A Cenomanian-Age Deep Continental Shelf Record of Cyclical Anoxia, Gulf of Mexico, South Texas*

Harry Rowe[1], Stephen C. Ruppel[1], and Lisa Moran[2]

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Abstract

While many Cretaceous paleoceanographic reconstructions have focused on global-scale oceanic anoxia events (OAEs) like that which occurred at the Cenomanian-Turonian Boundary (CTB), we focus on defining paleoceanographic changes that occurred prior to the CTB interval. Specifically, we present a chemostratigraphic record of mixed carbonate-siliciclastic sedimentation from what is interpreted to be a deep-shelf succession preserved in a drill core from Bee County, South Texas (Shell Oil Co., J.A. Leppard #1). This succession unconformably overlies Albian strata and is believed to predate most of the Eagle Ford-age deposition of South Texas. Biostratigraphic constraints define the ~140-foot thick succession as mostly lower Cenomanian, with approximately 30 feet of middle-upper Cenomanian, unconformably overlain by ~20 feet of Campanian strata. A suite of 105 total organic carbon (TOC) values range from 1% to 6% in the Cenomanian strata, and from ~0.5% to 3.5% in the Campanian strata.

A chemostratigraphic record for the drill core was generated using a suite of 830 major and trace element analyses obtained at an average sample spacing of two inches. Stratigraphic changes in the major element composition are generally reflective of bulk mineralogical changes, largely interpretable in the context of changing facies. Lower Cenomanian strata are dominantly calcitic (60+/-12% $CaCO_3$), middle and upper Cenomanian strata are less calcitic (42+/-12% $CaCO_3$), and Campanian strata are slightly higher than those of the lower Cenomanian (62+/-7% $CaCO_3$). Whereas the bulk major element geochemistry dominantly reflects changes in a simple two-component (calcite and clay mineral) depositional system, trace element signatures reveal exceptionally large, cyclical variations throughout the lower Cenomanian interval. The dominant signatures of anoxia/euxinia are best defined by vanadium and molybdenum (Mo). Eight stratigraphically distinct episodes of lower Cenomanian-age anoxia are defined by Mo enrichment factors (EF-Mo) higher than 100; and furthermore, several of the enriched intervals are defined by multiple peaks, indicating an oceanographic process that generates a pattern of redox-driven cyclicity in the sediments. It is hypothesized that the cyclicity is a manifestation of the paleo-oxygen minimum zone (OMZ) impinging on the deep shelf. However, the RSTE pattern could represent a very high-resolution record of the Middle Cenomanian Event (MCE).

Selected Reference

Rowe, H., N. Hughes, and K. Robinson, 2012, The quantification and application of handheld energy-dispersive x-ray fluorescence (ED-XRF) in mudrock chemostratigraphy and geochemistry: Chemical Geology v. 324-325, p. 122-131.

Website

Blakey, R., 2012, Early Cenomanian Paleogeography: Web accessed August 20, 2013. http://cpgeosystems.com/namK100.jpg

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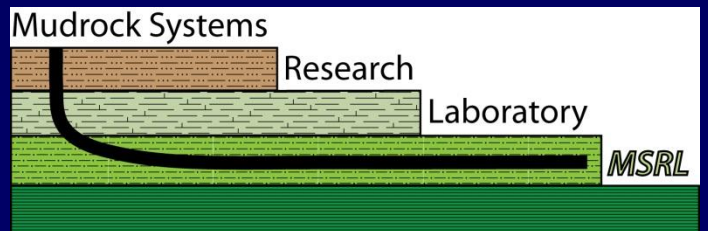
AAPG 2013, Pittsburgh, PA



Acknowledgements

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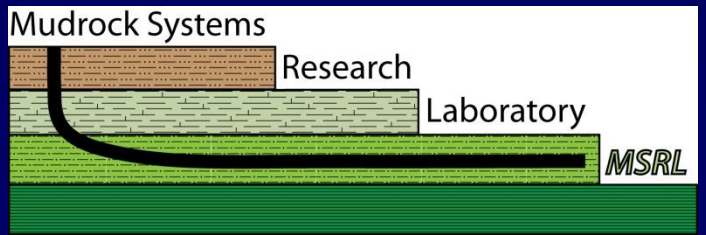
BEG: Bob Loucks, Bill Ambrose, Nathan Ganser, Michael Nieto

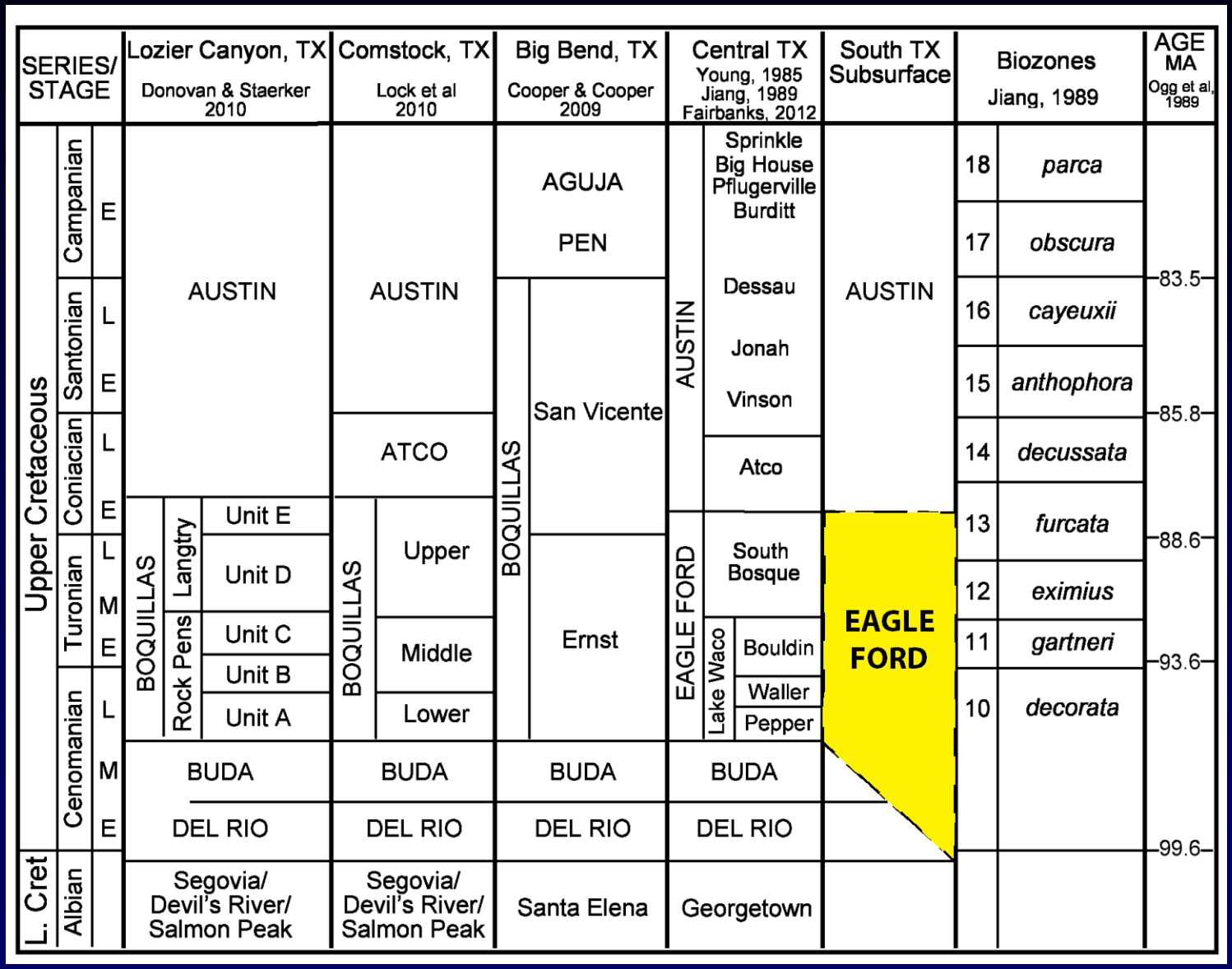
Bruker Elemental—for continued interaction on instrumental advances



Considerations

- Many studies of the Cenomanian have focused on the Cenomanian-Turonian Boundary and Ocean Anoxia Event #2 (OAE2).
- Less effort has been placed on understanding OAE2 precursors or the overall post-Albian conditions leading up to OAE2.
- We describe and interpret a chemostratigraphic record of pre-OAE2 paleoceanographic conditions from South Texas that may ultimately shed light on the evolution of the oceans toward OAE2-like conditions.
- We'll also make some general comments about chemostratigraphy because of its burgeoning (but often unchecked) use.

Upper Cretaceous Stratigraphic Column

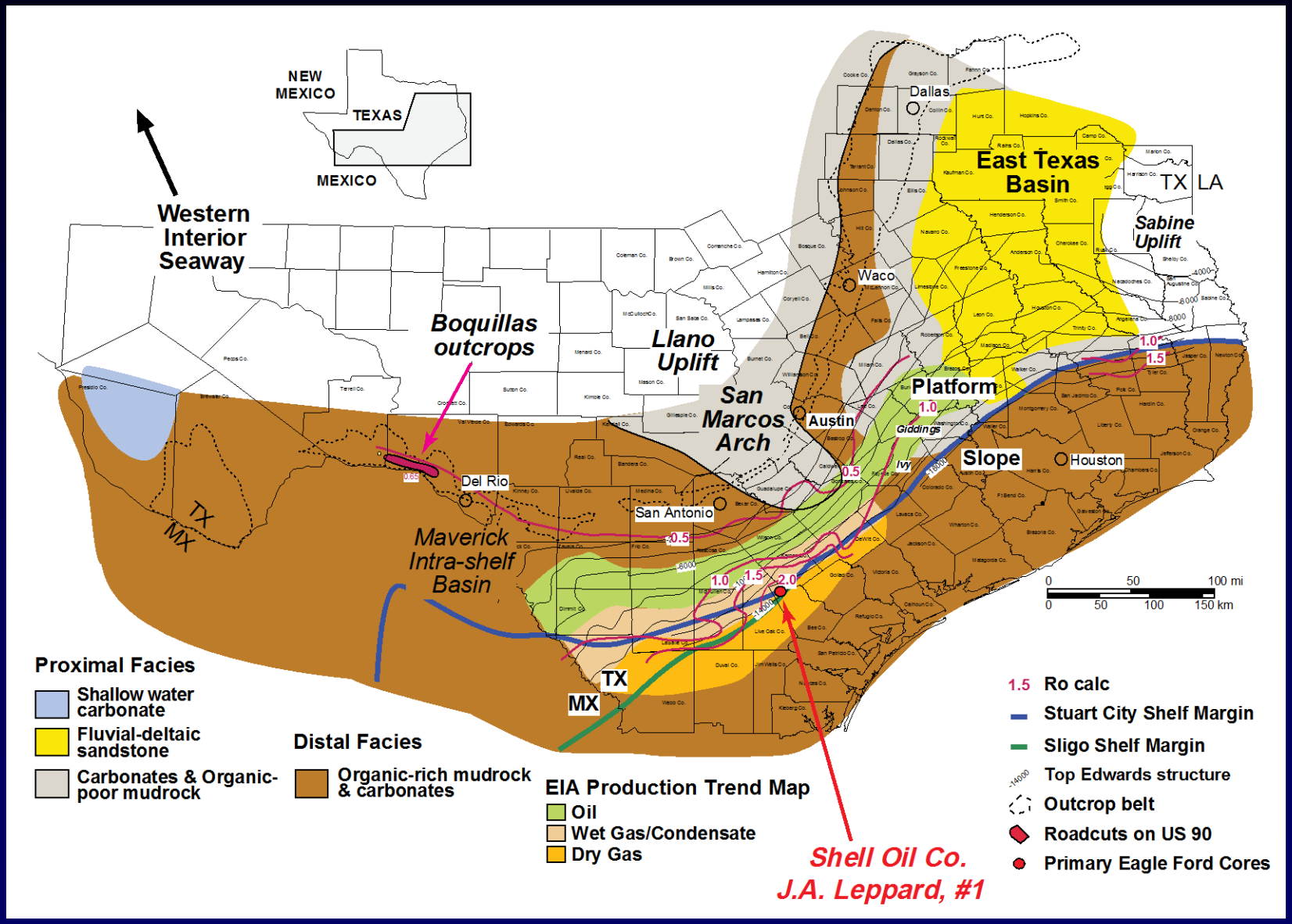


Core Background

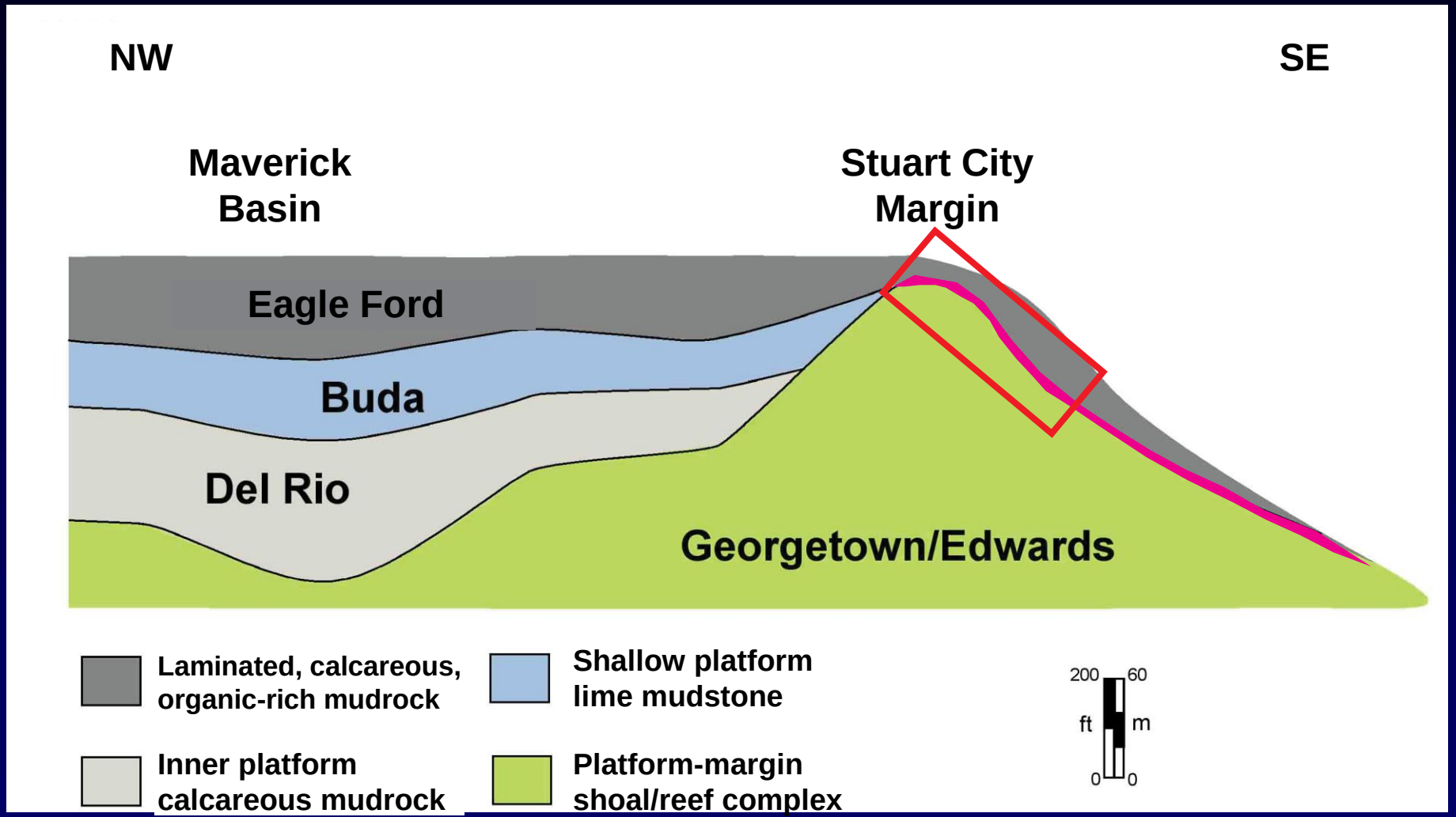
- Shell Oil Co. J.A. Leppard #1
- NW Bee County, South Texas
- ~140 feet long; Depth: 13670 to 13530 ft
- Biostratigraphy based on nanofossil identification (Jim Pospichal, Bugware, Inc.)
- Lithostratigraphy based on observations made on slabbed face and thin sections
- 830 samples analyzed for bulk elemental geochemistry, TOC, δ^{13}C-TOC. Chemostratigraphy based on methods and calibrations outlined in:

  -Rowe et al., 2012, The quantification and application of handheld energy-dispersive x-ray fluorescence (ED-XRF) in mudrock chemostratigraphy and geochemistry. Chemical Geology v. 324-325, p. 122-131.

Core Location: Proximal to Stuart City Margin



Simple Dip X-Section



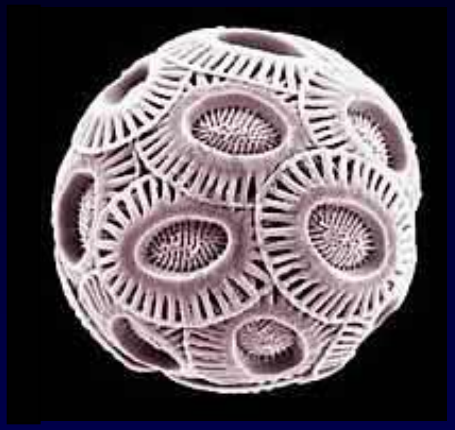
Eagle Ford Carbonate Sediment Types

Dominant

- Planktonic flora/fauna
  - Globigerinid foraminifera
  - Nanoplankton (coccoliths)

Globigerinid foraminifera

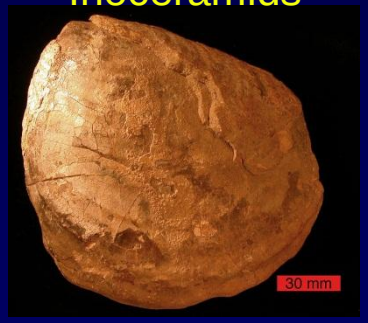
Coccoliths



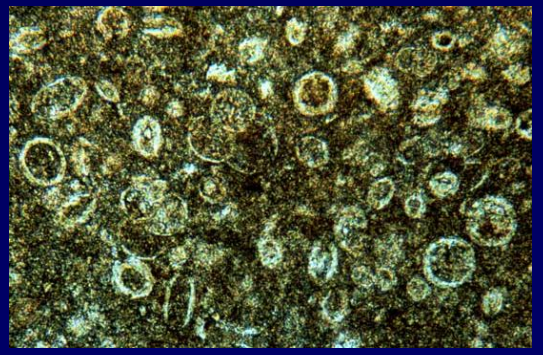
Subsidiary

- Benthic fauna
  - Inoceramid pelecypods
  - Echinoids
- Nektonic/plantonic flora/fauna
  - Cephalopods
  - Calcispheres (dinoflagellates ?)

Inoceramids



Calcispheres

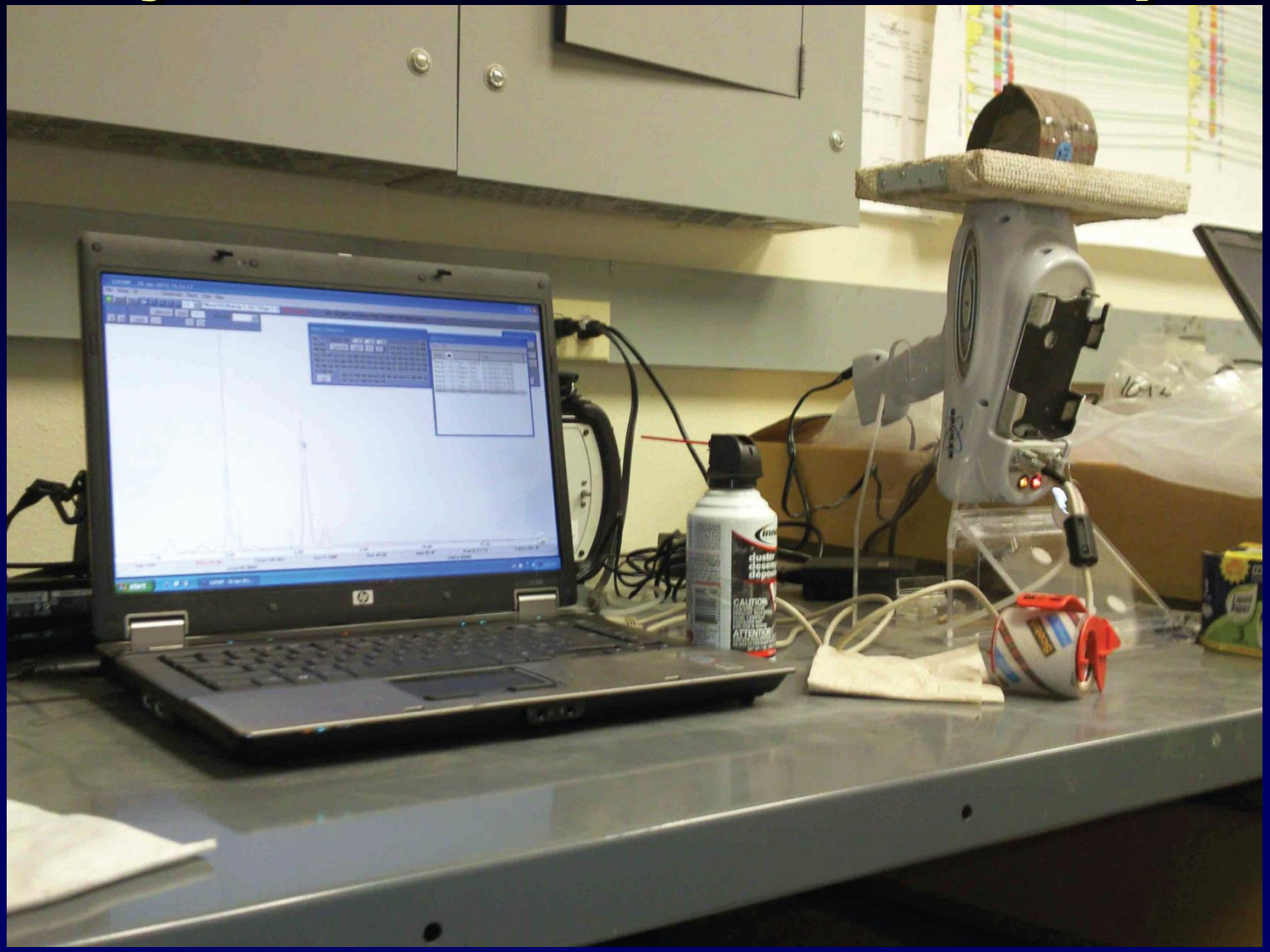


Typical Eagle Ford Facies and Variability

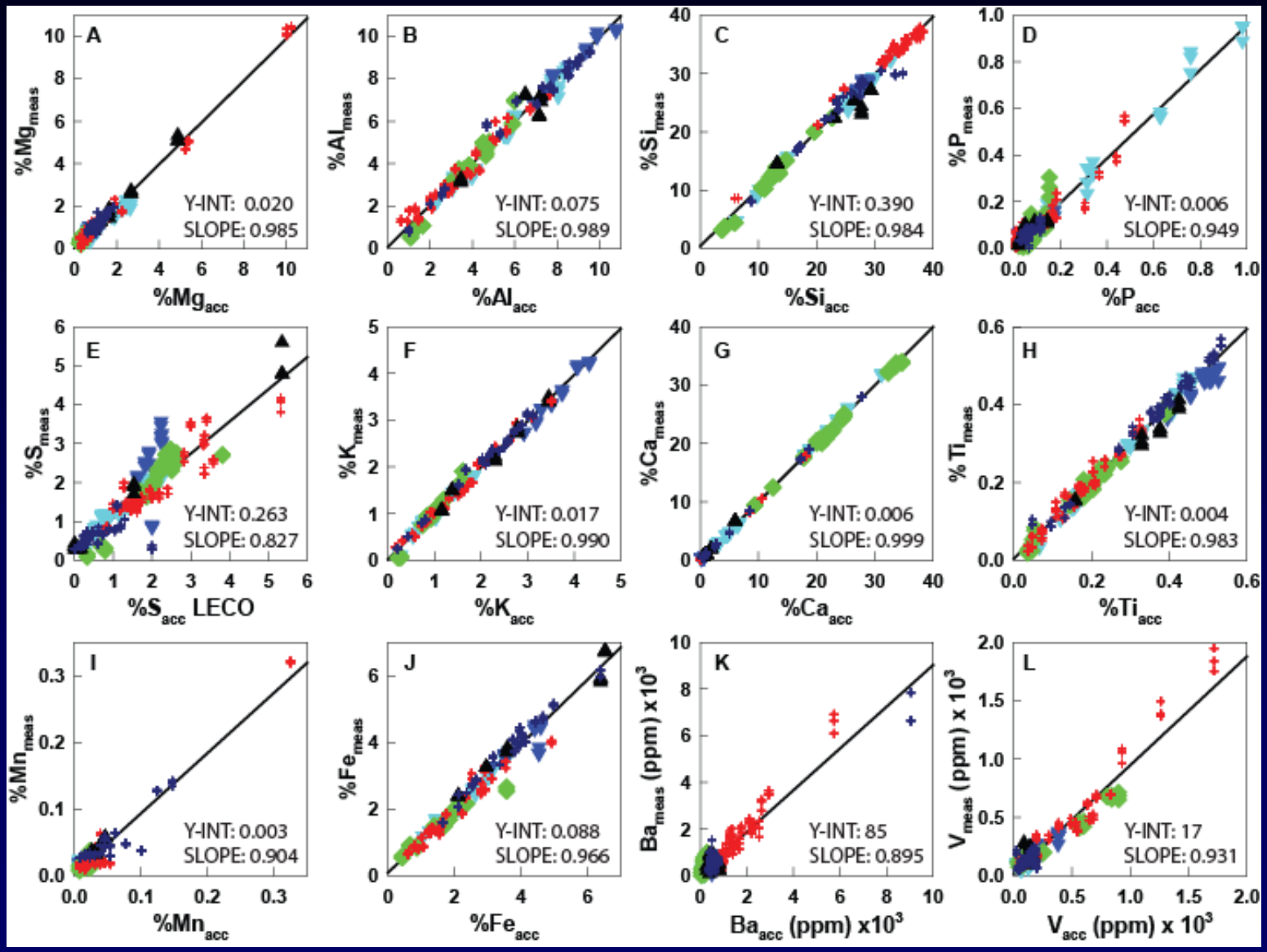
Calcareous Foram-Nanoplankton
Mudrock-Lime Packstone

Calcareous Nanoplankton Mudrock

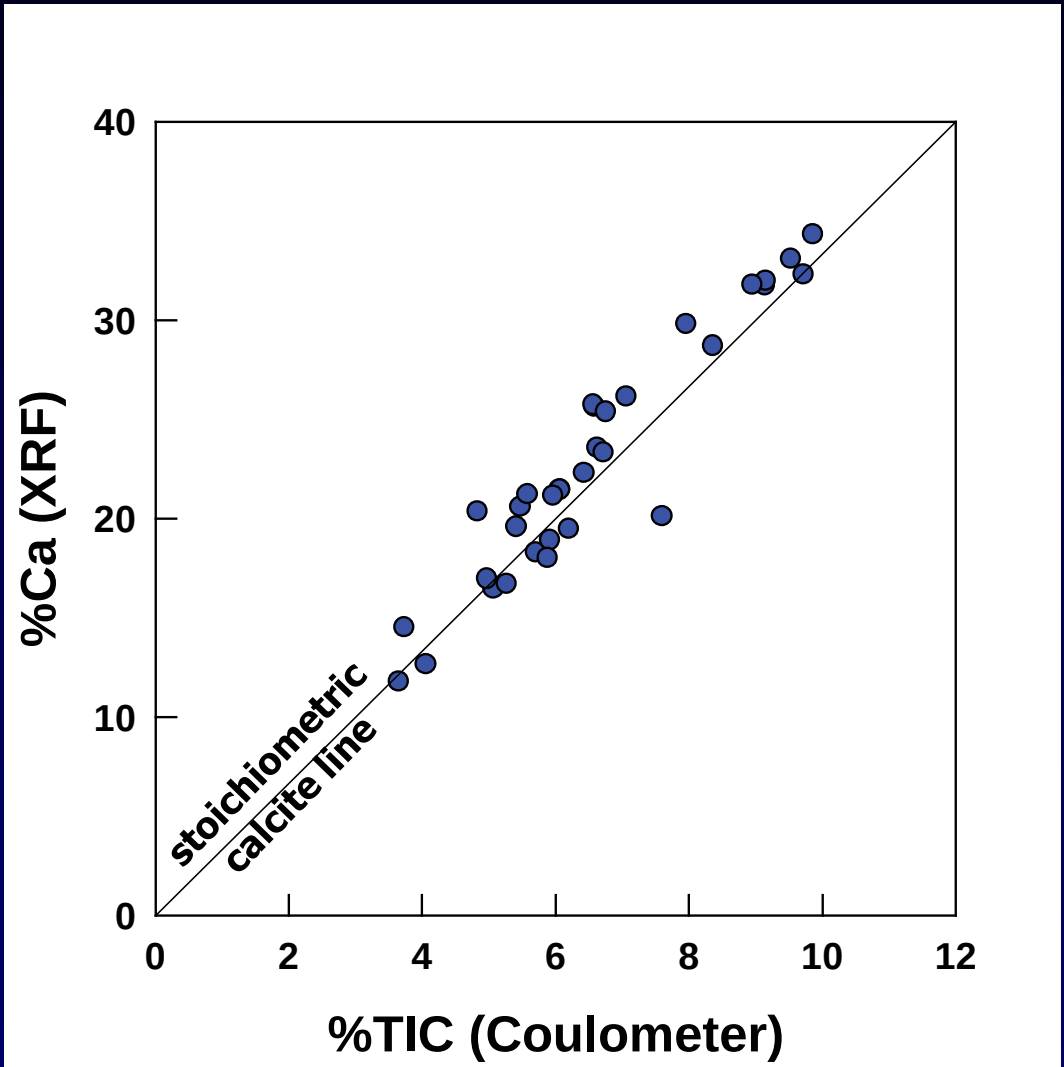
Quantitative Method of Obtaining Major/Trace Element Geochemistry



Major Element Calibration

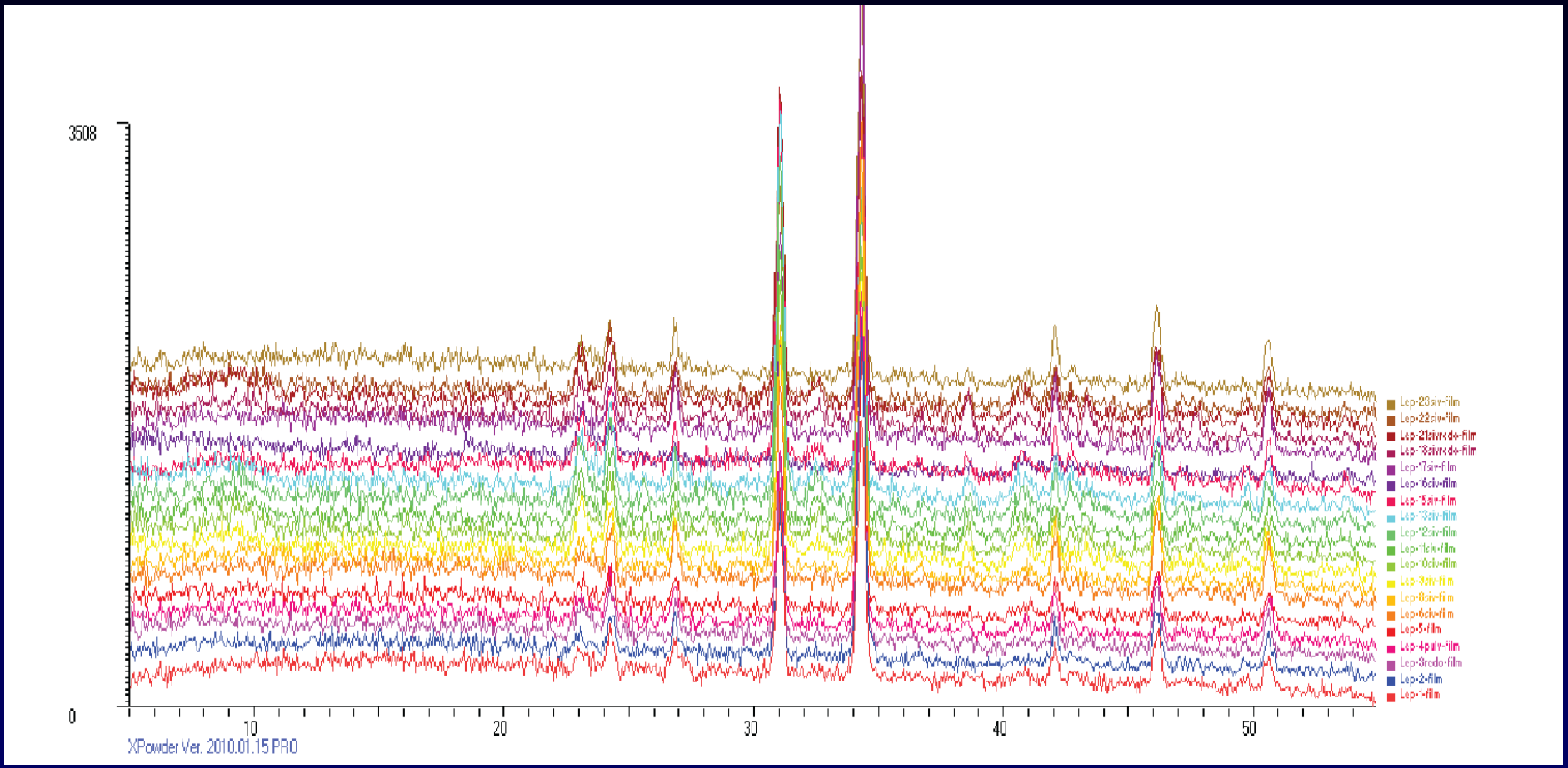


A "Check" on Accuracy

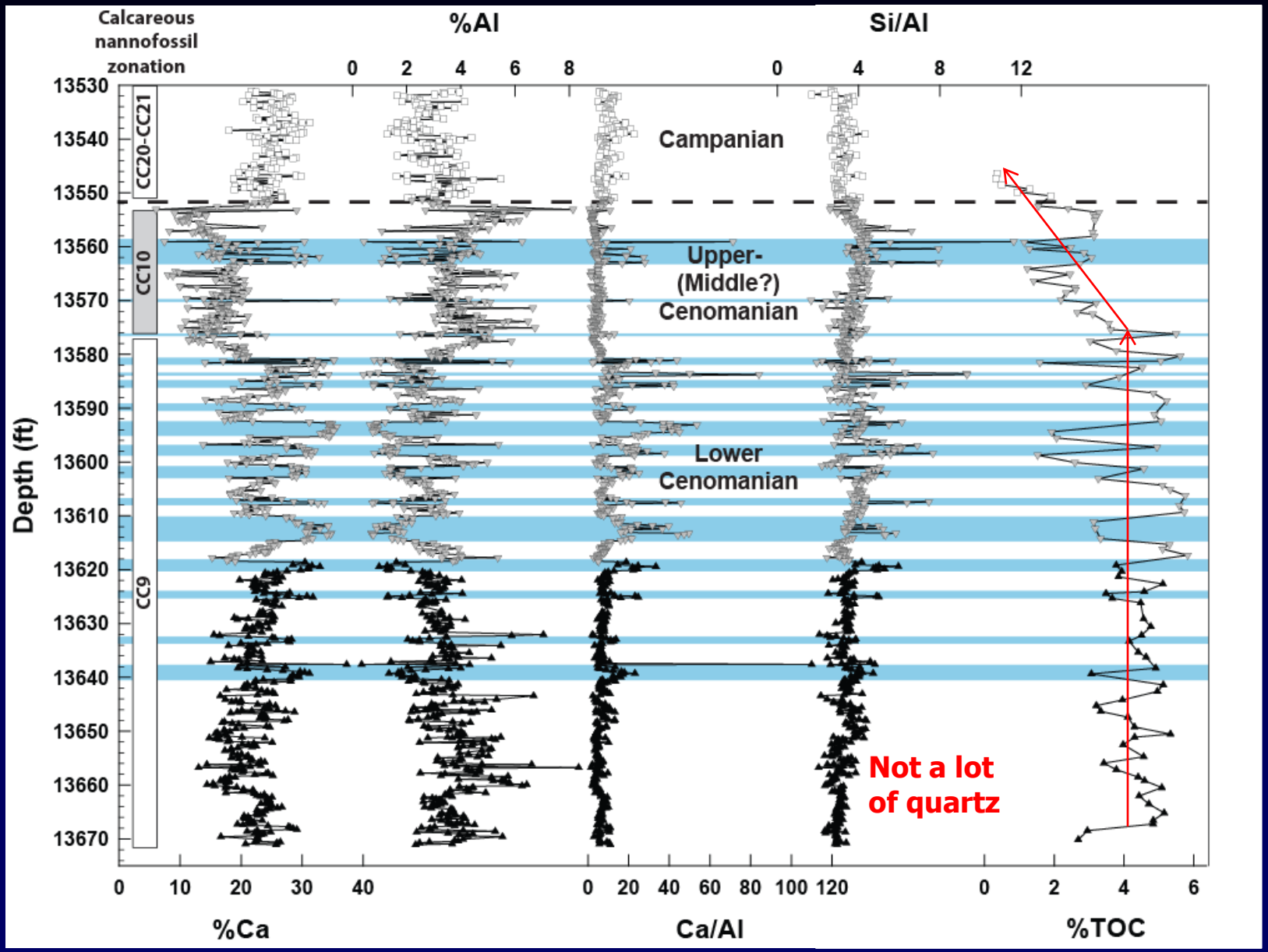


- Why don't all of the points fall ON the line?
- Why would we ever get points that fall significantly BELOW the line?
- Why would they fall significantly above the line?
- What is another quick "check" that one can make to evaluate accuracy?

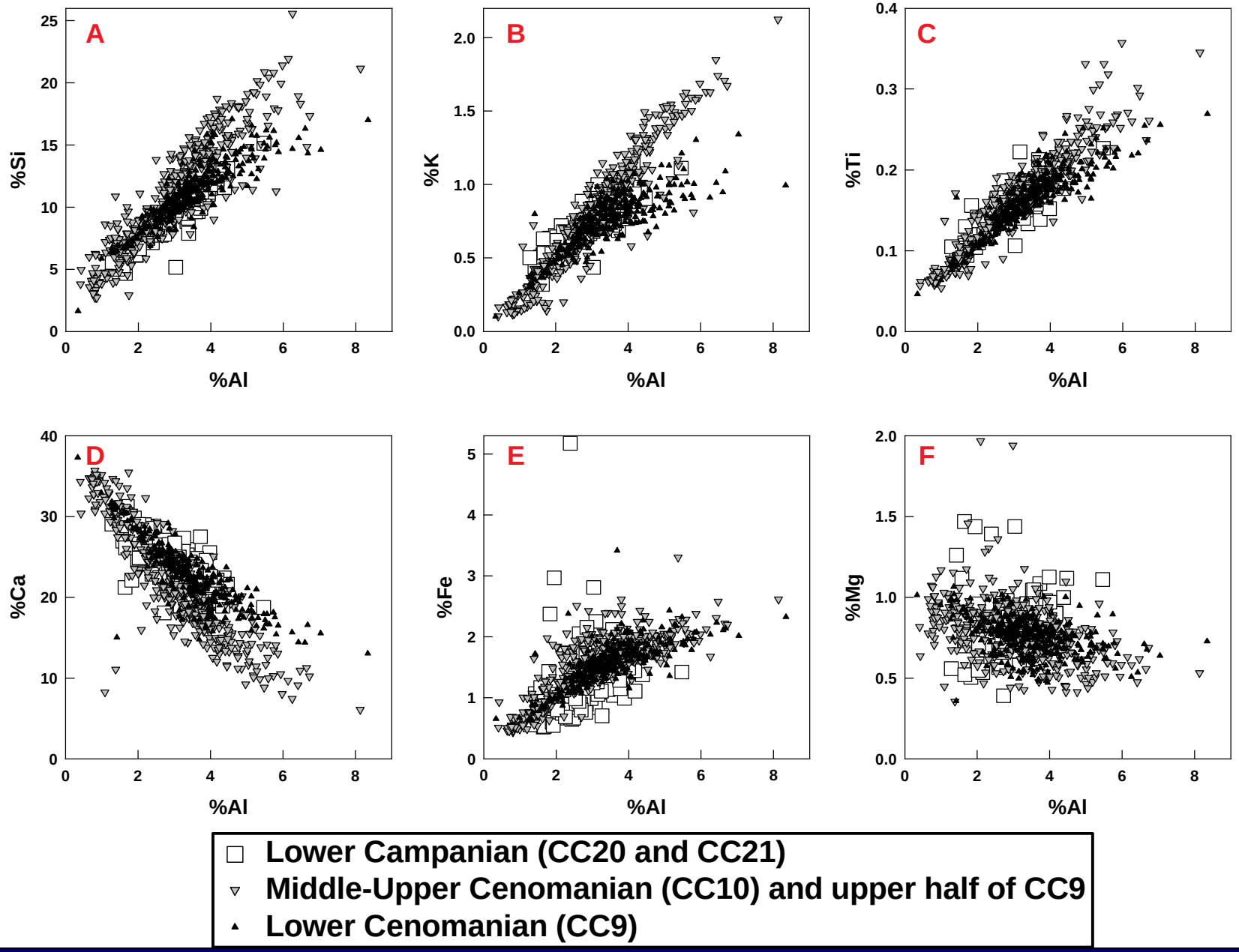
Rapid XRD (Insitu, Inc.)



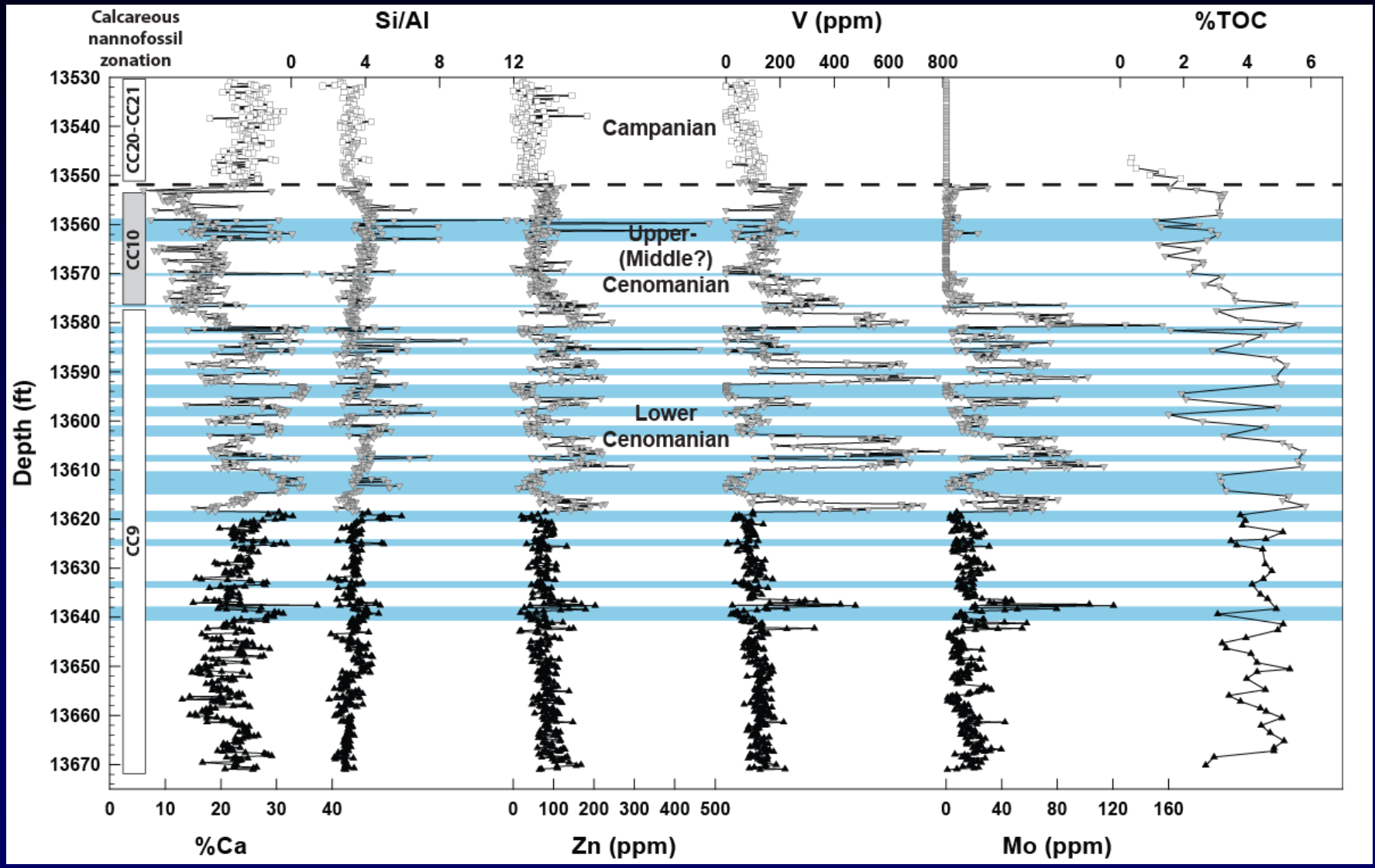
Leppard Core Chemostratigraphy



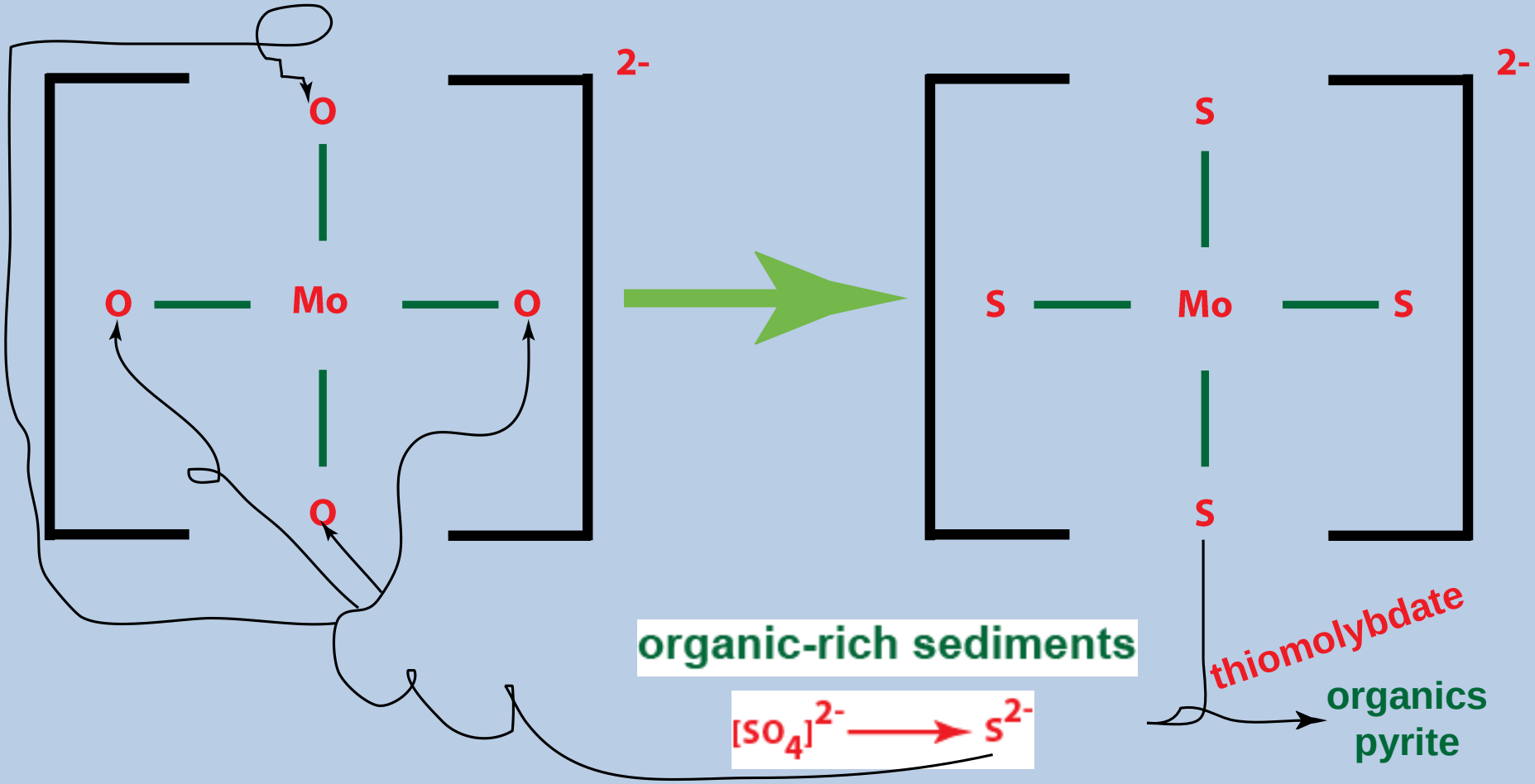
Leppard #1, Bee County, TX



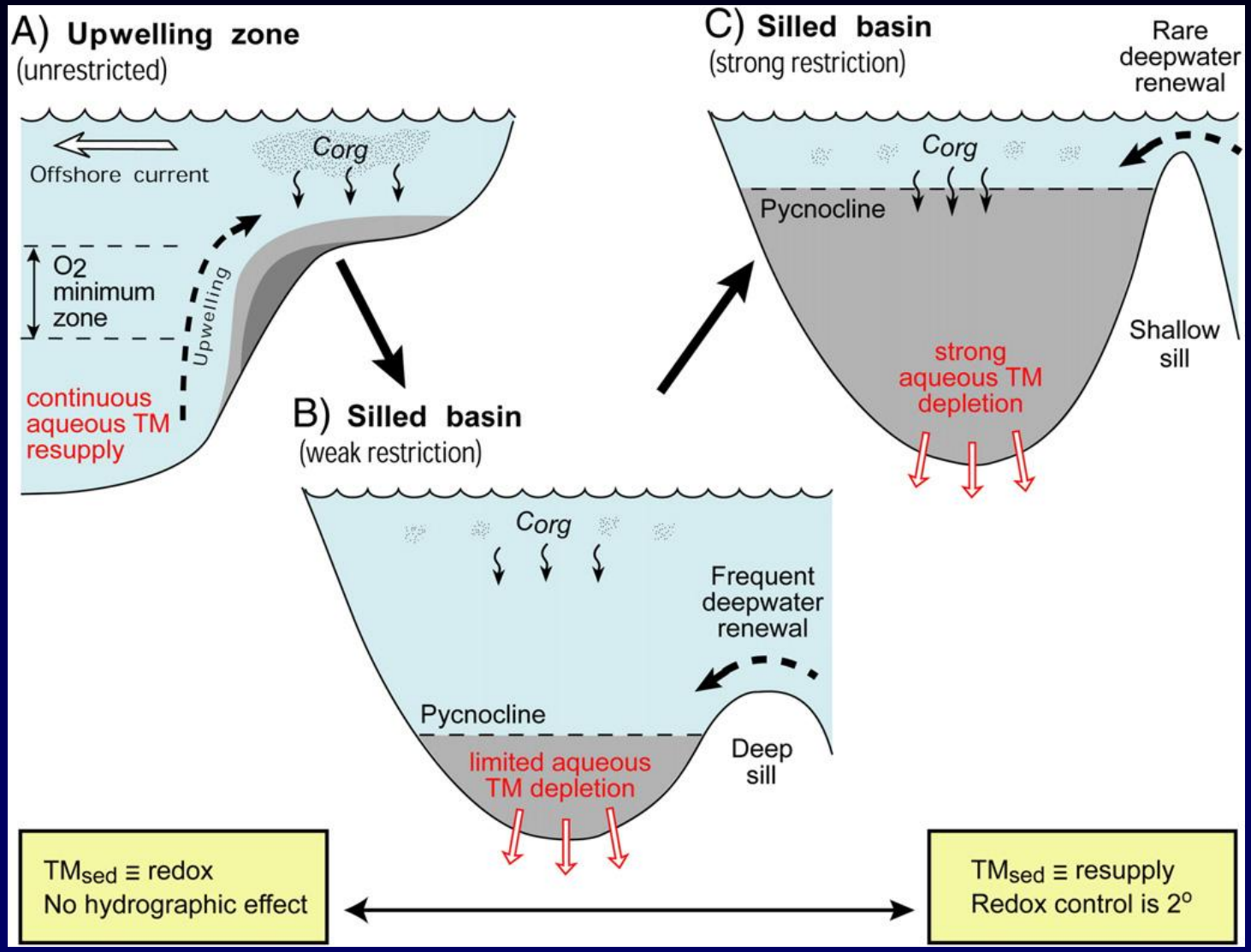
Leppard Core Chemostratigraphy



Utilization of Mo for Evaluating Euxinia/Renewal Time

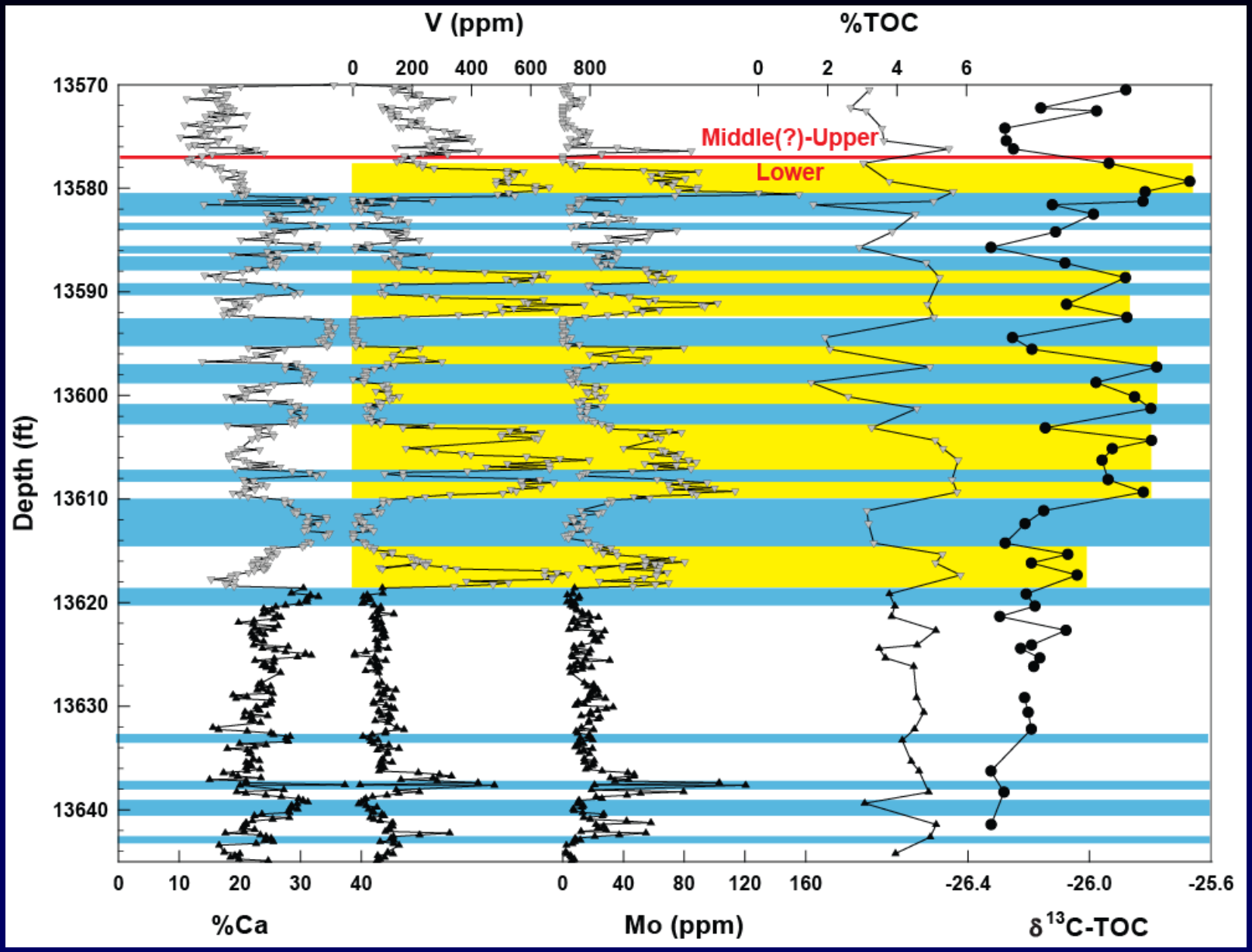


Environment for Mo Enrichment

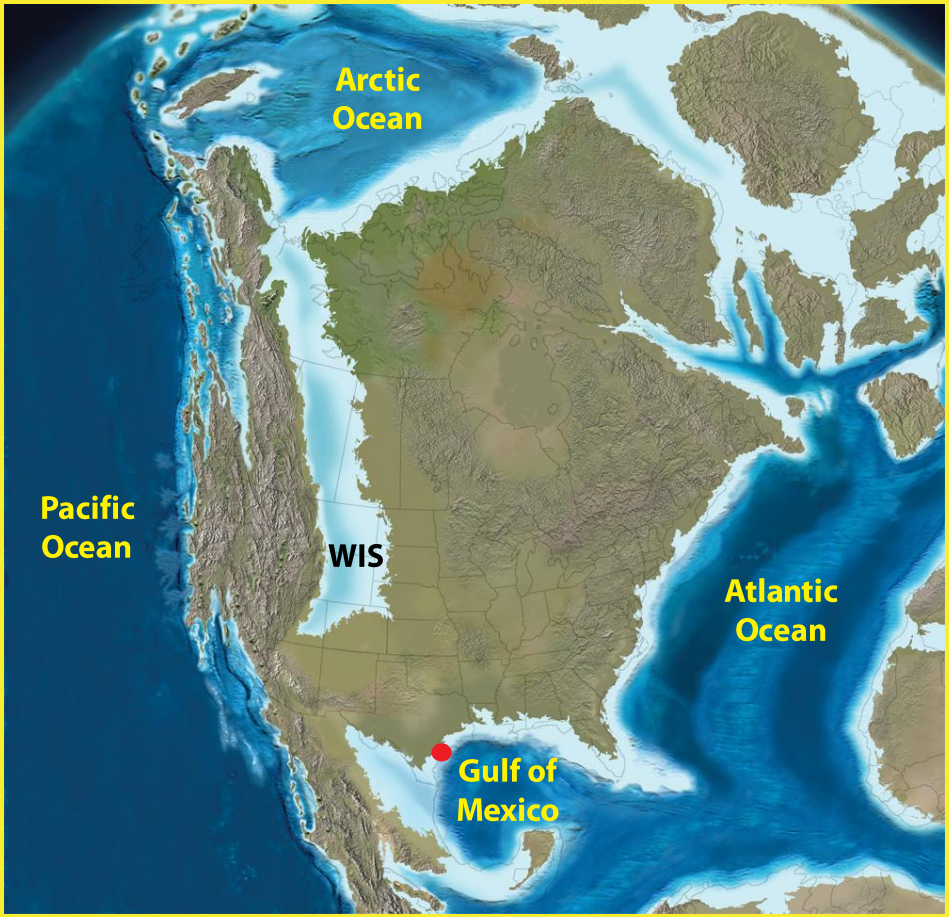


Algeo and Rowe, *Chemical Geology*, 2012

Zoom in on Lower Cenomanian

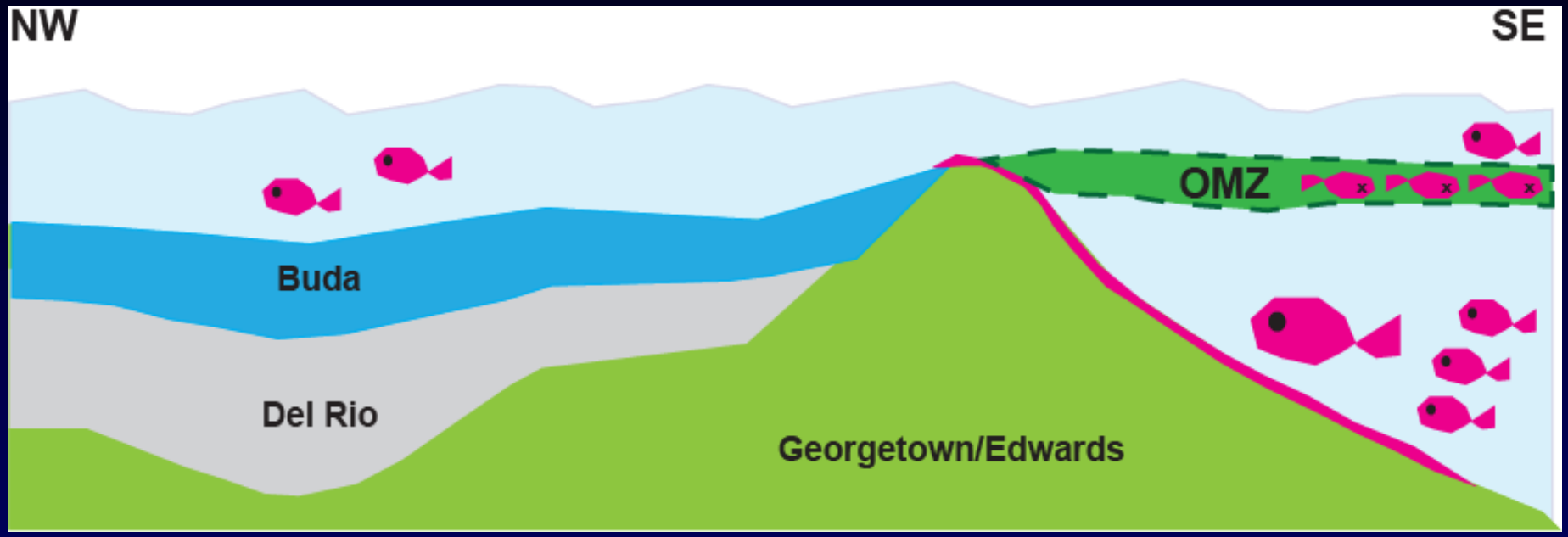


Early Cenomanian Paleogeography



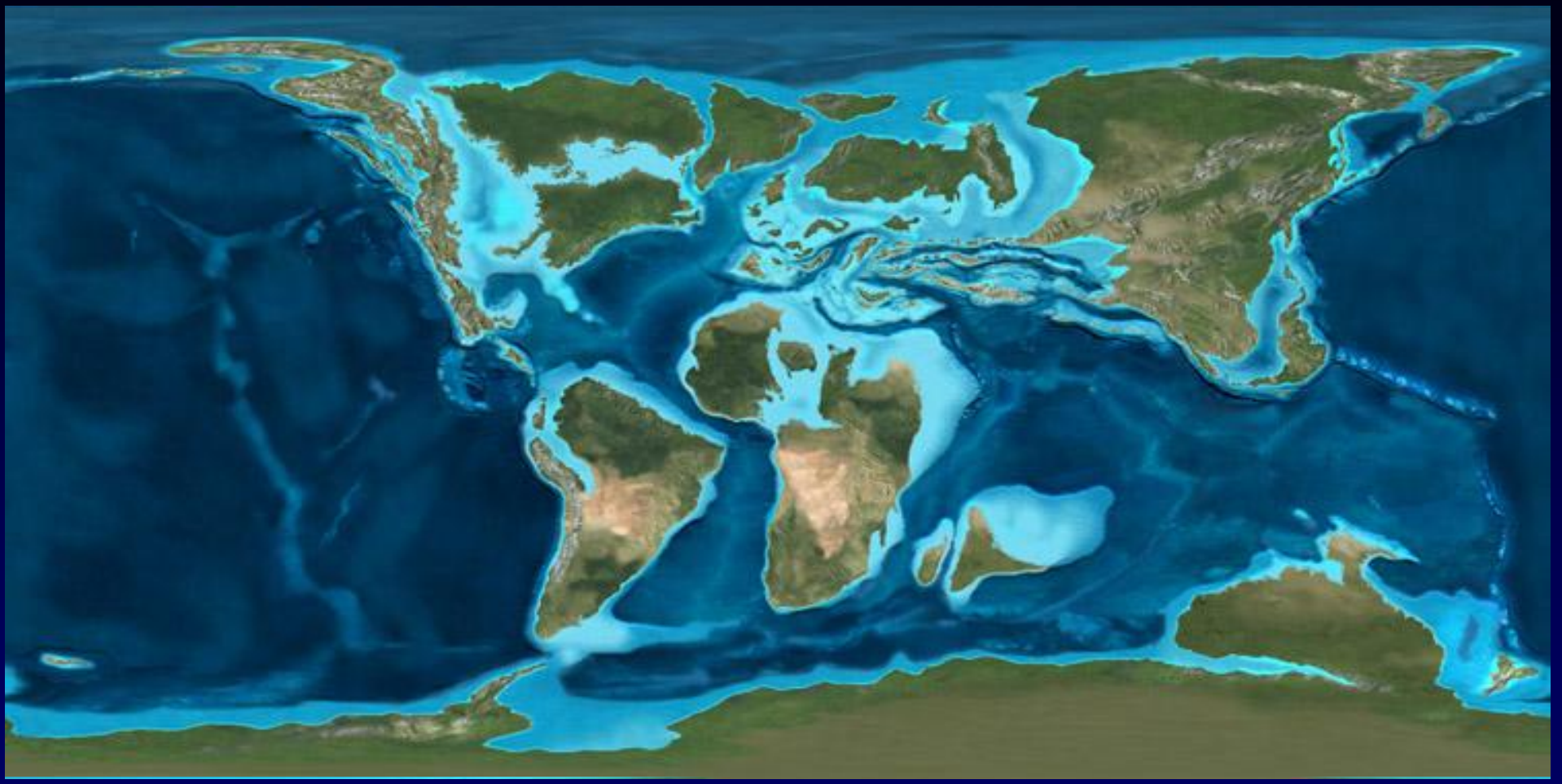
Paleogeographic reconstruction of early Cenomanian (100 Ma; Blakey (2013); http://cpgeosystems.com/nam.html). The approximate location of the drill core is indicated with the red dot. Note, the Western Interior Seaway (WIS) was open to the Arctic Ocean, but was not yet linked with the Gulf of Mexico.

Impingement of Oxygen Minimum Zone (OMZ) onto Outer, Deeper Shelf



- Occurrence, expansion, and contraction of the OMZ along the outer shelf could create the trace element and TOC signatures observed.
- The overall rhythmic (cyclical) pattern of redox changes may suggest the influence of a forcing mechanism that also tends to be cyclical (i.e., orbital forcing).

Transition from Early to Late Cenomanian



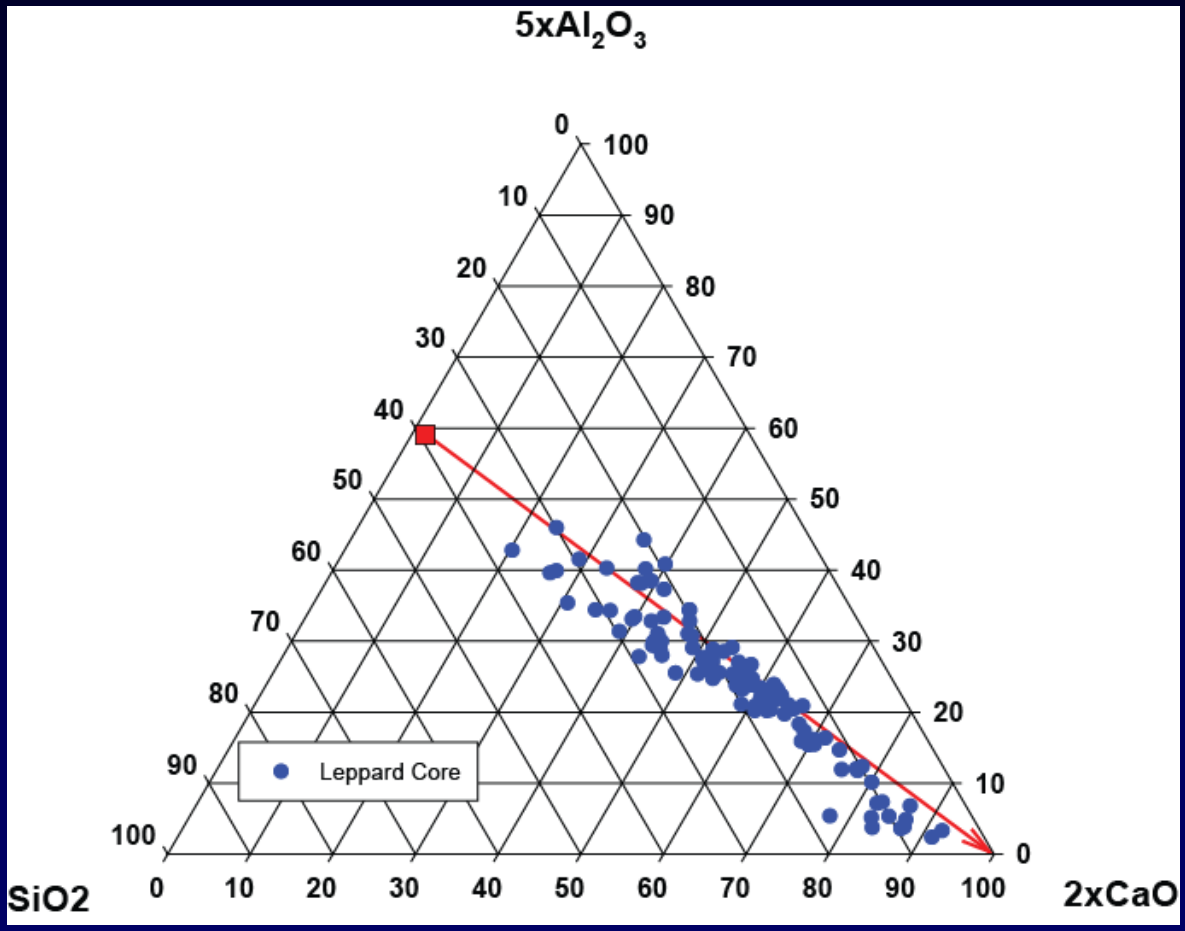
- On a broader scale, the Leppard record provides a stronger understanding of conditions just before(?) the opening of the WIS.
- Sea level was lower, and then rose during the WIS establishment—this would have triggered "true" Eagle Ford deposition inboard of the Leppard site (behind the Stuart City Margin).

CONCLUDING COMMENTS

- Tremendous effort focused on characterizing the OAE-2 at the Cenomanian-Turonian Boundary (CTB)
- Much less effort toward resolving pre-OAE2 episodes or events during Cenomanian (some work on "Middle Cenomanian Event")
- Based on core biostratigraphy, we do not believe the Leppard record preserves the OAE2, and it is unclear how much of the Middle-Late Cenomanian is preserved
- The redox variability (e.g., Mo, V) may reflect impingement of the OMZ upon the outer shelf.
- The Leppard is unique in that it is an older record of Eagle Ford lithofacies and redox variability

Extra Slides

Calcite - Clay - Quartz Ternary

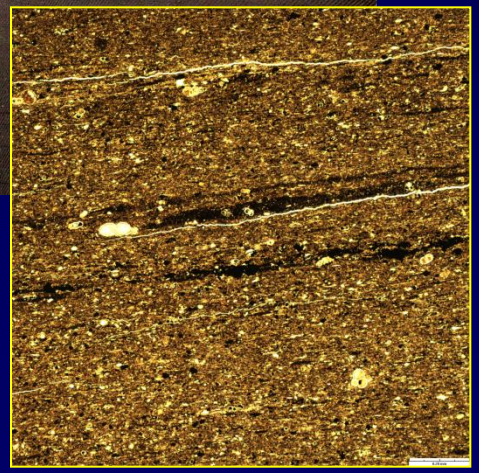


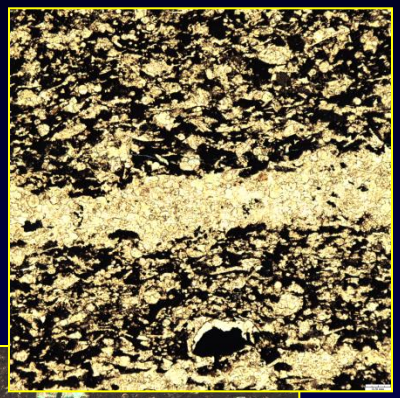
Dominant *Lower* Eagle Ford Carbonate Facies

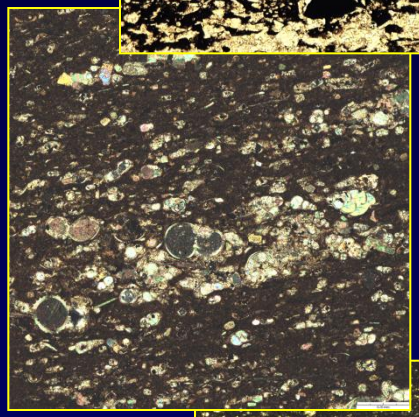
Calcareous
Nanoplankton
Mudrock

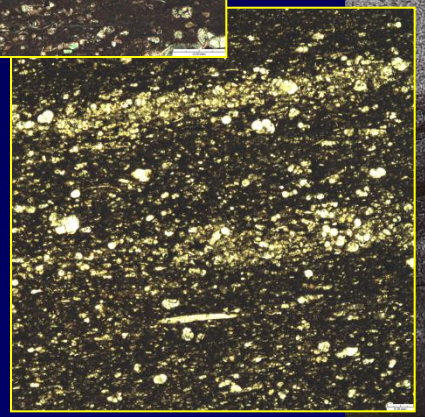
Subsurface

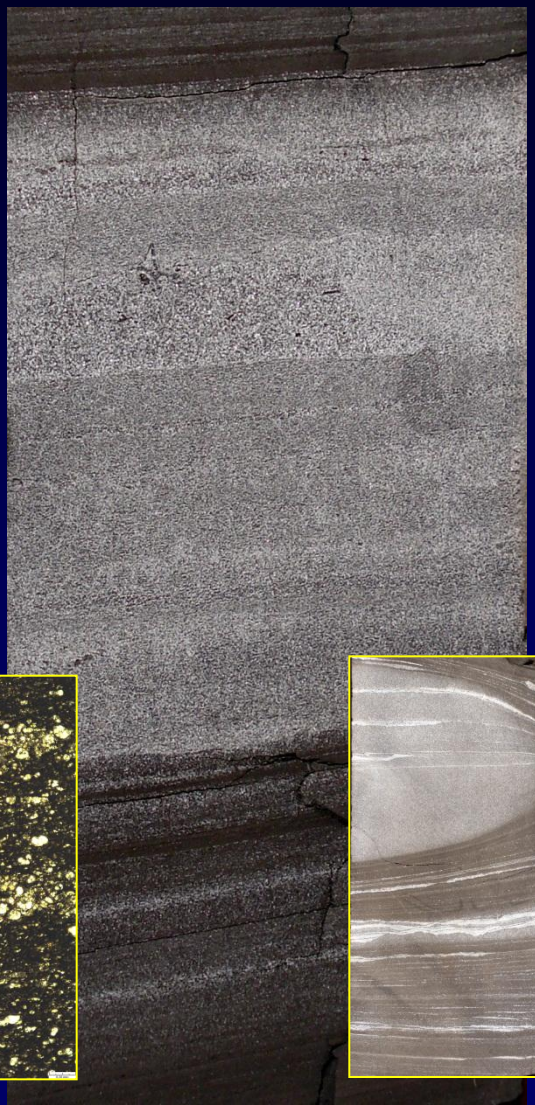
Calcareous
Foram-Nanoplankton
Mudrock-Lime Packstone











Eagle Ford - Austin Facies

Austin

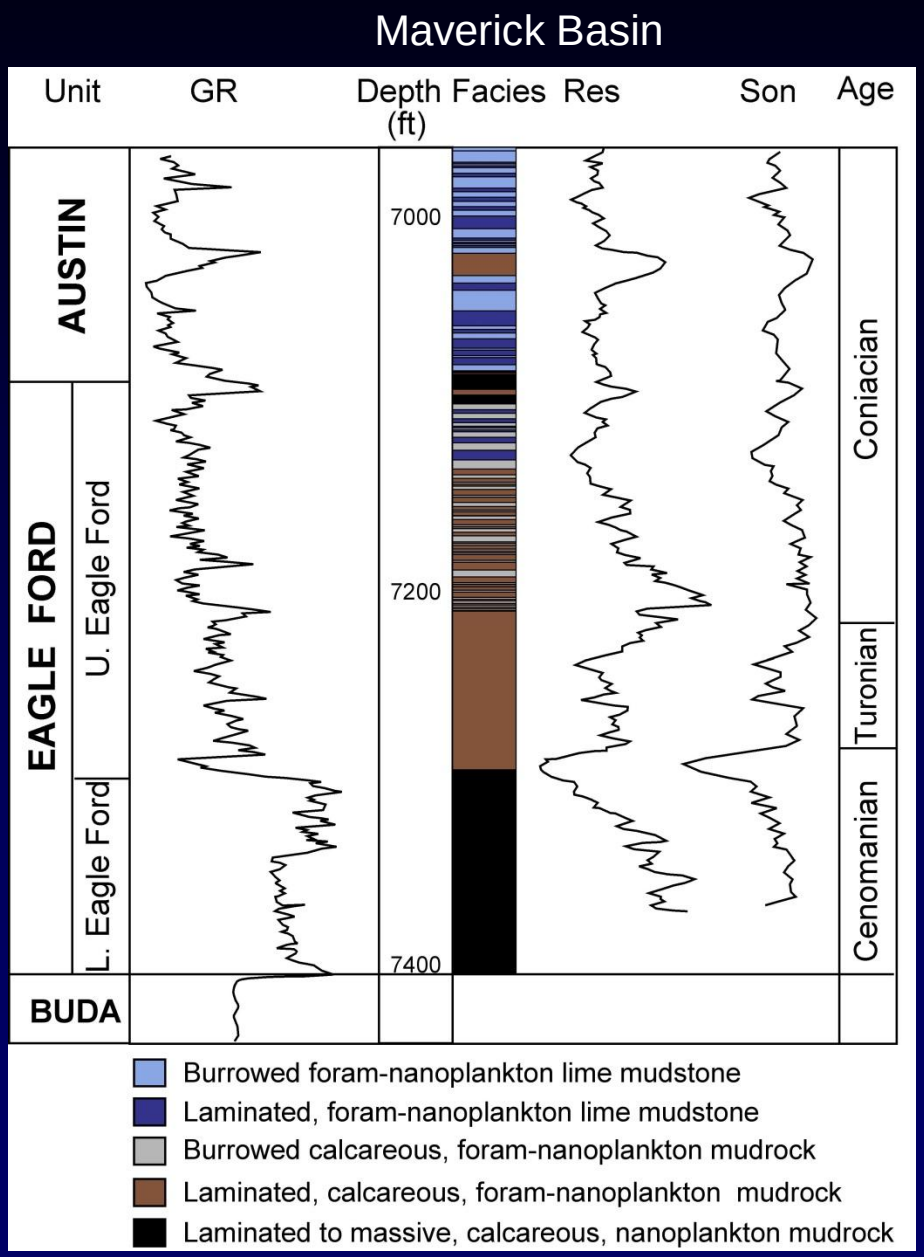
- Proximal, cyclic, burrowed to laminated foram-nanoplankton, limestone

Upper Eagle Ford

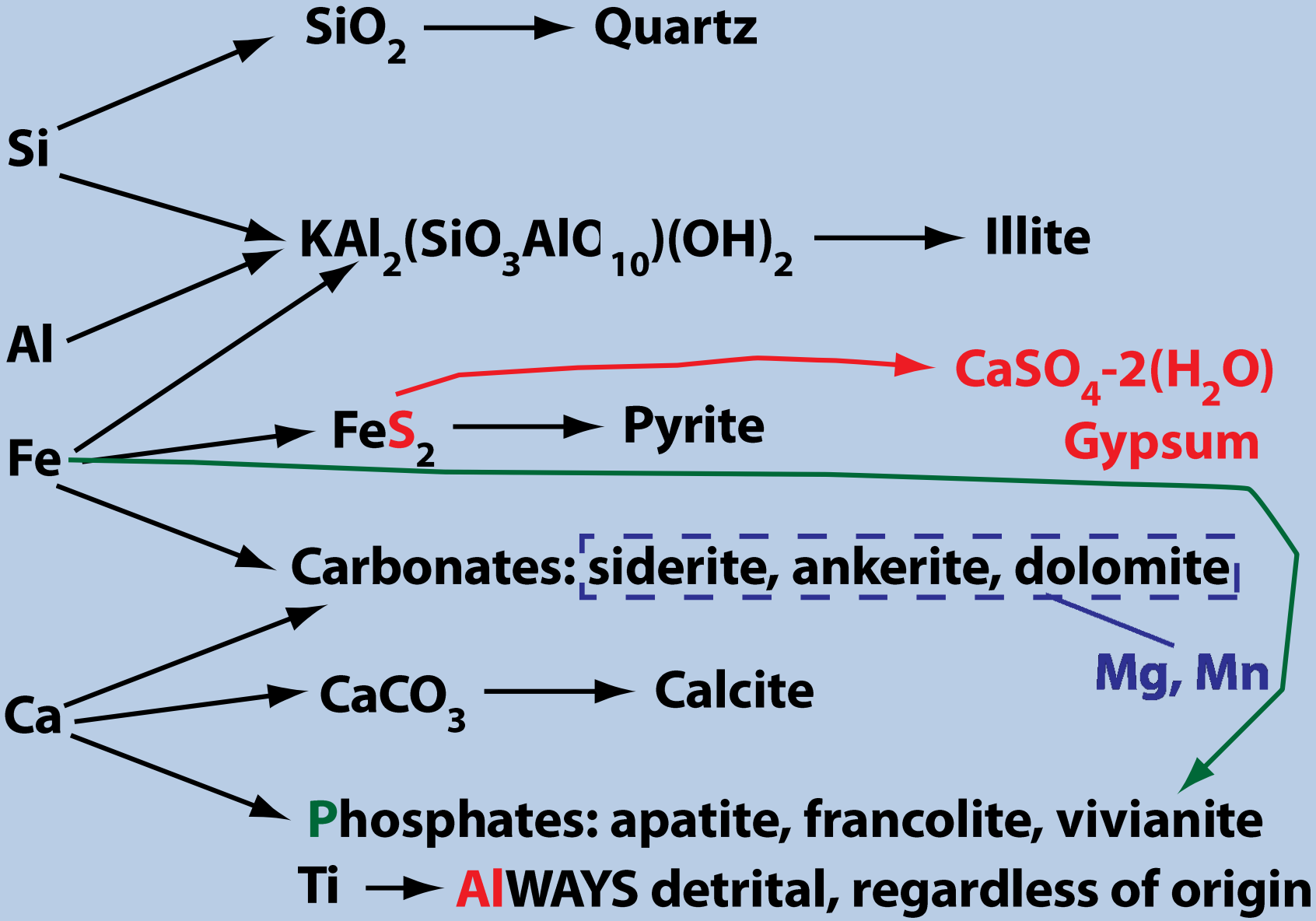
- Medial, cyclic, laminated to burrowed, foram-nanoplankton, mudrock to limestone

Lower Eagle Ford

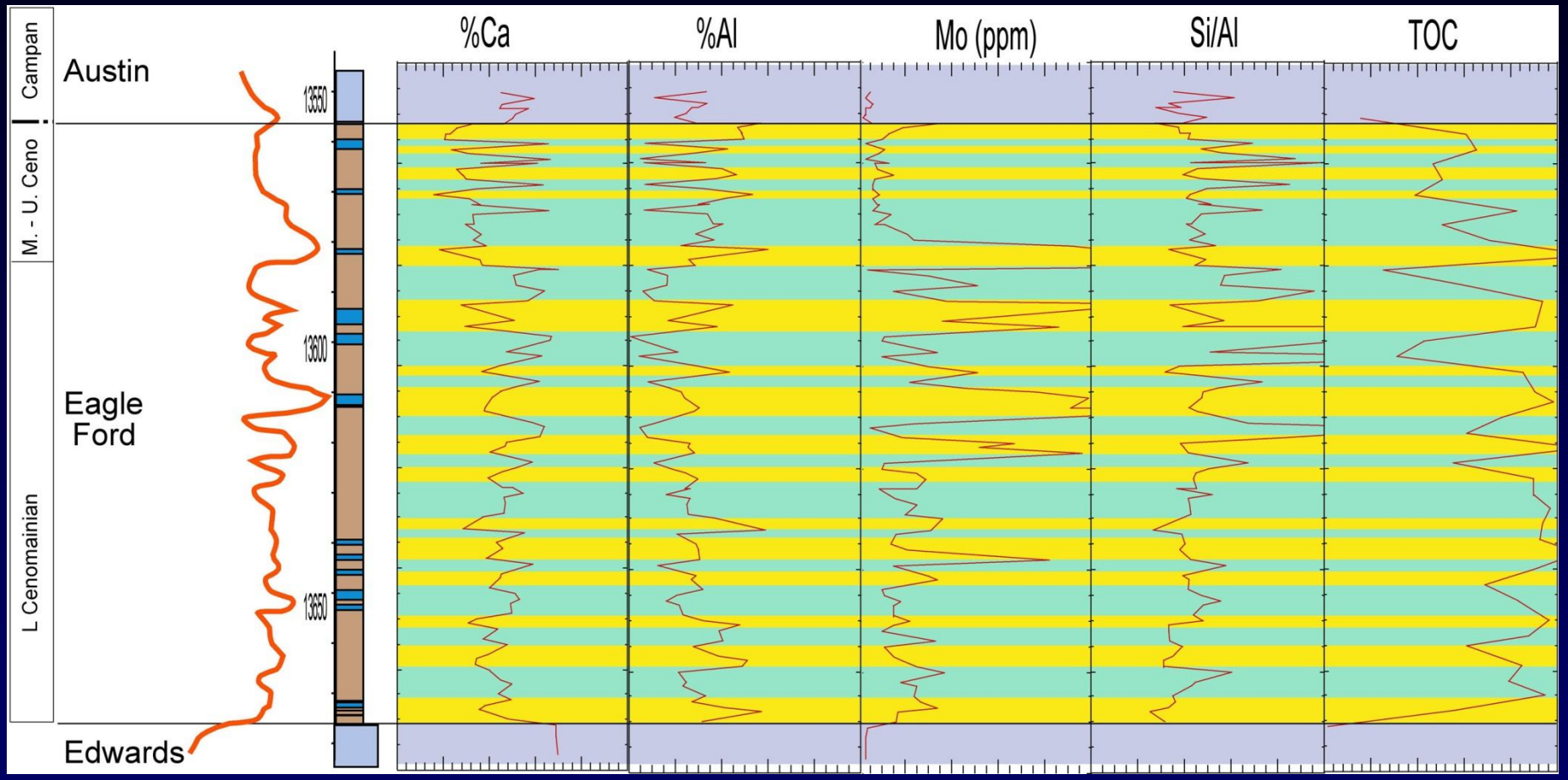
- Distal, laminated to massive nanoplankton-foram calcareous mudrock



Geochemical Model for Sample Mineralogy



High Resolution Facies Definition from Geochemistry



Foram-nanoplankton packstone

Calcareous nanoplankton mudrock

Stuart City Margin, Maverick Basin