Tectonic Forcing, Subsidence and Sedimentary Cyclicity in the Upper Cretaceous, Western Interior, U.S.A.*

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Introduction

Sequence stratigraphy is an observationally based method for interpreting sedimentary cyclicity. Stacking patterns of progradation, retrogradation and degradation are related to the balance of sedimentary accommodation versus sediment supply. While often related to eustasy, accommodation is also controlled by tectono-subsidence. Based on over 50 global examples, regional subsidence and uplift rates are usually greater than rates of sea level rise/fall for durations greater than about one million years (Figure 1). Thus, in many basins, the larger-scale patterns of sedimentary cyclicity are driven by tectonics.

The Upper Cretaceous of the Western Interior is an ideal laboratory to evaluate stratigraphic response to tectono-subsidence. Based on the stratigraphic framework, geohistory analyses, mapped shorelines and interpreted 2nd-order system tracts, there is a strong correlation between subsidence rates and shoreline trajectories/stacking patterns (Rudolph et al., 2015). Large scale transgressions correlate with marked increases in subsidence, while strongly regressive intervals correspond to periods of low subsidence (or uplift). For example, the widespread transgression that occurs above the Turonian (e.g., Niobrara-Baxter-Cody) is associated with a large increase in regional subsidence. And the strongly progradational interval in the upper Campanian that occurs throughout Wyoming (e.g., Ericson-Allen Ridge/Pine Ridge-Parkman/Teapot) corresponds with uplift in proximal areas and reduced subsidence rate in more distal areas.

Subsidence and Cyclicity

Six phases of subsidence have been defined for southern Wyoming (Figure 2):

1. Phase 1 (100-90.5 Ma) is dominated by flexural effects in the foredeep adjacent to the active Sevier thrust front and very low subsidence in the fore- to back-bulge position. This interval (~Frontier Formation) is reservoir-prone and is characterized by progradation of shallow-marine and coastal plain facies towards the east.
2. Phase 2 (90.5-82.5 Ma) sees a regionally large increase in the subsidence rate, attributed to long-wavelength "dynamic" effects. Both Laramide and Sevier flexural effects are also noted. A profound transgression is evidenced by the deposition of seal- and source-prone mudstones in the lower Baxter/Niobrara formations. The upper portion is aggradational to very weakly progradational.

3. Phase 3 (82.5 Ma-80 Ma) has no Sevier flexural effects observed, but an increasing amount of basin differentiation, interpreted as related to nascent Laramide deformation. This interval is increasingly progradational from bottom to top.

4. Phase 4 (80-74 ma) is associated with the onset of significant Laramide deformation. Regional uplift in proximal areas and an overall decrease in subsidence rate in distal areas is interpreted as the driver of a "forced regression" (degradational stacking). Phase 4 is the period when the reservoir-prone fluvio-deltaic Ericson-Parkman/Teapot formations were deposited (Figure 3).

5. Phase 5 (74-66Ma) is characterized by an increase in subsidence, and a marked transgression culminating in the offshore Lewis shale. The lower Lewis is a seal and source rock. Subsidence is largely related to Laramide flexural effects. With moderation of rates, progradational basin fill dominates in the upper Lewis to Lance formations.

6. Phase 6 (66-62 Ma) sees widespread uplift and erosion on discrete uplifts and cessation of marine influence.

Moreover, the patterns of large-scale cyclicity changes along strike (Figure 4). As described above, the transect through the Green River to Powder River Basin shows a complicated large-scale stacking pattern with three complete 2nd-order cycles in the Upper Cretaceous, correlative to regional subsidence/uplift events. A transect through the Uinta to North Park Basin has only two cycles, with much less complexity in the Campanian-Maastrichtian stacking and subsidence. In the Uinta-Piceance-Park Basin area, the large-scale stacking is more subtle, with a change from weakly progradational to strongly progradational correlating with a modest decrease in subsidence rates. There appears to be a correlation between estimates of upper Campanian to Maastrichtian flexural rigidity (EET) and the different subsidence provinces. The Wyoming area has low EET extending farther to the west and more evidence of early Laramide uplifts and flexural effects. We speculate that this may have been related to differences along strike in the subducting Farallon Plate – perhaps the angle of subduction or the character of the downgoing plate. Much further work is needed to investigate this possibility.

Subsidence-driven large-scale cyclicity controls exploration play elements, especially reservoir-seal couplets. Along-strike variability in regional subsidence is important in controlling the petroleum system play elements of source, seal, and reservoir. It also indicates variation in lithospheric architecture/processes. Drivers may include variations in the angle and nature of the subducting plate.

The partitioning of the antecedent foreland by Laramide deformation in the late Campanian to Maastrichtian influenced deposition in profound ways. A complex, source-to-sink view of the depositional systems is necessary to understand the relative contributions of regional versus local controls (Figure 5).

References Cited

Aschoff, J.L., and R.J. Steel, 2011a, Anatomy and development of a low-accommodation clastic wedge, Upper Cretaceous, Cordilleran foreland basin, USA: Sedimentary Geology, v. 236/1-2, p. 1-24.

Aschoff, J., and R.J. Steel, 2011b, Anomalous clastic wedge development during the Sevier-Laramide transition, North American Cordilleran foreland basin, USA: GSA Bulletin, v. 123/9-10, p. 1822-1835.

DeCelles, P.G., 1994, Late Cretaceous–Paleocene synorogenic sedimentation and kinematic history of the Sevier thrust belt, northeast Utah and southwest Wyoming: GSA Bulletin, v. 106, p. 32-56.

Haq, B.U., J. Hardenbol, and P.R. Vail, 1987 Chronology of fluctuating sea levels since the Triassic: Science, v. 235/4793, p. 1156-1167.

Hansen, J., M. Sato, G. Russell, and P. Kharecha, 2013 Climate sensitivity, sea level and atmospheric carbon dioxide: Philosophical Transactions of the Royal Society A, v. 371/2001, 31p. Website accessed September 3, 2018, http://dx.doi.org/10.1098/rsta.2012.0294.

Kirschbaum, M.A., and R.D. Hettinger, 2004, Facies analysis and sequence stratigraphic framework of upper Campanian strata (Neslen and Mount Garfield Formations, Bluecastle Tongue of the Castlegate Sandstone, and Mancos Shale), eastern Book Cliffs, Colorado and Utah: USGS Digital Data Series DDS-69-G, 40p.

Rudolph, K.W., W.J. Devlin, and J.P. Crabaugh, 2015, Upper Cretaceous sequence stratigraphy of the Rock Springs Uplift, Wyoming: The Mountain Geologist, v. 52/3, p. 13-118.

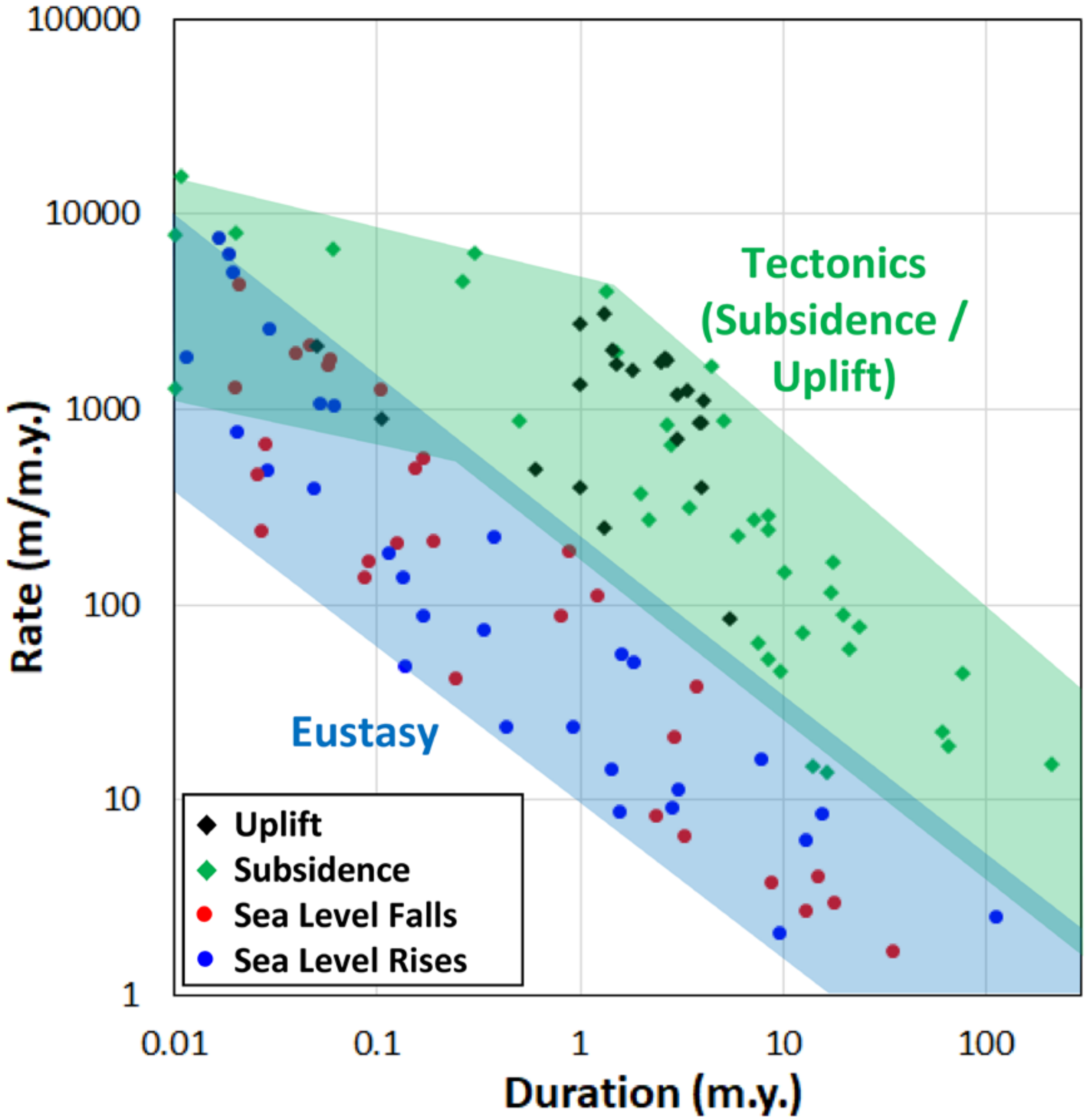

Figure 1. Log-log graph of accommodation rates versus the duration of those changes. Sea level rises and falls are derived primarily from the isotopically-based Neogene curve of Hansen et al. (2013), augmented by the Cenozoic-Mesozoic sea level curve of Haq et al. (1987). The uplift and subsidence estimates are both original work and derived from a wide variety of published sources. The original work includes the North Sea, West Siberia Basin, East Natuna Basin, Western Interior, U.S.A., North Slope, Alaska, and Malay Basin.

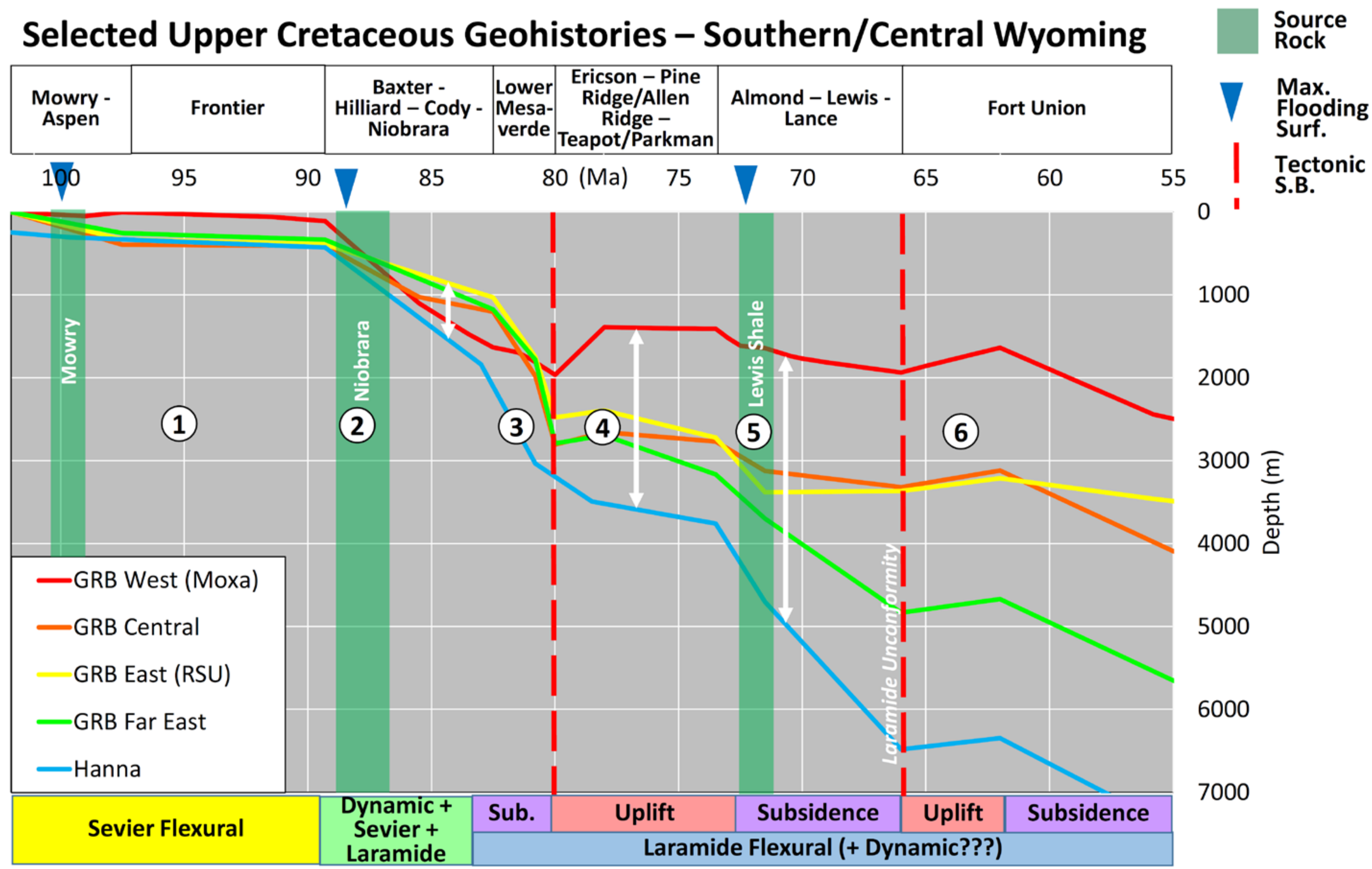

Figure 2. Selected geohistories from south and central Wyoming. See text for discussion.

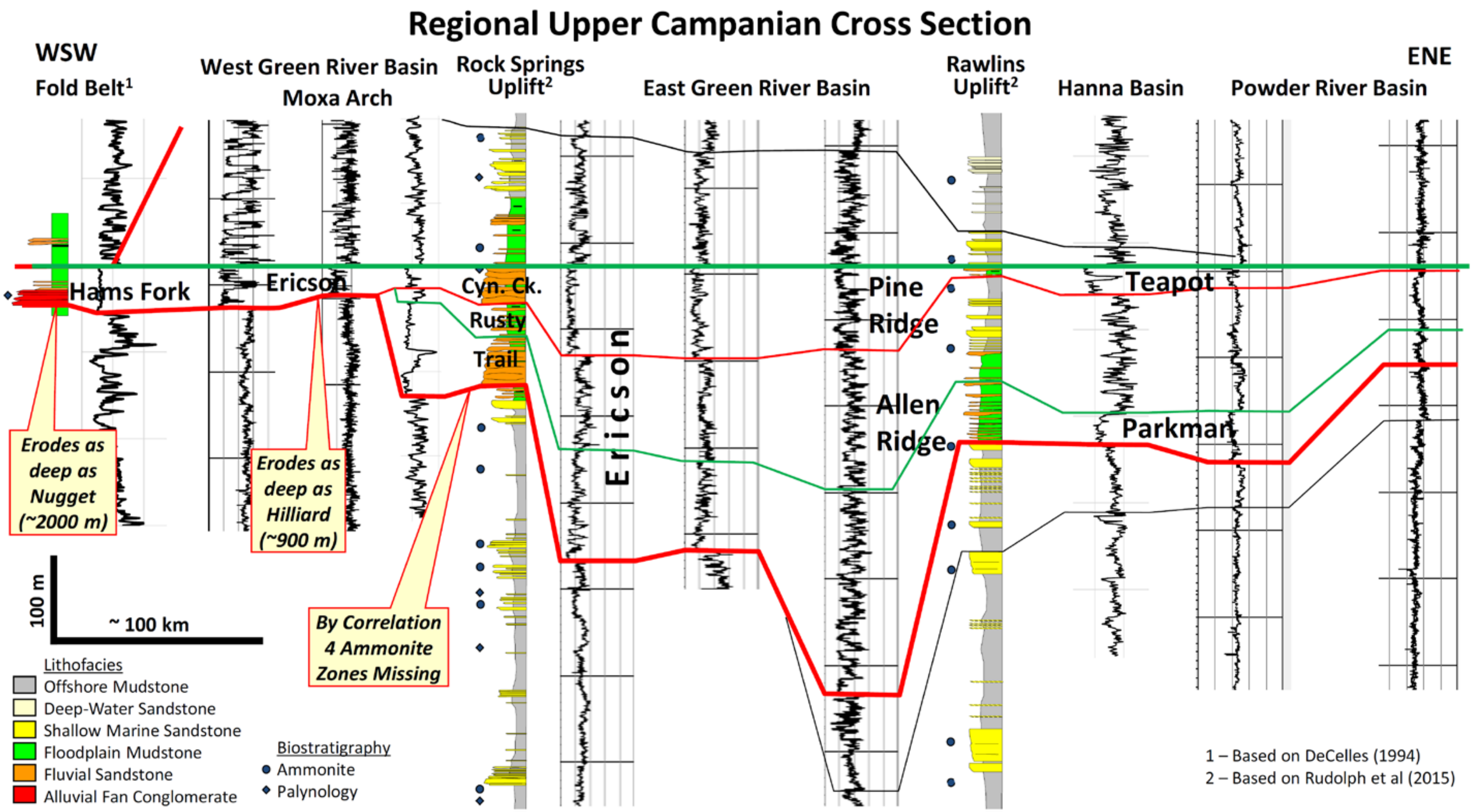

Figure 3. Regional upper Campanian stratigraphic cross section (datum: top Ericson/Teapot abandonment or transgressive surface).

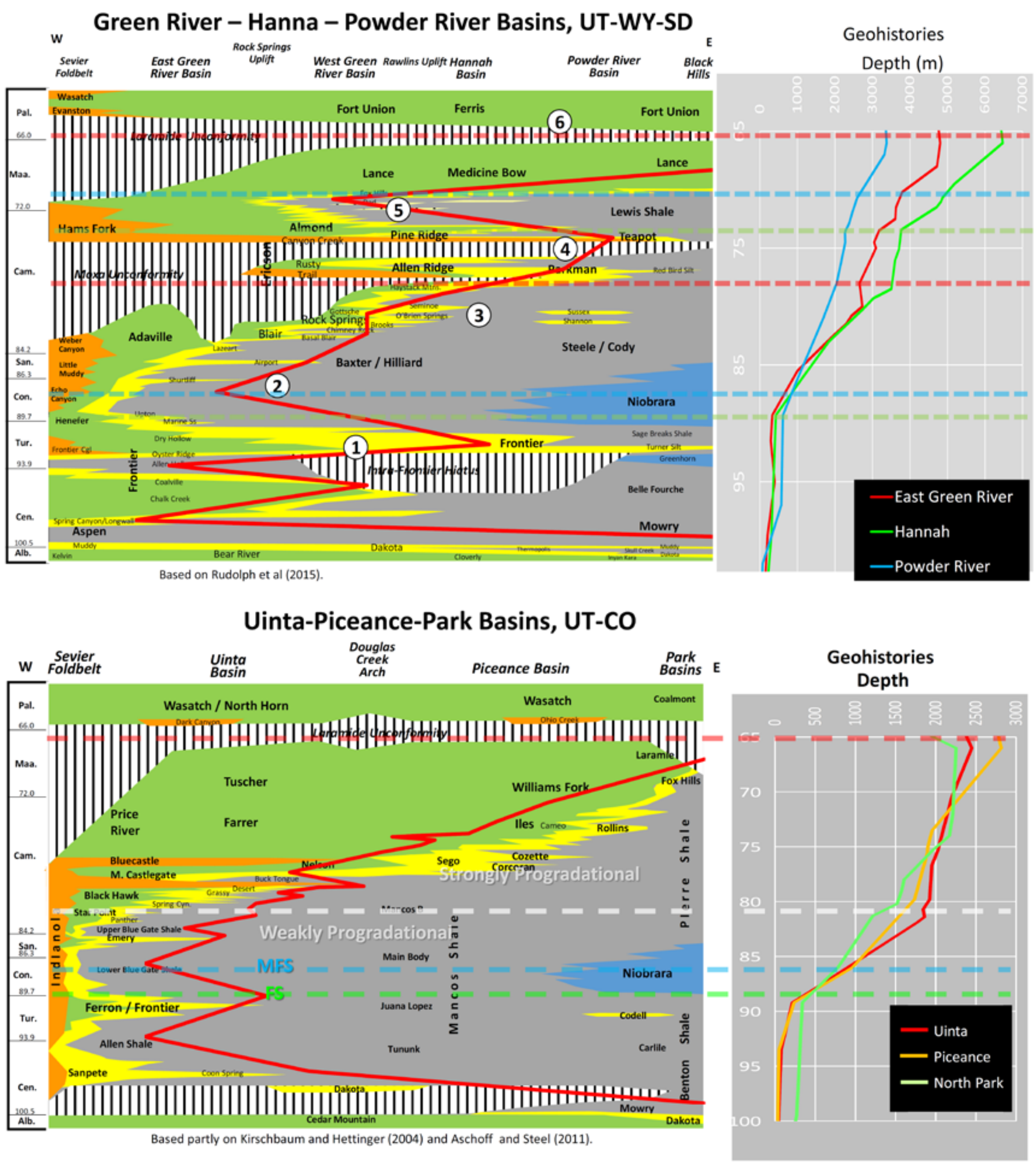

Figure 4. Chronostratigraphic charts for the Green River-Hanna-Powder River basins (top) and Uinta- Piceance-Park basins (bottom) with annotated shoreline trajectories and representative geohistories (at right). See text for further description.

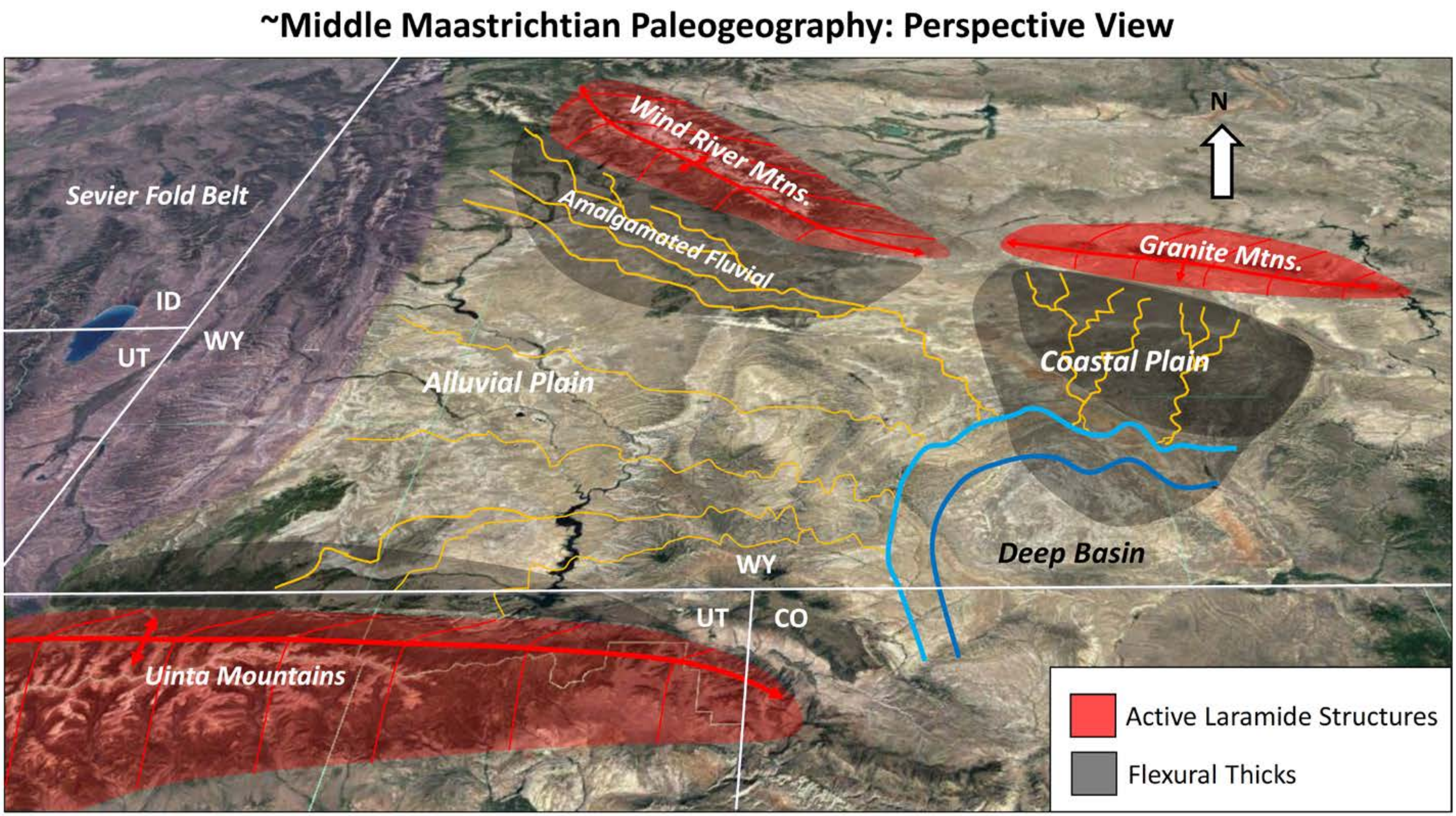

Figure 5. Schematic perspective view of middle Maastrichtian paleogeography of southwest Wyoming. Laramide uplifts and associated flexural sub-basins influenced environments via sediment supply and accommodation.