Sequence stratigraphy in ramp settings--With application to upper Cretaceous rocks in the San Juan Basin

Dag Nummedal

1992, pp. 185-186. https://doi.org/10.56577/FFC-43.185

in:

San Juan Basin IV, Lucas, S. G.; Kues, B. S.; Williamson, T. E.; Hunt, A. P.; [eds.], New Mexico Geological Society 43rd Annual Fall Field Conference Guidebook, 411 p. https://doi.org/10.56577/FFC-43

This page is intentionally left blank to maintain order of facing pages.

SEQUENCE STRATIGRAPHY IN RAMP SETTINGS—WITH APPLICATION TO UPPER CRETACEOUS ROCKS IN THE SAN JUAN BASIN

(Précis of keynote speech to 43rd Annual Field Conference, October 2, 1992)

DAG NUMMEDAL
Department of Geology and Geophysics, Louisiana State University, Baton Rouge, Louisiana 70803

Sequence stratigraphy provides a perspective on the stratigraphic record in which correlation of rocks is based, in part, on conceptual models of how sediments are transferred from source areas to sinks in sedimentary basins. Fundamental to such "genetic stratigraphy" is the recognition that erosional surfaces ("source diastems") in some locations correlate in time to packages of rocks elsewhere. Some authors refer to this as the "principle of reciprocal sedimentation." A sequence stratigraphic study of a sedimentary basin is a sophisticated chronostratigraphic analysis in which the distribution of both rocks and their bounding surfaces are properly accounted for in time and space.

Sequence stratigraphy, as currently practiced, began with Larry Sloss' investigations in the late 1940s and 1950s of the large-scale North American Phanerozoic record. Sloss documented that six interregional unconformities could be recognized across the North American craton, and that these ("source unconformities") correlated with intervals of deposition along the continental margins (the Cordilleran and Appalachian "basins"). Extensive work by scientists at Exxon Production Research in the 1970s and 1980s greatly expanded on the early ideas, and established most of the present conceptual underpinnings of sequence stratigraphy. Among the most widely applied concepts is that of "systems tracts" which are depositional systems linked by common sedimentary processes and deposited during specific phases of sea level change.

Most published sequence stratigraphic models for all basin types have been explicitly or implicitly influenced by the "passive margin" idea, that sediments were exported into the deep sea, beyond the continental margin, during relative sea level fall and that shelf edge deposits, when they occur, overlie the sequence boundary in the form of a lowstand prograding complex (Vail et al., 1991), or shelf margin systems tract. The highstand and lowstand systems tracts, thus, are on opposite sides of the sequence boundary, and commonly widely separated spatially. This model carries the implication that in ramp settings, where one commonly can trace a sequence boundary in the form of a subaerial erosion surface along the upper surface of regressive deltaic sandbodies (e.g., the Blackhawk Formation in the Book Cliffs), there might be sandstones of a lowstand systems tract above this same sequence boundary somewhere farther into the basin (Van Wagoner et al., 1990, 1991). Candidates for such detached lowstand sandstones, however, are hard to find. Detailed seismic data from late Pleistocene lowstand deltas along the Louisiana and Texas shelf margin, and reexamination of the deltaic stratigraphic record of Upper Cretaceous rocks of the San Juan Basin and the Book Cliffs, make it clear that these lowstand problems have arisen because of the failure of existing ramp models to properly account for strata that are deposited during relative sea level fall.

I believe that many of the extensive Upper Cretaceous delta successions of the Western Interior, including some in the San Juan Basin, were deposited during periods of relative sea level fall. Whereas this phase of sea level change is commonly recorded only as an unconformity or bypass surface in the stratigraphic record on passive margins, it is quite clear that in ramp settings part of the falling sea level cycle is recorded as deposits. The strata associated with the last part of the fall have the greatest preservation potential. There is always a delta at the mouth of a prograding river, whether relative sea level is rising, standing still or falling. This deltaic package is carried seaward, with the prograding shoreline, during sea level fall. The sedimentation processes involved include continued supply from the headwaters of the river, combined with reworking of alluvial valley and older delta plain sediments in response to lowering of the graded river profile. As a result, deltas associated with falling relative sea level may prograde rapidly, and far. In contrast, deltas associated with rising relative sea level are unlikely to be very extensive, because the gradual elevation of the graded fluvial profile will in this case produce a rapid increase in upstream accommodation space, and relatively slow rates of sediment supply to the river mouth.

Perhaps the most appropriate way of designating the deposit associated with relative sea level fall is to refer to it as the *falling sea level system tract* (Nummedal, 1992). Chronostratigraphically, the falling sea level systems tract may, in part, correspond to the basin floor fan, but this connection is far from proven. Besides, there probably are no basin floor fans in Cretaceous deposits of the Western Interior. The lower boundary of the falling sea level systems tract lies at the transition from sigmoid to oblique-progradational clinoforms. This change is also the beginning of offlap. Depending on the magnitude of fall, there may or may not be a marked change in facies at this boundary. The upper boundary is associated with change from offlap to renewed onlap (downward shift on onlap) in nearshore and nonmarine facies. Also, this boundary displays a facies discontinuity reflecting abrupt shoaling (e.g., estuarine facies overlying truncated lower shoreface).

Both the lower and upper boundaries of the falling sea level systems tract may be considered sequence boundaries and are used as such by different authors. Vail et al. (1991) used the lower surface as the sequence boundary and referred to this systems tract as the "lower lowstand prograding complex." Posamentier et al. (in press) considered the deposit to be a part of the lowstand systems tract, and the process is referred to as a "forced regression." Van Wagoner et al. (1990, 1991) used the upper surface as the sequence boundary and referred to this systems tract as "highstand." Although technically consistent, the highstand designation is inappropriate because the seaward portion of this systems tract is deposited while relative sea level is at its lowest point in the cycle.

The falling sea level systems tract is represented by many well-known stratigraphic units in the Upper Cretaceous succession of the San Juan Basin. I interpret the main body (C-tongue) of the Gallup Sandstone to reflect relative sea level fall, because a distinct, regional sequence boundary (exposure surface) climbs stratigraphically seaward through this lithostratigraphic unit (Nummedal and Riley, 1991). In updip areas around Gallup, the sequence boundary is exposed at the contact between tongues D and C, as designated by Molenaar (1983). In this area, estuarine facies (C-tongue) erosionally overlie truncated lower shoreface (D-tongue). At the downdip pinch-out of the Gallup Sandstone, the sequence boundary becomes indistinguishable from the base of distributary channels. Seaward of the lowstand shoreline (in the most distal Gallup Sandstone and associated Mancos Shale) the sequence boundary is a conformity. Another example of this falling sea level systems tract may be present in the distal parts of the Point Lookout Sandstone, as reported by Wright et al. in this volume. Many of the Dakota Sandstone tongues in the San Juan Basin were probably also formed during relative sea level fall, but their sequence stratigraphy is still inadequately documented for this hypothesis to be tested.

Does it really matter whether relative sea level went up, down or sideways during deposition of these stratigraphic units? For two reasons, I believe the answer to this question is yes. First, as discussed at the beginning of this paper, sequence stratigraphy is all about correlating rocks and surfaces in a correct chronostratigraphic framework. Our chronostratigraphic interpretations will be vastly different if we believe that sequence boundaries somehow were superimposed *after* deposition of these regressive sandstones, as strict application of some earlier sequence models would imply, rather than during their progradation, as I have argued above. Second, from the practical perspective of exploration and production of oil and gas, we need to know the spatial distribution of source rocks, reservoirs and seals. If the model I have outlined in this paper is correct, then the shoreface sandstones represent the falling sea level systems tract and the estuarine and fluvial deposits above are the lowstand. In my experience, these estuarine lowstand deposits are often the best reservoir rocks in the entire sequence. If the alternative ramp sequence model, which fails to recognize falling sea level deposits, is correct, the sea level fall that postdated deposition of the (highstand) regressive shoreface sandstones would itself be associated with lowstand deposits farther into the basin. Surrounded as they would be by Mancos Shale, these "lowstand" sandstones might be great reservoirs.

REFERENCES

Molenaar, C. M., 1983, Principal reference section and correlation of the Gallup Sandstone and associated formations, northwestern New Mexico; *in* Hook, S. C., compiler, Contributions to Mid-Cretaceous Paleontology and Stratigraphy of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 185, p. 29–40.

Nummedal, D., 1992, The falling sea level systems tract in ramp settings: Abstract, SEPM Theme Meeting, Ft. Collins, CO, August 1992.

Nummedal, D. and Riley, G. W., 1991, Origin of Late Turonian unconformities in the San Juan Basin; *in* Van Wagoner, J. C., Nummedal, D., Jones, C. R., Taylor, D. R., Jennette, D. C. and Riley, G. R., Sequence stratigraphy applications to shelf sandstone reservoirs: AAPG Field Conference Guidebook, Sept. 21–28, 1991.

Posamentier, H. W., Allen, G. P., James, D. P. and Tesson, M., in press, Forced regressions in a sequence stratigraphic framework: concepts, examples, and exploration significance: American Association of Petroleum Geologists Bulletin.

Vail, P. R., Audemard, F., Bowman, S. A., Eisner, P. N. and Perez-Cruz, C., 1991, The stratigraphic signatures of tectonics, eustasy and sedimentology—an overview [Chapter 6.1]; *in* Einsele, G., Ricken, W. and Seilacher, A., eds., Cycles and events in stratigraphy: Berlin, Springer-Verlag, p. 617–659.

Van Wagoner, J. C., Mitchum, R. M., Campion, K. M. and Rahmanian, V. D., 1990, Siliciclastic sequence stratigraphy of well logs, cores and outcrops: concepts for high-resolution correlation of time and facies: AAPG Methods in Exploration Series, No. 7, 55 p.

Van Wagoner, J. C., Nummedal, D., Jones, C. R., Taylor, D. R., Jennette, D. C. and Riley, G. R., 1991, Sequence stratigraphy applications to shelf sandstone reservoirs: AAPG Field Conference Guidebook, Sept. 21–28, 1991.