Requiem for a Seaway: Tracking the Final Transgression of the Western Interior Sea in the Post-Apocalyptic World of the Paleocene*

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Abstract

Tremendous clastic influx to Laramide basins of the Western Interior during the latest Cretaceous-Paleocene (~70-58 Ma) coincided with a series of climatic, tectonic, extraterrestrial, and biological perturbations. The result is a complex record of extinction, radiation, shoreline migration, basin-filling, and rapid changes in local and regional depositional environments. Ammonites and inoceramids are the quintessential fossils of the Western Interior Sea (WIS), so their extinction at the K-PG boundary presents a paradox when interpreting fine-grained, Paleocene strata. Specifically, absence of marine body fossils from Paleocene strata has been cited as proof of continental origin. Abundant lignite, coal, plant fossils, and freshwater body fossils are consistent with this interpretation. Sedimentary structures common in tidally-influenced fluvial channels were recognized in the early Paleocene (~66-65 Ma) Ferris Formation (FF) in the mid-1990's. Large lakes can experience wind tides, so mechanical tidal processes do not necessitate connection to a marine basin. In the late 1990's to early 2000's, discovery of unambiguously marine ichnofossil assemblages in the western Hanna Basin's (HB) FF challenged the paradigm and necessitated major revision of local and regional reconstructions of the Paleocene WIS. Preserved within sandy estuarine bars and silty deltaic deposits similar the modern Trinity River and bayhead delta on the Texas coast, these assemblages include *Bergaueria*, *Rhizocorallium*, *Rosselia*, *Arenicolites*, *Palaeophycus*, *Thalassinoides*, *Ophiomorpha*, *Skolithos*, *Psilonichnus*, *Planolites*, and *Siphonichnus*. Mapping a ~325 m thick succession of early Paleocene strata (~65-63.5 Ma) around the western HB reveals a series of marine flooding events followed by coal accumulation. A similar succession of interfingering coals and marine strata occurs in the later Paleocene (~59-58 Ma) Hanna Formation, demonstrating that leaves and other freshwater fossils represent transported material into restricted, marine bays in at least some successions. Ichnofossils provide key insights into shoreline migration, sediment-

routing to the Gulf Coast Wilcox sands, and the final Paleocene transgression of the WIS that has for so long remained obscured by the absence of open marine body fossils.

Selected References

Slattery, J., W. Cobban, K. Mckinney, P. Harries, and A. Sandness, 2013, Early Cretaceous to Paleocene Paleogeography of the Western Interior Seaway: The Interaction of Eustacy and Tectonism: Wyoming Geological Association 68th Annual Field Conference, Ed. Marron Bingle-Davis, Casper, WY, Volume: 68, DOI: 10.13140/RG.2.1.4439.8801.

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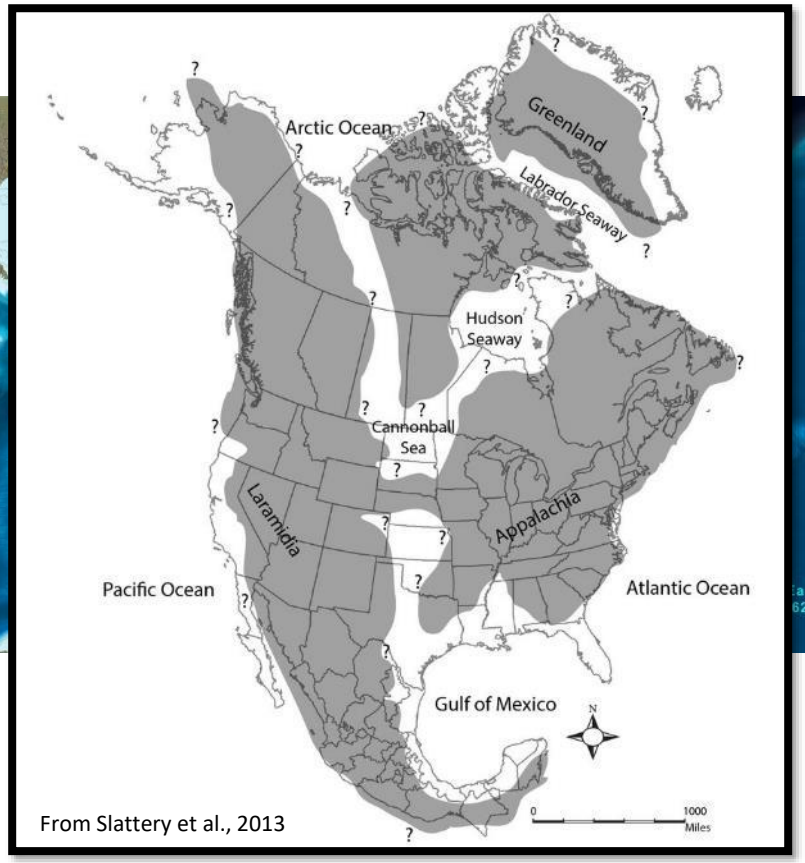
- George Pemberton for identifying the first *Bergaueria* from the Hanna Basin.
- Glenn Sharman and Pete Flaig for reigniting my interest in the Paleocene-Eocene transition of southern Wyoming.
- My wife Bonnie for putting up with my insane travel schedule and never-ending obsession with burrows, rocks, and fieldwork.

The Paradigm

Retreat of the epicontinental sea was a response to eustatic sea level and was largely complete by the end of the Cretaceous... *but is this consistent with the data*?

75 Ma



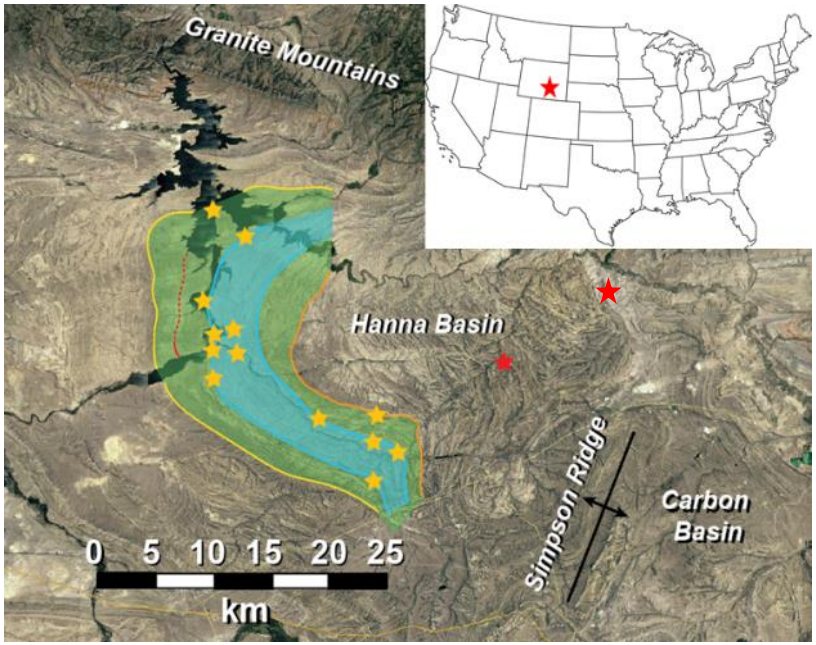
From Slattery et al., 2013

62-57 Ma

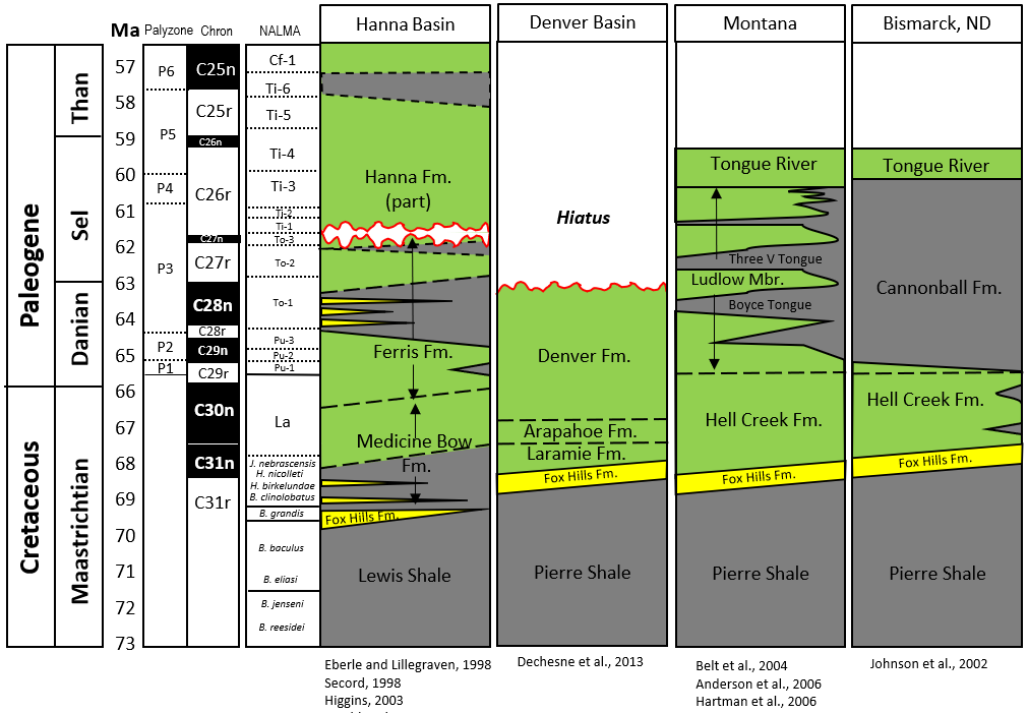
Maps from Blakey, 2012-2014

Location and Age

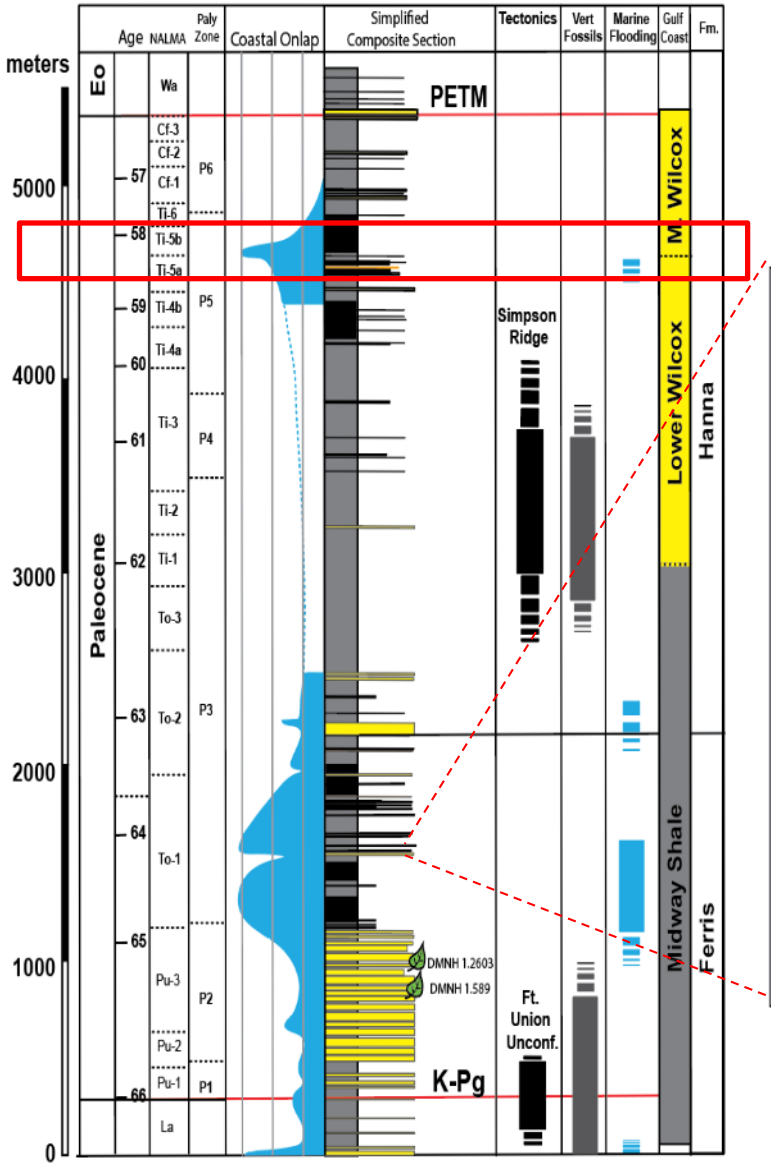
- Ferris and Hanna fms. span the latest Cretaceous through early Eocene (~67-54 Ma).
- Occupy the Hanna and Carbon basins in south-central Wyoming.
- Paleontological studies and economic importance of coal lead to excellent biostratigraphic control.
- Ongoing work on the K-Pg and P-E transitions by a variety of researchers.



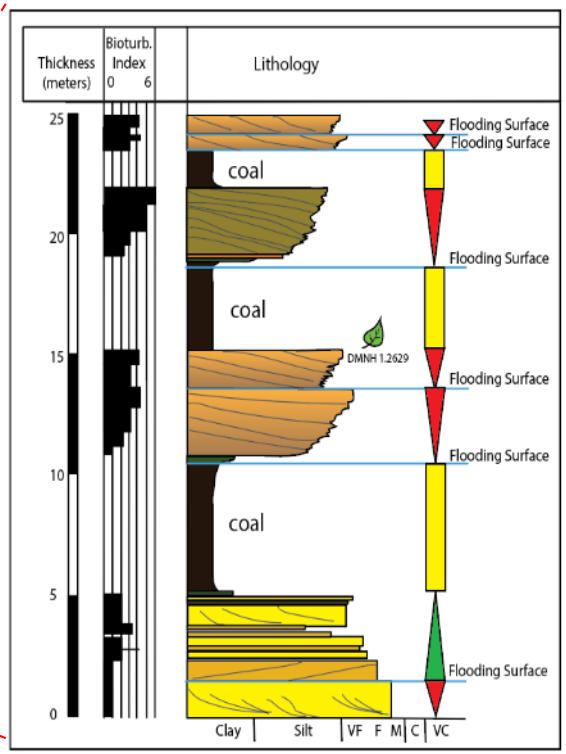
- Stars denote locations where marine ichnofossils have been documented.
- Ferris Fm. outcrop belt is highlighted.
- Hanna Fm. indicated by red stars.

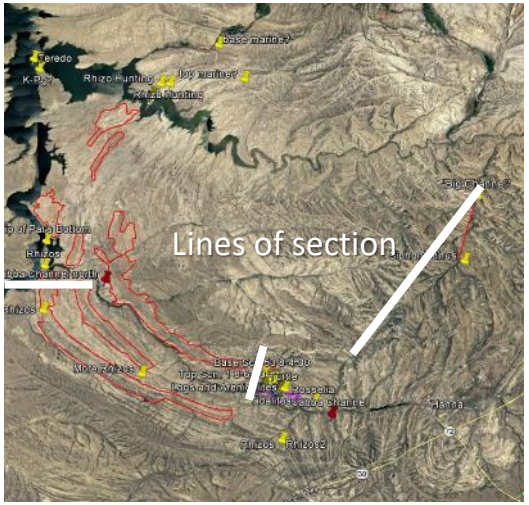


Paleocene Stratigraphy



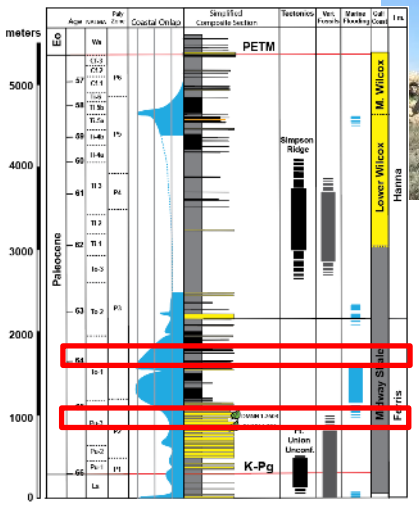
- Abundant, mineable coal and channel-form sandstone bodies lead to interpretation as completely continental units.
- Ichnofossils and detailed analysis of sedimentology reveals complex interaction of marine and nonmarine deposition.



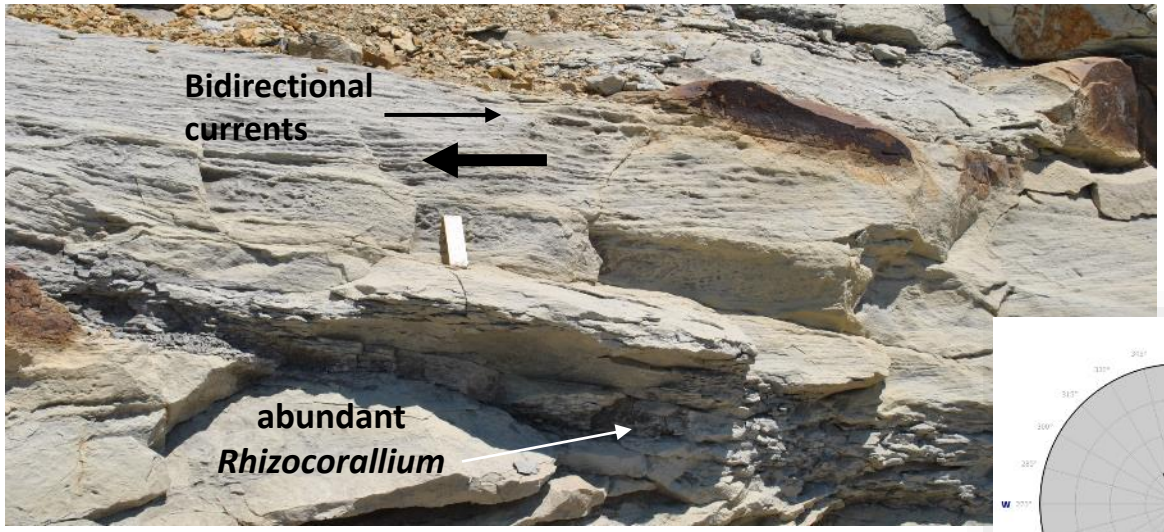


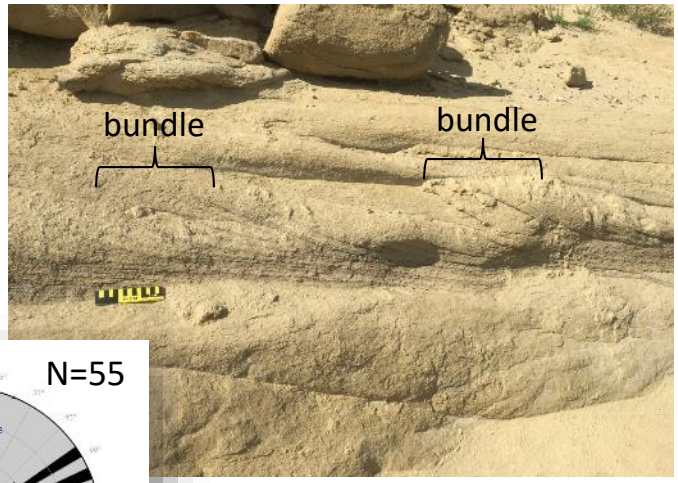
Sandy Bars in Channels: Fluvial by Default?

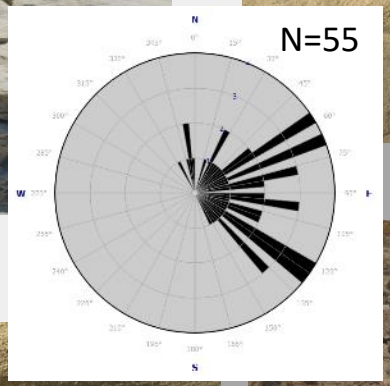
- Previous studies focused on presence of sandy bedforms and overall geometry.
- By mid-1990's, sedimentology and ichnology indicated presence of marine influence.
  - Tidalites
  - Marine ichnofossils and Selachian teeth
- Abundant marine traces in the surrounding mudstone and siltstone.



Tidal Indicators in Sandy Bars



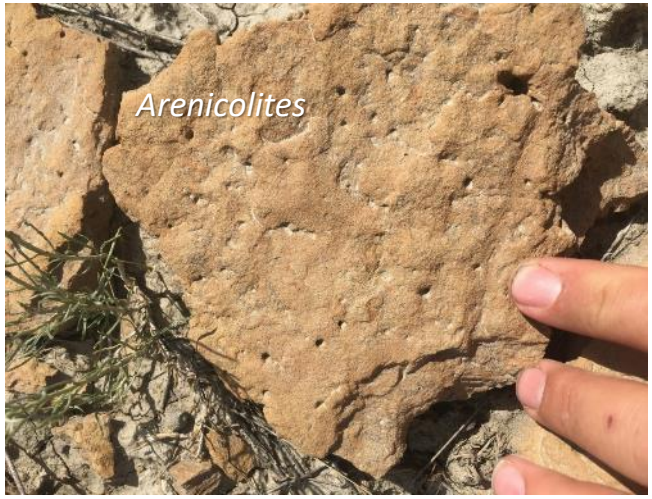




- First recognized in the late 1990's but weren't enough to shake the paradigm.
- Include double mud drapes, bundled, organic-draped foresets, reverse bedding, and abundant reactivation surfaces.
- Dominant flow is to the east, with NE and SE components.

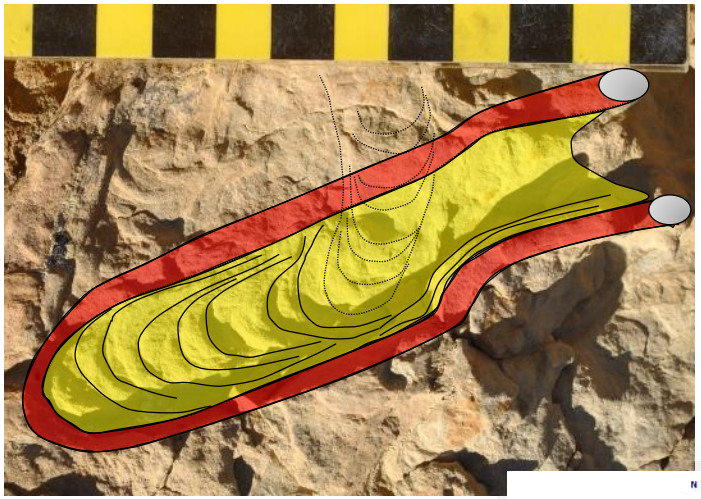
Marine Ichnofossils in Paleocene “Nonmarine” Strata

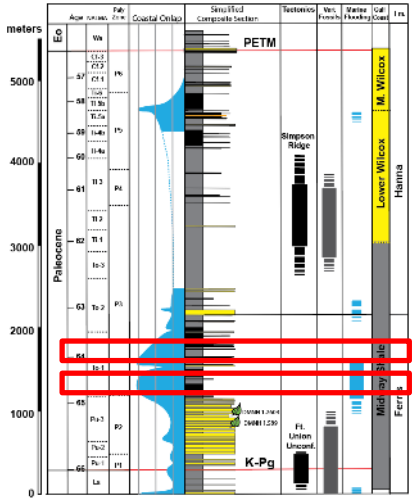
- Moderate diversity of marine ichnotaxa typical of bays, deltas, and estuaries.
- Present in channels, delta fronts, mouth bars, tidal flats and bayfill deposits.
- ***Reveal major Paleocene transgressions.***

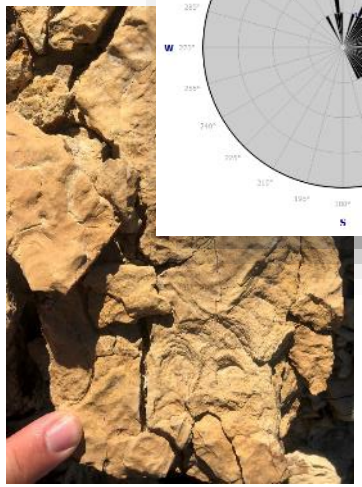


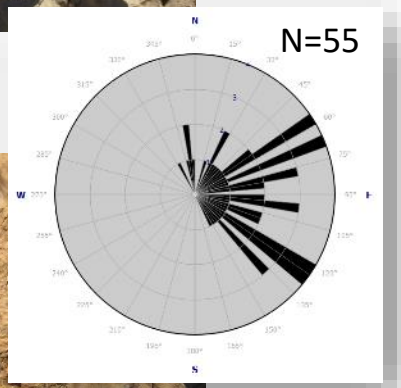
Ichnofossils as Physicochemical Proxies

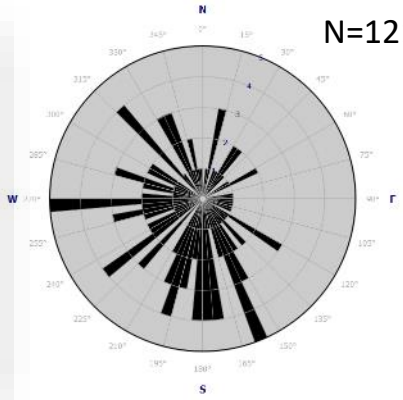
- *Rhizocorallium* is the most abundant and spectacularly preserved in the Ferris Fm.
- *Rhizocorallium commune* var. *irregulare* is the dominant ichnospecies.
- Restricted to ***shallow marine environments*** (Cruziana ichnofacies).







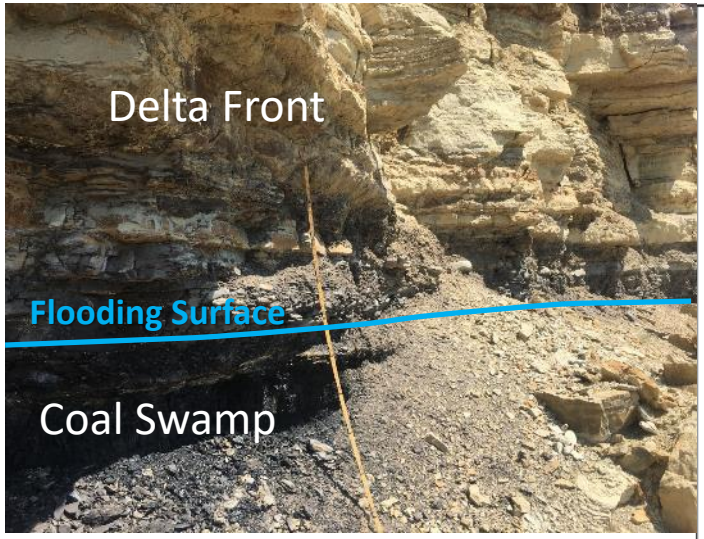


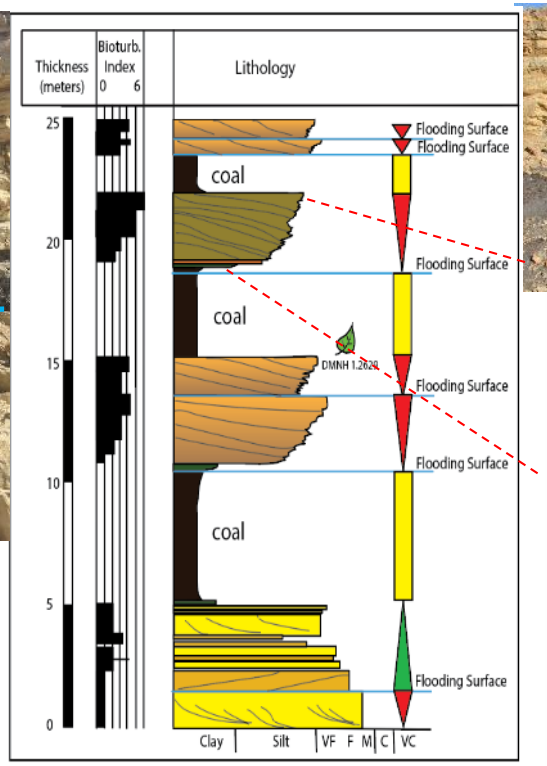


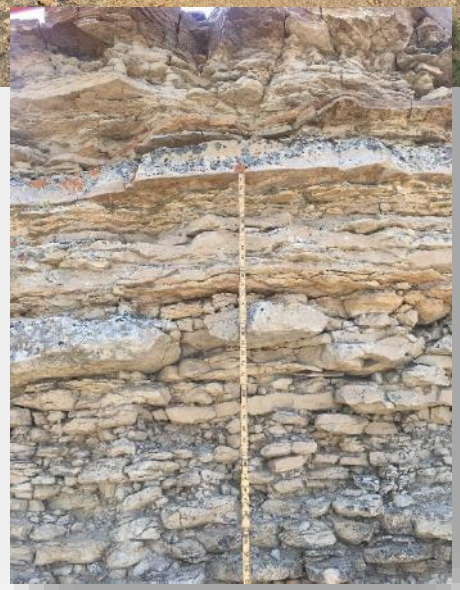
- Testing the hypothesis that *Rhizocorallium* preferentially orients with the apex of the spreite directed landward.

Early Torrejonian (ca. 64-63 Ma) Bayhead Deltas

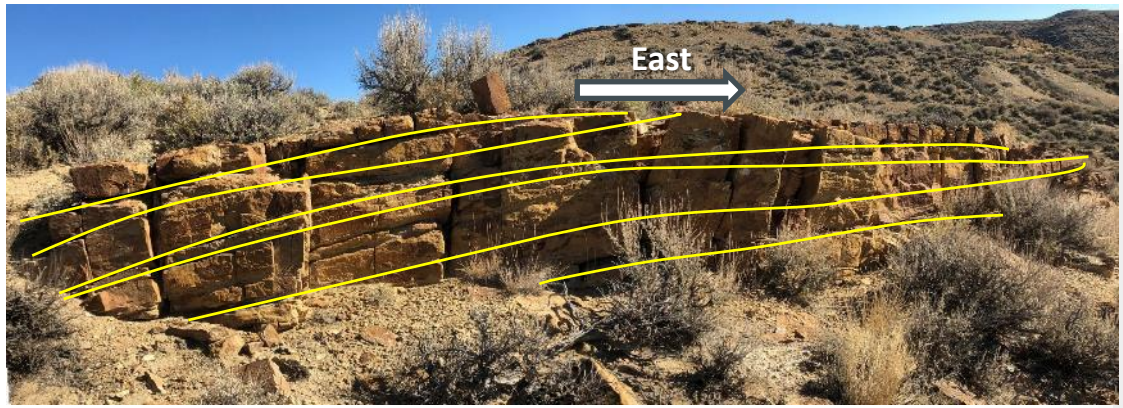
- Very fine-grained sand and silt between coal and carbonaceous shale beds 2-3 m thick, individual lobes ~1.5 km wide.
- Abandonment surfaces are completely churned by *Rhizocorallium*.
- Accessory traces include *Arenicolites*, *Skolithos*, *Bergaueria*, *Ophiomorpha*, *Siphonichnus*, *Palaeophycus*, and *Rosselia*.

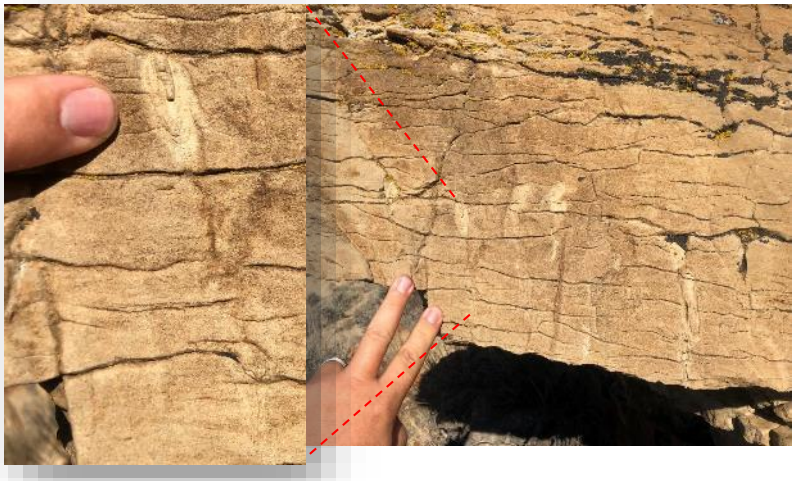


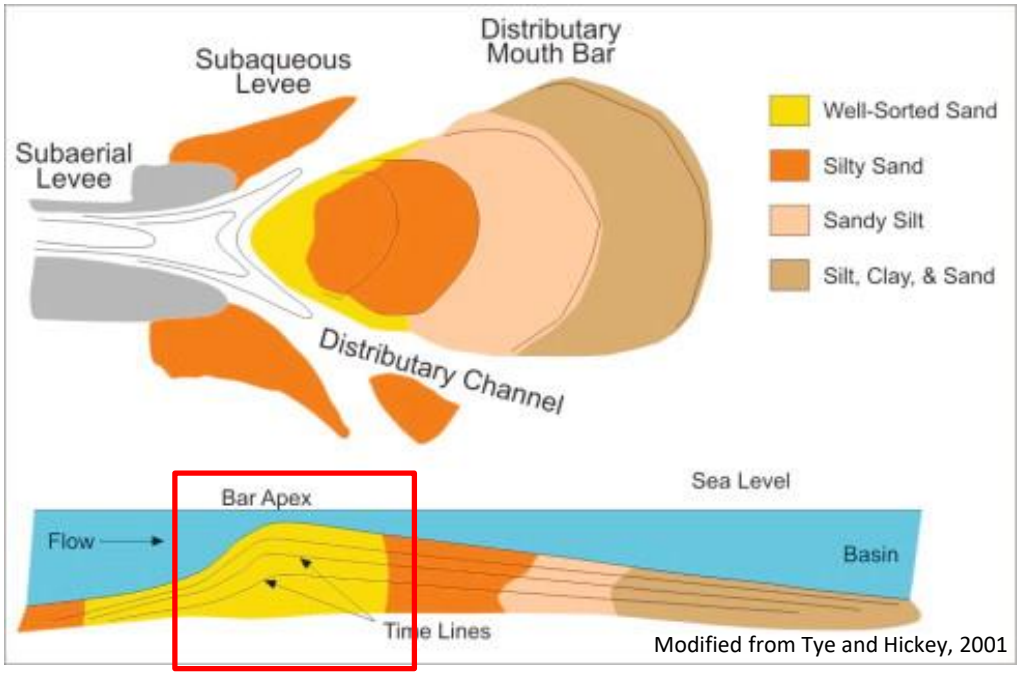




Rosselia in Torrejonain (~63.5 Ma) Distributary Mouth Bars

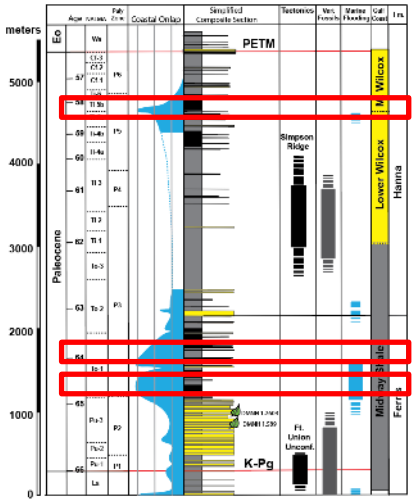






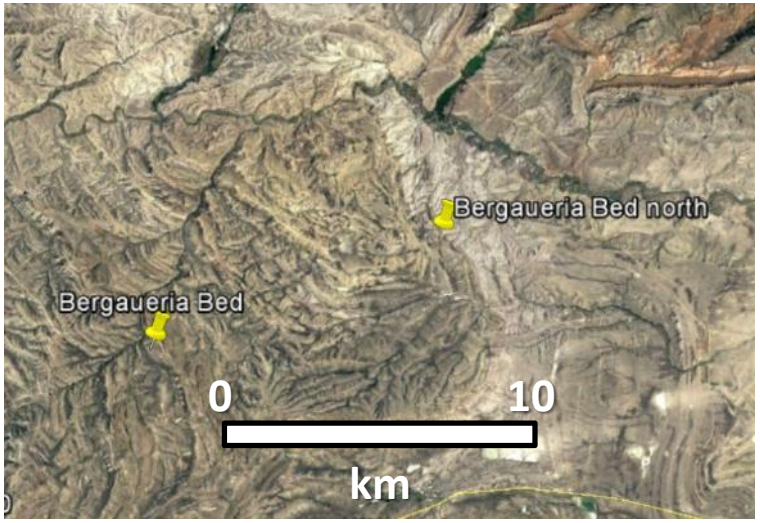
Modified from Tye and Hickey, 2001

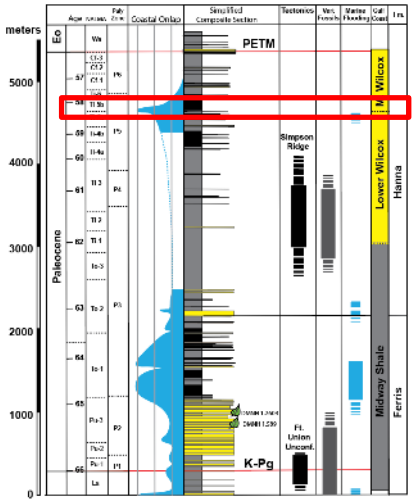
Bergaueria in ~64-63 Ma *and* ~58-57 Ma Bayhead Deltas and Bayfills



- Identified in 1998 by George Pemberton in the early Paleocene and since found throughout the marine interval and in a younger section.
- Resting trace of anemones. Common in sandy delta fronts in settings like the Permian Kookfontein Fm. in the Karoo Basin and the Cretaceous Ferron Sandstone in Utah.
- ***Fully marine ichnofossil.***

Bergaueria Bed—57-58 Ma Marine Flooding Event

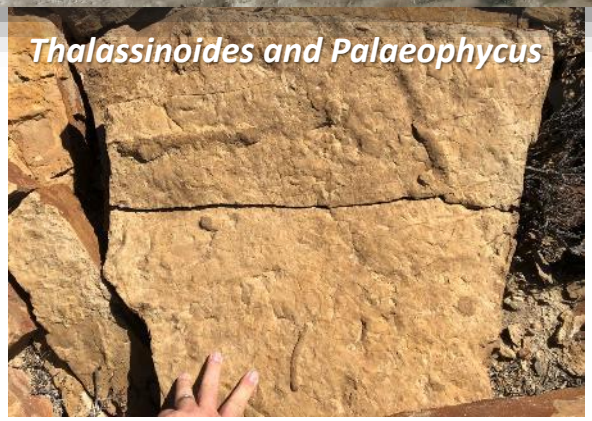




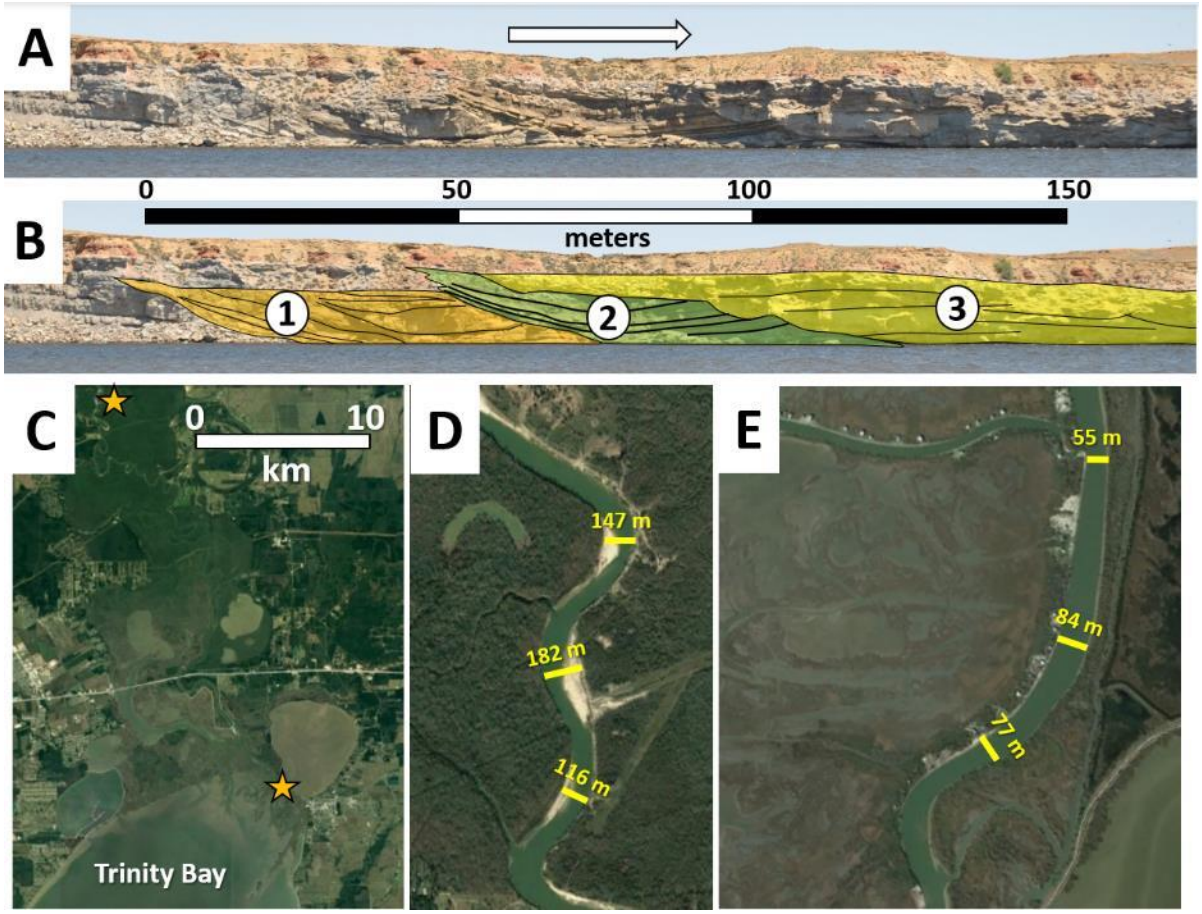
- Traceable for 10 km across the Hanna Formation.
- Constrained by paleobotanical data.
- Additional marine traces are present.
- Represents a marine flooding event younger than previously recognized deposits in the WIS, BUT is time-equivalent to the Waltman Shale.
- Wilcox provenance questions arise.

Shallow Subtidal to Intertidal Flats in the 64-63 Ma Torrejonian

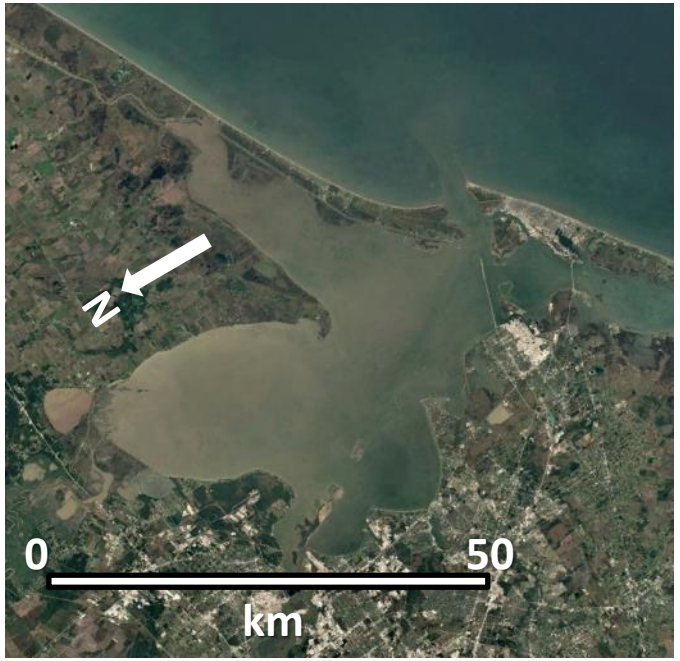
- Shrimp, worm, and bivalve burrows.
- Very fine sand.
- Combined flow ripples.
- Wood, leaves, and logs.



Depositional Context and Analogs—Ferris Fm.

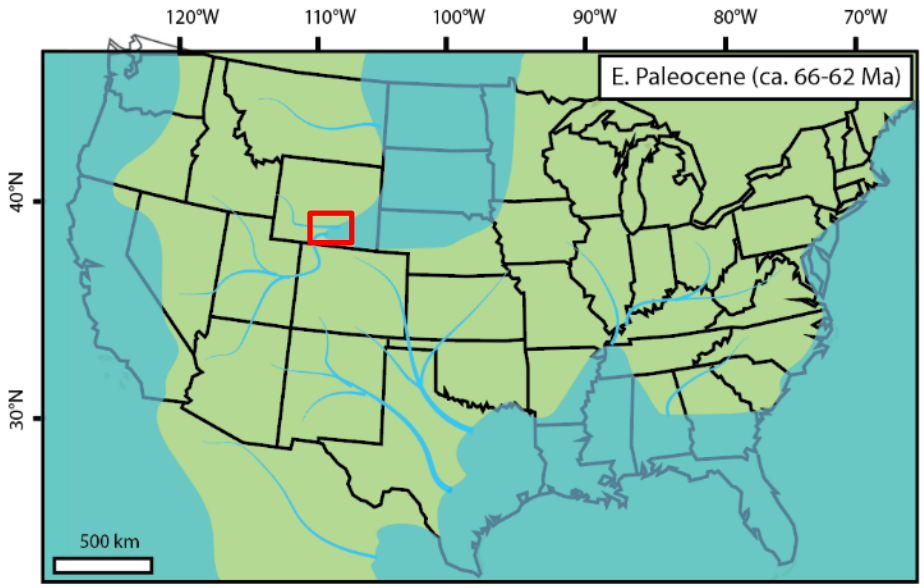


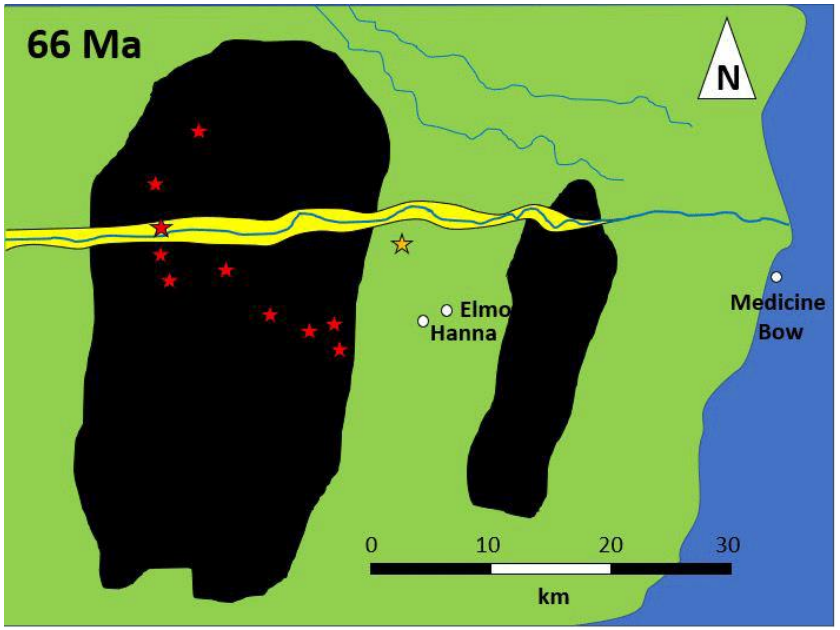
- Channel dimensions are a good match for the modern Trinity River distributary channels on the Texas coast.
- Presence of *Psilonichnus* and *Rhizocorallium* indicates periodic incursion of brackish water during low flow stage.
- Abundant leaves, logs, and woody fragments mirror modern Trinity bay system.
- No shorefaces or remnants of barrier islands have been identified.



Hanna Fm. is similar, but not as long-lived, represents a more rapid transgressive event followed by fast regression.

Regional and Local Paleogeography





- Detrital zircon data indicate that the Hanna Basin area didn't contribute to the Wilcox Group until nearly the Eocene.
- Simpson Ridge Anticline is a likely location for a barrier system (now gone).
- Modern Galveston is ~47 km seaward of the Trinity bayhead delta.
- Simpson Ridge is ~20-37 km seaward of Ferris bayhead deltas.
- ***Shown here is the minimum extent of the seaway. Possibly flooded further to the north and west.***

Conclusions

- K-Pg Boundary wasn't the end of the world for the WIS!
- Major marine transgressions of the WIS in the early (~65-63.5) and late (58-57) Paleocene.
- Youngest marine or brackish ichnofossils in the Western Interior are in the Hanna Fm. (58-57 Ma).
- Tidally influenced channels, bayhead deltas, bays, and tidal flats are present in the Ferris and Hanna Fms.
- There is a lot of work to be done in the Waltman Shale (probably at least partly marine) and other Paleocene strata.
- Wilcox sourcing remains problematical.
- Make friends with paleobotanists! They are a treasure trove of quantitative data.
- Thank you.