Nearshore along-strike variability: Is the concept of the systems tract unhinged?

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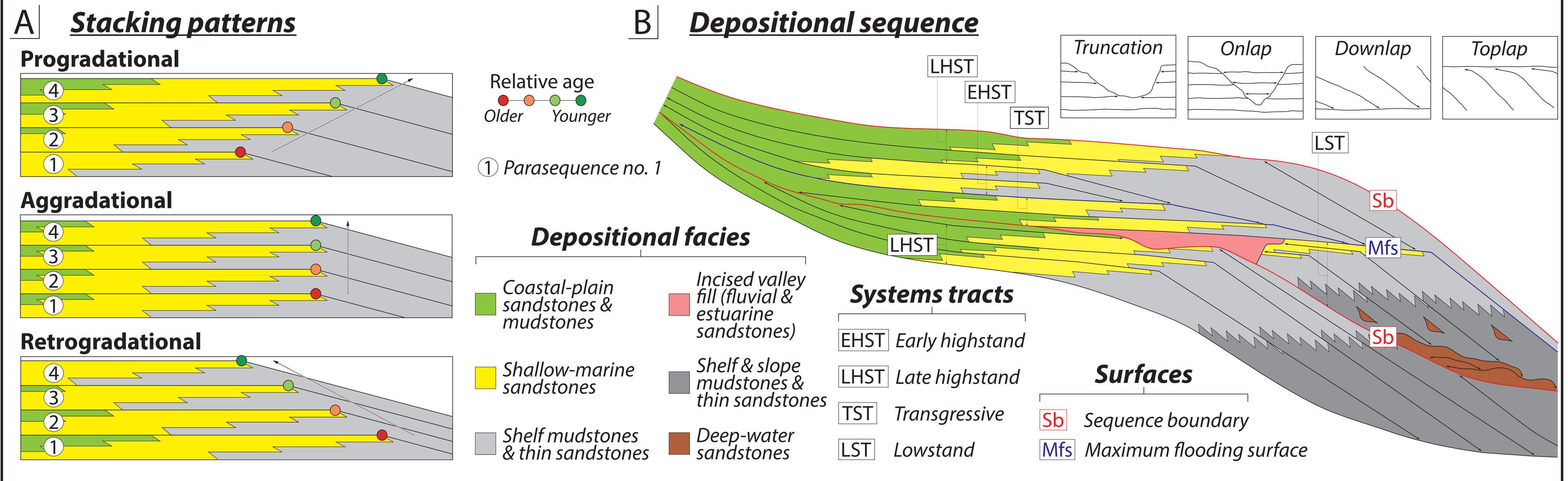
1. Abstract

Sequence stratigraphic models assume that nearshore strata have relatively consistent and laterally persistent stacking at the systems tract scale and therefore may not fully describe the three-dimensional stratigraphic architecture in areas displaying marked nearshore along-strike variability. A stratigraphic model of nearshore deposits is presented that corrects for this assumption by explaining variations in along-strike stratal geometries in terms of a systematic change in the orientation of a shoreline trend or clinoform rollover, a scenario comparable to deflection around a hinge. The model defines hinge zones that are both fixed and moving with respect to time, and was created from outcrop, well-log, and seismic reflection data. Model end members predict contemporaneous progradational, aggradational, and retrogradational stacking bounded by surfaces displaying significant along-strike changes in architecture, implying that sequence stratigraphic surfaces can be diachronous. We advocate examining the impact of stratigraphic variations parallel to depositional strike by testing for the presence of uniform versus differential progradation, phenomena responsible for creating unhinged and hinged nearshore depositional systems, respectively. Understanding these differences will improve subsurface predictions and provide a more complete understanding of the stratigraphic evolution of sedimentary basins.

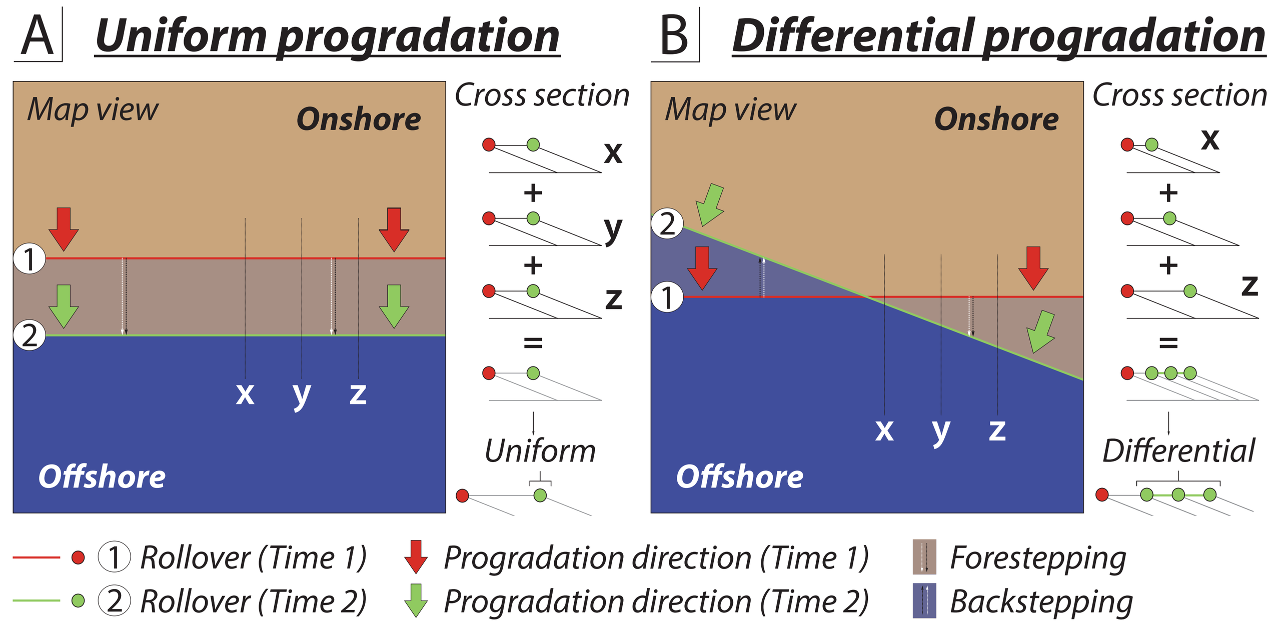
2. Stratal stacking patterns and the depositional sequence



A: Stacking patterns used to define systems tracts

B: Conventional interpretations imply consistent lateral stacking (i.e., no significant strike variability)

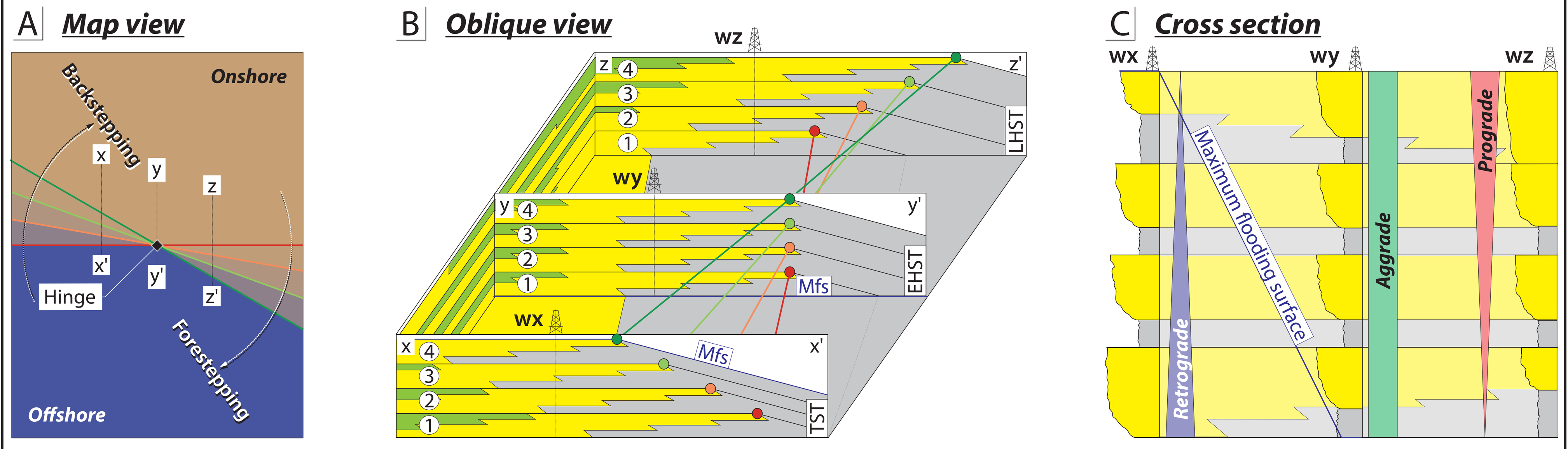
3. Conceptual depositional models



A: Uniform progradation results in equal and coincident rollover movement, as illustrated in cross-sections x, y, and z (on right). Where projected onto the same plane, uniform progradation manifests as a single point.

B: Nearshore lateral variability creates along-strike differences in rollover position. Superimposing rollover trends in cross-sections x, y, and z illustrates increased progradation away from the intersection of rollover 1 and 2 that defines a hinge to the left of line x.

4. Hinge Model

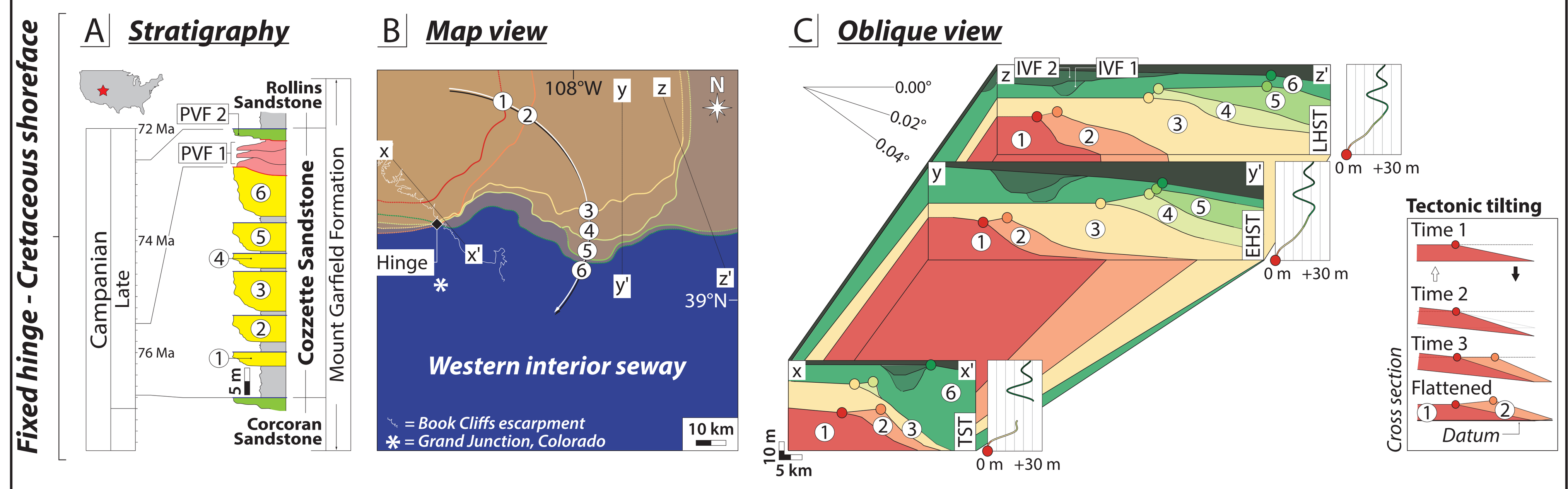


A: Map view illustrating how backstepping and forestepping result in clinoform retreat and advance, respectively.

B: Oblique view illustrating along-strike changes in stacking: retrogradational—transgressive systems tract (TST), aggradational—early highstand systems tract (EHST); and progradational—late highstand systems tract (LHST). Depositional facies include coastal plain (green), shallow marine (yellow), and shelf (gray). Mfs—maximum flooding surface.

C: Hypothetical well-log cross section (wx-wy-wz) highlighting strike-parallel changes in stacking. Lines drawn at the top of shallowmarine sandstone intervals represent physical stratigraphic surfaces, whereas lines at the bases delineate facies changes.

5. Fixed and moving hinges for the Cozzette Sandstone (Book Cliffs, Piceance Basin, Colorado, USA)

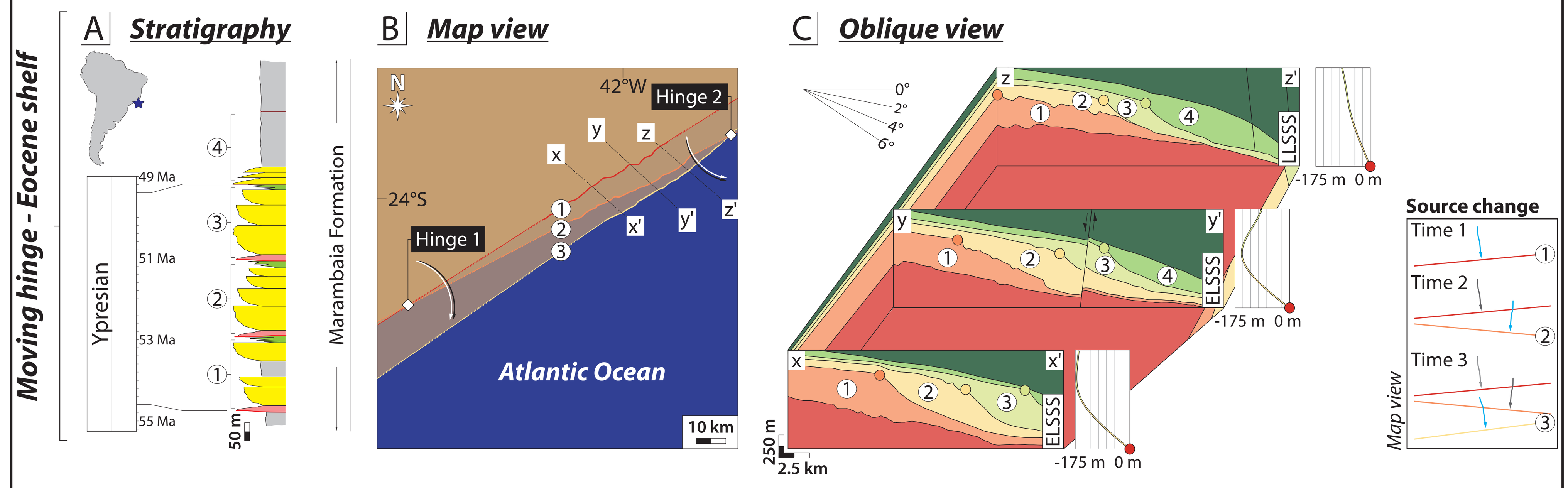


A: Generalized stratigraphic column and age control for parasequences 1–6 in the Cozzette Sandstone. Deposits include shallow-marine (yellow), paleovalley fill (PVF, pink), coastal plain (green), and marine (gray) facies. Red lines denote sequence boundaries and blue lines denote flooding surfaces. Cretaceous (Campanian) ages were defined using ammonites (*Didymoceras nebrascense, D. stevensoni*, and *Exiteloceras jenneyi*; see Madof et al., 2015).

B: Map view of rollover trends associated with the Cozzette parasequences illustrates locations of the projected hinge zones.

C: Spatial variations in stratigraphic architecture across cross-section panels x-x', y-y', and z-z'. Relative sea-level curve (right) was created by plotting rollover positions through time. The gap in x-x' is caused by stratigraphic pinch-out of parasequence 5 west of y-y'. Postdepositional tectonic tilting is depicted for the Cozzette (far right), highlighting back-tilted stratal geometries caused by flattening on the downlap surface. LHST—late highstand systems tract; EHST—highstand systems tract; TST—transgressive systems tract.

6. Moving hinge: Marambaia Formation (Santos Basin, Brazil)

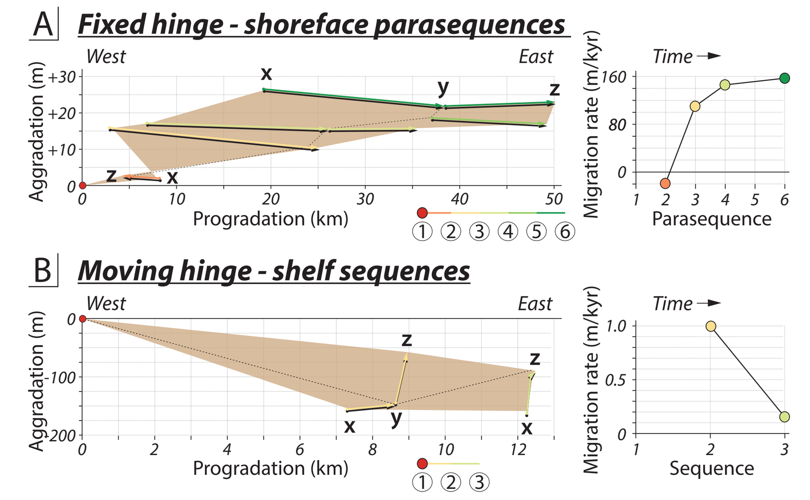


A: Generalized stratigraphic columns and age control for sequences 1–4 in the Marambaia Formation (see description of A). Eocene (Ypresian) ages were determined using planktonic foraminifers (*Morozovella acuta, M. aequa, and Acarinina pseudotopilensis*; Alicia Kahn, 2015, personal communication).

B: Map view of locations of the projected hinge zones, Marambaia sequence.

C: Architectural changes in the Marambaia Formation and differences in relative sea level resulted from changes in source area. Blue arrows depict the direction of active outbuilding for sequences 1–3. LLSSS—late lowstand sequence set; ELSSS—early lowstand sequence set.

7. Along-strike variations in rollover position

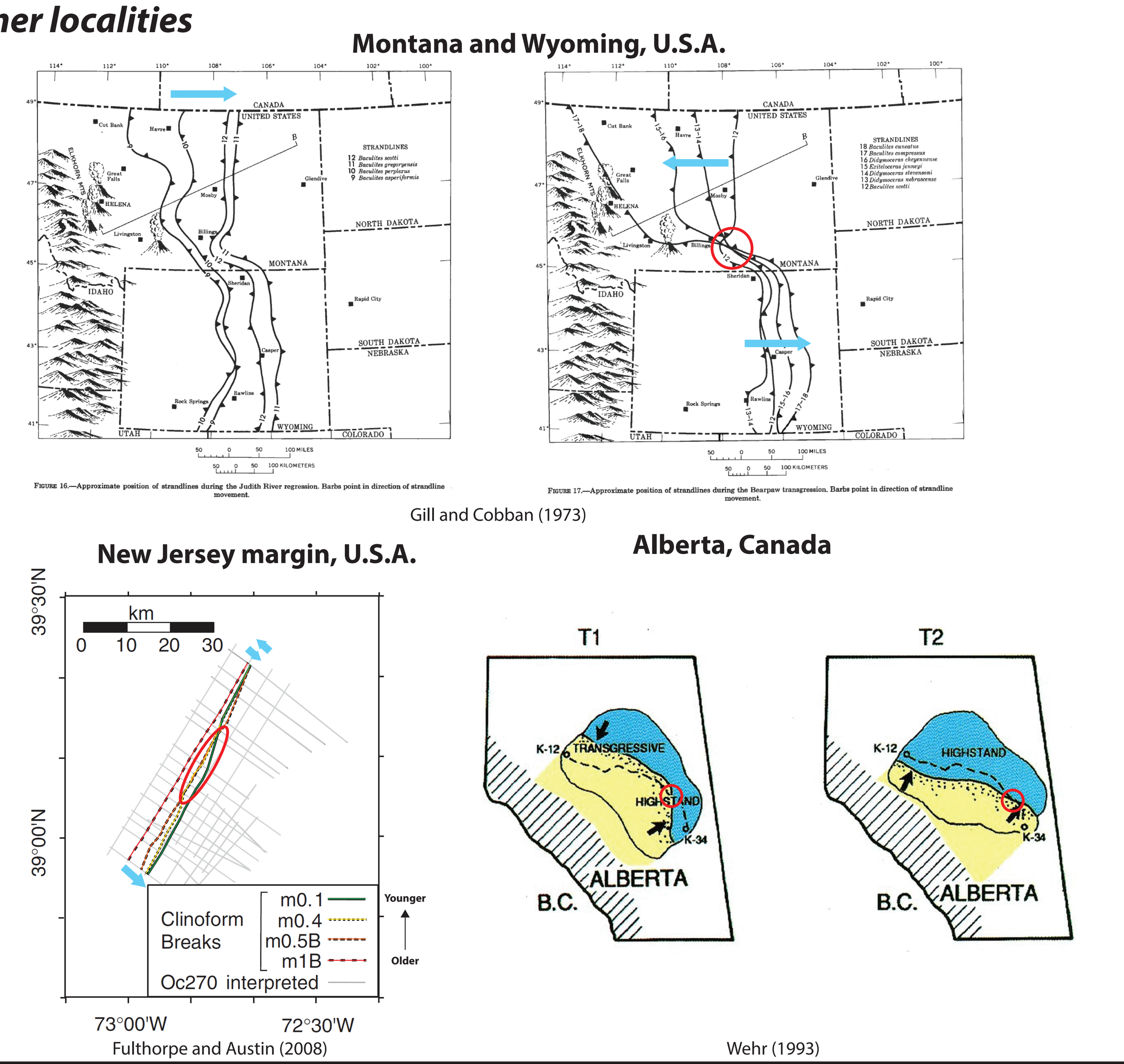


Plots are projected onto a single plane and illustrate progradation distance versus aggradation thickness. Arrows denote vectors projected from x, y, and z, and show intraparasequence and sequence variability. The shaded area highlights the magnitude of progradation and aggradation between adjacent parasequences and sequences. Arrows (left) are used to calculate migration rates (right), based on average cycle length (i.e., duration/cycles).

A: Differential progradation in the fixed hinge parasequences of the Cozzette Sandstone shows an increase in along-strike variability.

B: The moving hinge sequences of the Marambaia Formation show a decrease in progradation magnitude with time.

8. Observations from other localities



9. Conclusions

Stratigraphic hinge models provide simple geometric tests of uniform or spatially variable sedimentation in nearshore systems:

- **Fixed hinge:** roughly stationary area defined by convergence of shoreline or rollover trends.
- **Moving hinge:** two or more hinges that are spatially separated or move through time.

Hinge zones can predict stacking patterns through interpolation of shoreline or rollover trends between or beyond data points.

Always be vigilant of the "3D menace" (or opportunity) in interpretation!

10. References

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