Rapid Paleoenvironmental Change during the Paleocene-Eocene Thermal Maximum (PETM), Bighorn Basin, WY*

Mary J. Kraus[1], Daniel Woody[1], Jon Smith[2], and Stephen Hasiotis[2]

Search and Discovery Article #50160 (2009)
Posted January 16, 2009

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, TX, April 20-23, 2008

[1]Dept of Geological Sciences, University of Colorado, Boulder, CO. (mary.kraus@colorado.edu)
[2]Department of Geology, University of Kansas, Lawrence, KS.

Abstract

Interbedded alluvial paleosols and avulsion deposits were analyzed through a PETM section. Based on morphologic features, paleosol profiles can be assigned to a particular position along a paleosol continuum that ranges from well drained to poorly drained end members. Using this qualitative approach, paleosols in the main PETM interval developed under drier conditions than pre-PETM paleosols. Quantitative estimates of mean annual precipitation (MAP**)** using a paleosol climofunction confirm this conclusion. The paleosols also show that seasonality increased during the PETM. The stratigraphic distributions of manganiferous rhizoliths and crayfish burrows, both of which are absent or less common in the PETM part of the section, also show lower water tables and increased seasonality during the warming event.

The alluvial architecture also changes in the PETM interval. Avulsion deposits separate successive paleosols from one another through the section. Those in the main body of the carbon isotope excursion (CIE) are finer grained and less well developed than those below or above the PETM interval. Consequently, the avulsion deposits tend to be incorporated into the paleosols, and paleosols are more densely spaced. The thick red paleosols that characterize the PETM interval are the result of the welding of vertically superposed paleosols. Paleosol complexity also changes. Multiple horizons and intense overprinting of pedogenic features dominate paleosols in the main body of the CIE. In contrast, paleosols directly above and below the PETM interval are relatively simple, with few subdivisions of the B horizon(s) and fewer signs of pedogenic overprinting. These features suggest that sediment accumulation was slower and more episodic during the main body of the PETM interval than in deposits directly below and above. The changes in deposition are linked to climatic controls.

Rapid paleoenvironmental change during the Paleocene- Eocene Thermal Maximum (PETM), Bighorn Basin, WY

MARY KRAUS
and
DANIEL WOODY
Dept of Geological Sciences
University of Colorado

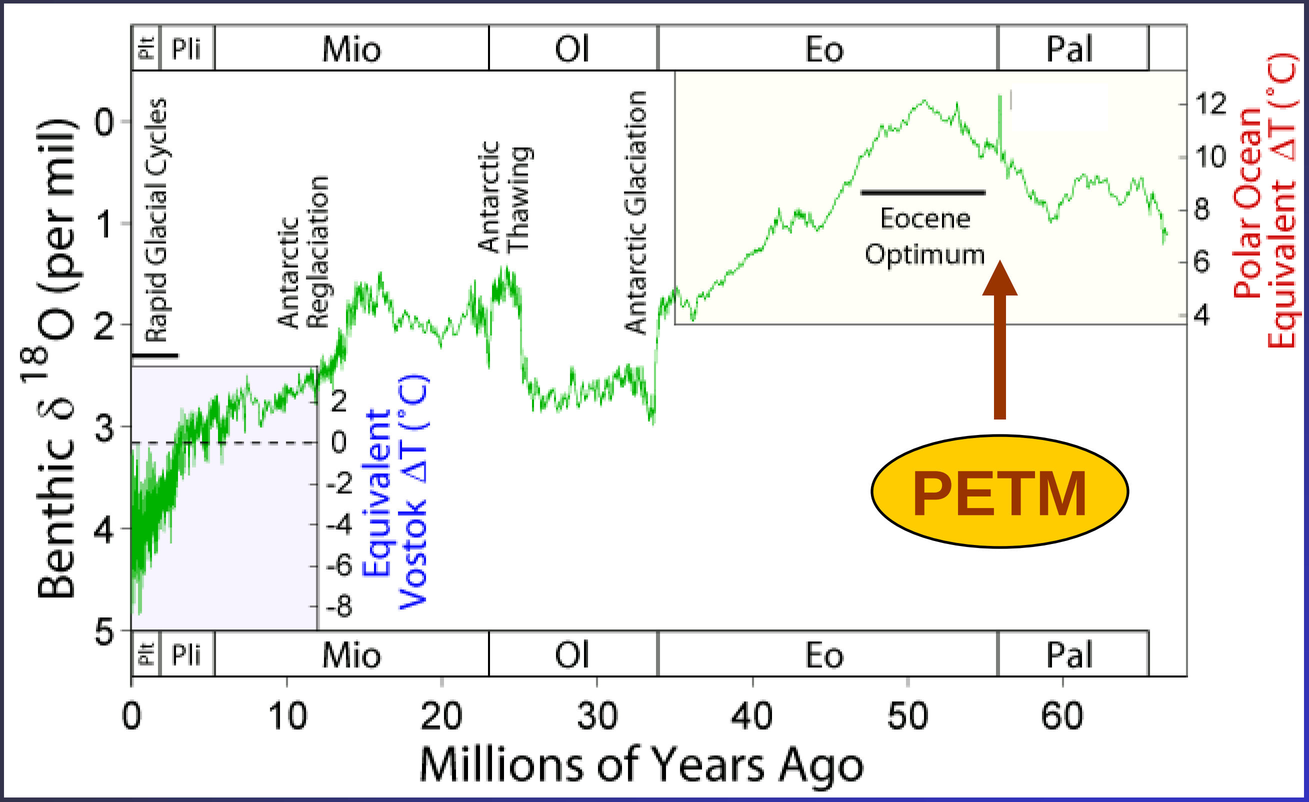
JON SMITH
and
STEPHEN HASIOTIS
Dept of Geology
University of Kansas

Acknowledgments

Kraus and Hasiotis thank:

National Science Foundation
WHERE DISCOVERIES BEGIN

Paleocene/Eocene boundary



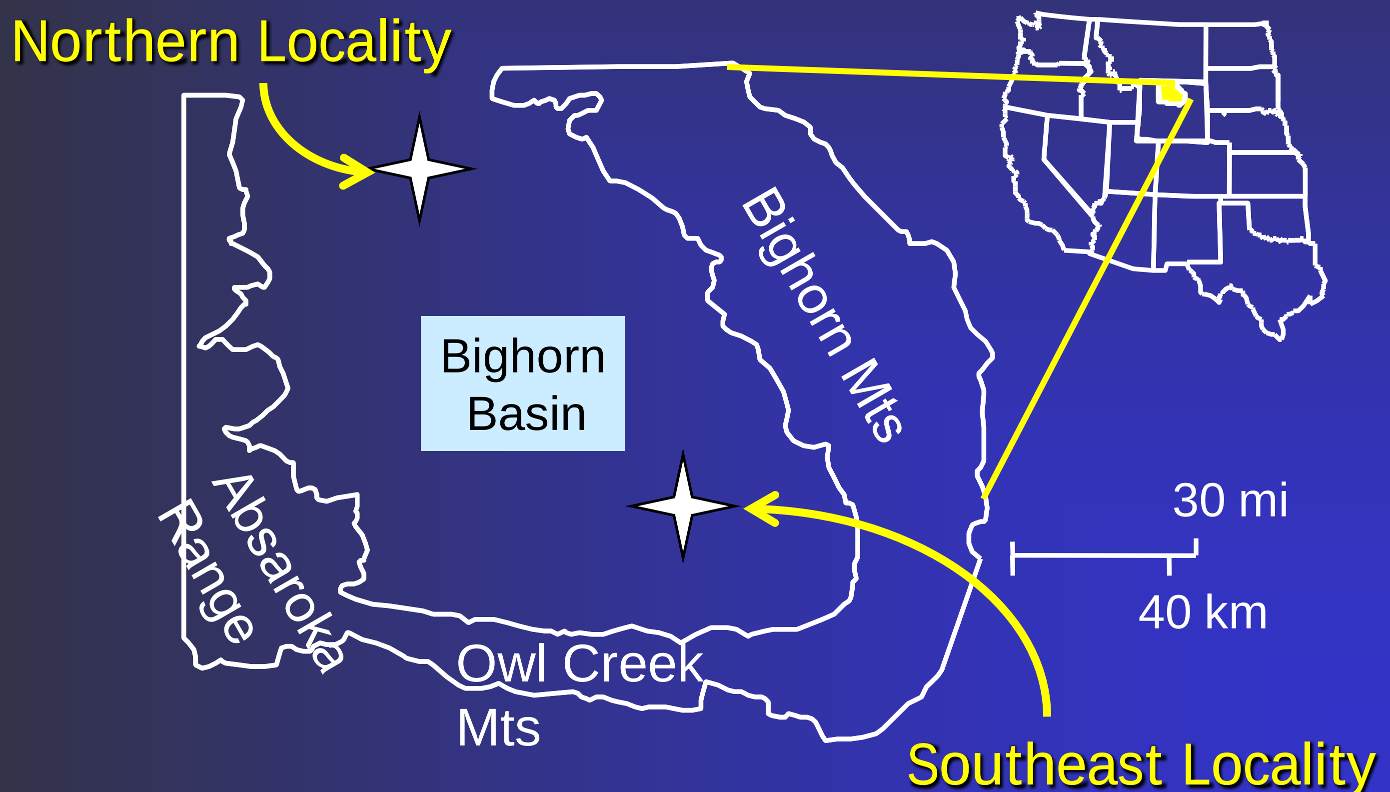
- Oxygen isotope data show dramatic global warming Paleocene-Eocene Thermal Maximum or PETM
- Short-lived: Only ~150,000 – 200,000 years
- Warming was rapid – analog for modern

Problem & Significance

- Agreement that global temperatures rose
- Impact of global warming on hydrologic cycle less certain and more difficult to assess
- Information about precipitation critical to paleontologists and paleobotanists working to understand how biota responded to this episode
- Understanding past changes in water cycle critical to predicting how current global warming will affect the water cycle and water resources
- Need to go to a continental section to evaluate impact of warming on precipitation

Continental Example

- Studied primarily from marine cores, but excellent continental record in Bighorn Basin, WY – focus on northern locality but similar results in 2 other locations

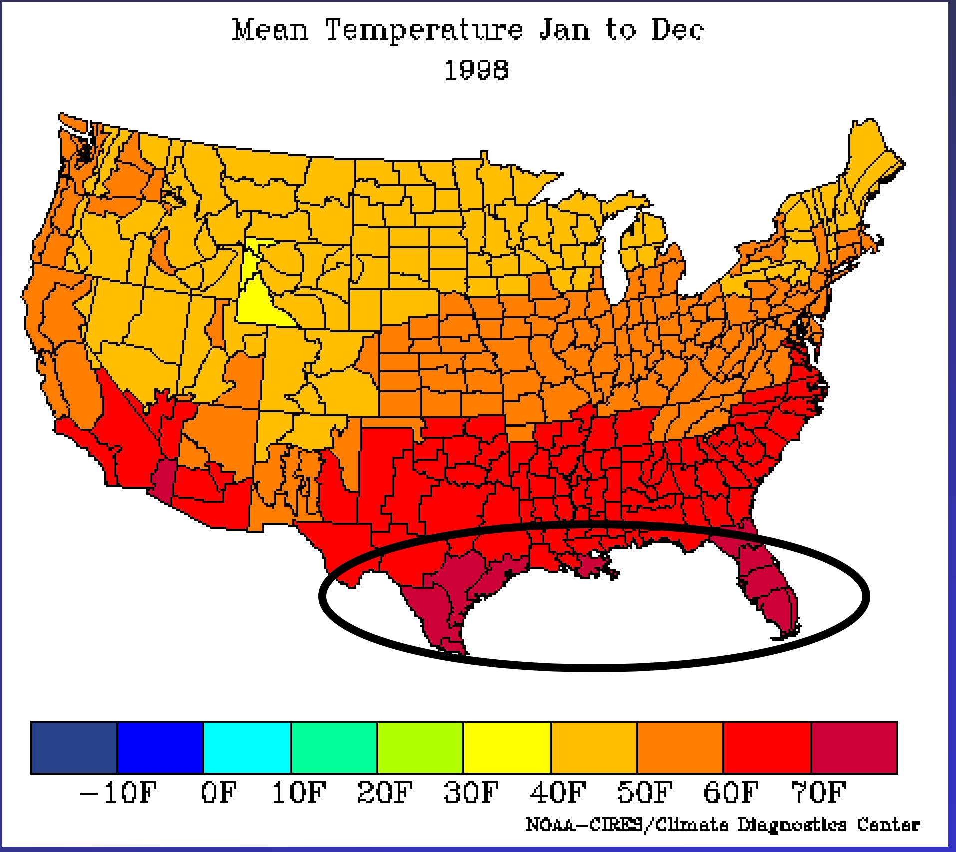


Talk Organization

- Paleoenvironment – climate and depositional setting
- Reconstructing paleoclimate
  - Paleosol morphology
  - Soil weathering indices
  - Trace fossils
- Reconstructing depositional history
  - Paleosol complexity
  - Paleosol density through section
- Climate and depositional changes through PETM interval

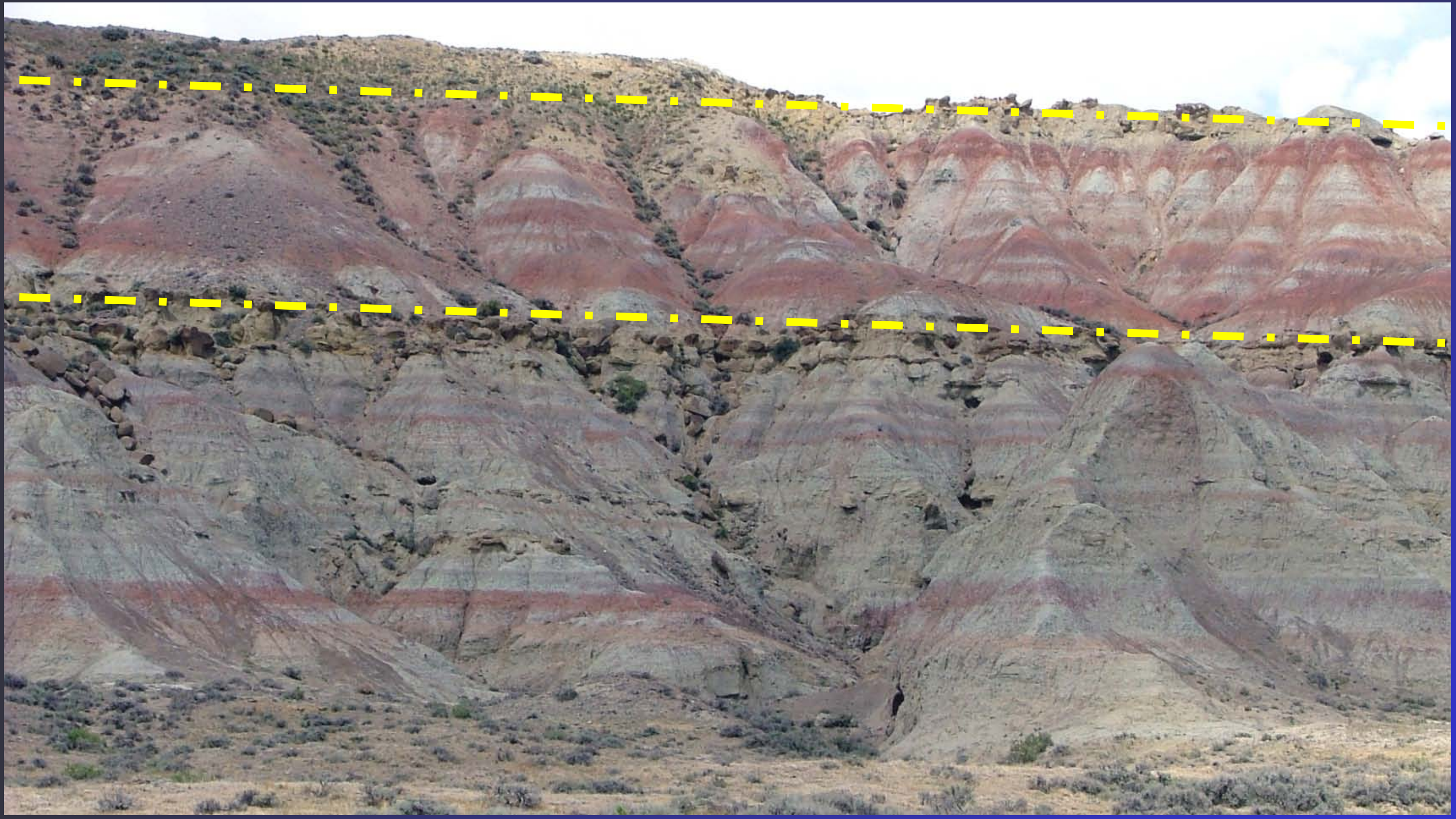
Bighorn Basin Climate

- Plant fossils and isotopes show Mean Annual Temperature of 20º to 25º C or 68 to 77º F
- Similar to Gulf Coast region today



Bighorn Basin – northern locality

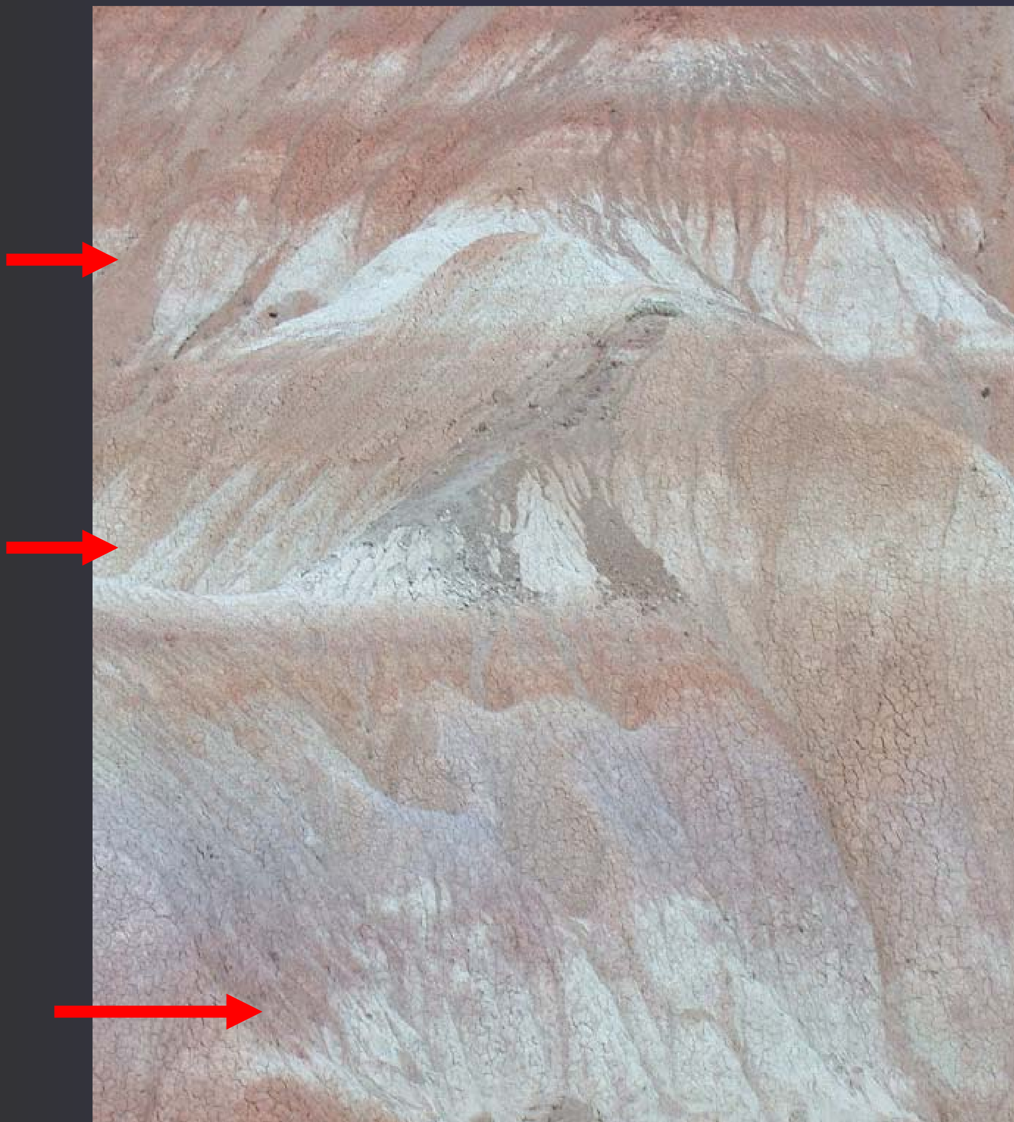
- PETM interval based on isotopes from carbonate nodules and organic carbon – 40 meters thick

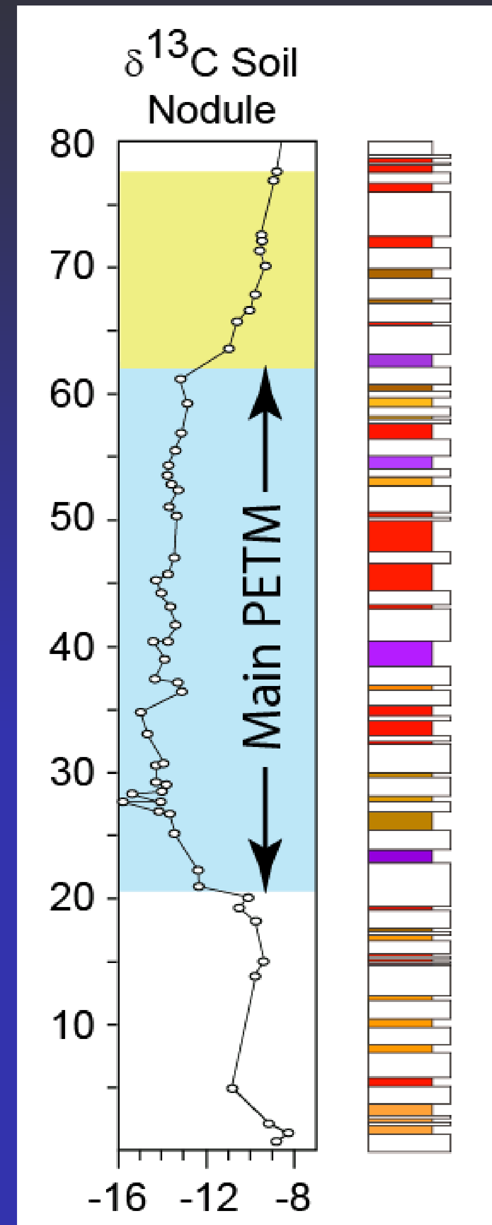


PETM Interval

- FLUVIAL DEPOSITS WITH EXCELLENT PALEOSOLS - COLOR BANDS ARE SOIL HORIZONS
- PALEOSOLS DEVELOPED PRIMARILY ON SLOWLY ACCUMULATING OVERBANK DEPOSITS
- ALTERNATE WITH COARSER-GRAINED AND RAPIDLY ACCUMULATING AVULSION DEPOSITS

PETM Interval





Paleosol Morphology

- Matrix color and mottle colors
- Presence/absence of ferruginous nodules
- Presence/absence of carbonate
  - carbonate nodules
  - carbonate along root traces

Red Paleosol - drier

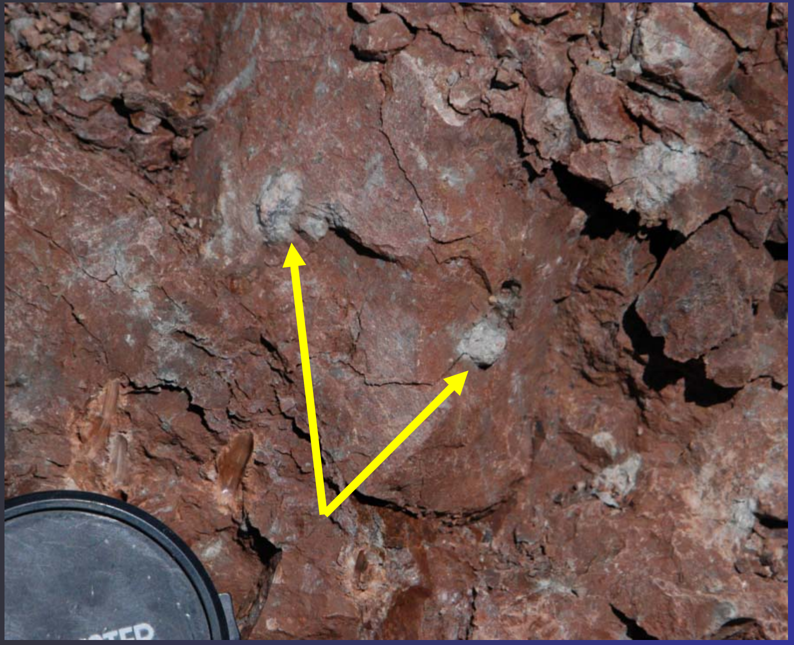
Purple paleosol - wetter

Ferruginous nodules

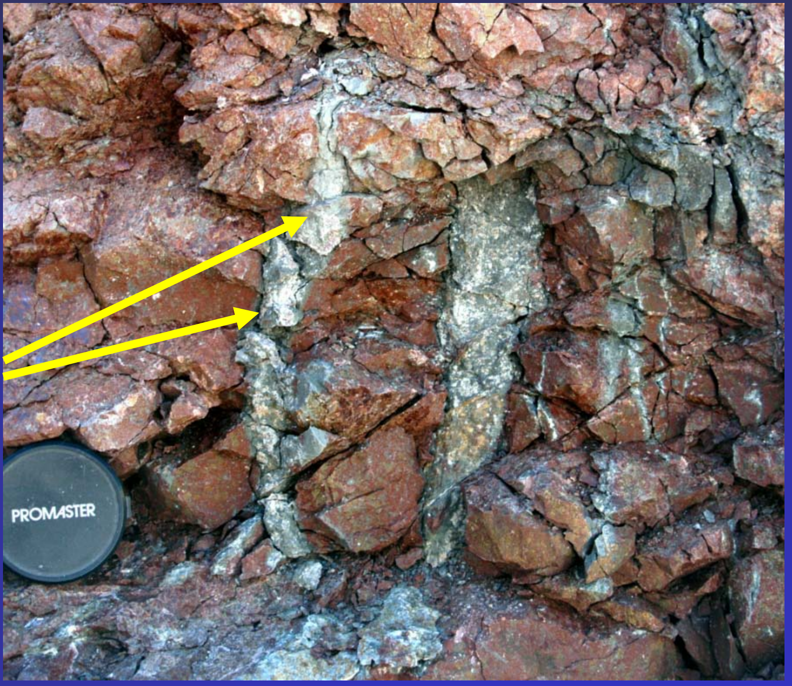
Presence - seasonal wetness

Absence - drier soil conditions

Soil carbonate - appears in two forms; both indicate drier soil moisture regime



Carbonate Nodules



Powdery carbonate along root traces

Paleosol Morphology

Paleosol color & different combinations of these other features allow each paleosol to be assigned a position on the paleosol spectrum below

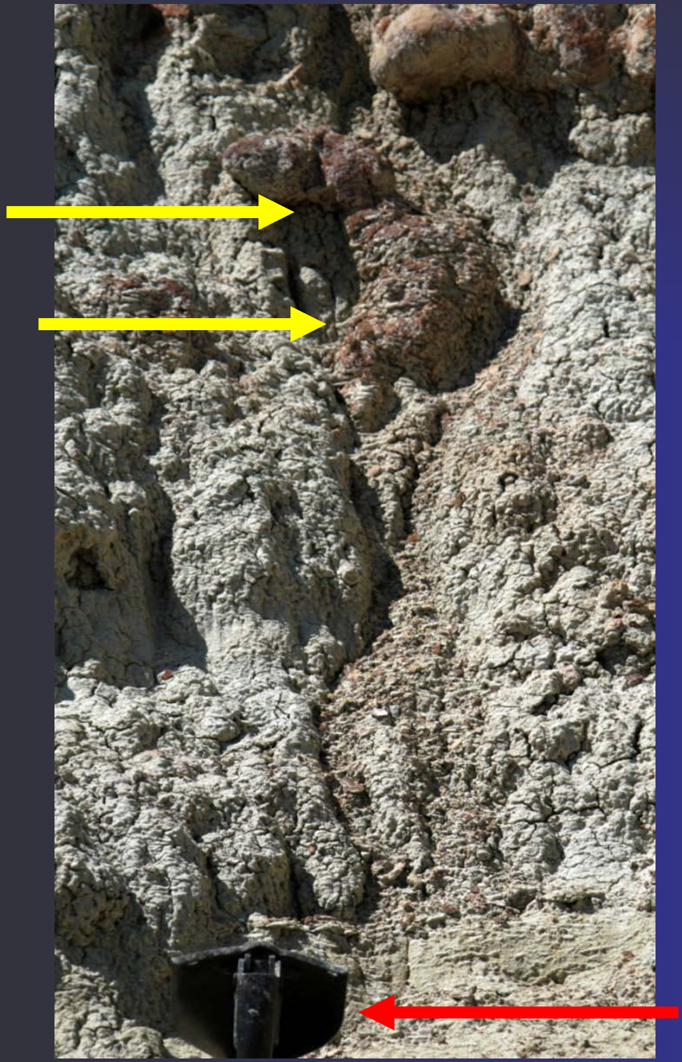
Red paleosol with carbonate and no ferruginous nodules

Red paleosol with no carbonate and no ferruginous nodules

Weathering Index and MAP

- Chemical index of alteration (CIA) commonly used to assess paleosol weathering
- Mean annual precipitation (MAP) can be estimated from CIA-K using empirical equation developed by Sheldon et al. (2002) from modern soil data
- Quantitative estimate of MAP

Trace Fossils

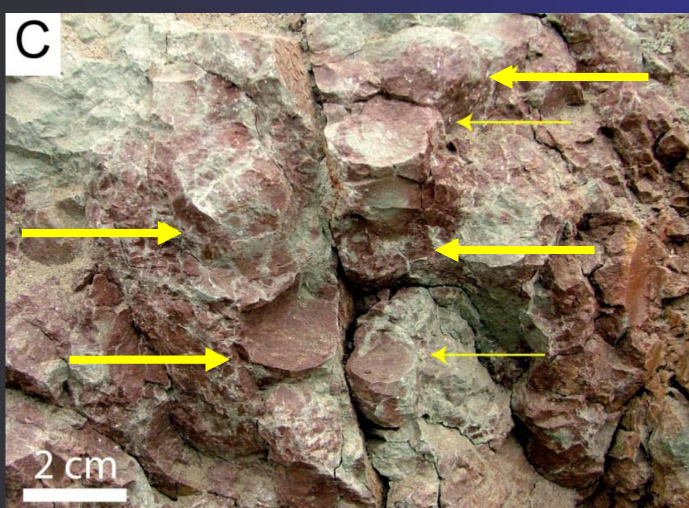


Manganiferous rhizocretions

- vertical cylinders that may branch
- contain manganese & iron oxides and carbon
- wet conditions during formation

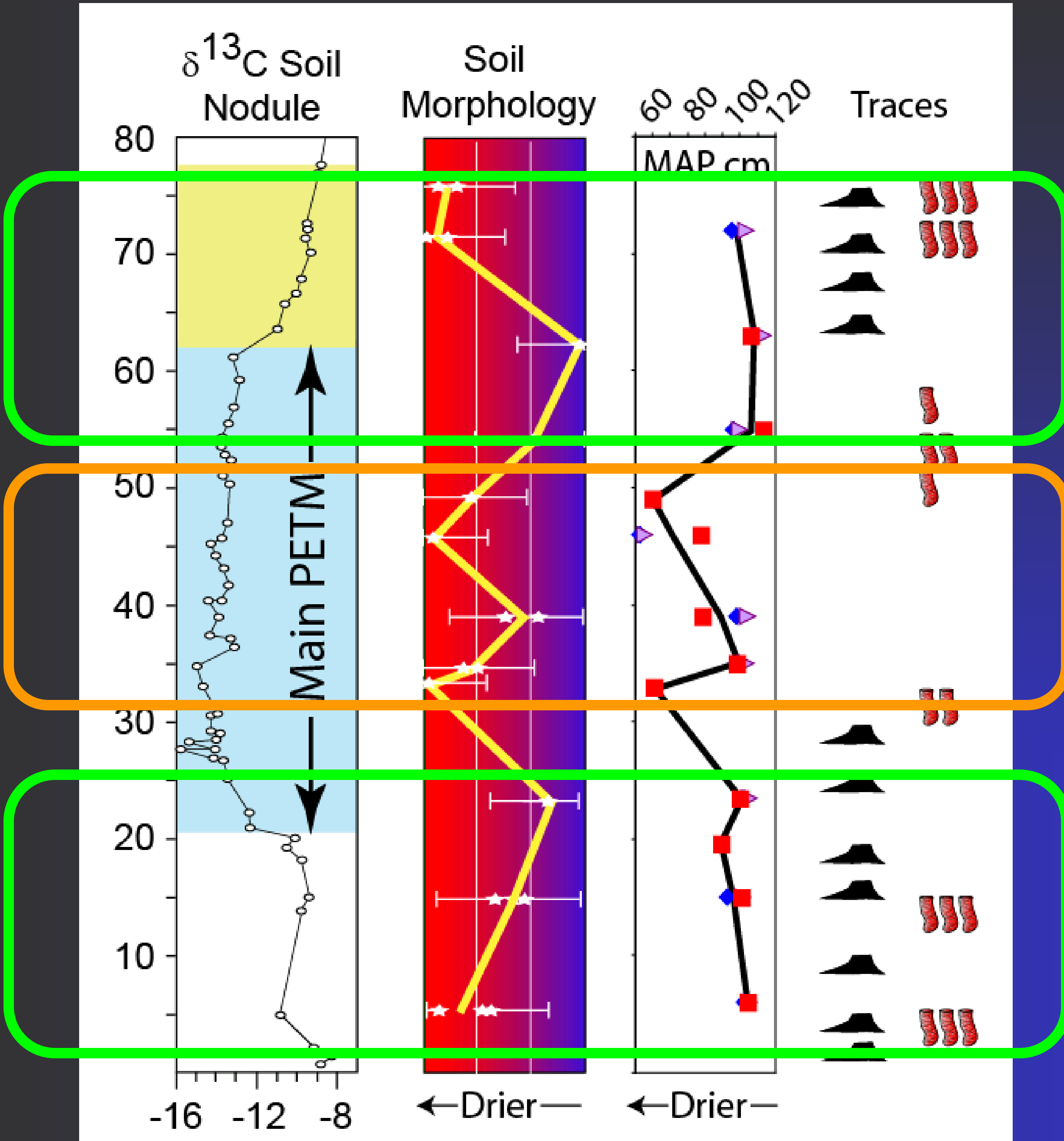
Shovel head for scale

Trace Fossils



Crayfish Burrows

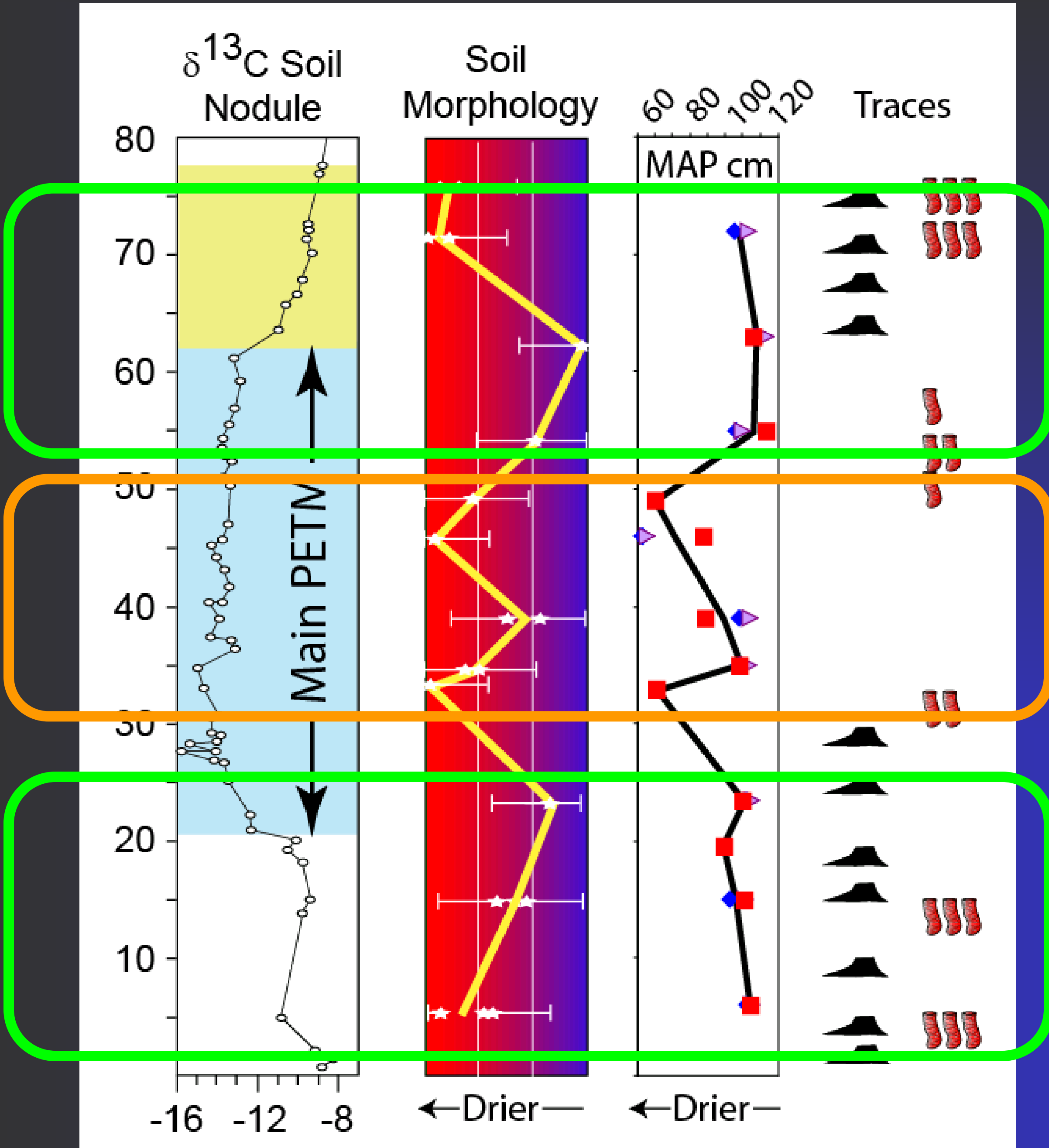
- live mostly in open waters
- burrow to escape drying out in areas of fluctuating water tables
- absence means lower water tables
- presence means wetter soils



Relatively wet based on MAP and traces

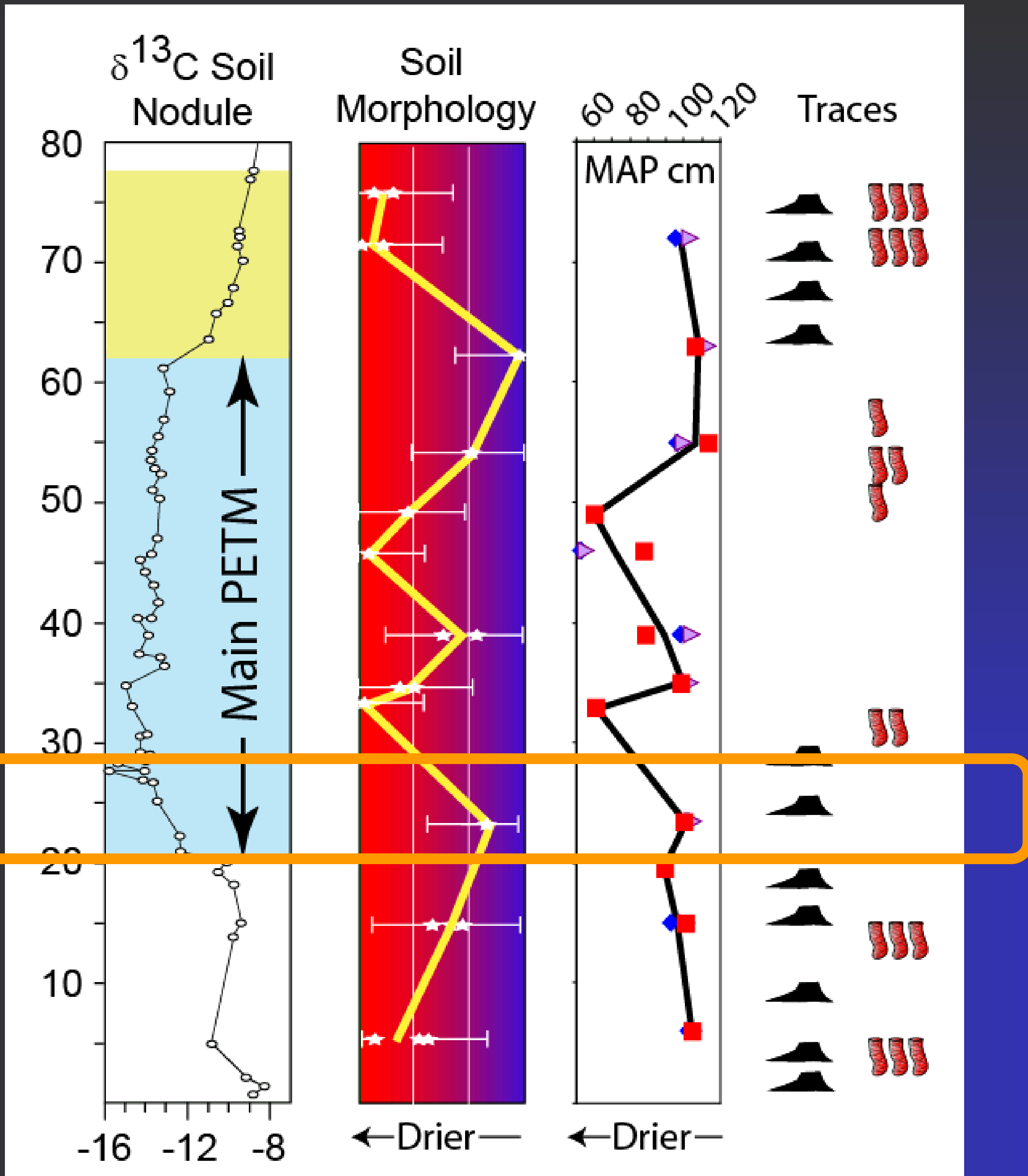
Drier based on morphology, MAP, traces

Relatively wet based on MAP and traces



Results suggest:

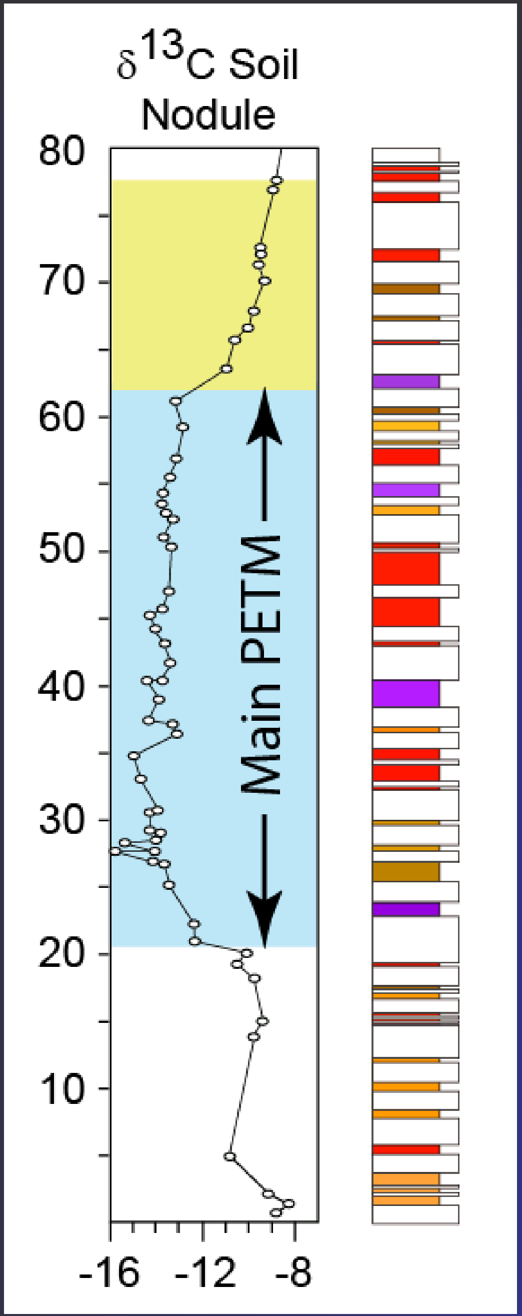
- Soil morphology spectrum may not be best estimate of soil moisture



Results suggest:

- Initial ~10 m of main body of CIE is sandiest interval in study section
- attributed to changing wet → dry & associated large sediment flux

Paleosol Density



- Similar to pre-PETM interval
- Densely spaced paleosols
- Thick red paleosols
- Few weak paleosols
- Widely spaced paleosols
- Prominent avulsion intervals
- More weak paleosols

Paleosol Density

Widely spaced and thinner paleosols -

- Typical of pre- and post-PETM intervals and lowest 10 m of PETM
- Suggest relatively rapid sediment accumulation rates
- And relatively frequent avulsion to produce “pale” packages

Thick, well-developed red paleosols

- Hallmark of PETM interval
- Multiple, densely spaced, thick red paleosols
- Avulsion deposits thin and worked in
- Suggests lower sediment accumulation
- So welding of different red profiles

Depositional and Pedogenic Synthesis

Pre-PETM and Post-PETM

- Wetter climate
- Relatively high water discharge and high sediment supply due to wet conditions
- Rapid rates of sediment accumulation
- Rate of sediment accumulation > rate of pedogenesis → widely spaced and non-welded paleosols

Depositional and Pedogenic Synthesis

Main Part of the PETM Interval

- Drier climate but some wetter episodes
- Lower water discharge and reduced sediment supply due to dry conditions
- Slower rates of sediment accumulation
- Rate of pedogenesis > rate of sediment accumulation leading to densely spaced and welded or overlapping paleosols

Selected References

NOAA—CIRES Climate Diagnostic Center: Web accessed 2 December 2008, (http://www.cdc.noaa.gov)

Sheldon, N.D., G.J. Retallack, and S. Tanaka, 2002, Geochemical climofunctions from North American soils and application to paleosols across the Eocene-Oligocene boundary in Oregon: Journal of Geology, v. 110/6, p.687-696.