# Distribution of anoxia and water mass circulation during the Cretaceous Ocean Anoxic Event 2 (Cenomanian-Turonian); a global carbon cycle perturbation in the Western Interior Seaway

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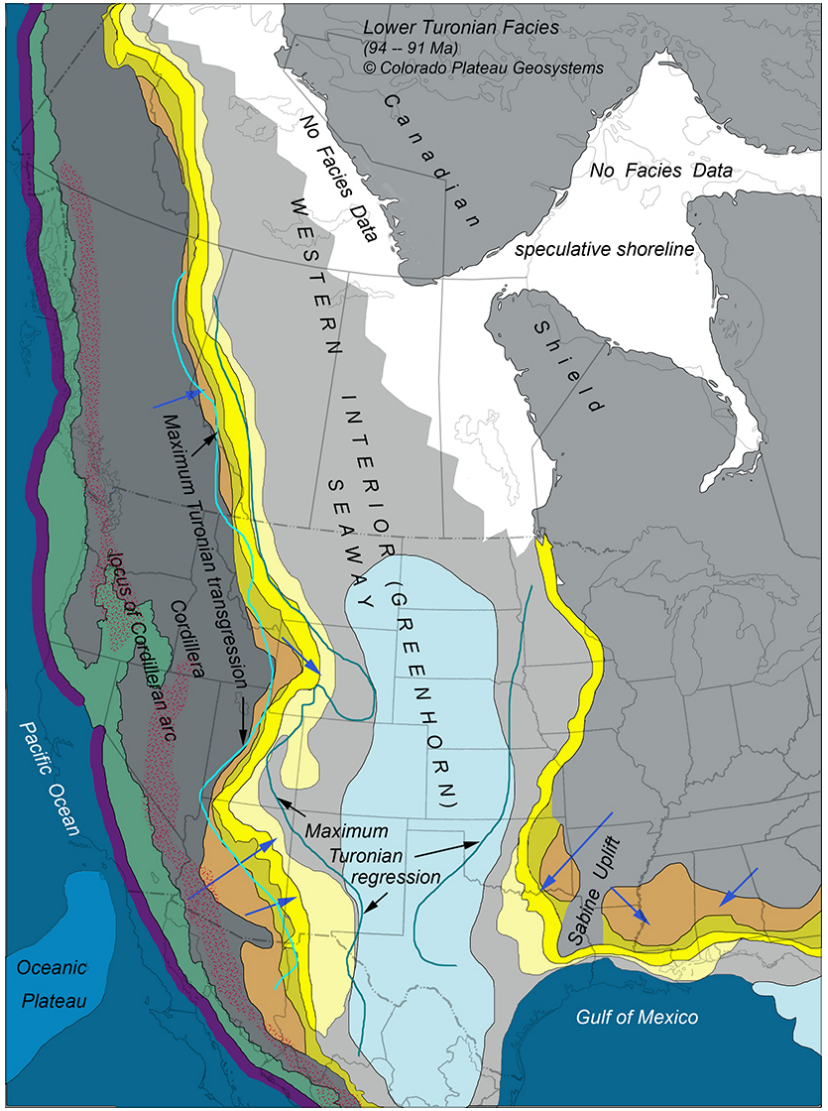
# Outline

- Brief paleogeography of the WIS/WIB during the Cenomanian-Turonian Boundary
- OAE2 evidence in the WIS/WIB during the Greenhorn Cyclothem
  - Sedimentological
  - Paleontological
  - Elemental, isotopic
  - Biomarker analyses
- Mixed signals
- Proposed approach of study

# Paleogeography of NA

## Cenomanian-Turonian Boundary (ca. ~94 Ma)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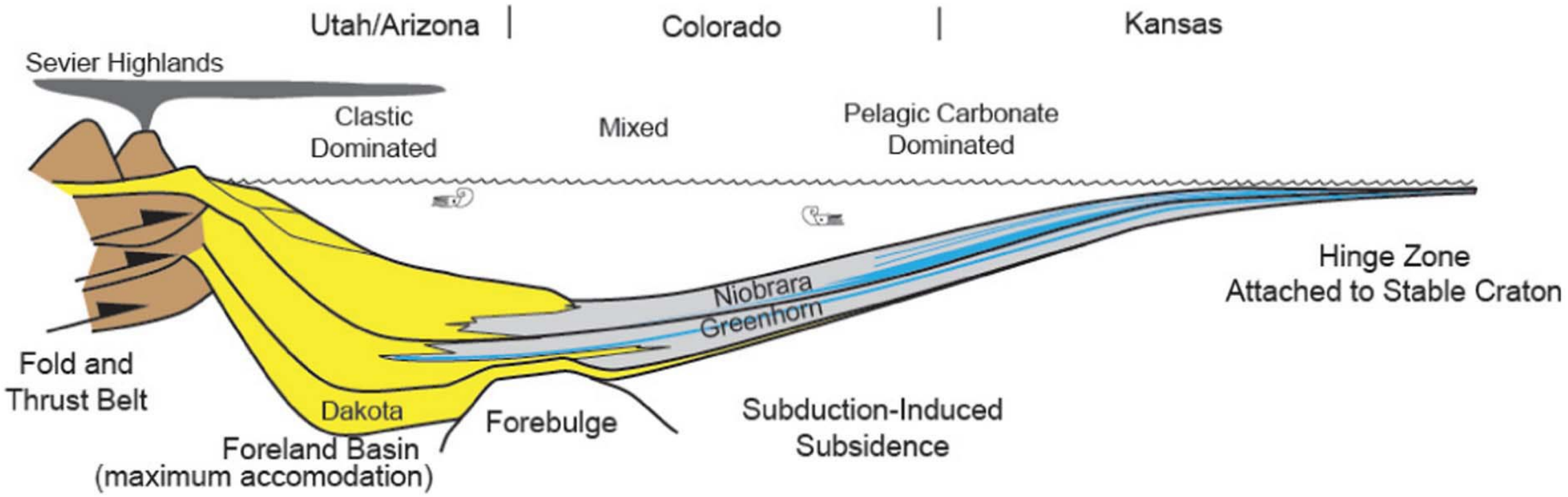
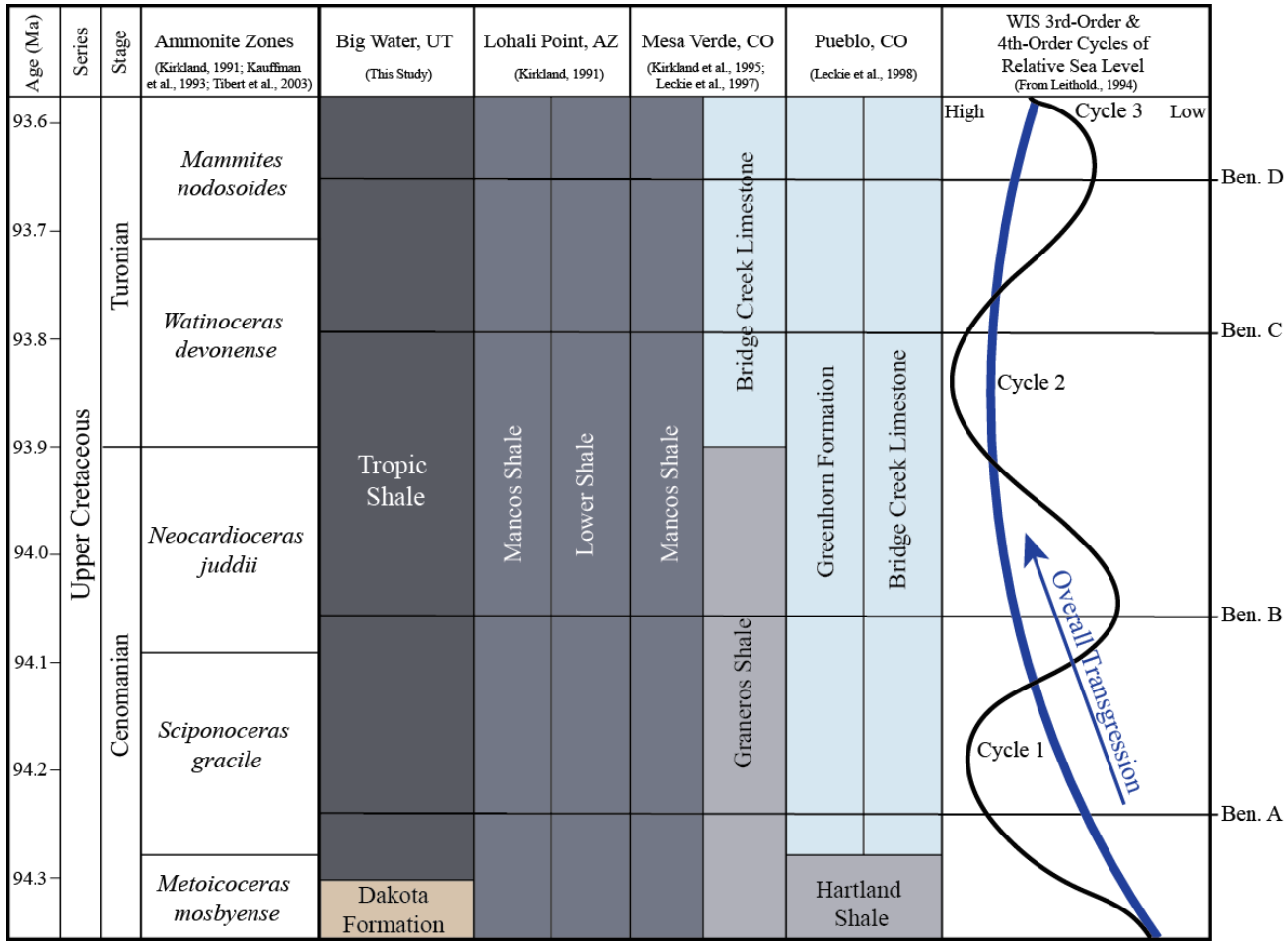
# Idealized cross section (Niobrara time)




Lowery et al., 2018 modified from Kauffman, 1984

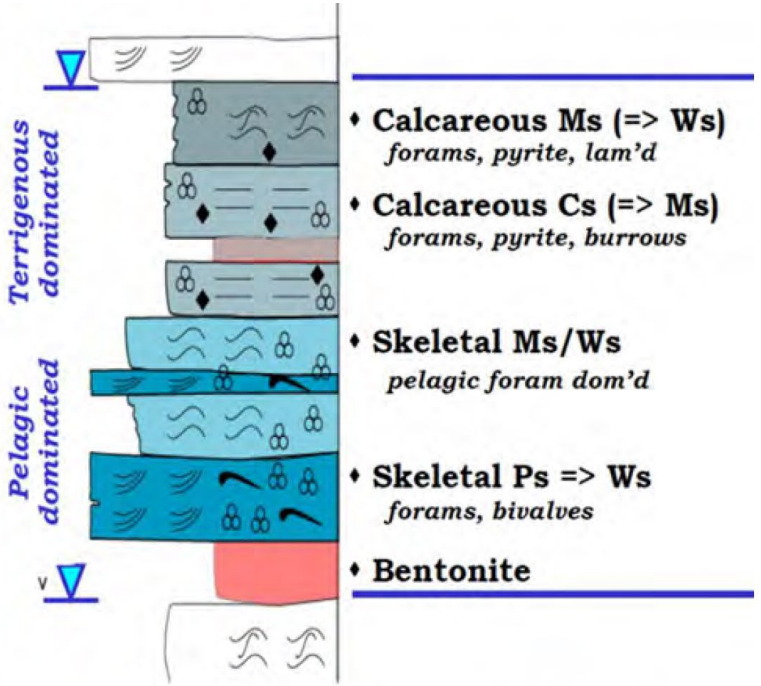
# Eustacy in the WIS during OAE2




Parker, 2016 (MSc Thesis); Leithold, 1994

# Bridge Creek LS at the CTB

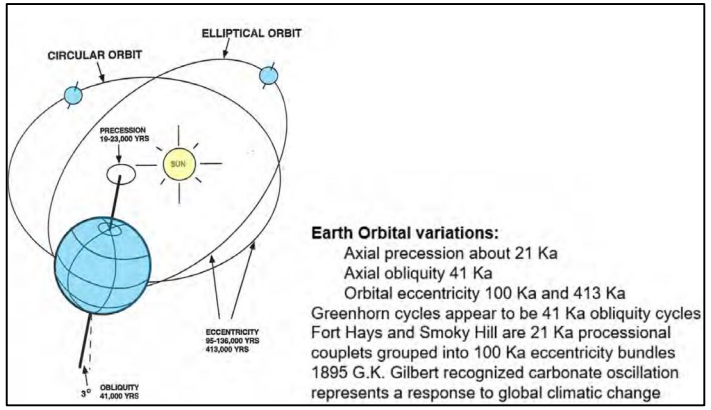
## Rhythmically interbedded LS & Shales

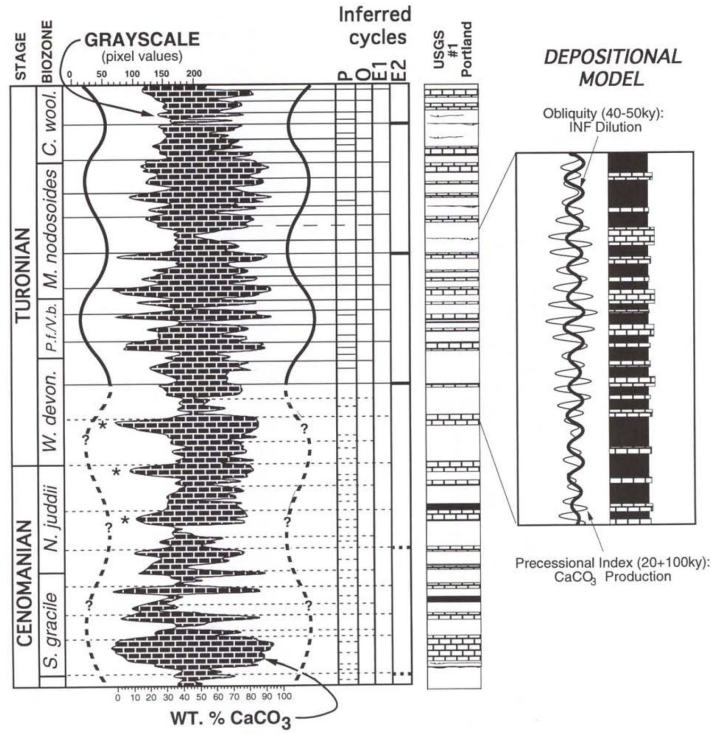




Wet phase deposition: Shales
Dry phase deposition: Limestones

Global Stratotype Section and Point (GSSP), outside Lake Pueblo (Sageman, Northwestern University)

Bohacs & Lazar, 2010; Gilbert, 1895; Kauffman, 1977; Kauffman & Caldwell, 1992; Sageman et al., 1998; Dodsworth & Eldrett, 2018…



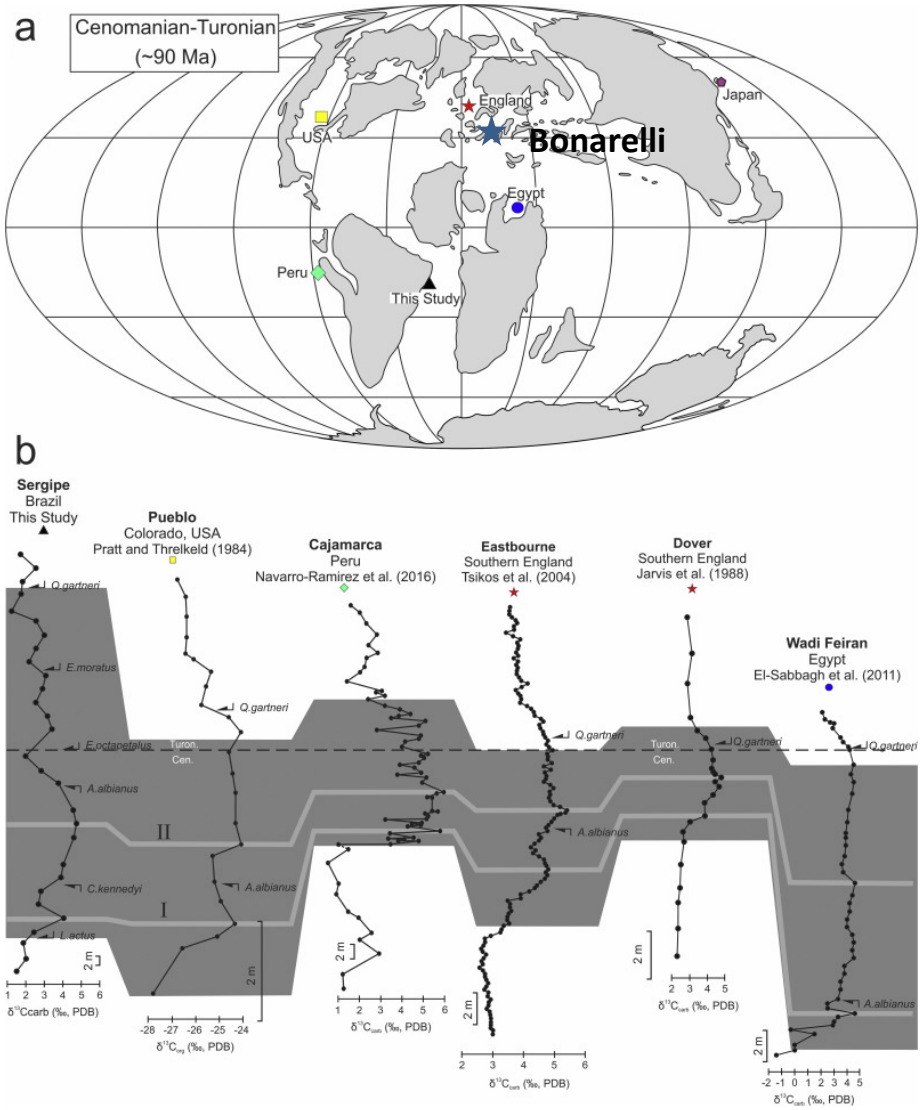
# Cenomanian-Turonian Boundary and OAE2

**Marked by significant positive shift in $\delta^{13}C$**

- Largest disturbance of global C cycle in the last 110 Ma
- Significant increase in C burial
- Widespread deposition of carbon-rich sediments
- Extensive organic matter preservation at sediment-water interface

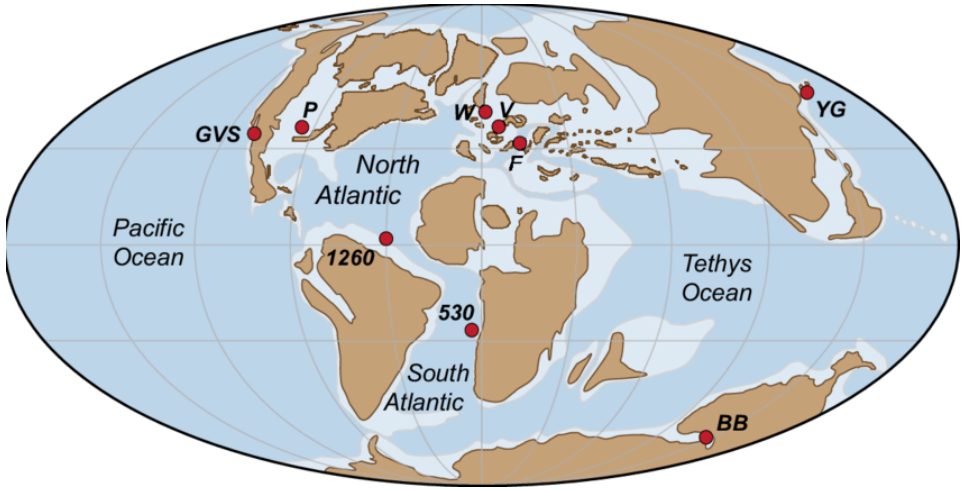
**Characterized by:**

- Black, interbedded shales* and bottom water anoxia (OAE2)*
- "Spikes" of marine productivity followed by stasis and likely eutrophication
- Turnover/extinction of marine invertebrate (53% of all marine species) & foraminifera heterohelix "shift"
- Increased atmospheric $CO_2$, $SO_2$, $H_2S$, and halogens
- Warm global temperatures and high oceans with periods of oxygen deficient or stratified water columns

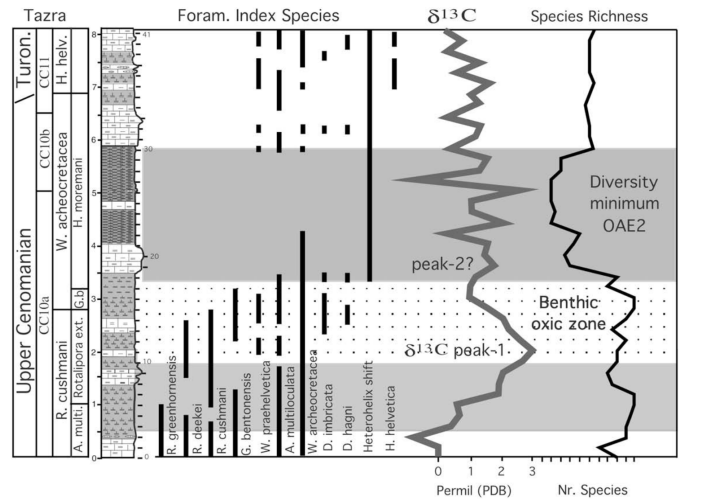


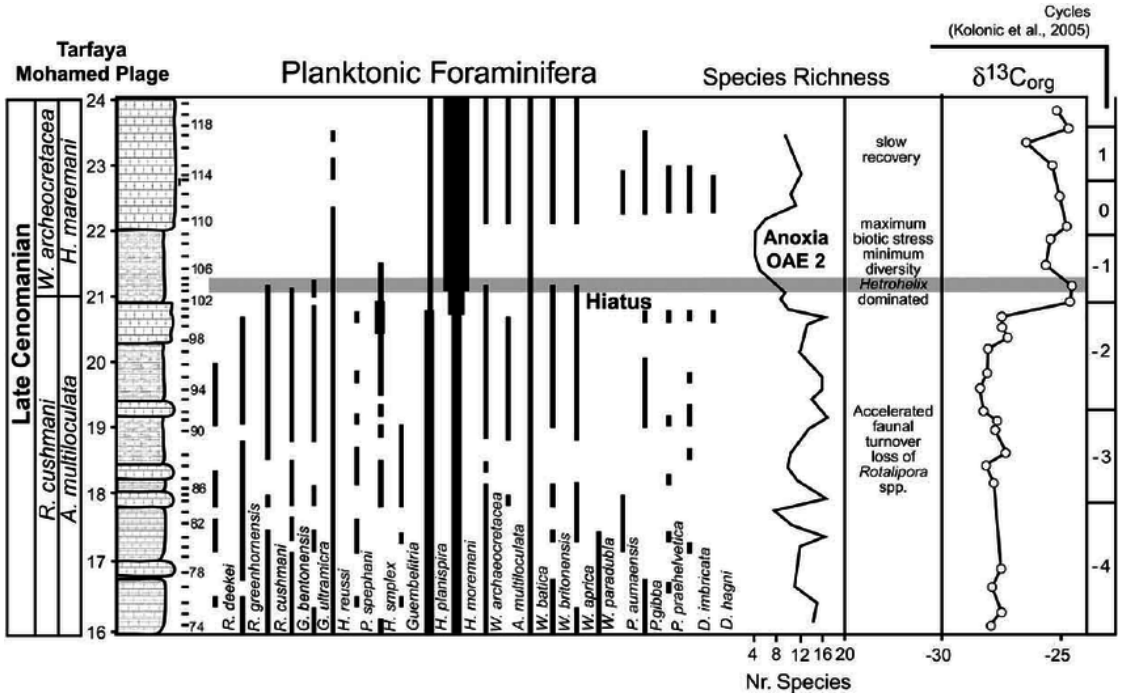

Valle et al., 2019 *Notable exceptions

# OAE2 Extinction and Turnover

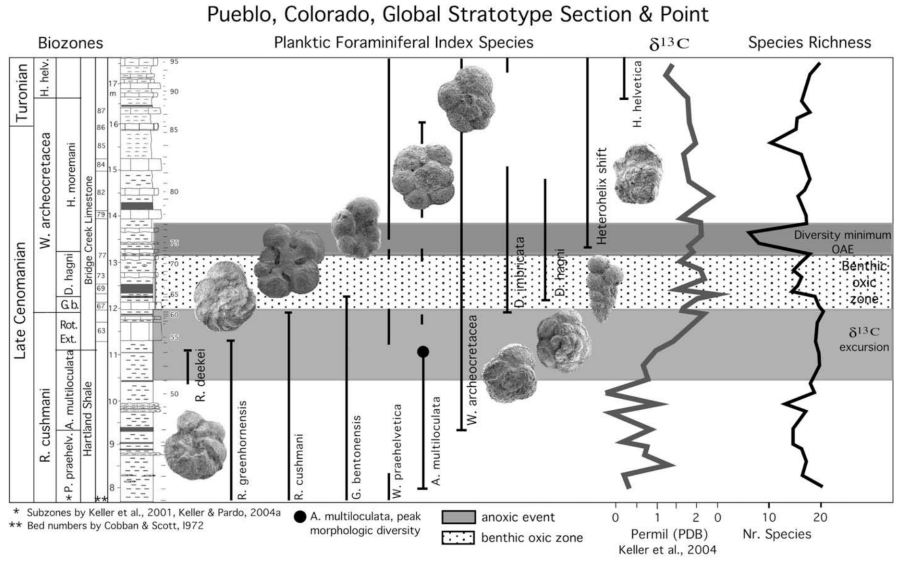



## Morocco




## Colorado

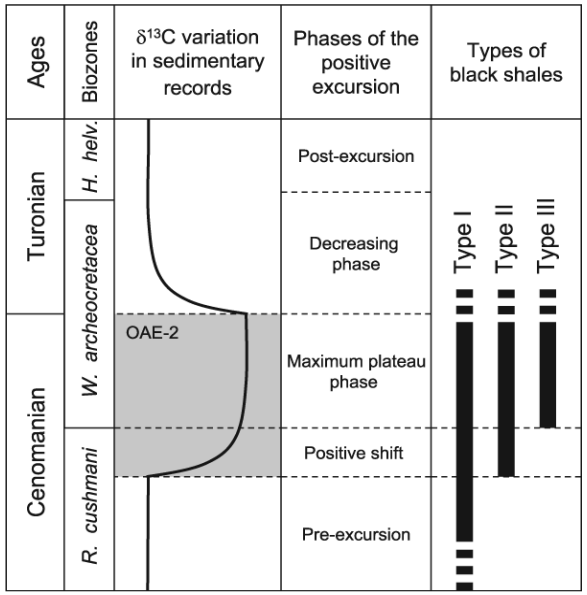



Keller et al., 2008; Mort et al., 2008; Corrick et al., 2019;

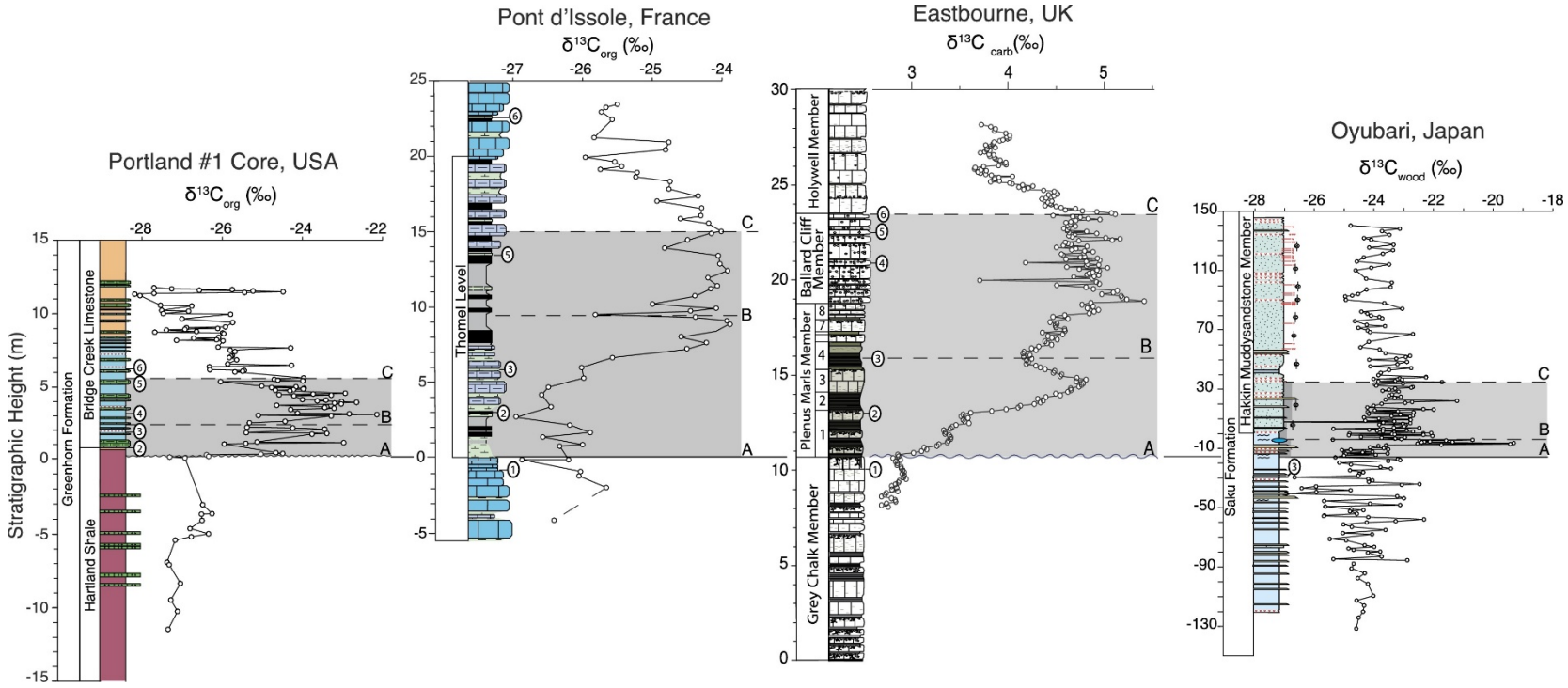
# Carbon Isotope Signal OAE2

OAE2 = 619 ± 39 kyr (UT) & 820 ± 25 kyr (Tibet)
Large perturbation in C but also O, N, Cr, Sc, Os, Re, Li, Cu, Co…

Idealized OAE2 C isotope excursion

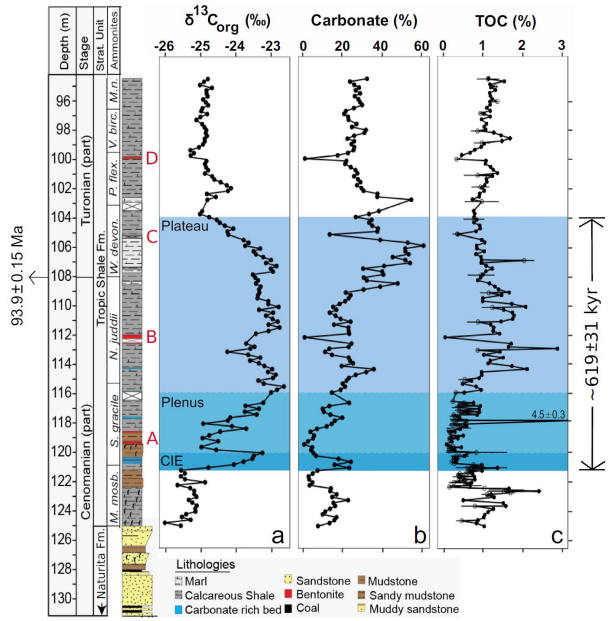


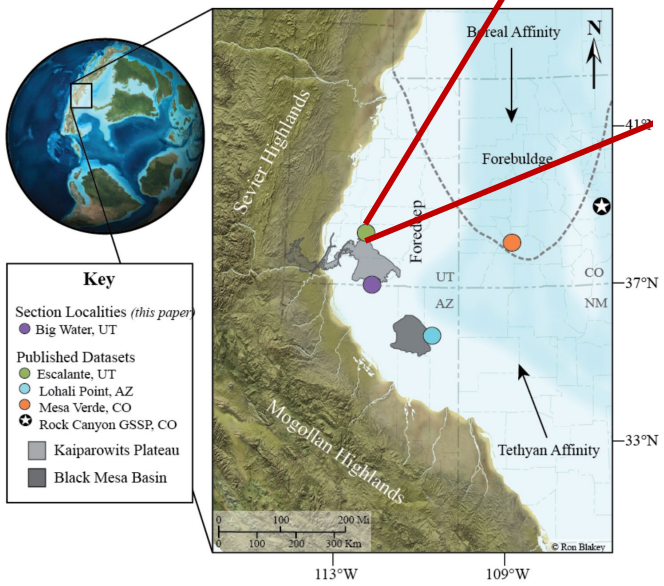

Positive C excursion recorded in inorganic and organic sources



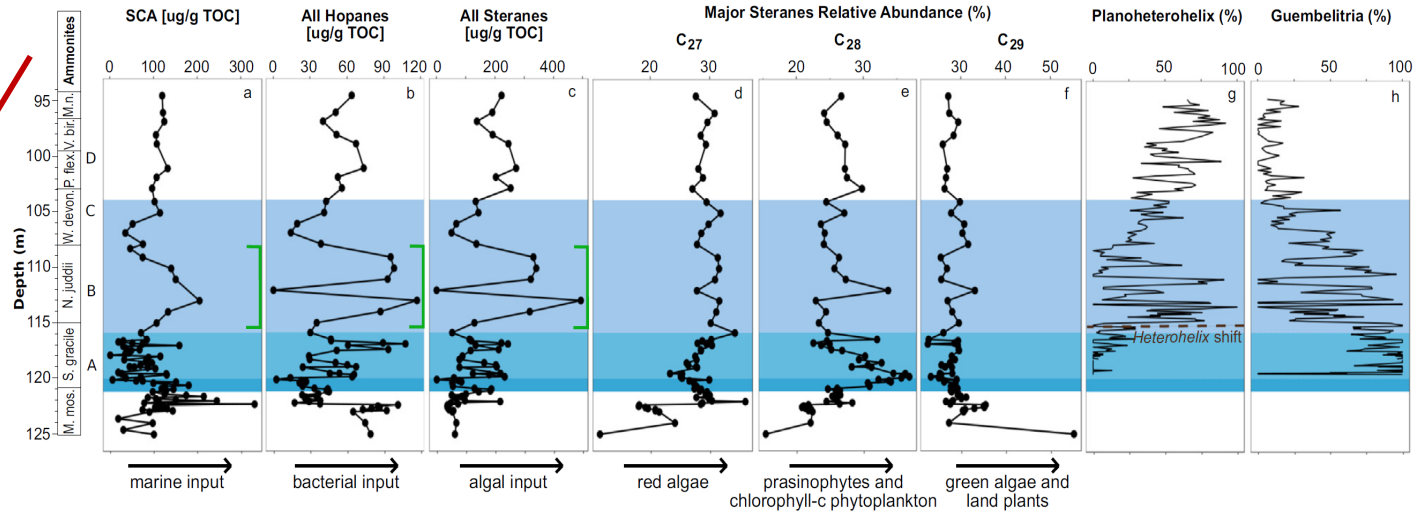

Keller et al., 2008; Du Vivier et al., 2015; Jones et al.,2019; Li et al., 2017

# Proximal, neritic Tropic Shale during OAE2




Evidence of Photic Zone Euxinia (PZE) and stratified water columns




Biomarker indicators of phototrophic sulfur oxidizing bacteria (PSOB)

- Hopane/sterane ratios
- Green/purple sulfur bacteria: Isorenieratane, okenane

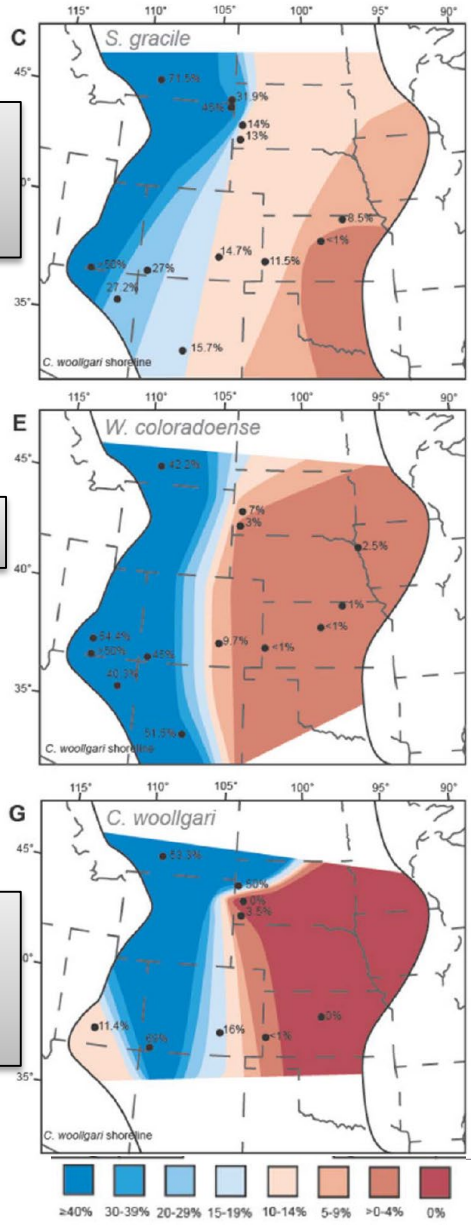
Parker, 2016 (MSc Thesis), Boudinot et al., 2020, Browne et al., 2020

# Mixed signals and mixing currents

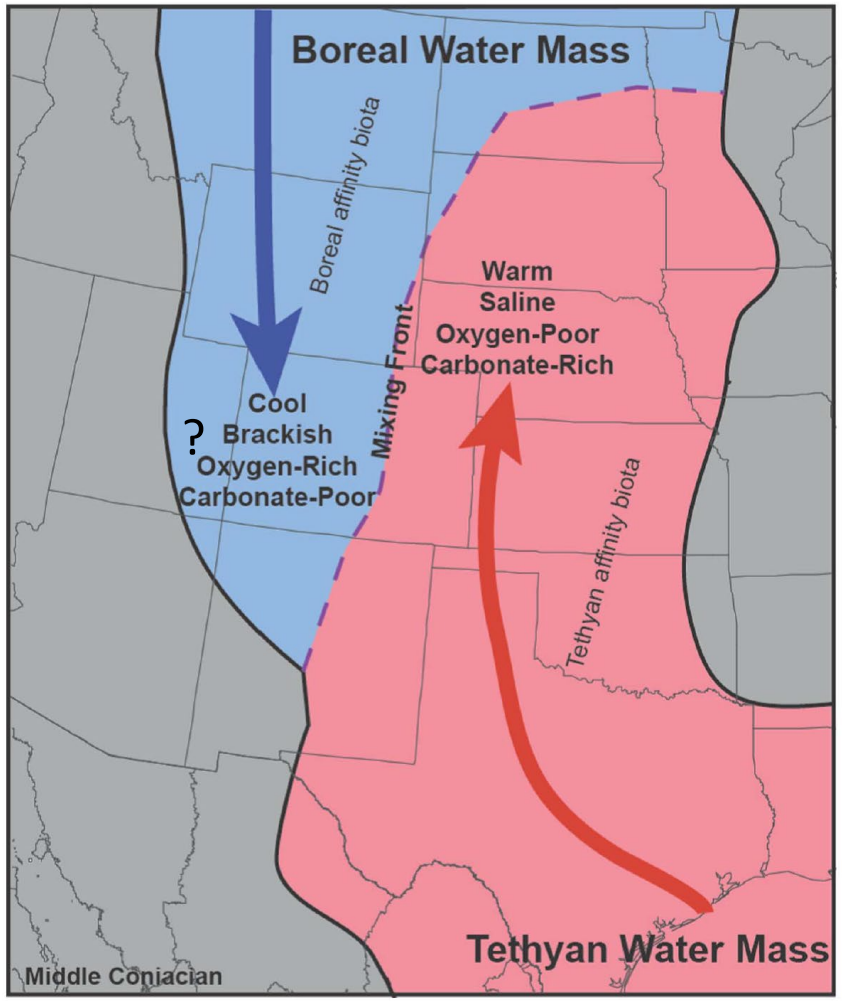
*S. gracile*:
Late Cenomanian
(ca. 94.15-94.15 Ma)

*W. coloradoense*

*C. woolgari*
Mid Turonian
(ca. 91.6-92.9 Ma)

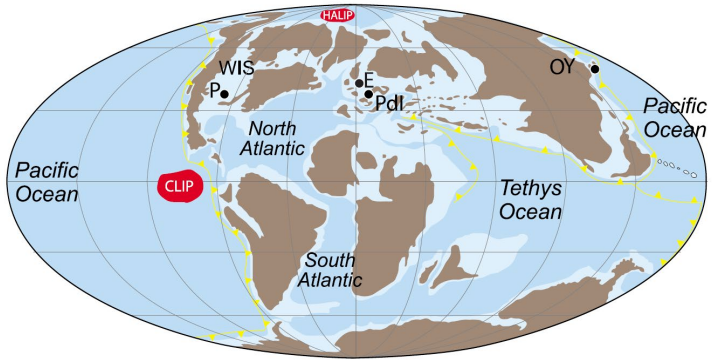



Benthic (epi- & infaunal) foraminifera proxy for bottom water oxygen content



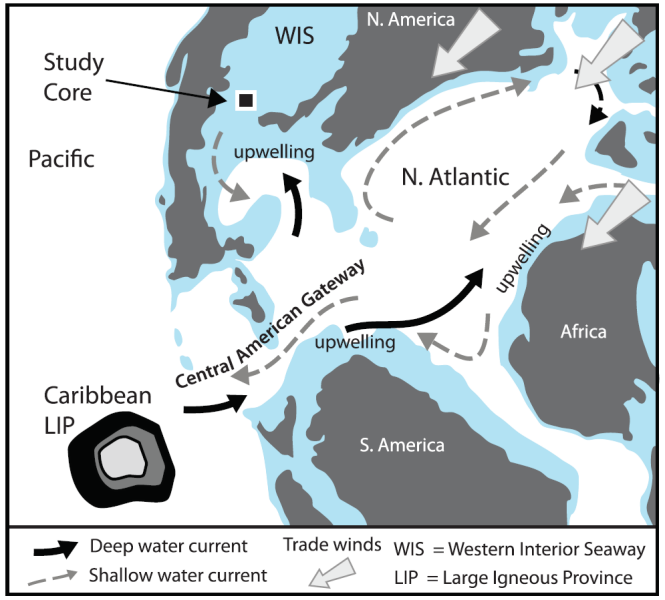

Lowery et al., 2018

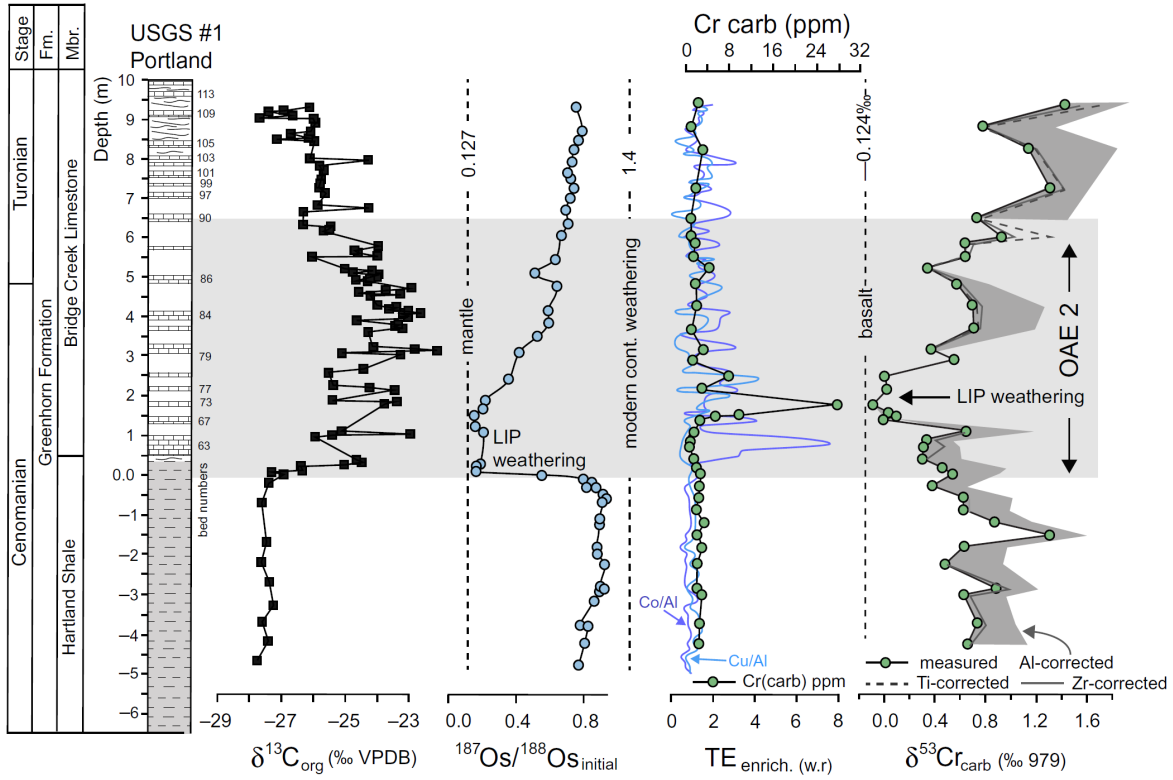
# Large Igneous Provinces (LIPs) and OAE2




HALIP: High Artic Large Igneous Province
CLIP: Caribbean Large Igneous Province

Os and Cr fractionation pathways may indicate marine vs. terrestrial origin




Du Vivier et al., 2015 Holmden et al., 2016

# LIP-influenced geochemical cycling & isotopic fractionation

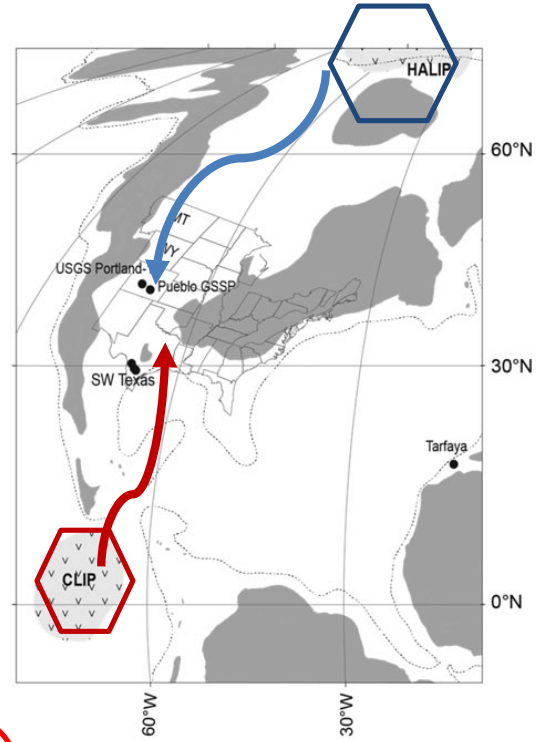
**Long-lived magmatic events with discrete pulses**

CLIP:

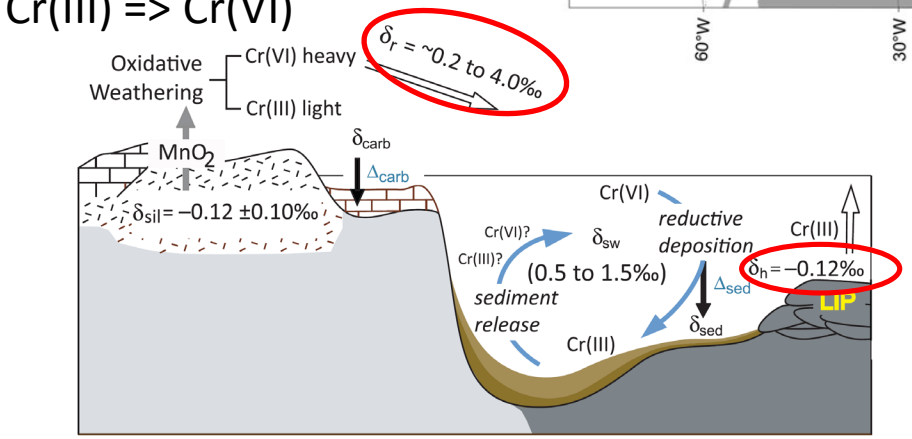
- 1st (Main) ~95-83 Ma
- 2nd ~81-69 Ma

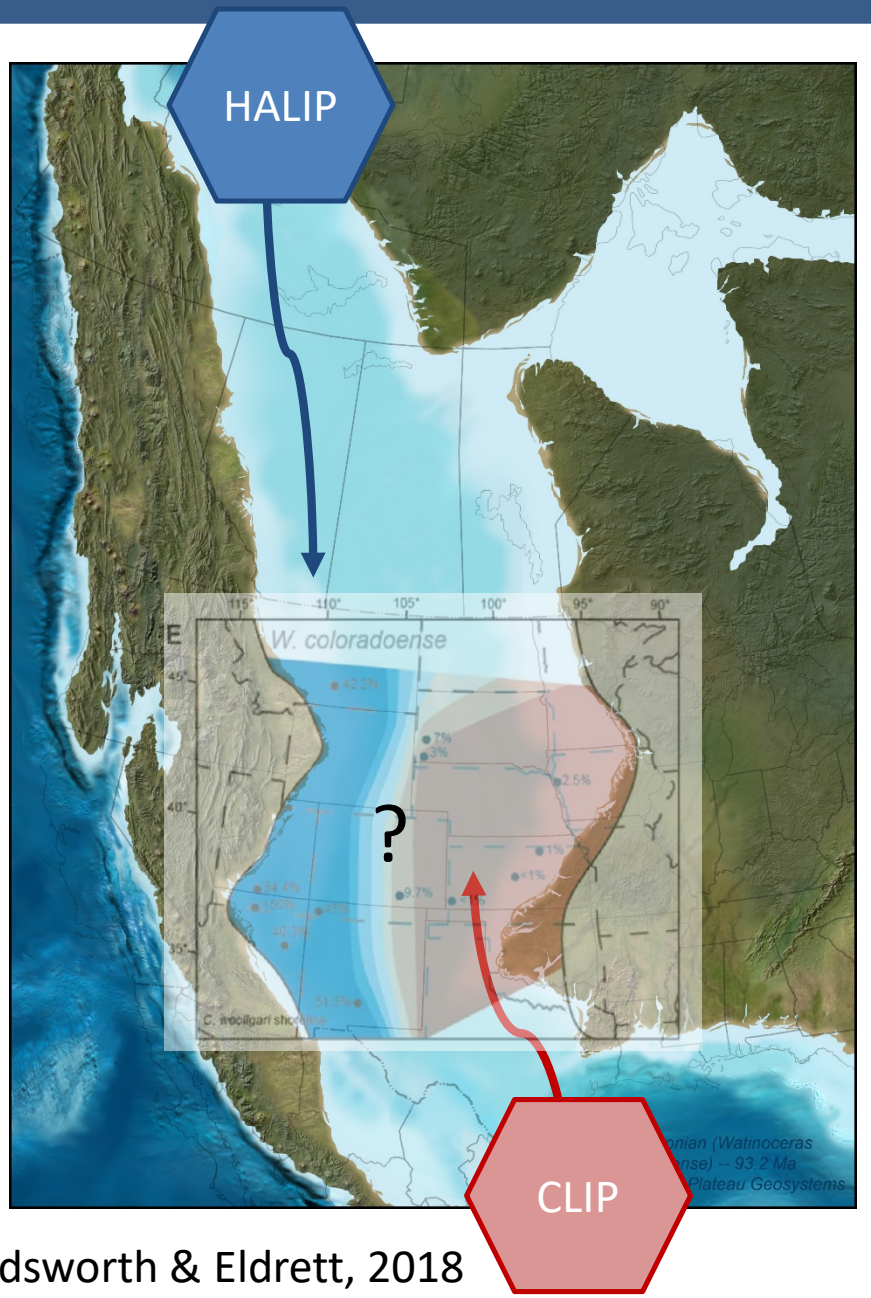
HALIP:

- 1st 130-83 Ma tholeiitic magmas
- 2nd 93-60 Ma calc-alkaline pulse




Cr(III) => Cr(VI)




Schröder-Adams et al., 2019; Holmden et al., 2016; Lowery et al., 2018; Dodsworth & Eldrett, 2018

# Proposed Study

- LECO TOC & Pyrolysis
- Whole Oil-extract GC
  - Biomarker analyses
- C-Isotope ($\delta^{13}$ organic and inorganic where necessary)
- Bulk elemental, trace and majors
- Fe-speciation ($Fe_{HR}/Fe_T$)
- Isotopic Cr ($\delta^{53}$), Os ($^{187/188}$), and possibly Re & Li (ppb) trace element ratios
- Benthic foraminifera proxies where available

**Phase I**

Redtail Field Bridge Creek LS

- Multi-proxy redox study attempt to differentiate oxygen state of water column, bottom water, sed-water interface before, during, and after OAE2
- Detect a submarine LIP weathering water provenance signature vs. continental weathering

**Phase II**

- W-E and N-S time-correlative variability: Mancos (Mancobrara), Tropic Shale
- Water mass circulation, restriction, and mixing in the WIS
- Relationship between water provenance and anoxia
- Assess degree of continental weathering to nutrient cycling during OAE 2 related to LIP emplacement

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