GEOCHEMISTRY OF THE NIOBRARA FORMATION AND OCEANIC ANOXIC EVENT III (OAE III): A REGIONAL STUDY IN THE WESTERN INTERIOR SEAWAY

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COLORADO SCHOOL OF MINES
MUDTOC

Outline

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- Introduction
- Overview of Late Cretaceous Events and the Niobrara Formation
- Geochemistry of OAE III in Denver Basin
  - Stable Isotope and Trace Elements Geochemistry of OAE III
- Changes in Organic Matter Composition
  - Source Rock Potential of the Niobrara Formation in the Western Interior Seaway
  - Biomarker Geochemistry of the Niobrara Formation Across the Western Interior Seaway
- Nutrient recycling, Paleoproductivity, and Paleoclimate of OAE III
  - Denver Basin
  - Western Interior Seaway
  - Hydrography of the Western Interior Seaway
- Conclusions
- Future Research Suggestions

Introduction

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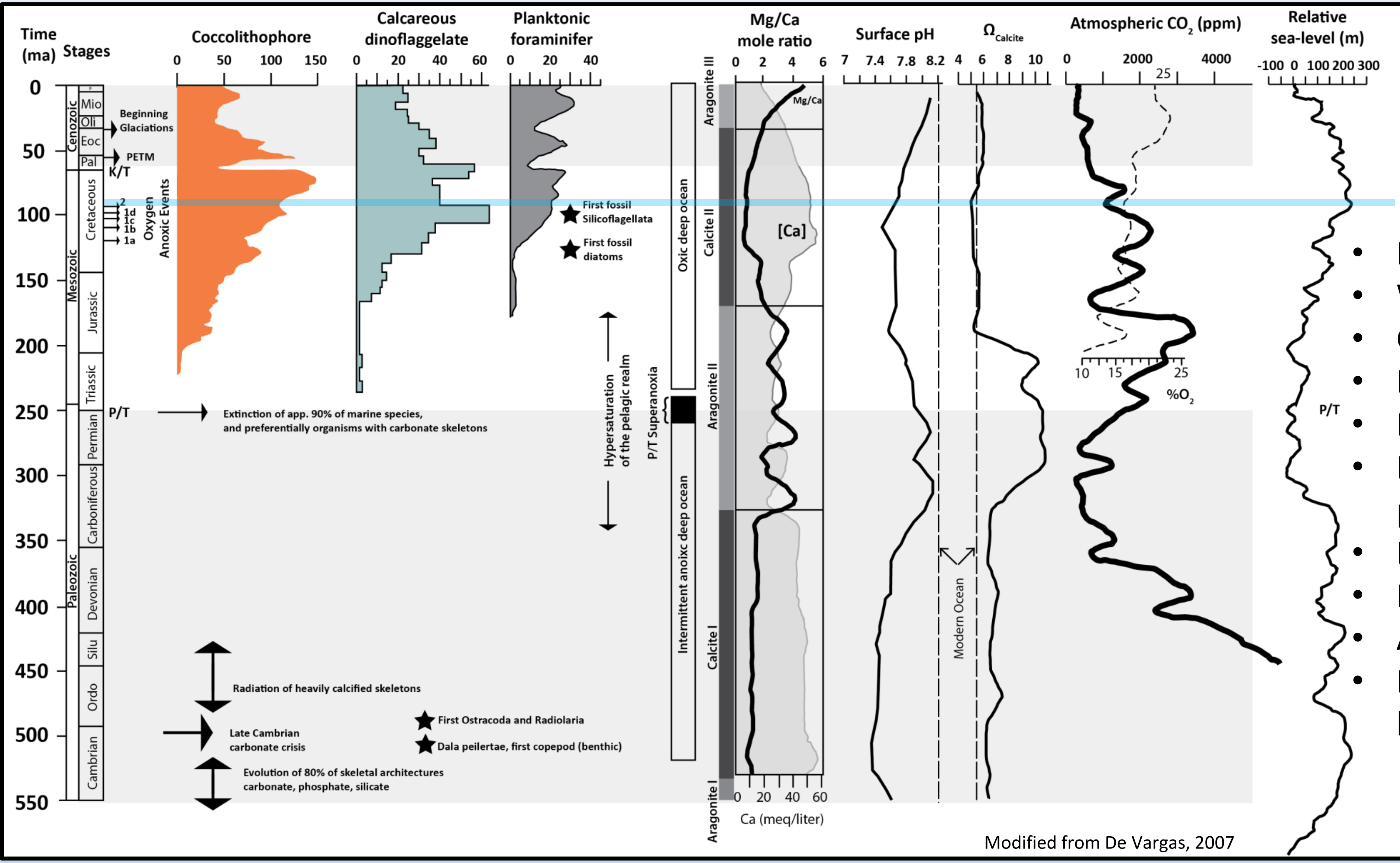
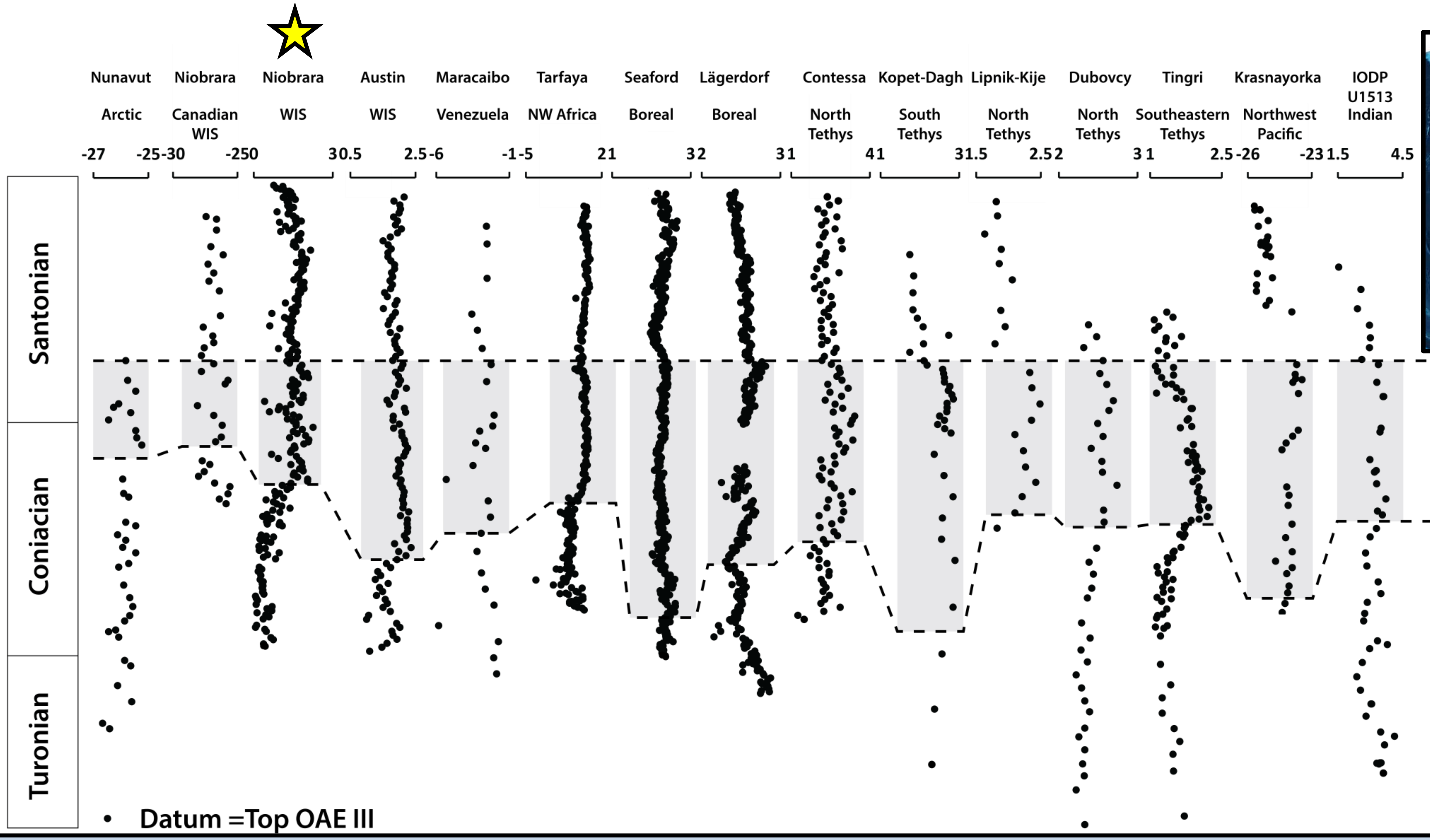
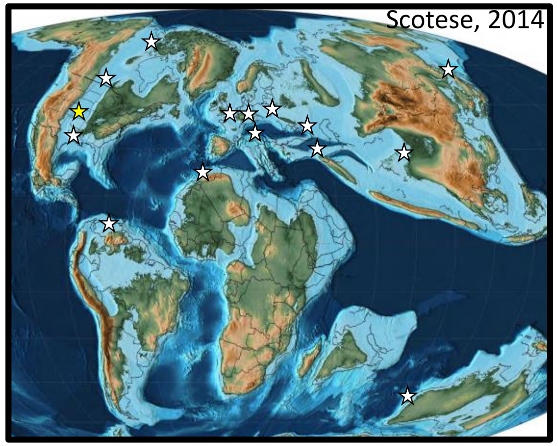


- Paleogeography
- Warmer surface temperatures
- Greenhouse conditions
- Lack of polar ice caps
- Rising sea-level conditions
- First appearance of flowering plants
- Diversification of insects
- Radiation of diatoms
- Abundant planktons
- Record contribution to biomass

Modified from De Vargas, 2007

Coniacian - Santonian





- Global vs. regional nature of the OAE III requires reassessment
- Carbon isotope trends can be correlated (CIE)
- The anoxia is not global (OAE)
- Positive carbon isotope excursion is global not confined to oceans

Oceanic Anoxic Events

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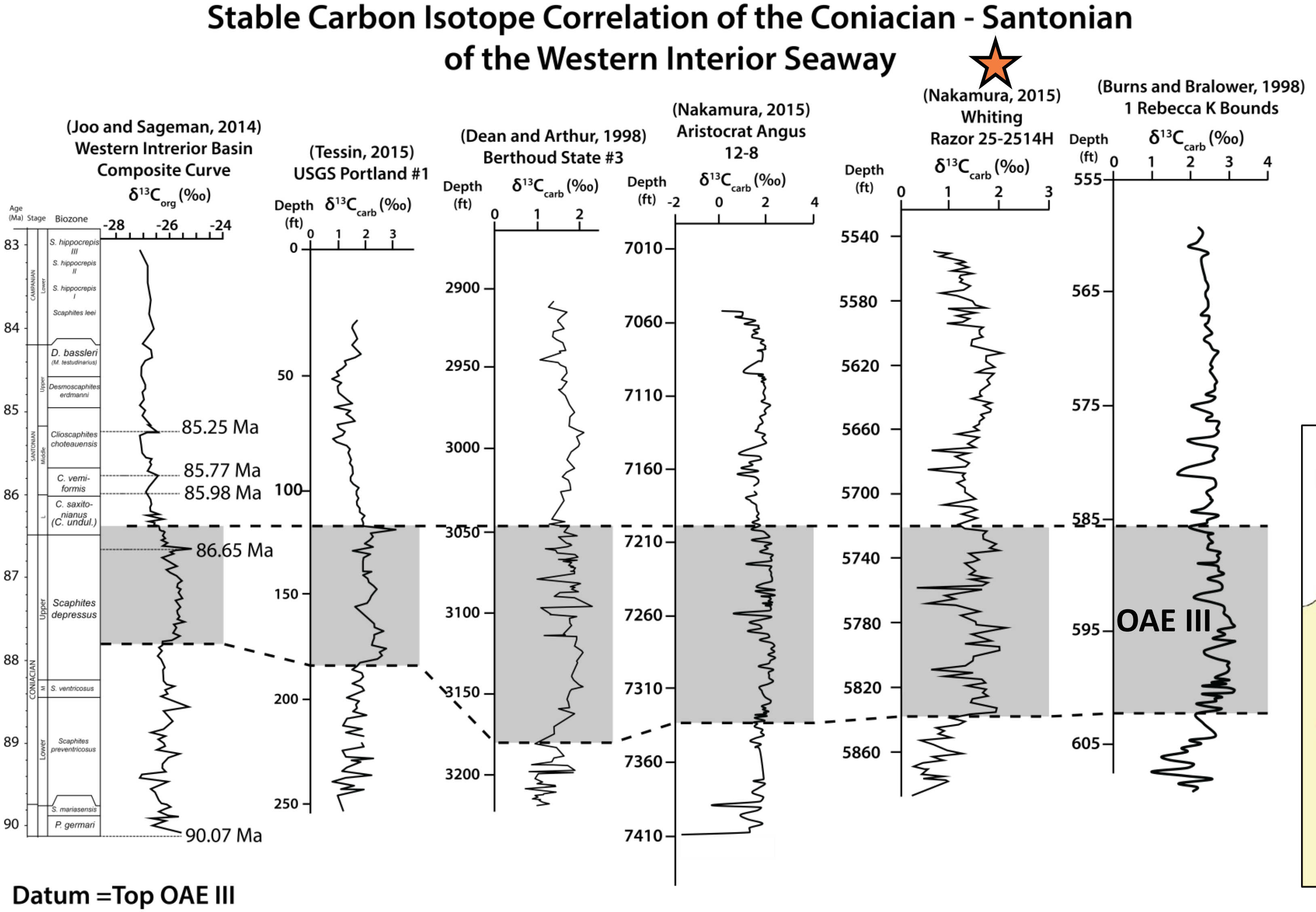
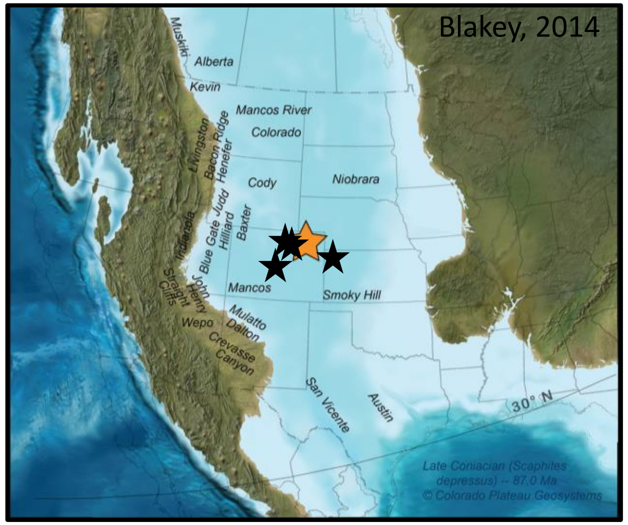
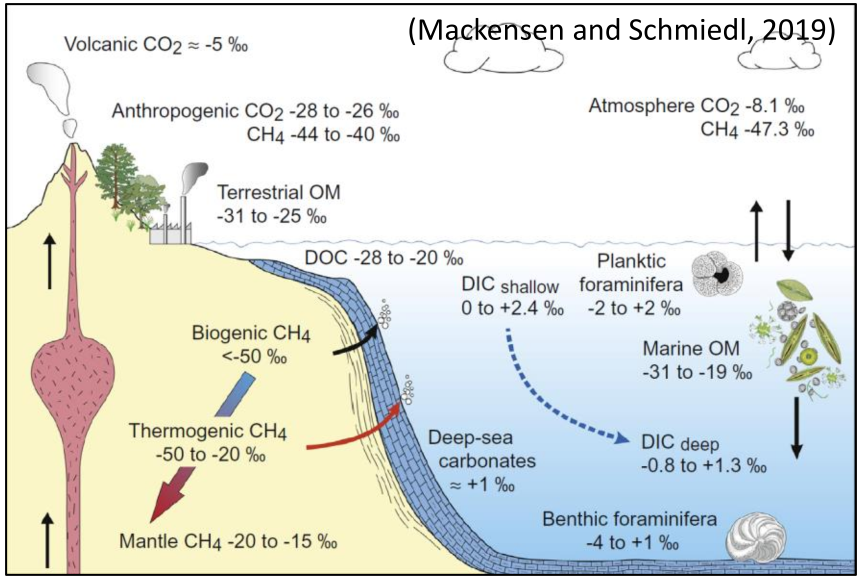
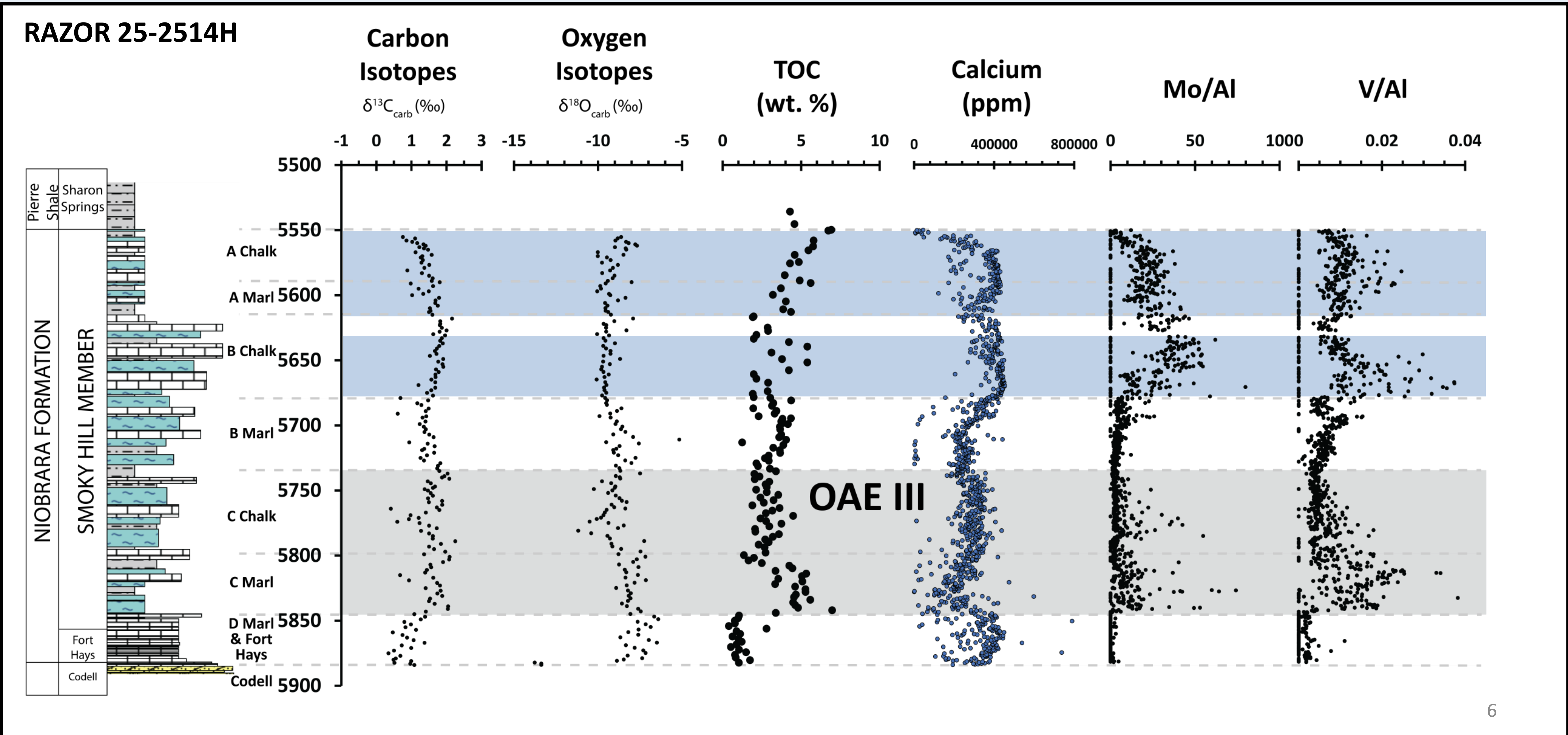


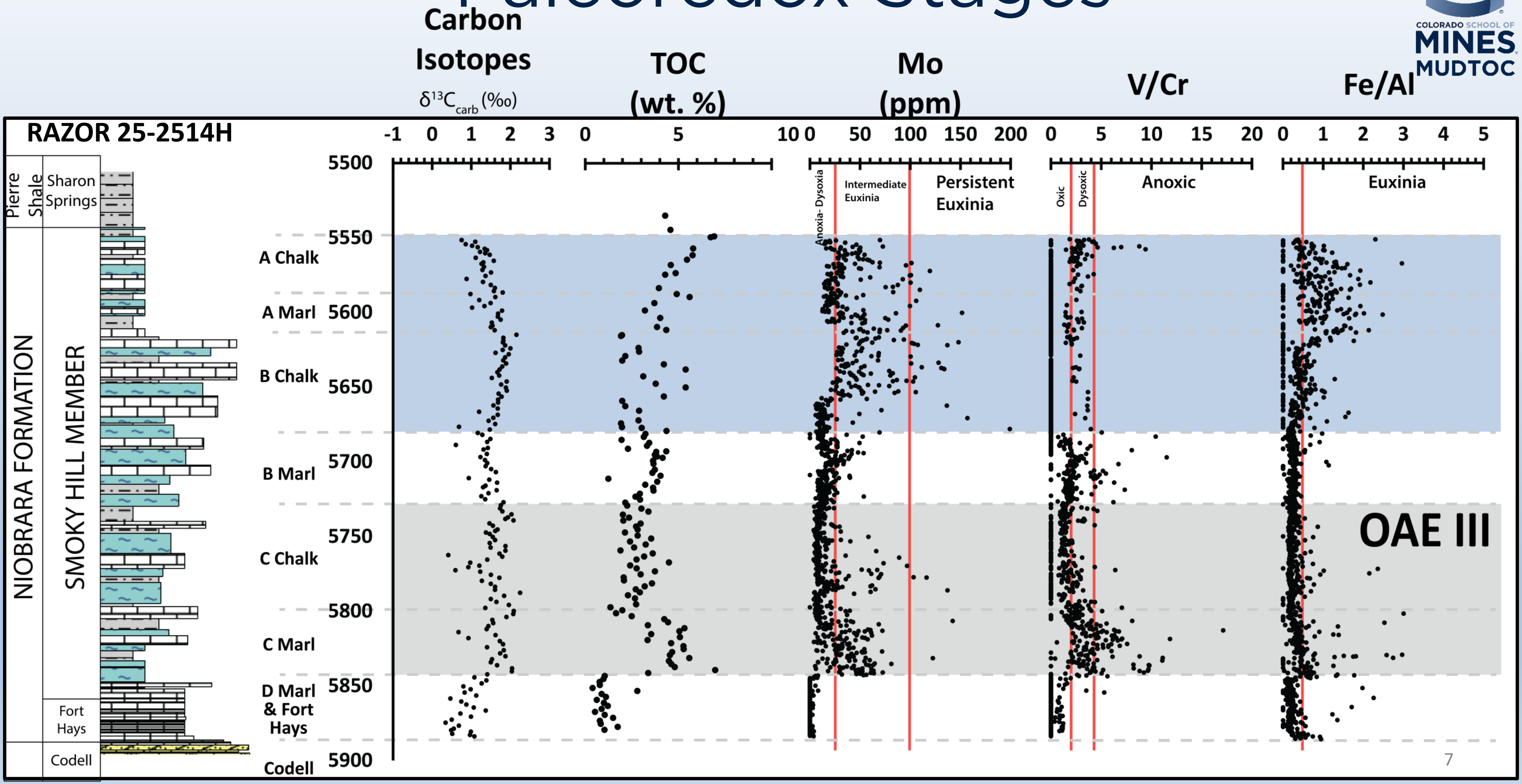




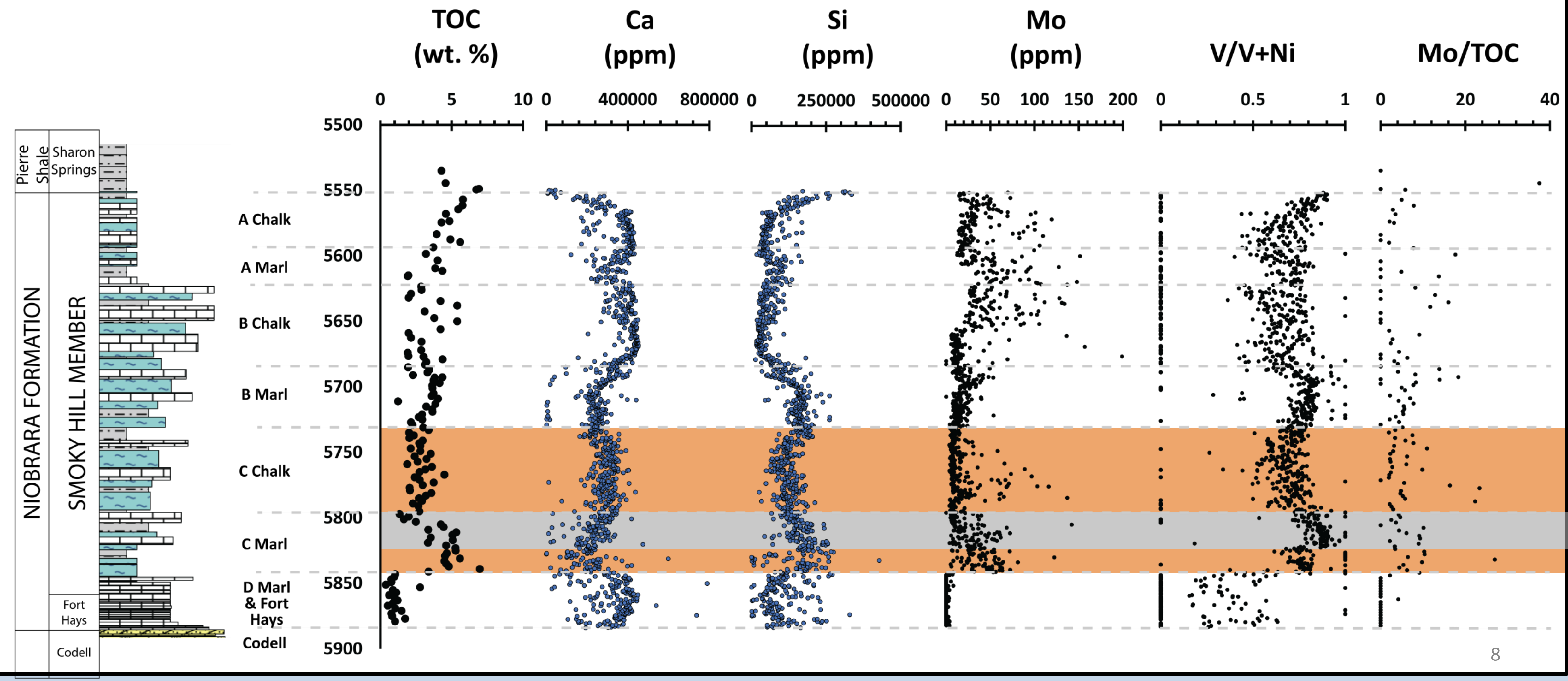
Oceanic Anoxic Event III



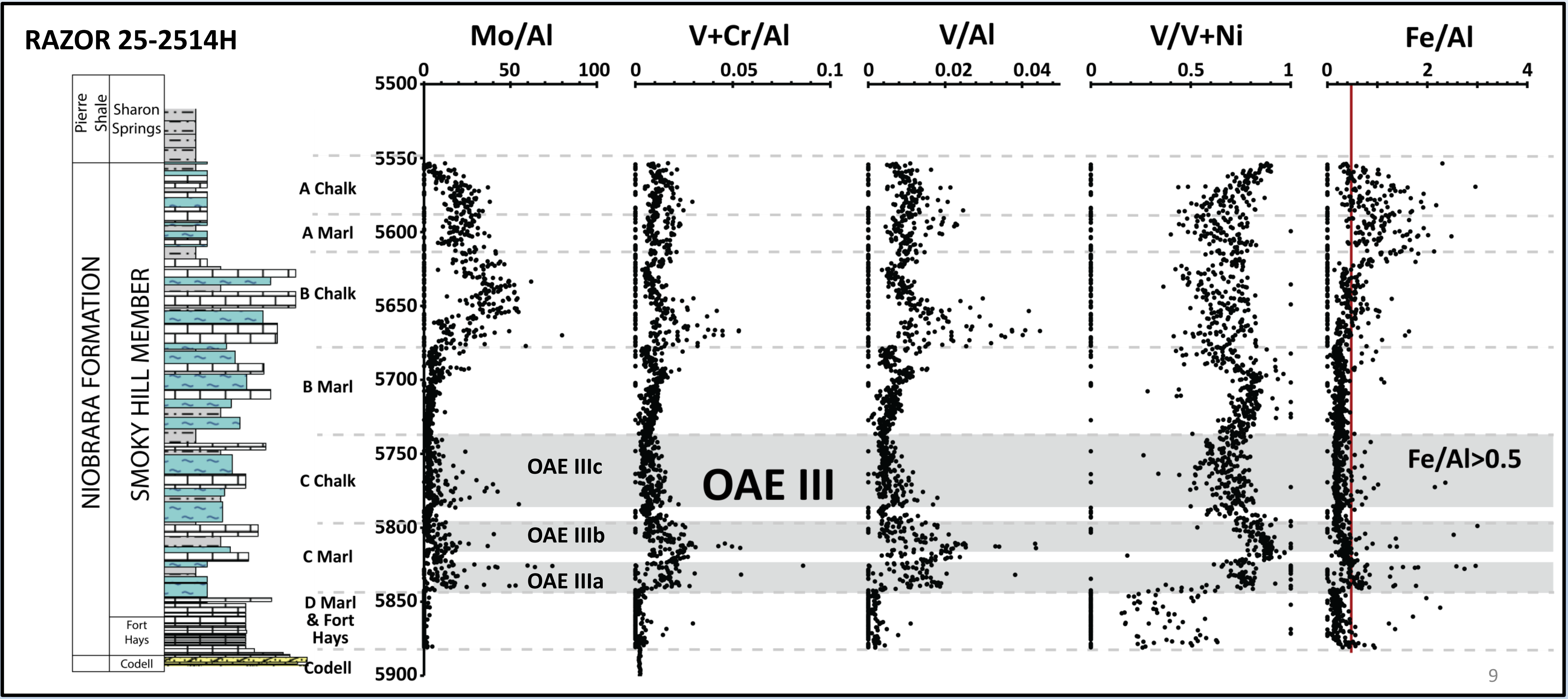
Paleoredox Stages



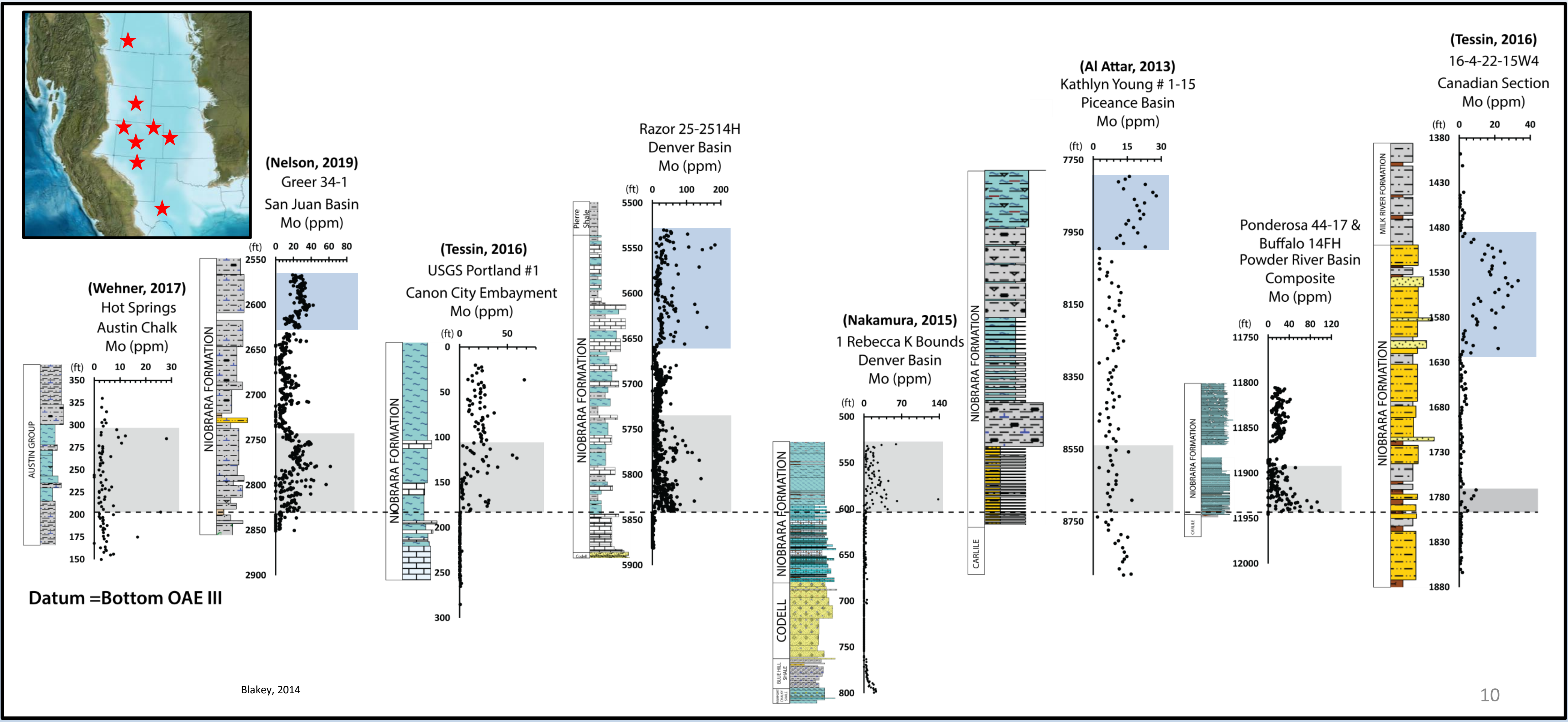
Water Column Stratification and Deep Water Mass Restriction



OAE III Subdivision



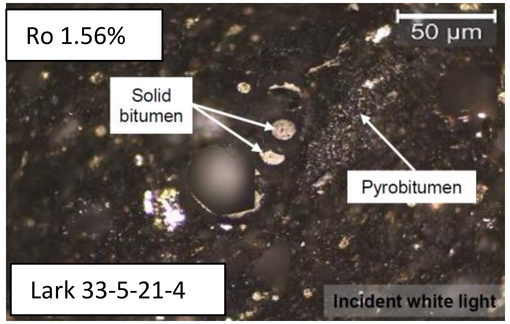
OAE III in the WIS



Source Rock Potential

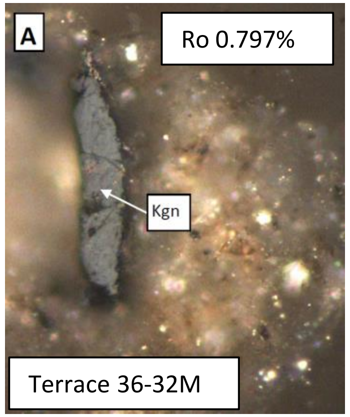
- Kerogen type II to II/III
- Depends on the location in WIS
- Close proximity to Sevier Highlands result in more woody material
- Oil and gas production

San Juan Basin

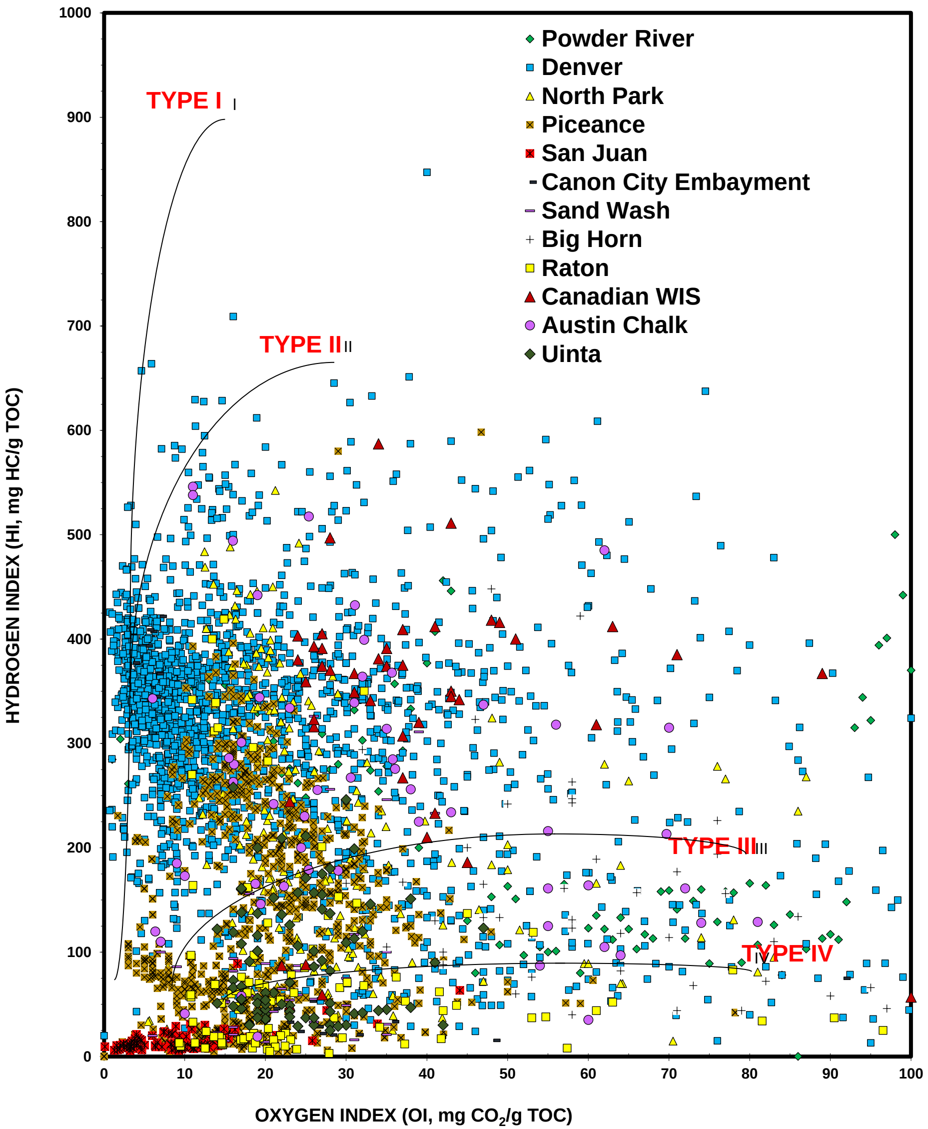


Red Willow

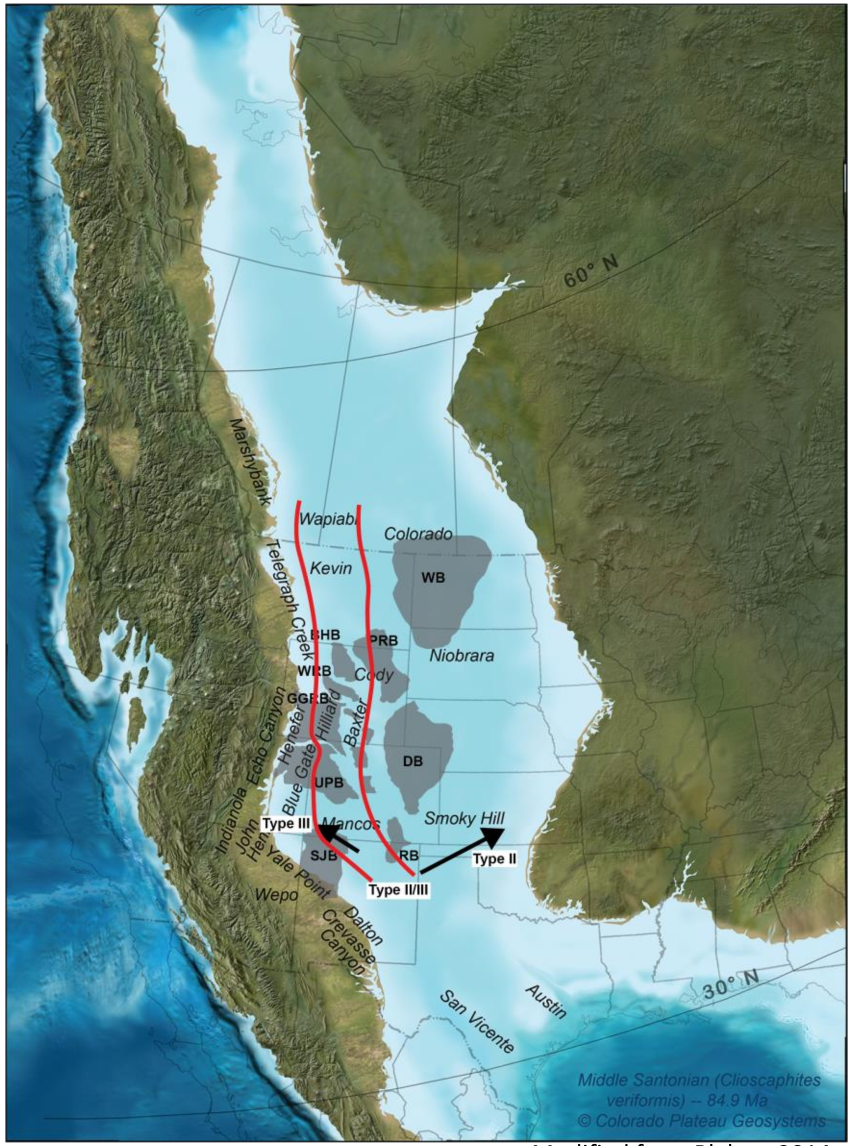
Denver Basin



Whiting

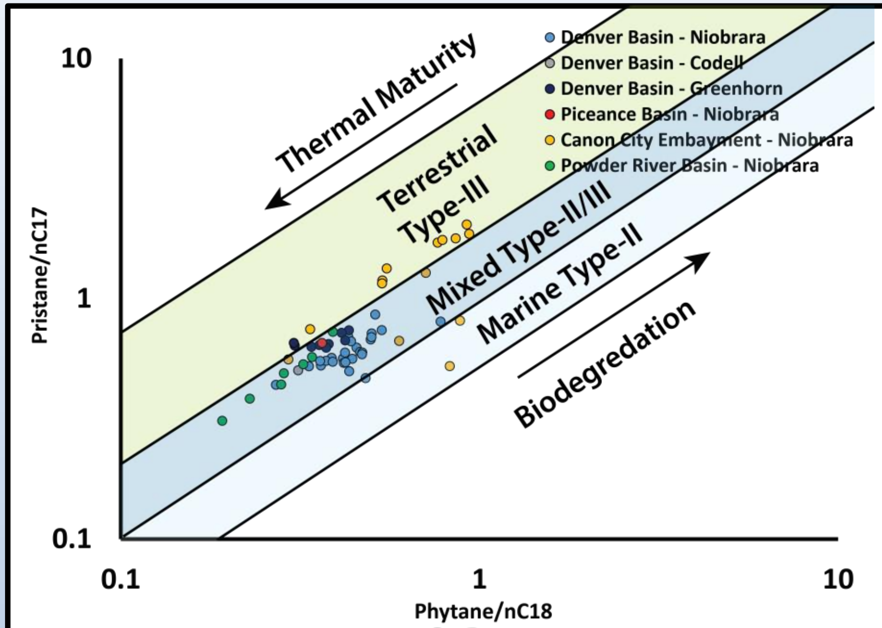


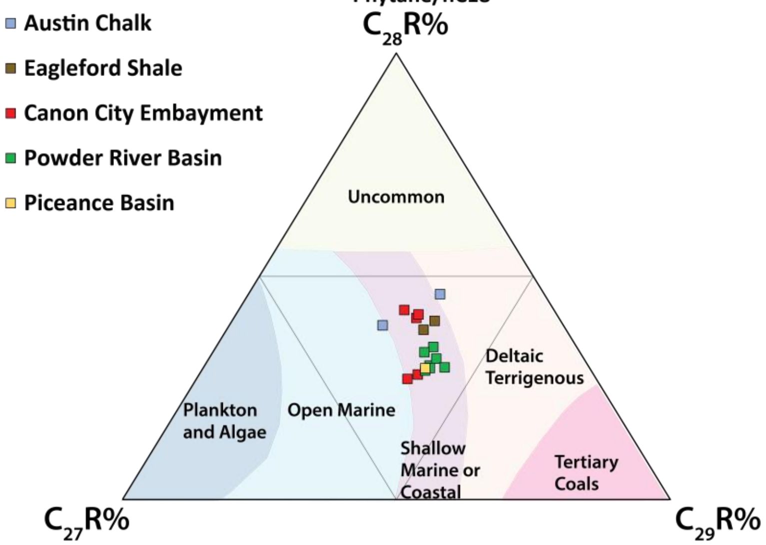
Data compiled from past studies, USGS, and the literature. Template modified from Weatherford Labs



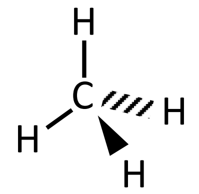
Modified from Blakey, 2014

Biomarker Geochemistry



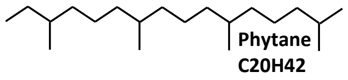


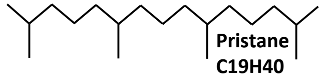
- n-alkanes
  - Concentrate along nC_{15} to nC_{19} indicating marine algae
  - nC_{25}+ present as terrestrial influence



N-alkane CH_4 Methane

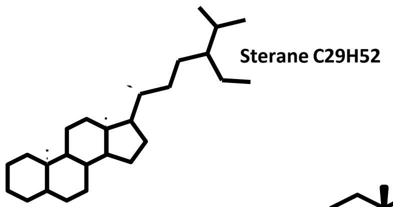
- n-alkanes vs. isoprenoids

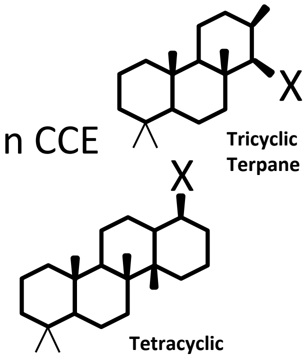




  - Pristane and phytane not always the most reliable proxy
  - Niobrara is type II/III
  - CCE samples higher biodegradation

- Steranes $C_{27} – C_{28} – C_{29}$
  - Algae – Shallow Marine/Coastal
- Steranes/Triterpanes
  - Piceance Basin stronger benthic conditions than CCE
  - PRB not resolved on GC
- C30 Sterane Index
  - More algal contribution in CCE than Piceance



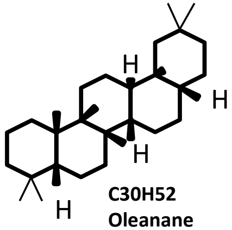


Tricyclic Terpane

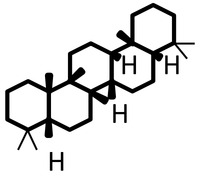
Tetracyclic Terpane

Biomarker Geochemistry

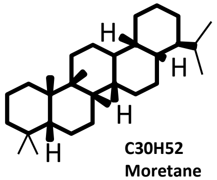
- Dinosteranes
  - Dinosterane index - CCE vs. Piceance
- Ol/H
  - Hypersalinity
  - Terrestrial input
- Ga/H
  - PRB more anoxic than CCE and Piceance
- Mo/H
  - Hypersalinity
  - Austin Chalk more hypersaline than CCE and Piceance
- Steranes/Hopanes
  - Eukaryotic vs. prokaryotic input
  - Maturity increases the ratio (Piceance)
  - CCE – mix of algae and bacteria



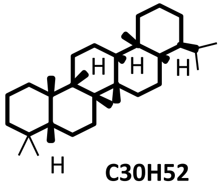
C30H52 Oleanane



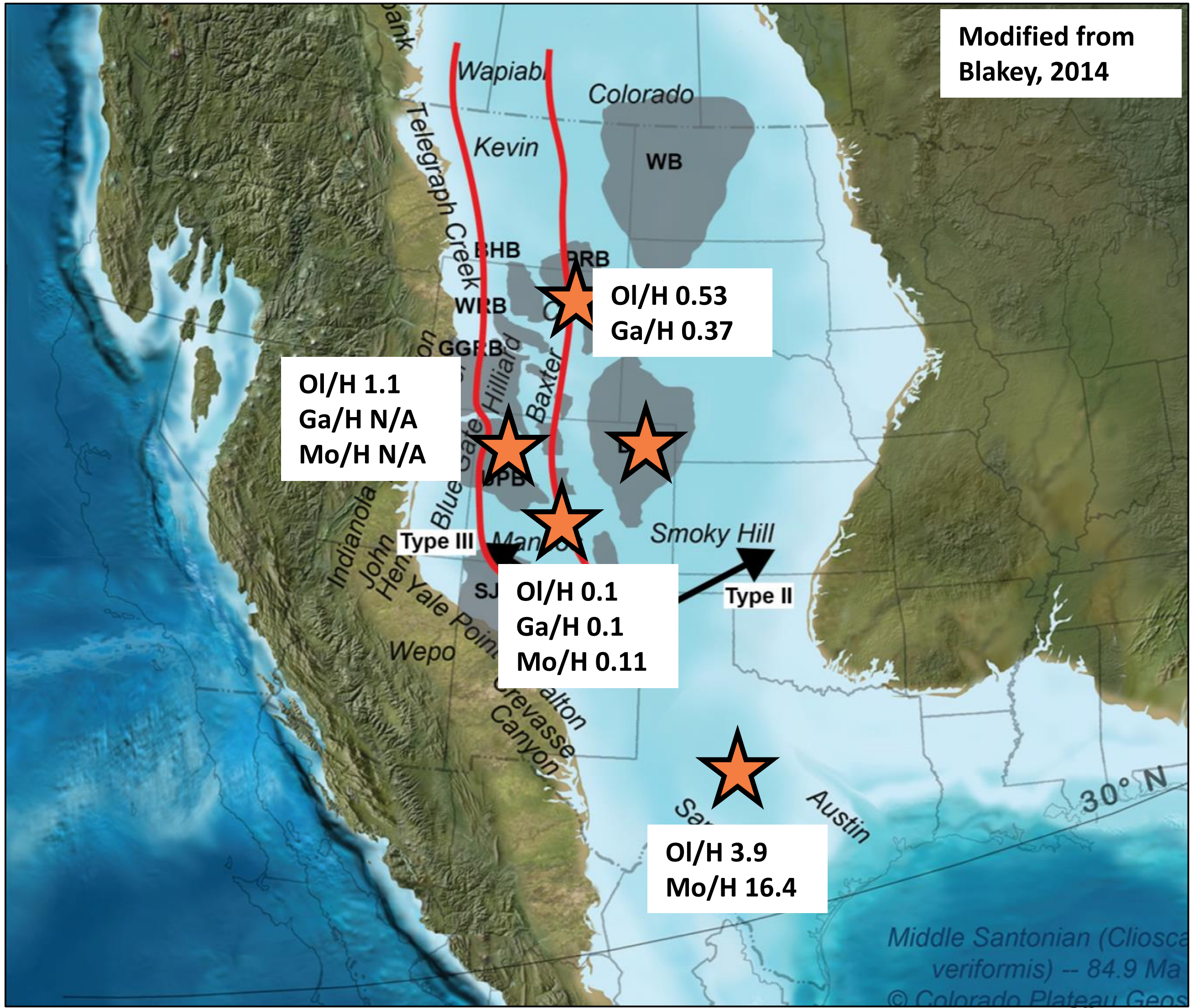
C30H52 Gammacerane



C30H52 Moretane



C30H52 Hopane



Organic Matter Composition Change

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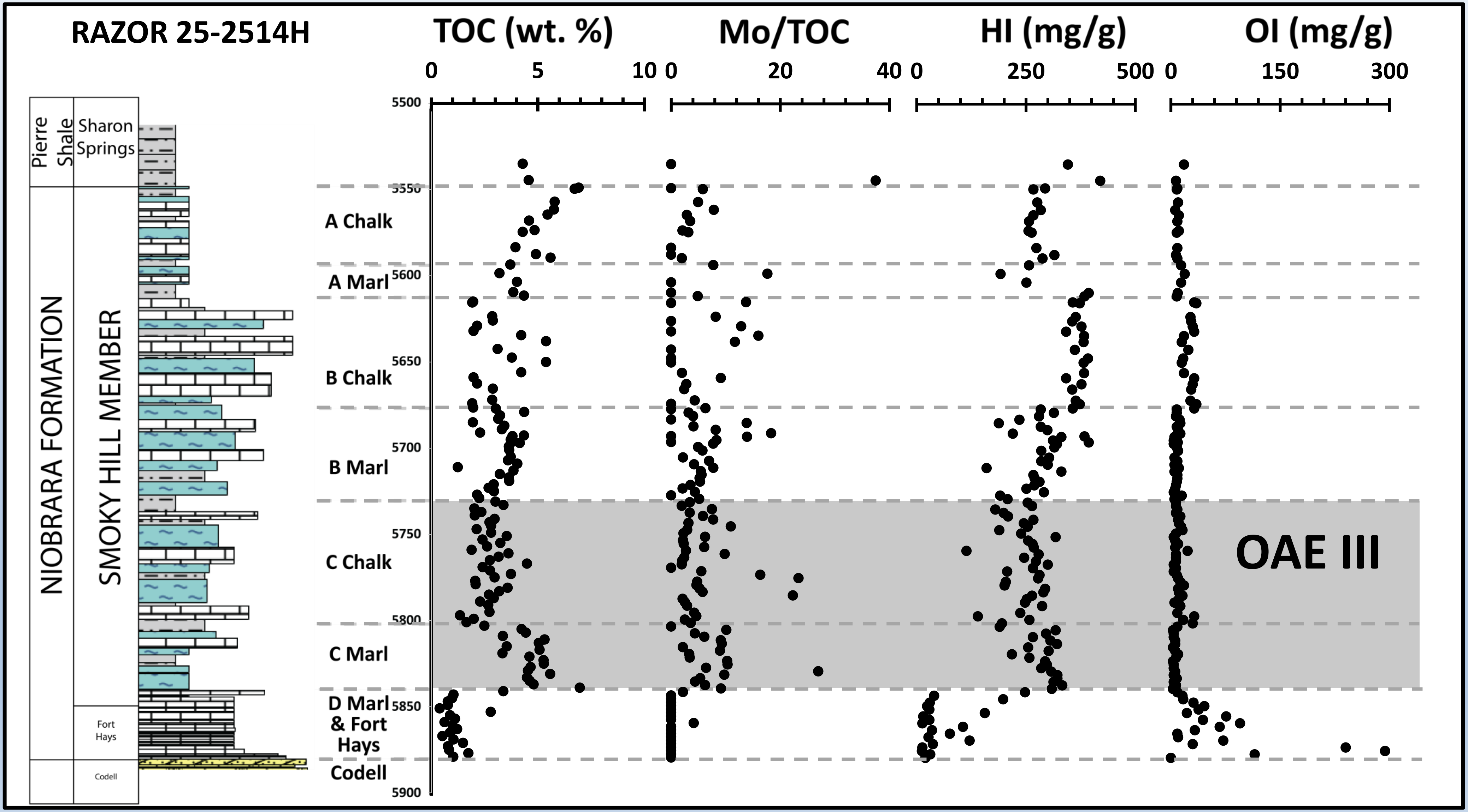
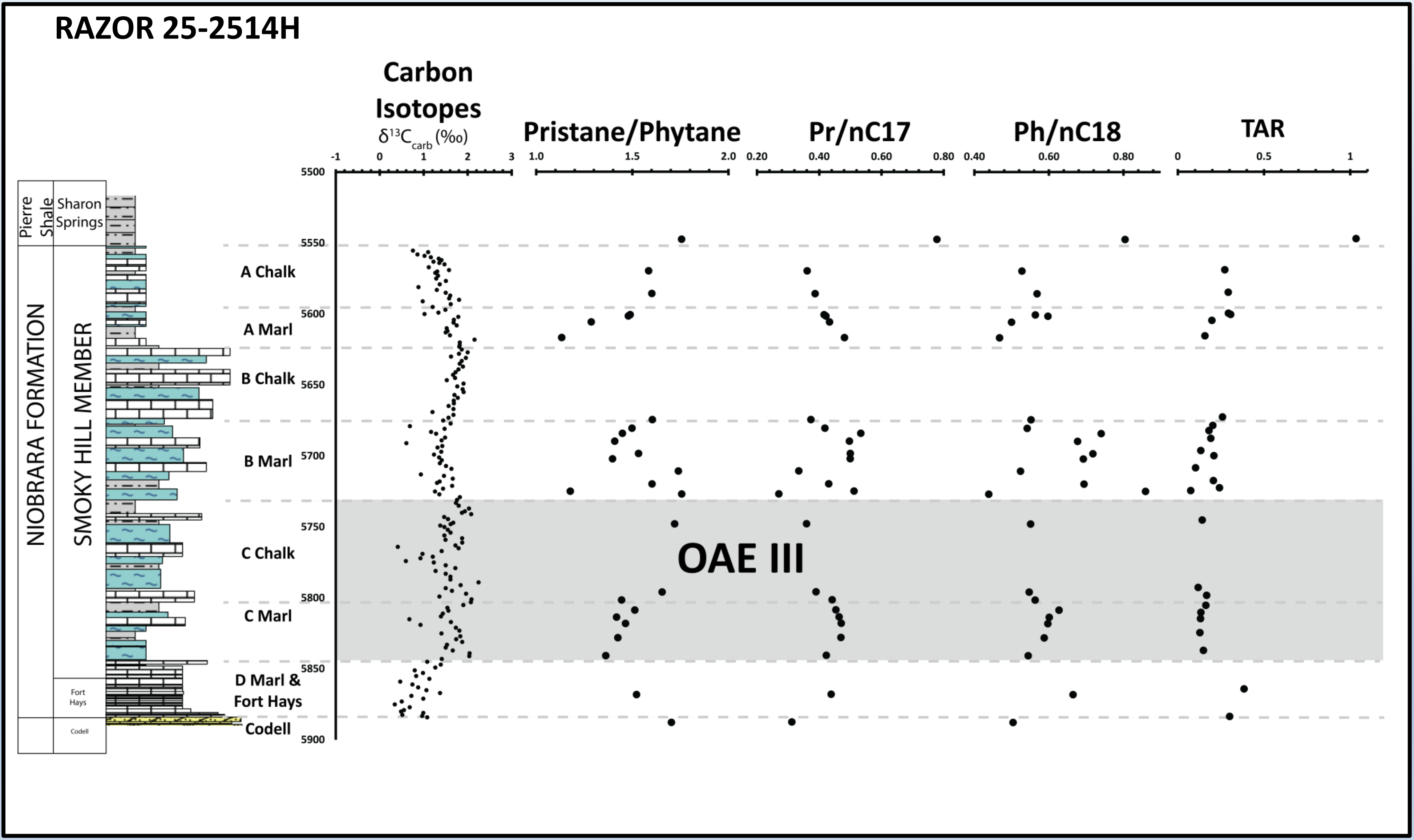
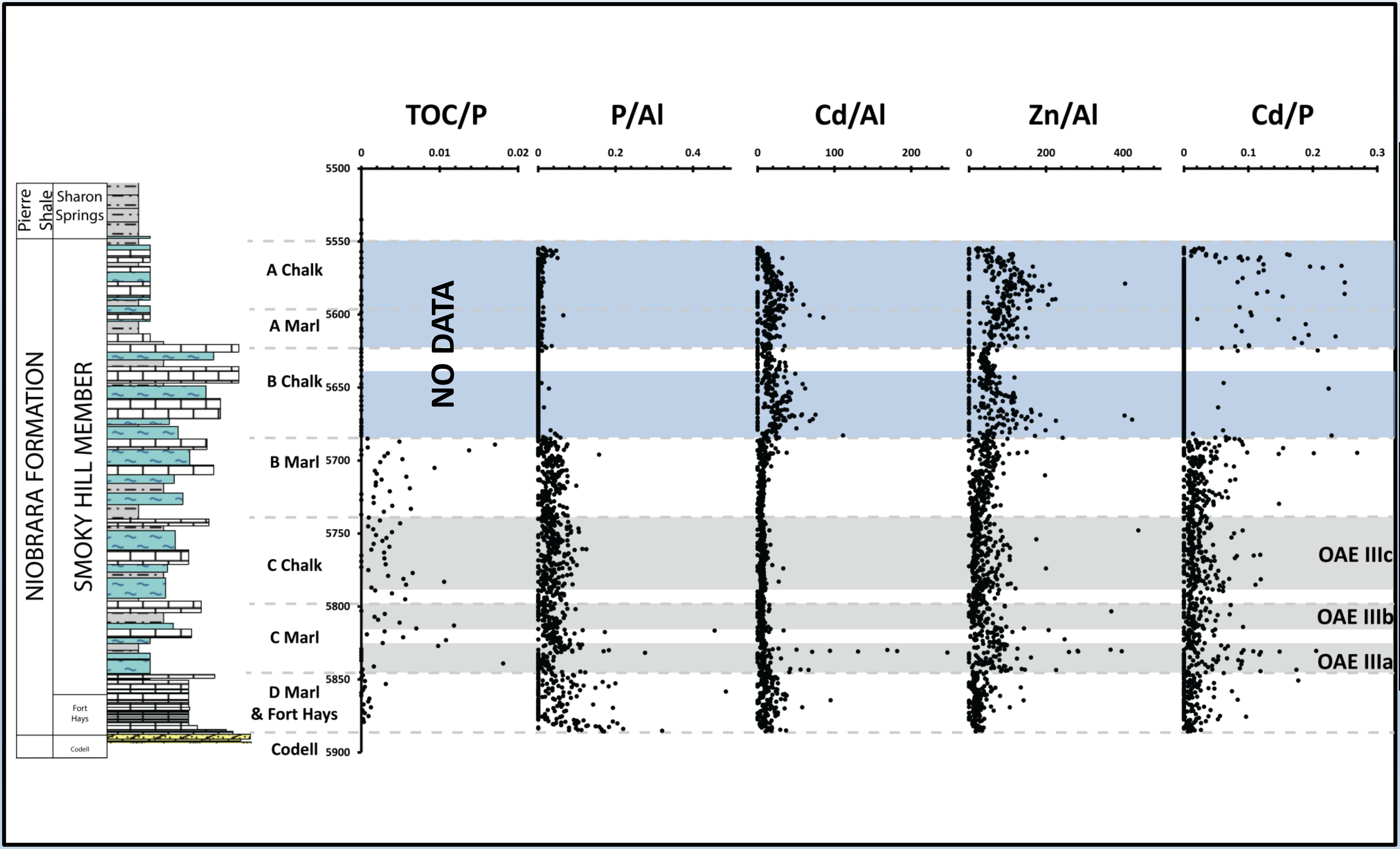


Organic Matter Composition Change



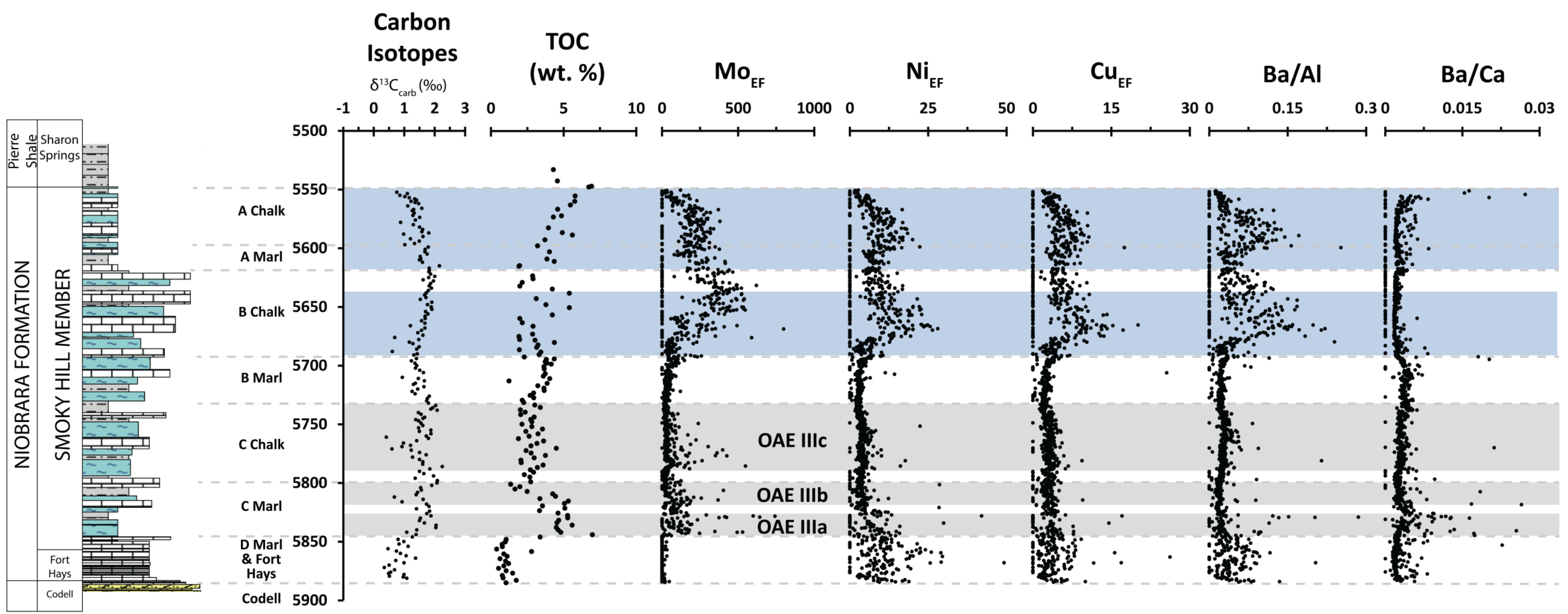
- Pr/Ph indicate oxygen depletion
- Pr/Ph not a reliable indicator
- OM composition changed
- More algae influence

Nutrient Recycling in Denver Basin

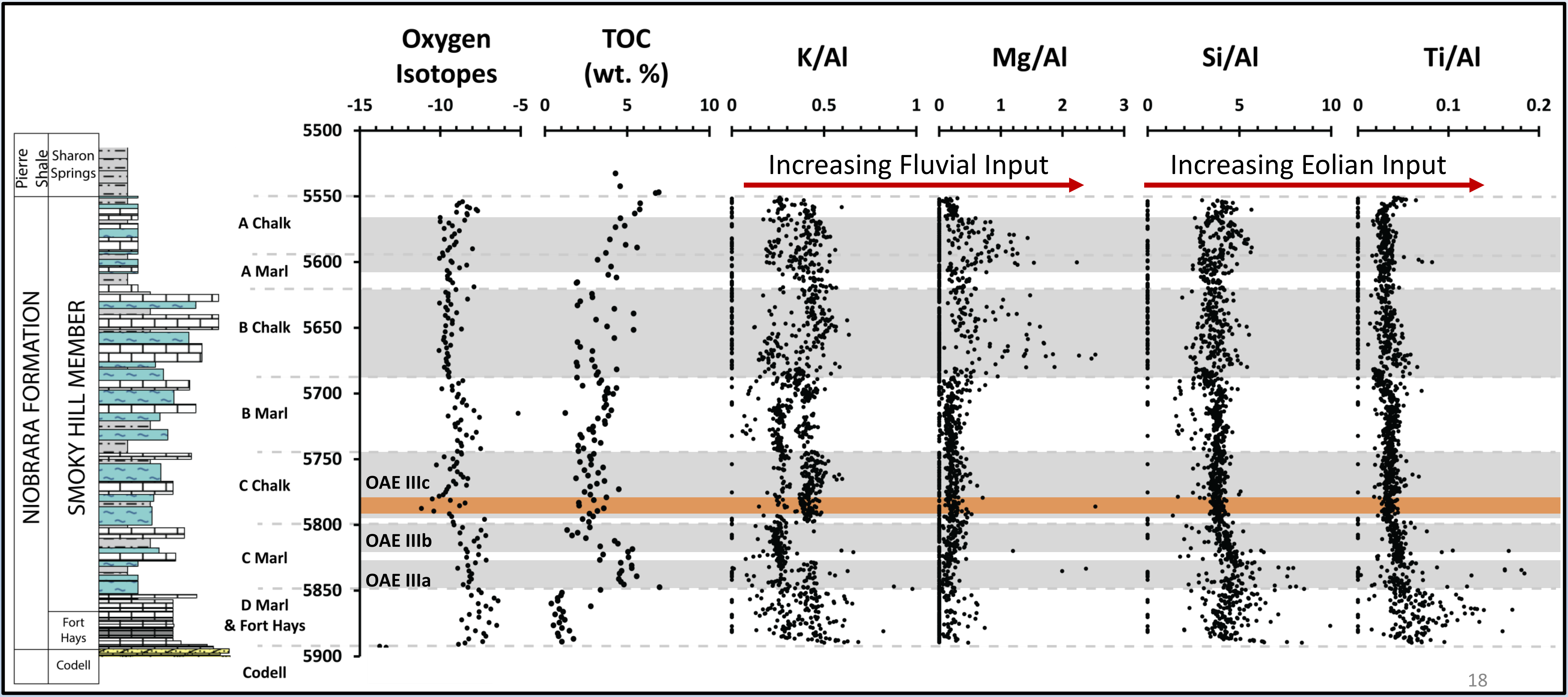


- P and Cd loss/retention
- P associated with redox
- Cd nutrient-like behavior
- Nutrients leave pore waters
- Continuous nutrient recycling = Increased Surface Production
- Pre-OAE Ph, Eh, and Salinity
- Zn increase – Algal population increase and increased rates of continental weathering
- ZnS or [Zn, Fe]S

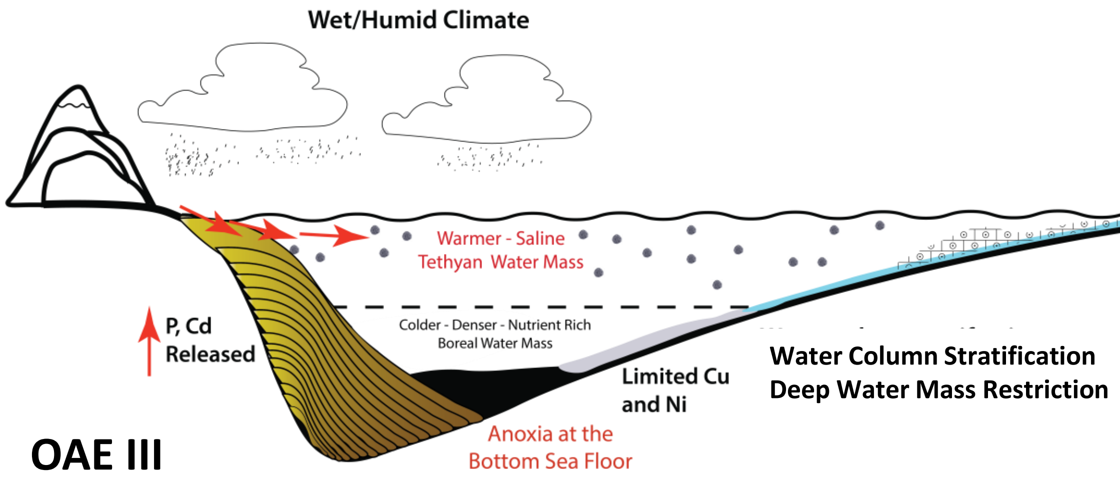
Paleoproductivity



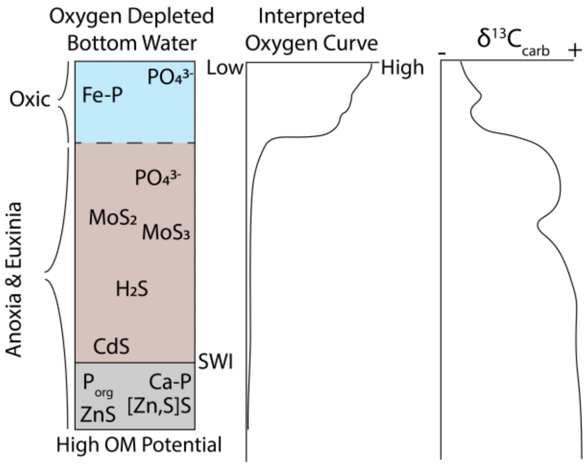
Paleoclimate – Dry vs. Wet/Humid

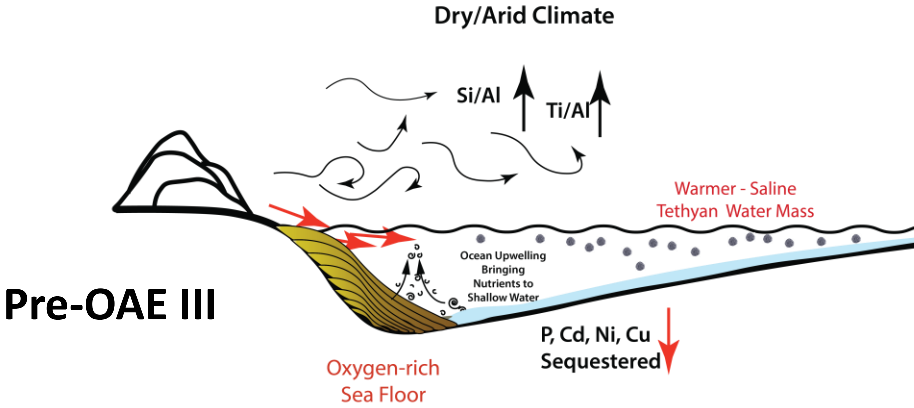


Hydrographic Model of OAE III

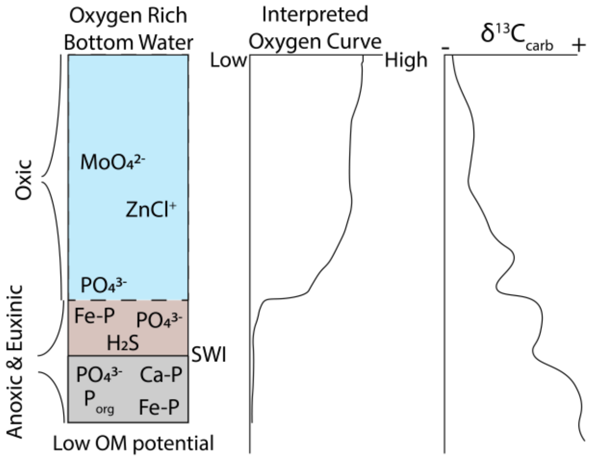


- •Higher K/Al and Mg/Al
- •Lower Si/Al and Ti/Al
- •P and Cd recycled
- •Higher Ba/Ca at the onset
- •Ni and Cu recovery
- •Higher Zn due to weathering
- •Higher TOC preservation
- •Carbon composition heavier

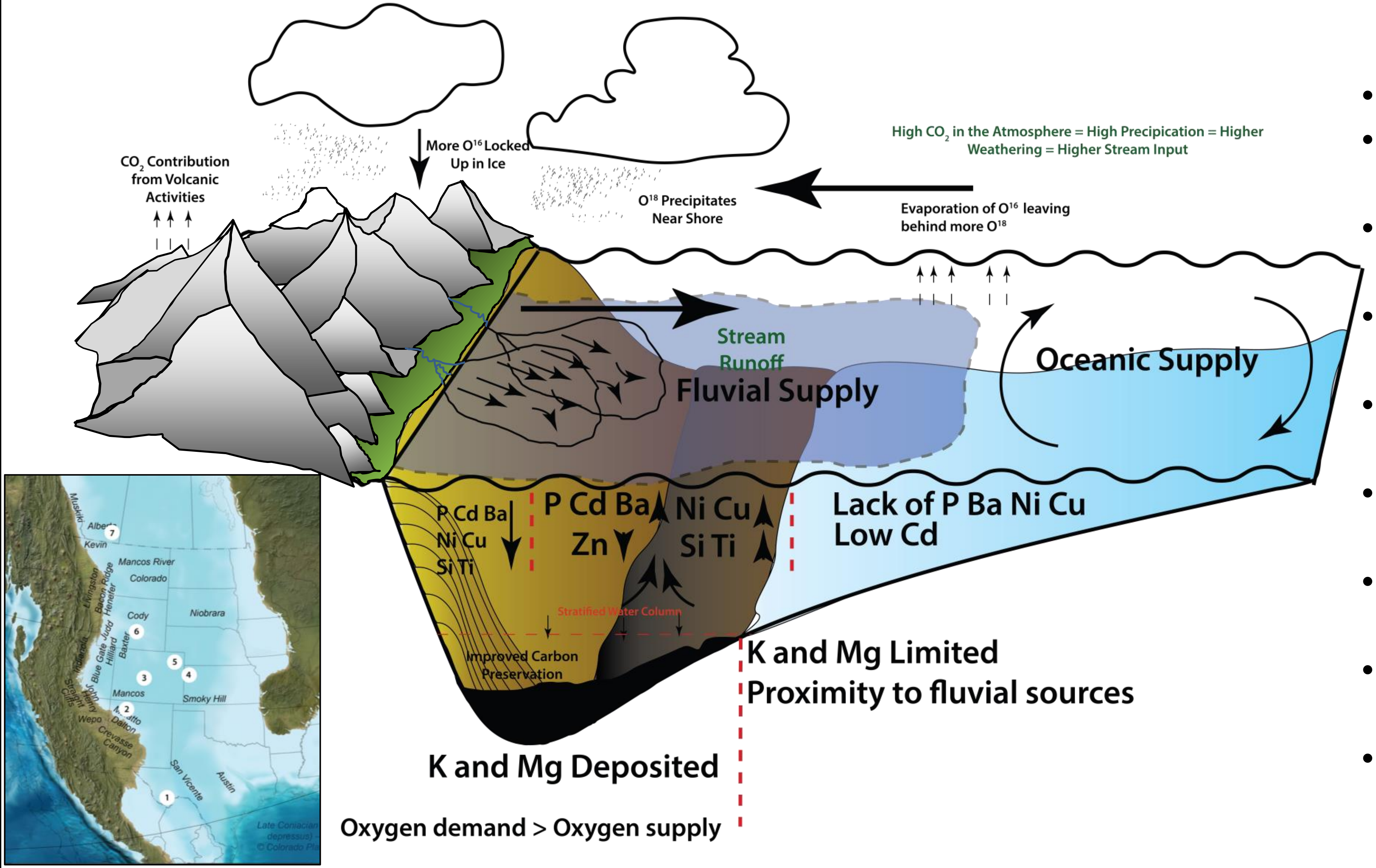




- •High K/Al and Mg/Al
- •Higher Si/Al and Ti/Al
- •P and Cd sequestered
- •Ni and Cu abundant
- •Low Zn - Lesser degree of continental weathering
- •Lower TOC preservation
- •Carbon composition lighter



Hydrography of the WIS



- Trends vary
- East – Central – West differs geochemically
- Deposition of elements focus on the western areas
- Redox control on deposition of nutrients
- Zn might be responsible from low Cd preservation
- Ni and Cu preservation depends on sulfate reduction
- Western parts display fluvial supply is not constant
- K and Mg deposition limited in east
- Ti and Si decreases - dry to humid

Conclusions

- OAE III is not anoxic globally – the CIE is global
- OAE III is better accentuated in the WIS and is a non-continuous series of oxygen depleted conditions
- Water column stratification and deep-water mass restriction were established
- Oxidizing conditions prevalent before the OAE III in the WIS
- WIS becomes oxygen depleted during the OAE III – Dysoxic to Euxinic – At least three distinct and stages
- Mo trends correlate across the WIS but with varying intensities
- OM composition changes during the OAE III, the OM deposited under anoxia based on SRA parameters and biomarkers
- Nutrients (P, Ba and Cd) are recycled leading to elevated productivity
- Cu and Ni limited at the onset of the OAE III but recovered during the C chalk deposition

Suggested Future Work

- High-resolution datasets are necessary to capture details
- B chalk, A marl, A chalk geochemistry – renewed anoxia
- Benthic foram stable oxygen isotopes in the WIS
- Os and Re isotopes – structural deformation/volcanism
- Sr isotopes for continental weathering rates
- Ba/Ca and Cd/Ca from foram samples
- Complete cores of the Niobrara Formation from the Rocky Mountain Basins
- Behavior of sulfides and sulfates in the Niobrara Formation
- Fe, Ba, Cd, P, Si, Ca, Mo, Zn, Ag, Cu, and Ni isotopes for paleoproductivity
- Biostratigraphic studies
- Nd isotopes – ocean circulation pathways

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