can be physically traced, correlation of well logs requires interpretation of surfaces from well to well. In the absence of key marker beds, such as ash horizons, developing a stratigraphic framework is enhanced by utilizing a sequence stratigraphic methodology. This sequence stratigraphic approach, one based on a hierarchy of stratal surfaces, is a method for dividing up a stratal section and predicting lithofacies from well to well. With this approach, different surfaces need to be identified in wells and mapped, typically in an iterative process. These surfaces include unconformities and flooding surfaces.

Recognition of basic stratal elements is the first step toward building a sequence stratigraphic framework whether working with subsurface data or outcrops. Clearly, lamina, laminasets, beds and bedsets are below resolution of some subsurface tools such as seismic reflection data, but these stratal elements are resolvable with different types of well log data and cores (Figure1). Observations from outcrop and core provide criteria to help identify surfaces in the subsurface. This method is facilitated by identification of stacking patterns of different beds from core data and calibration to the well log signature. Stacking patterns of different sedimentary structures provides a useful method for interpretation of physical processes that have affected various depositional environments and how these environments evolved through time. For example a progradational system may evolve from offshore mudstone to foreshore sandstone or coastal plain coal and mudstone (Figure 2). This approach has been in use for a number of years (see Harms and Walker, 1982), and has lead to recognition of parasequences described by Van Wagoner et al (1990). Parasequence stacking may provide insight into relative changes in sea level through time, which can be useful at a local field scale to a regional play scale

For correlation of shelfal rocks, the focus is on mapping sequence boundaries and parasequence boundaries or flooding surfaces. Flooding surfaces are widespread and exhibit a range of characteristics depending on the lithofacies that are juxtaposed (Figure 3). Usually, sequence boundaries are associated with regional

truncation or incision. With regional truncation in units like the Devonian Bakken, stratigraphic sections may need to cover 10's of kilometers, whereas incised valleys can cover a range of scales from 10's of meters m to 10's of kilometers. Within incised valleys the base of the valley fill is a sequence boundary. Locally, this boundary is picked at abrupt change in facies identified from core data and/or the abrupt change in well log properties – gamma-ray, resistivity and density among others (Figure 4). Additionally, sequence boundaries can be picked where the juxtaposition of facies is not predictable, such as where non-marine rocks, like coal, overlie marine mudstone.

References:

Harms, J.C., Southard, J.B., and Walker, R.G., 1982, Structures and sequences in clastic rocks: SEPM Short Course No. 9

Van Wagoner, J.C, Mitchum, R.M, Campion, K.M. and Rahmanian, V.D, 1990, *Siliciclastic Sequence Stratigraphy in Well Logs, Cores and Outcrops: Concepts for High Resolution Correlation of Time and Facies*: American Association of Petroleum Geologists Methods in Exploration Series, Tulsa, 7, 55 pp.

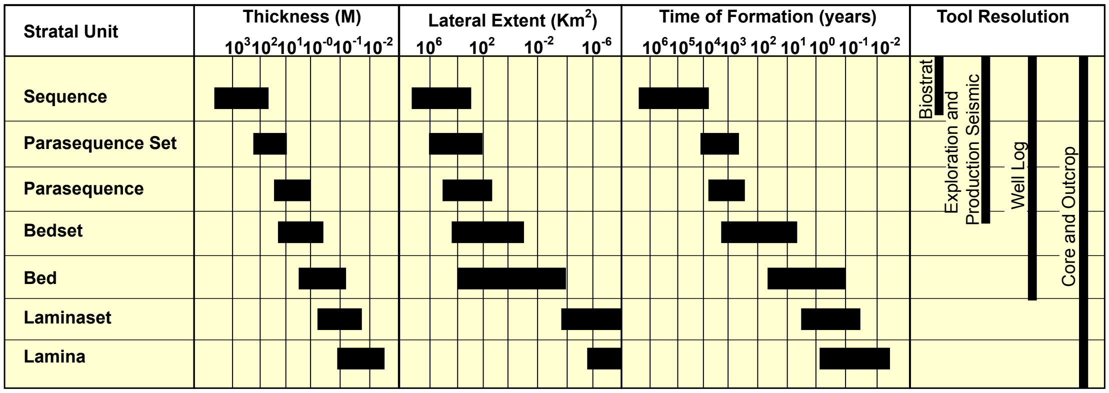

Figure 1. Hierarchy of stratal units , typical thickness, lateral extent, time of formation and tools used for study. Well log curves like gamma profiles can resolve beds that are 25 cm or thicker (modified from Van Wagoner et al, 1990).

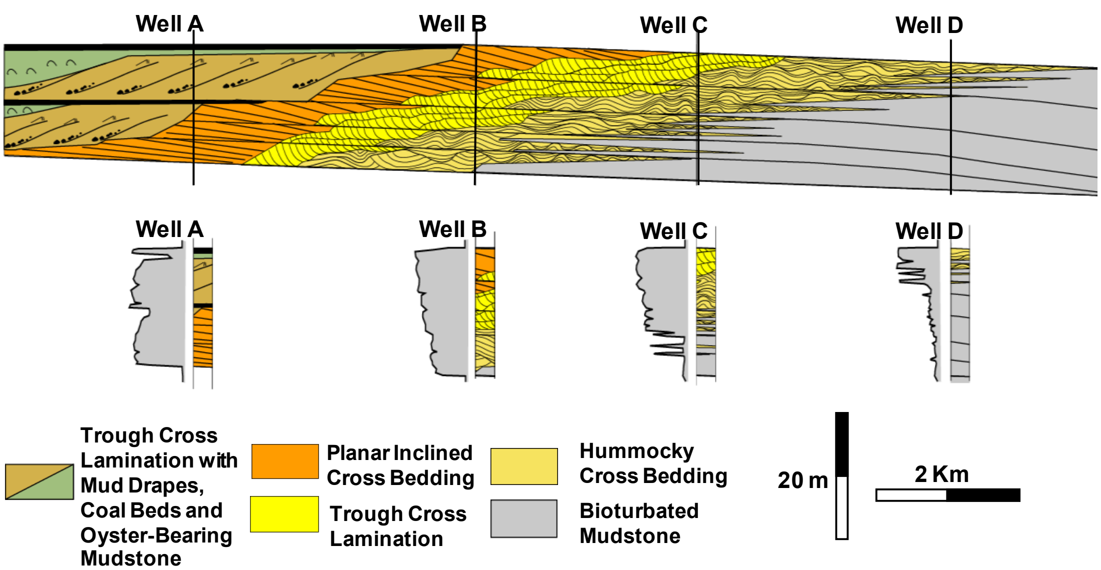

Figure 2. Lateral facies patterns in a shoreface setting with typical gamma-ray log signature. The well log patterns change have a predictable change in character as the facies change laterally. The thickness and width of facies belts is approximate, but most depositional systems exhibit lateral change, hence correlation of well logs should account for facies changes.

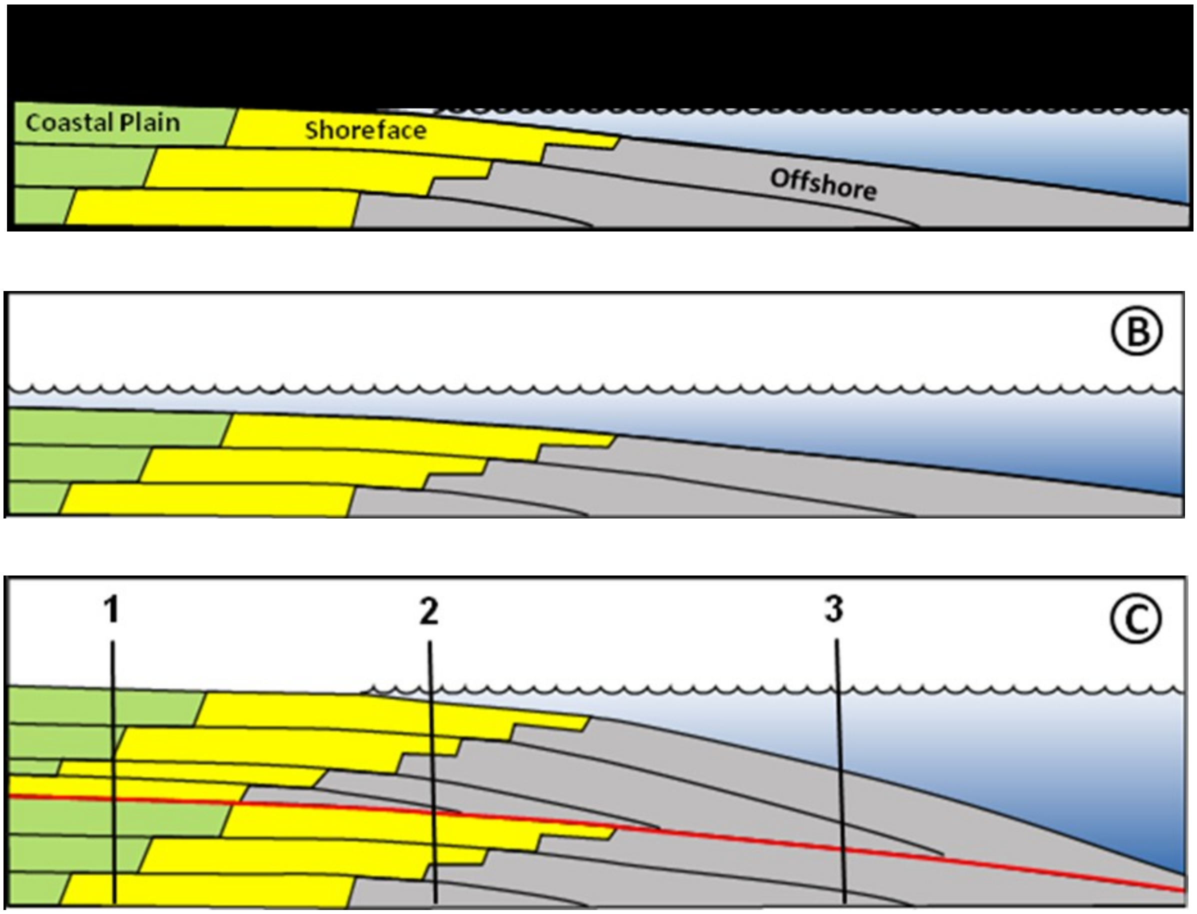

Figure 3. Development of a typical shallow-marine parasequence; **A**, the shoreline system progrades and aggrades in a basinward direction; **B**, progradation of the system is marked by a flooding event that “drowns” the coastal area; and **C**, a shallow-marine unit progrades and aggrades over the previous parasequence. The parasequence boundary is marked by a solid red line. The characteristics of the parasequence boundary are different at the three sections with different lithofacies juxtaposed at the boundary; schematic facies belts include coastal plain, shoreface, and offshore.

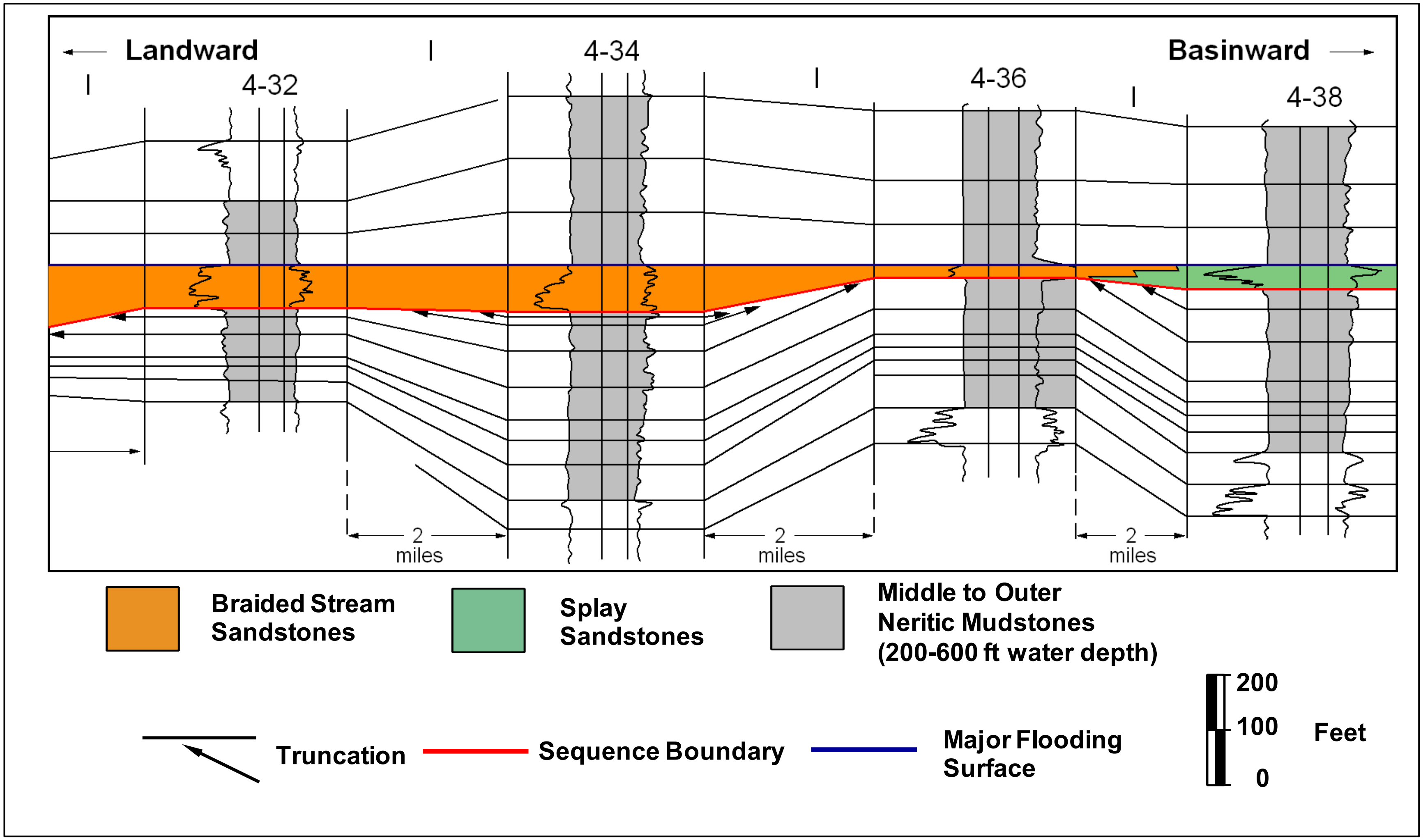

Figure 4. Characteristic log signature of an incised valley filled with a fluvial sandstone-prone facies cut into marine mudstone. The abrupt change in facies and interpreted truncation pattern are key elements in recognition of a possible sequence boundary. Vertical lines show positions of wells used in correlation but not shown in this diagram (modified from Van Wagoner et al, 1990).