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Evaluating Source to Sink Controls on the Permian Record of Deep-Water Sedimentation in the Delaware Basin, West Texas, USA*

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Search and Discovery Article #50247 (2010)
Posted February 26, 2010

*Adapted from 2008-2009 AAPG Distinguished Lecture.

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Abstract

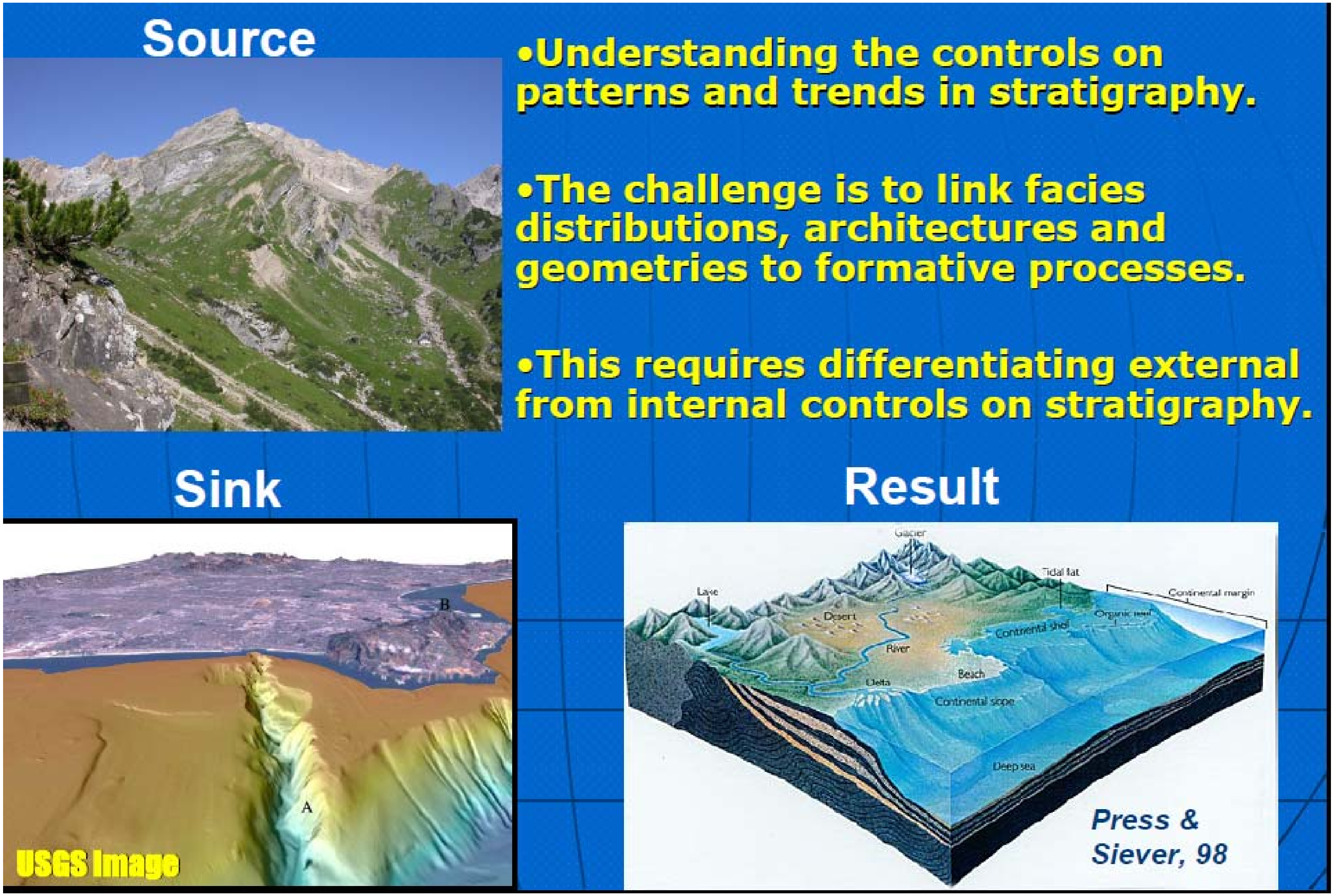
Linking basin-restricted subaqueous flows to external controls governing their initiation is difficult. Even though the influence of these controls (tectonics, eustasy, and climate) is best resolved in the basinal strata, internal controls (i.e., gradient, substrate mobility, topography and flow run-out length) can have a more profound effect on deep-water sedimentation style and resulting patterns. Source-to-sink correlations relating tectonic, eustatic and climatic forcing to deep-water facies, lithology, sedimentary bodies, and stratigraphic cycles were analyzed from 488 sedimentological profiles and detailed (20-m thick) mapping of continuous shelf-to-basin outcrops (255-km^2 area) correlated (355 well logs and 3300 km of 2D seismic) across the 33,500-km^2 Delaware Basin.

The record of external forcing, resolved in basinal strata, is obscure outside of the basin, and is only confidently isolated from internal controls through complete basin analysis. Tectonic movements controlled the staggered onset of deep-water clastic sedimentation from at least seven shelf feeders encircling the Delaware basin. Basin-restricted siltstone intervals correlated throughout the basin help define a threefold hierarchy of stratigraphic cycles within the Brushy Canyon lowstand systems tract (LST) of one 3rd-order composite sequence (1-2 my.). Although along-strike variations in sediment supply change the thickness, lithology and architecture of these basinal cycles, stratigraphic changes in multiple criteria permit regional correlation that reflects basin-scale sea-level change. Repetitive, multi-scale and organized clustering of varve-like laminations, present in carbonate, evaporite and clastic strata, reflect precipitation-modulated climate.

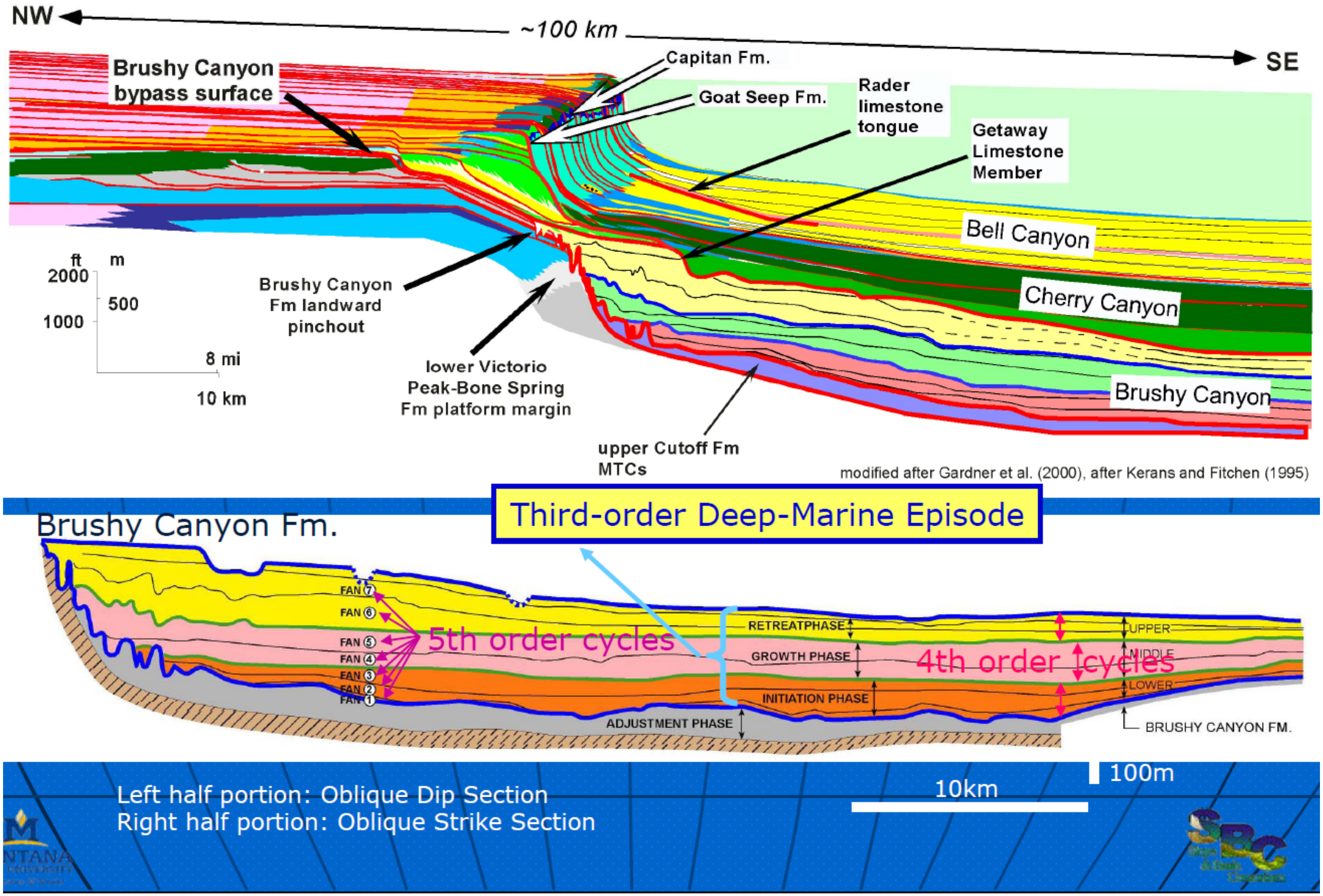
Stratigraphic changes in multiple criteria correlated throughout the basin suggest an evolution in sedimentation attributed to changes in relative sea level, which can be correlated across the Delaware basin. Younger carbonate MTDs of the Cherry Canyon Formation incise the

Brushy Canyon LST top and resemble those at its base; both of which record mass failure during highstand outbuilding of carbonate ramps. Siltstone, resembling the basal drape, also is found at the LST top. Condensed sedimentation, recorded by the basal siltstone drape, most likely correlates to continual sea-level fall separating highstand and lowstand deposition, whereas the younger siltstone records the end of gradual sea-level rise and represents a downlap surface for the overlying Cherry Canyon LST. This is indicated by strata in the upper 100m of the Brushy Canyon LST showing an upward increase in shelf-derived carbonate allochems (>50%), a decrease in sand percent (<40%), and an increase in the thickness and organic richness of siltstones (>300%). This latter attribute suggests a decreased frequency of sandy subaqueous flow deposition. Furthermore, stratigraphically equivalent strata derived from the same shelf feeder system yet source-distant, show a doubling in silty sandstone and feldspar content that records hydraulic fractionation of grain size and mineralogy within these subaqueous flows. In this case, longitudinal fractionation was enhanced by more complete flow transformation enabled by transport along smoothed depositional profiles during late LST. Both slope expansion and back-stepping of aggradational upper-slope channels record decreased system efficiency, while more elongate basin-floor thicks in this upper part reflect the decreased sediment volume. These depositional patterns record a gradual sea-level rise and suggest that its onset commences within the LST. Organic-rich sand-poor basinal facies bracketing this LST could have been deposited during either sea level rise or fall because they simply record sediment starvation; this is only indirectly related to an extrinsic control.

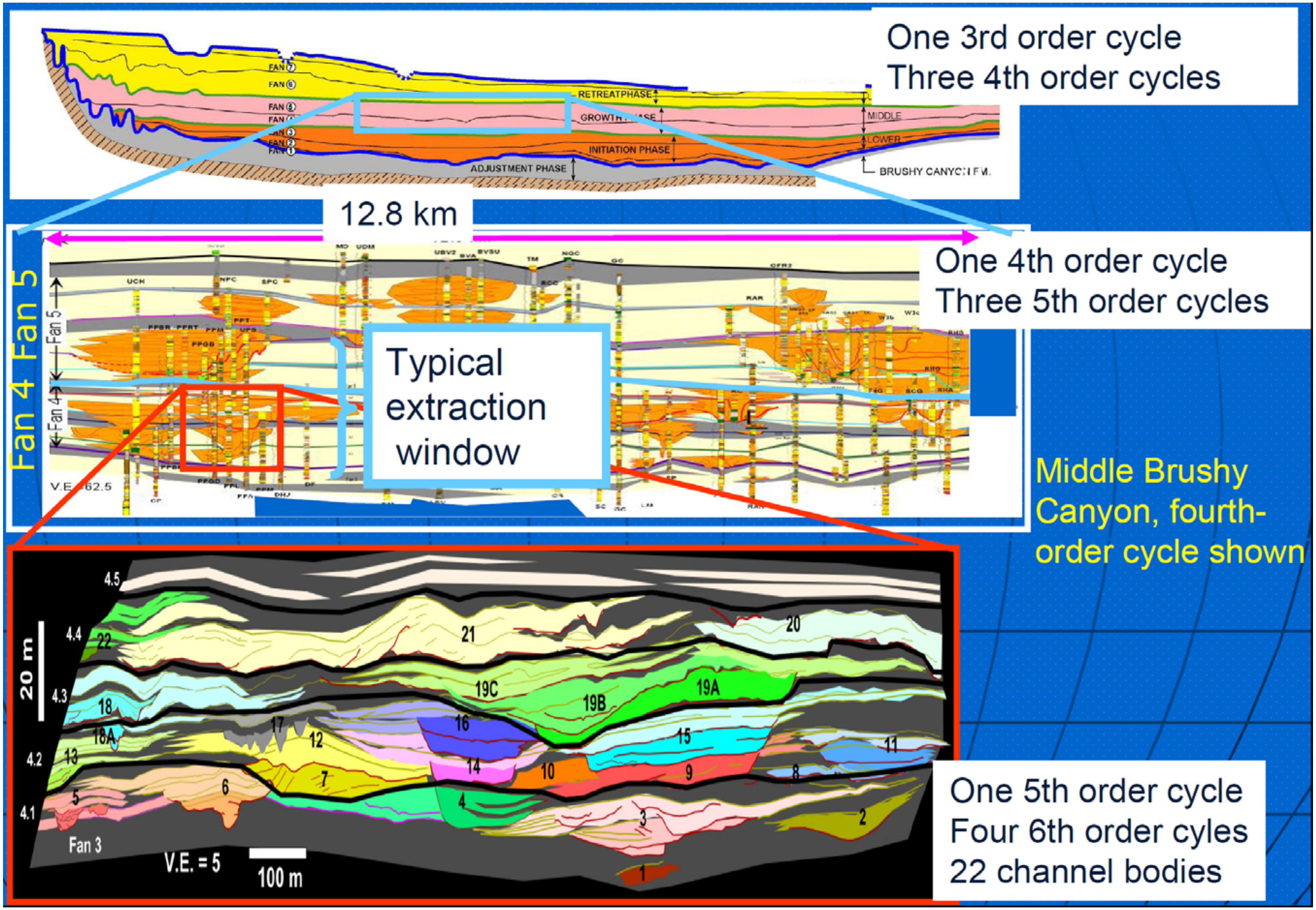
As the ultimate sediment sink with a fragmented shelf record, these external controls are best resolved from the basinal record, but internal changes in gradient, substrate mobility, topography, and run-out length, have a greater impact on subaqueous flow behavior, which requires complete characterization of the basin to differentiate from external signatures.



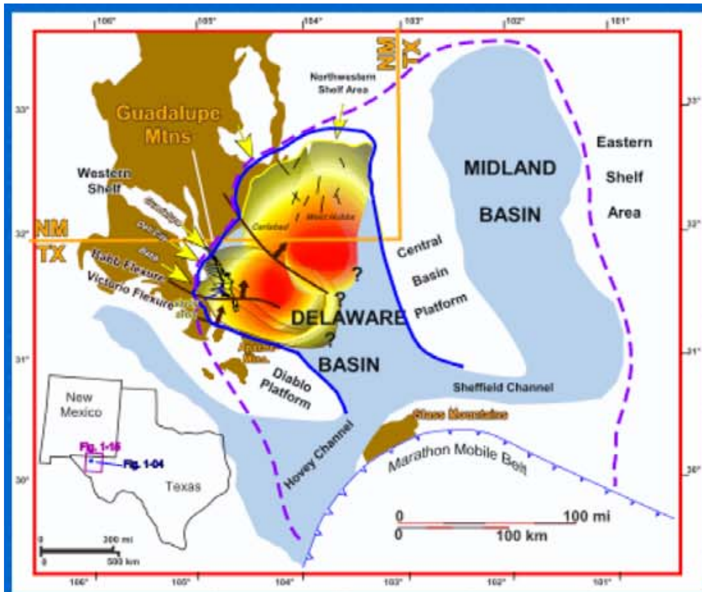
The “Holy Grail” of stratigraphy: Source, sink, and result.

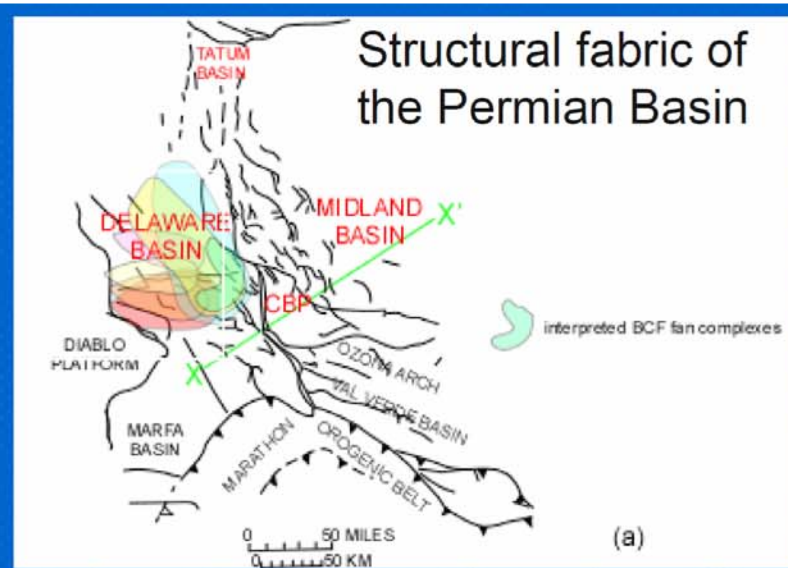


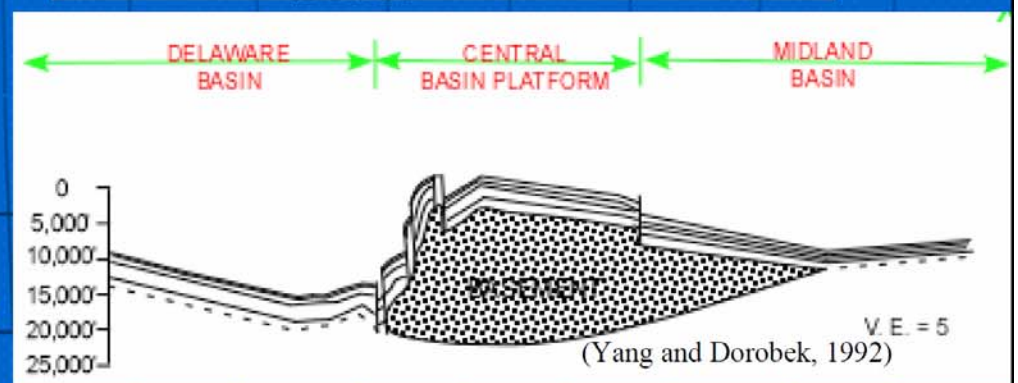
Stratigraphic framework: Second- and third-order stratigraphic cycles.



Stratigraphic framework: Hierarchy of stratigraphic cycles.







Differential subsidence in foreland sub-basins determined:

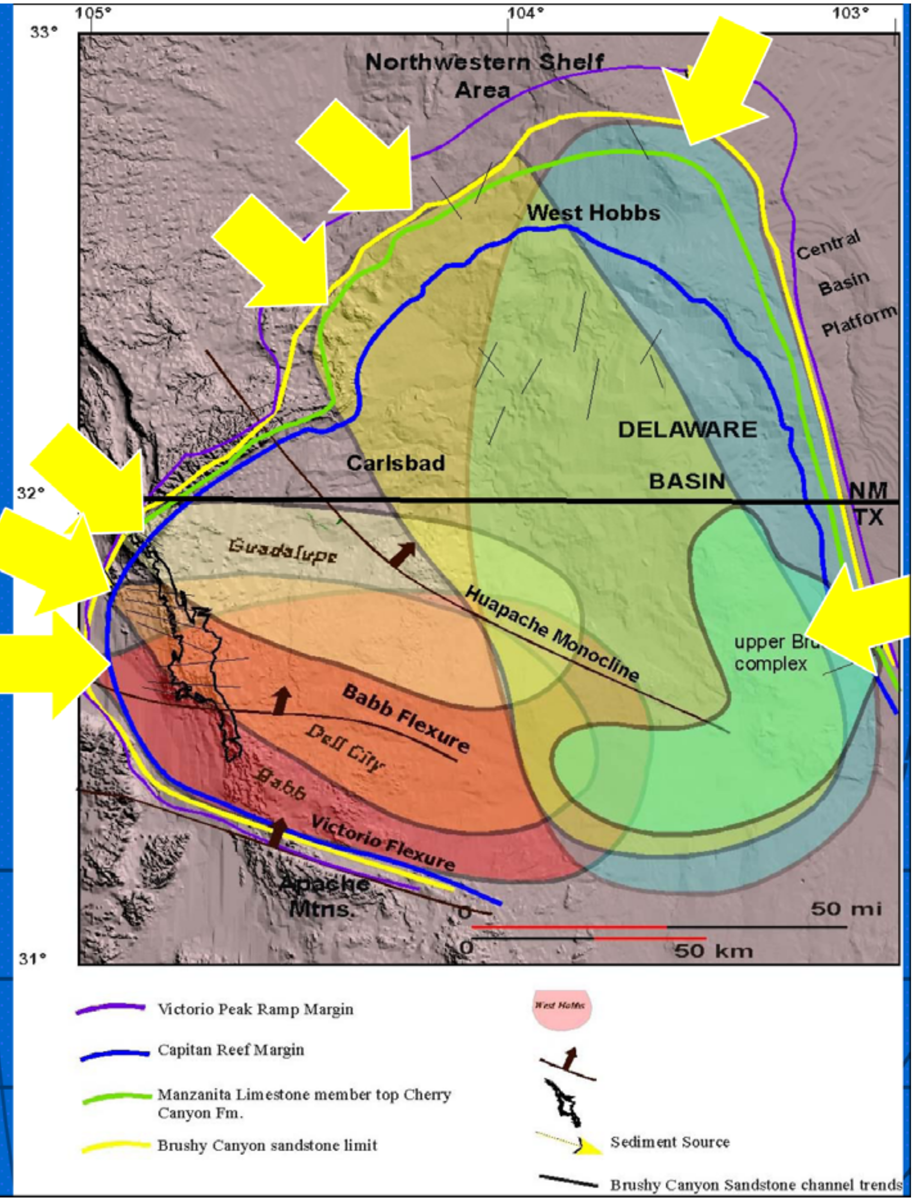
- **basin depocenters**
- **delivery of coarse sediment fraction**

Timing of deposition from seven different shelf sediment sources

Generalized tectonic map and structural cross section across Delaware and Midland basins.

Clockwise Shift in Deep-Marine Depocenters in Delaware Basin

- 250 km long and 180 km wide area encompassing approximately 33,500 km²
- Colored lines outline multiple carbonate platform margins with the youngest Capitan Reef Complex forming a narrow belt that extends for 600 to 700 km around the basin
- Tectonically driven changes in the onset of deep-marine sedimentation in basin related to eastward diminution of subsidence linked to flat-slab subduction.



Clockwise shift in deep-marine depocenters in Delaware Basin.

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