Sequence Stratigraphic and Stable Isotopic Expression of the Over-Filled to Balanced-Filled Tipton Member of the Green River Formation, WY*

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Search and Discovery Article #50141 (2008)
Posted November 20, 2008

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

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Abstract

Deposits of Eocene Lake Gosuite record numerous lake-type transitions, which together constitute the Green River Formation (GRF) in Wyoming. The Scheggs and overlying Rife Bed of the Tipton Member represent a shift from over-filled (fluvial/lacustrine) to balanced-filled (fluctuating profundal) lake systems within Lake Gosuite. Though preliminary stratigraphic analysis shows the transition from over-filled to balanced-filled lake type to be gradual, significant variations in mineralogy, organic content, and stratigraphic lithofacies distinguish the Scheggs and Rife Beds. Additionally, preliminary stable isotopic data indicate a dramatic $\delta^{18}O$ increase of 10-15 per mil between the underlying Luman Tounge and the top of the Tipton Member. Such a shift might suggest that a major source of low $\delta^{18}O$ water was diverted away from the basin during Tipton deposition. Alternatively, a shift towards dryer climatic conditions could also be responsible.

In the over-filled regime, as represented by the Scheggs Bed and the laterally-equivalent Farson Sandstone, major streams entering the lake deposited deltaic sandstones that correspond to potentially high-quality reservoirs. This sand supply appears to have been reduced following the Scheggs-Rife contact, as major lake expansion and back-stepping of the Farson sand deposits are observed in the Rife Bed. At this time, the lake system became both sediment-starved and thermally stratified. These conditions are conductive to the development of highly rich lacustrine source rocks, as evident in the high-grade oil shales of the Rife Bed. Both the Scheggs and Rife facies are important as source rock analogues for other basins worldwide, and also for their direct value as oil shale deposits.

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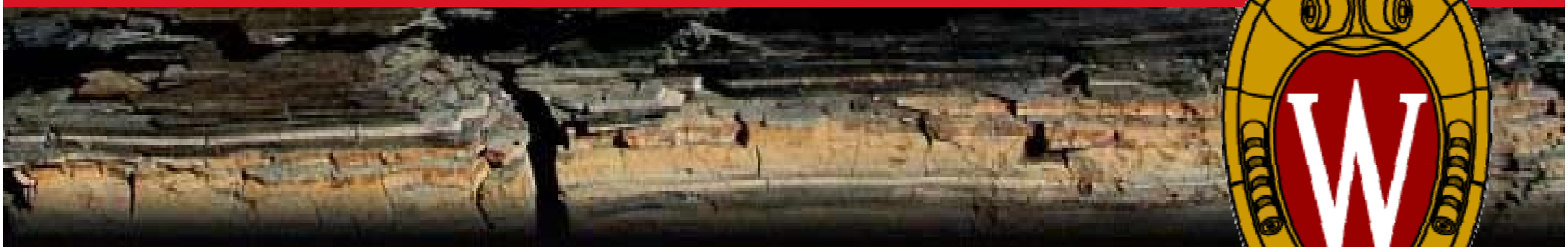

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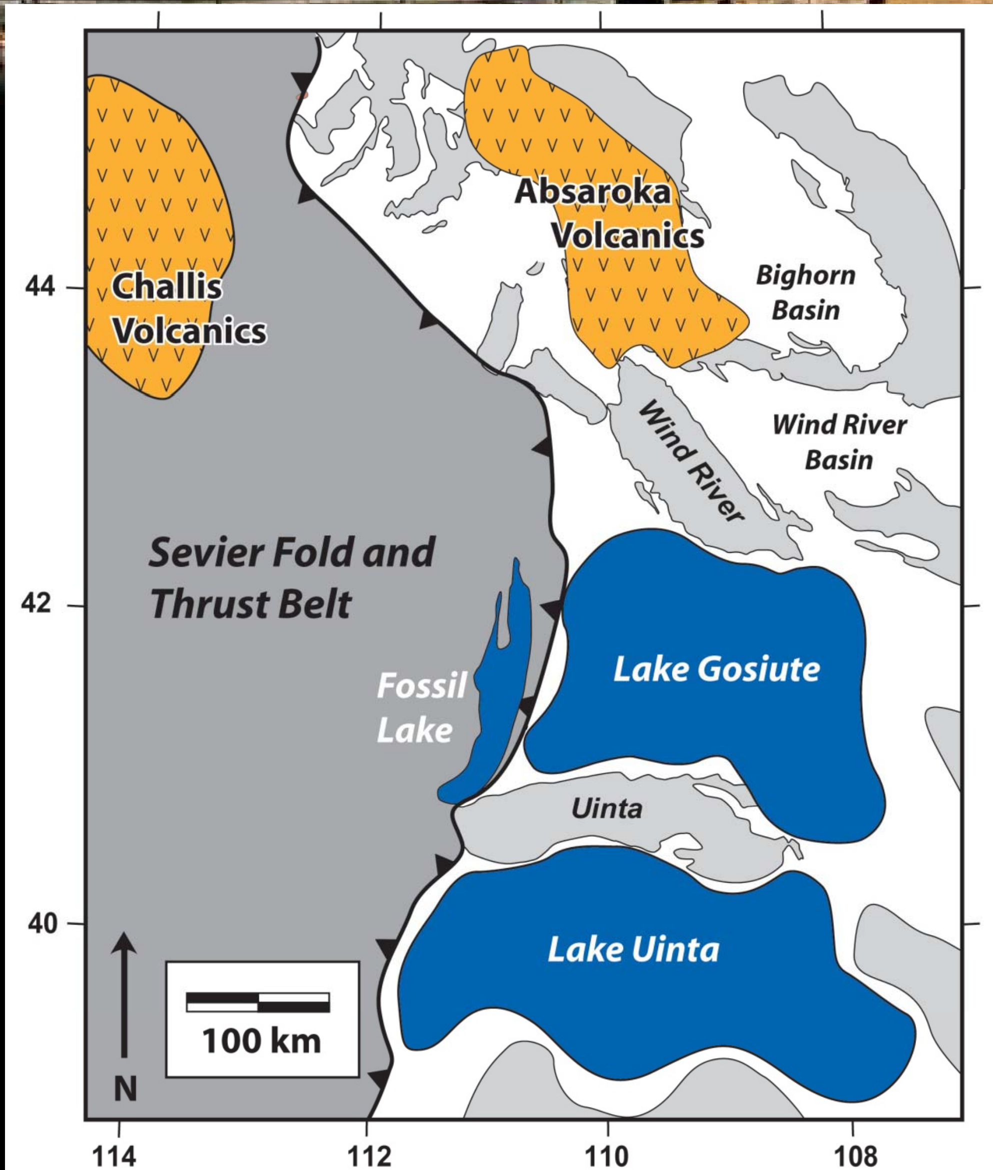
Outline

Eocene Lake Gosuite



TECTONIC SETTING

- Cordilleran Foreland
- Laramide-style uplifts impound basin; interrupt longitudinal drainage

SEDIMENTATION (GGRB)

- Laramide shortening
- 5.5 Myr of deposition (52.5 - 47 Ma)

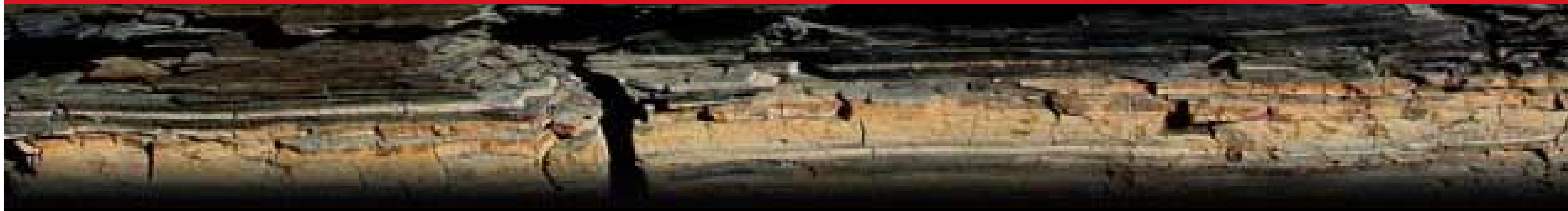
Smith et al., 2003, 2008

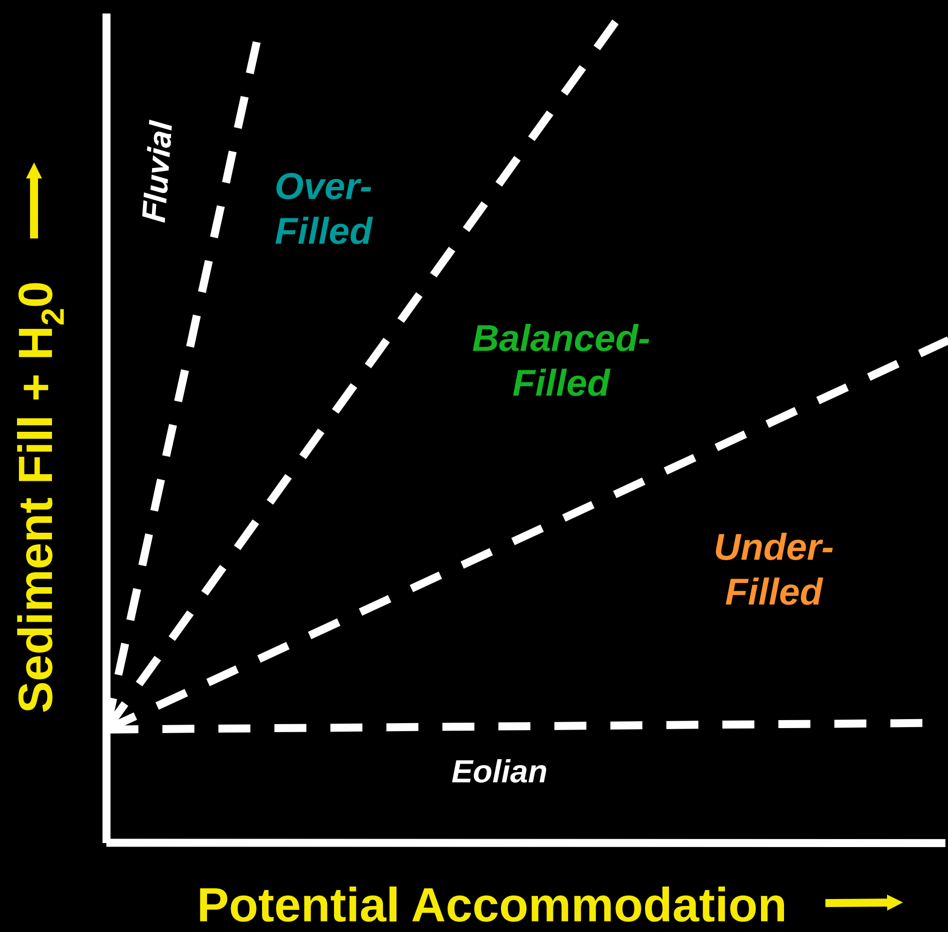
EOCENE CLIMATE

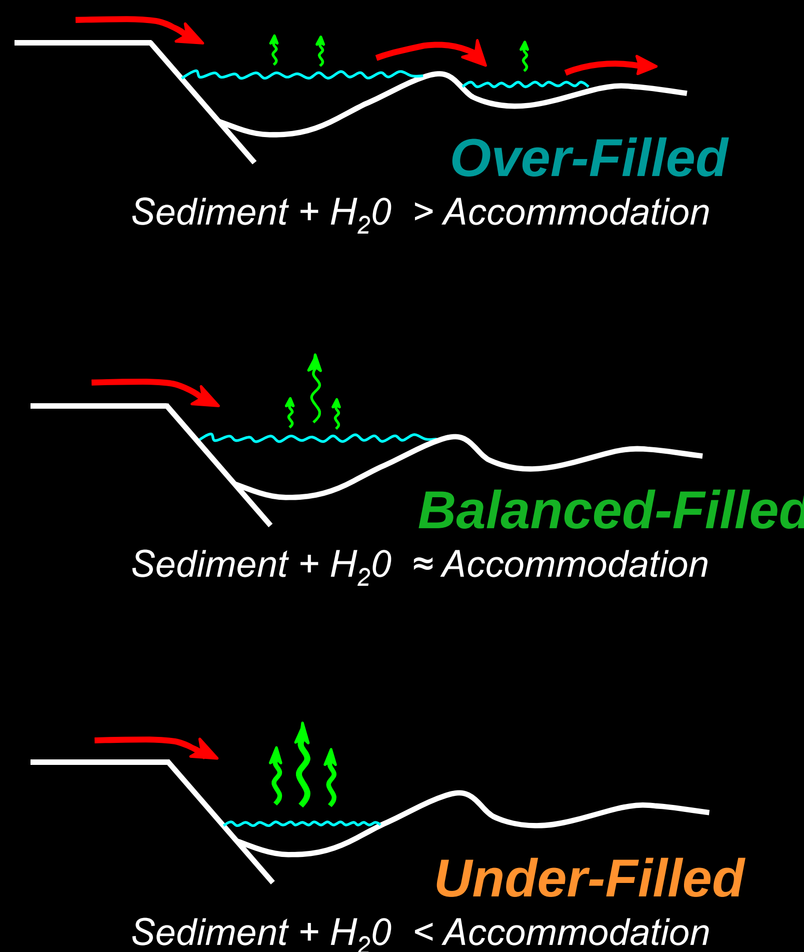
- Subtropical (15 - 23°C)
- Humid (75 - 100cm precip/year)
- Moderate seasonality

Marwick, 1994; Wilf, 2000

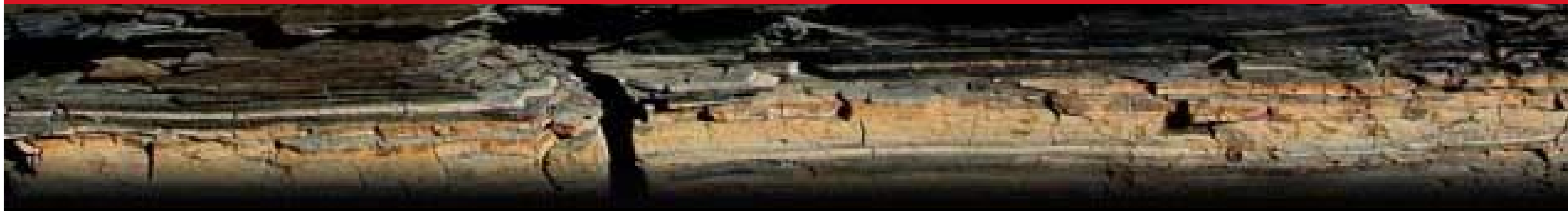
Lake Type Model - Carroll and Bohacs, 1999



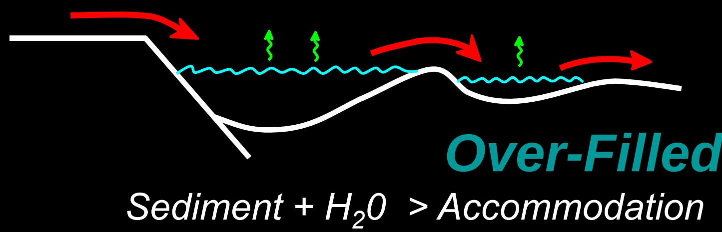




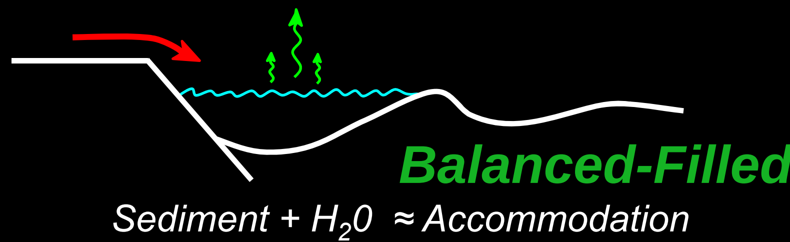
Lake Type and Source Potential - Bohacs et al., 2000



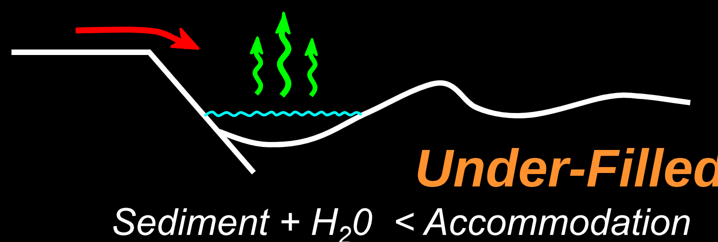
- Fluvial-Lacustrine lithofacies assemblage
- Land-plant, charophytic and aquatic algal organic matter
- Low to Moderate TOC
- Low-quality oil shale



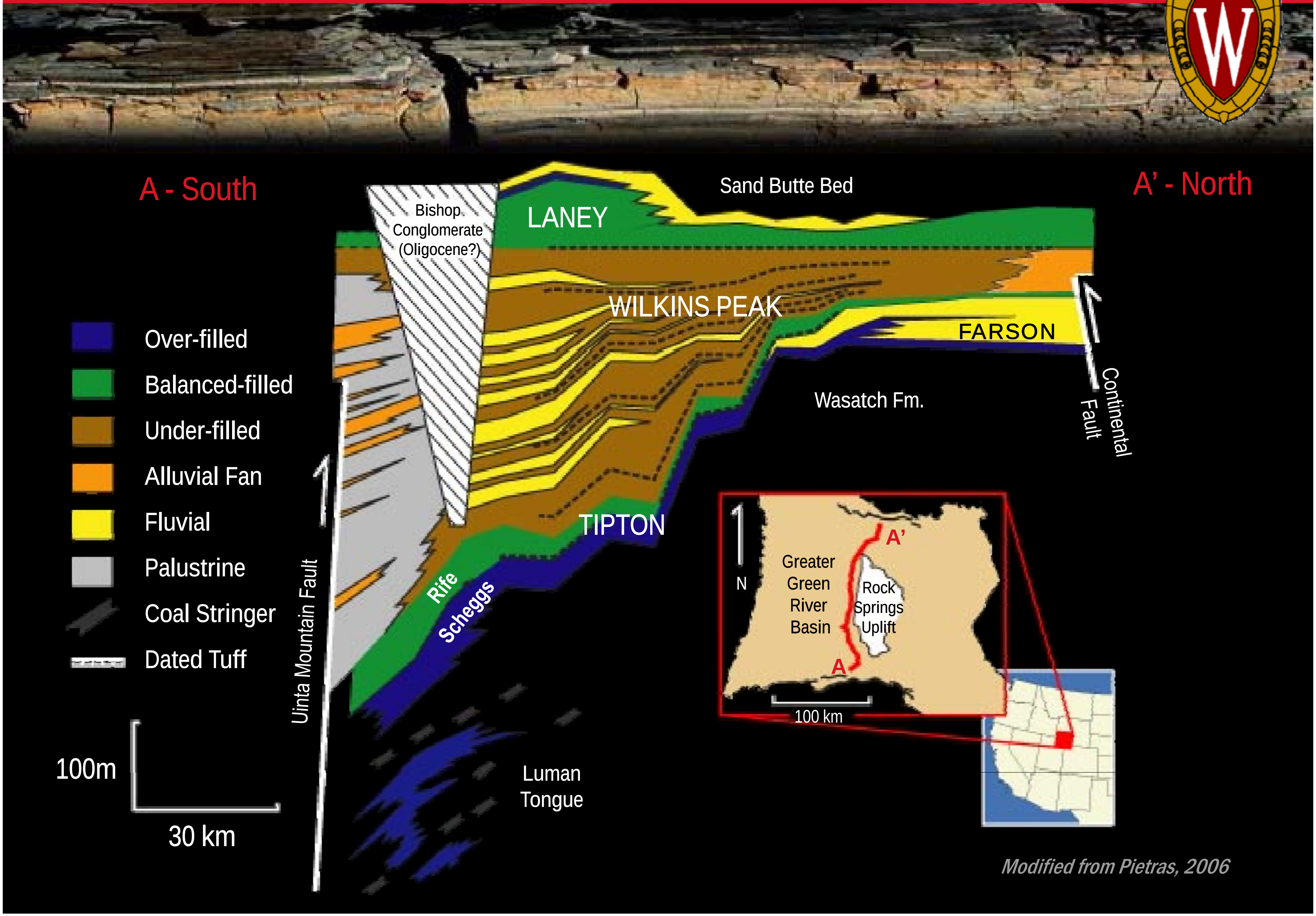
- Fluctuating-Profundal lithofacies assemblage
- Aquatic algal organic matter
- Moderate to High TOC
- High-quality oil shale



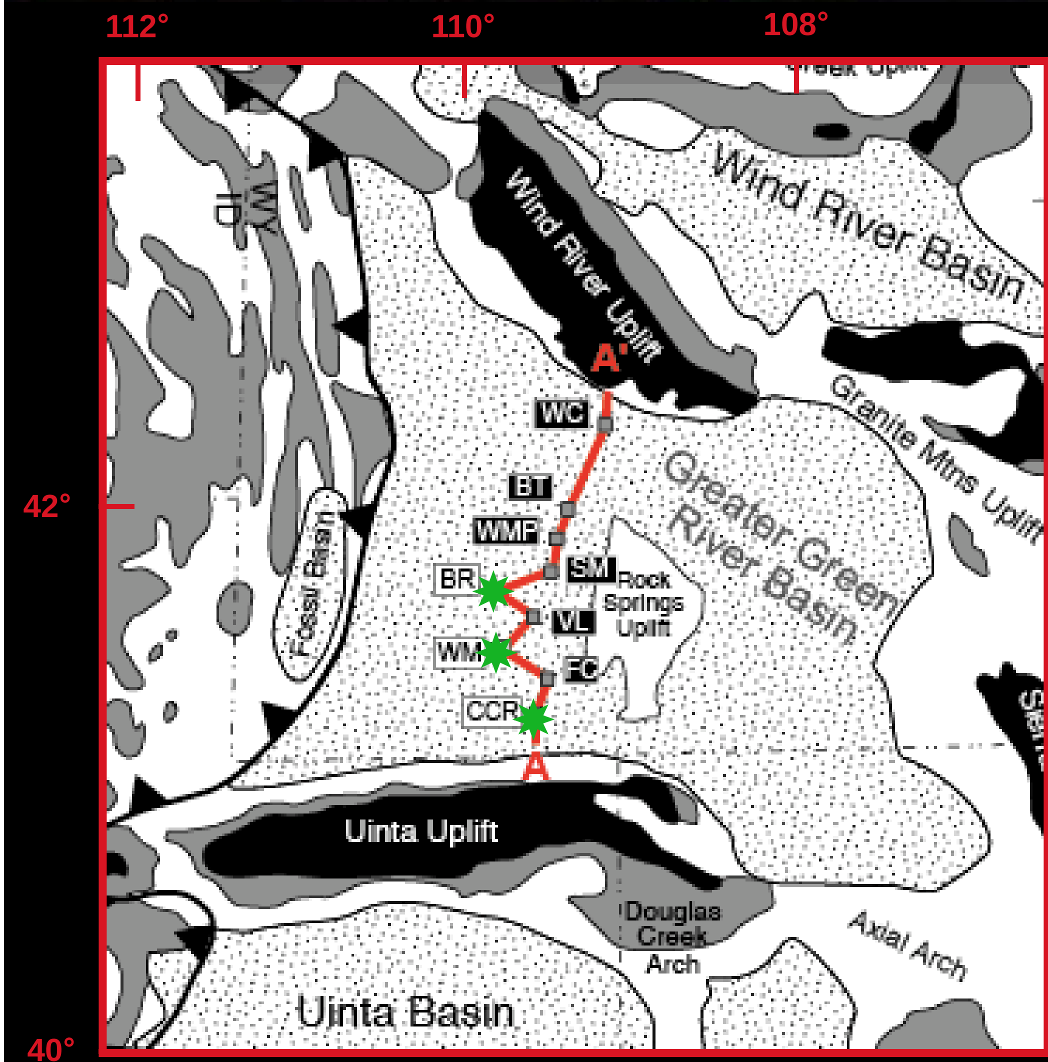
- Evaporative lithofacies assemblage
- Algal-bacterial organic matter
- Overall low TOC (with sporadic high intervals)



Green River Formation, Wyoming

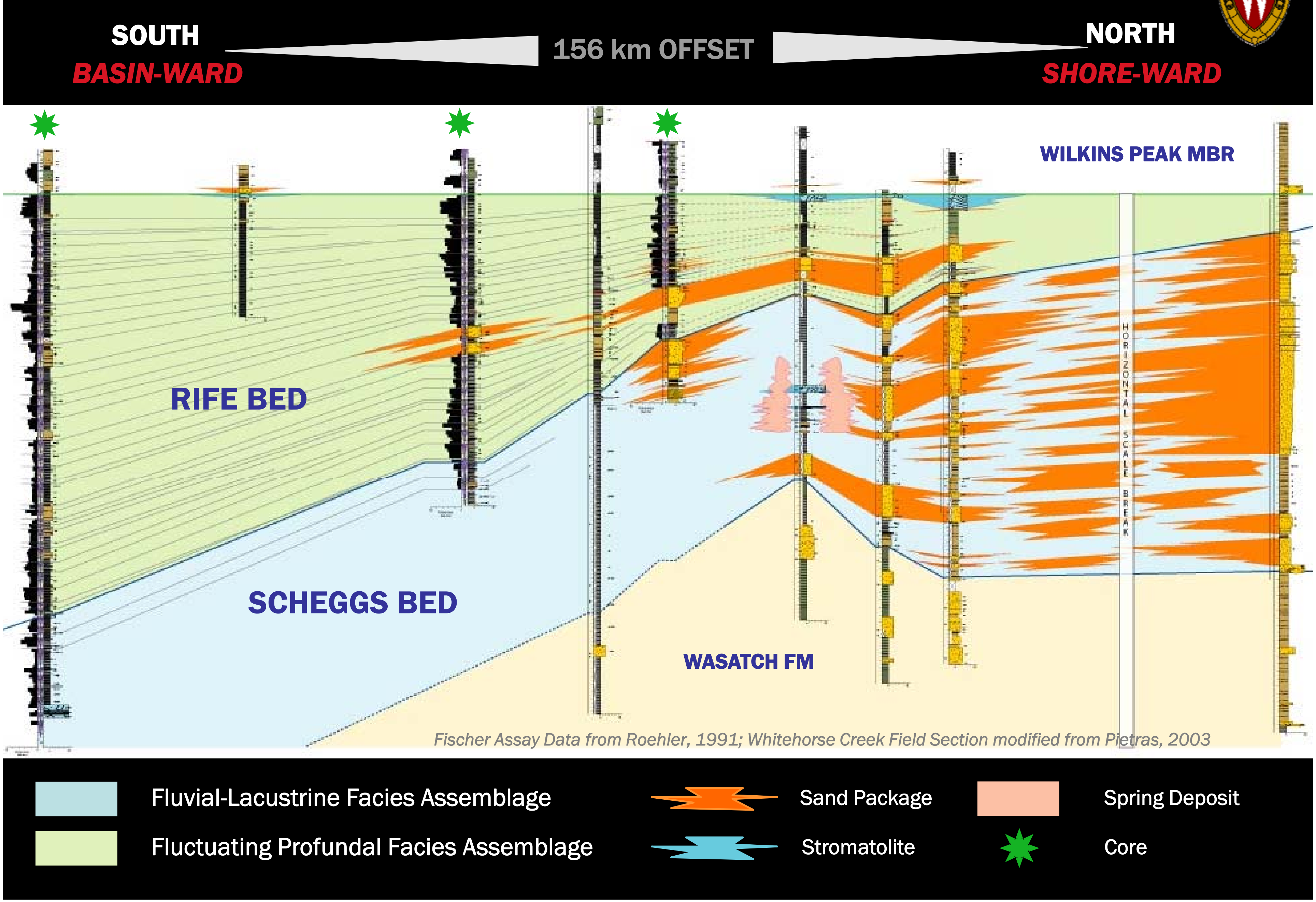


Constraining the Tipton Transition: METHODS

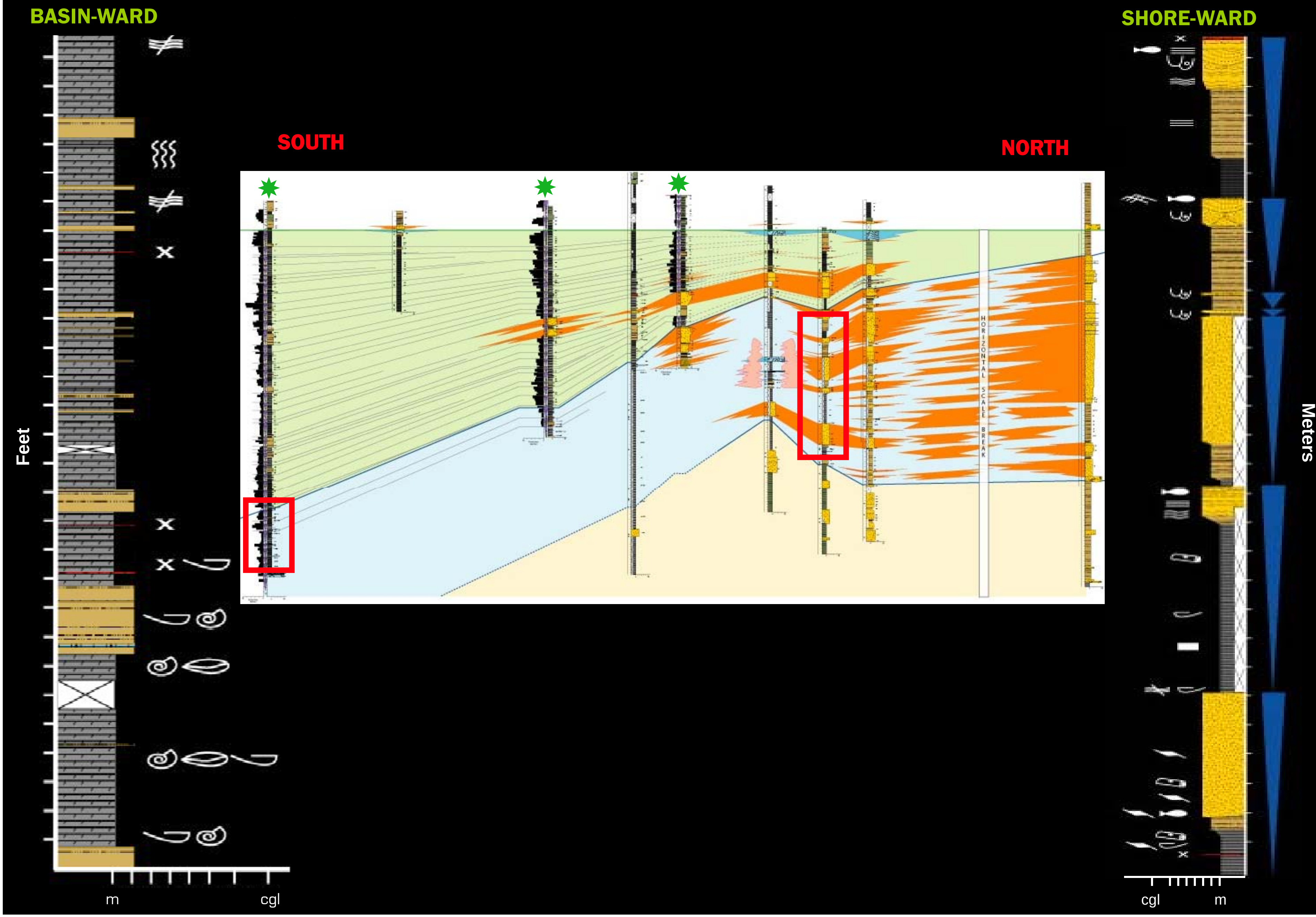


- **3 core, 6 field sections described at cm-scale resolution**
- **Represent N-S transect of >150km, from deep profundal to marginal depositional environments**

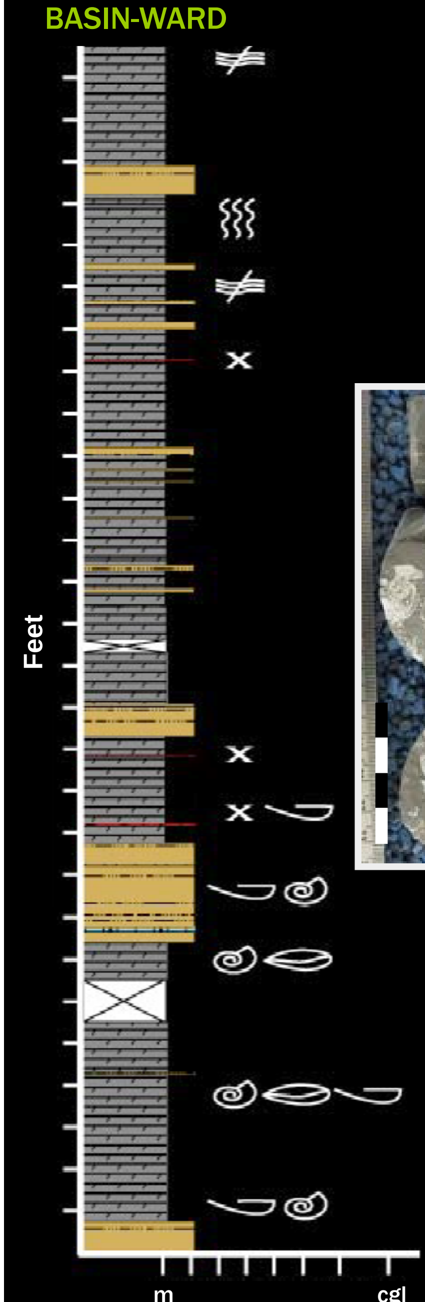
Tipton Member Across the GGRB



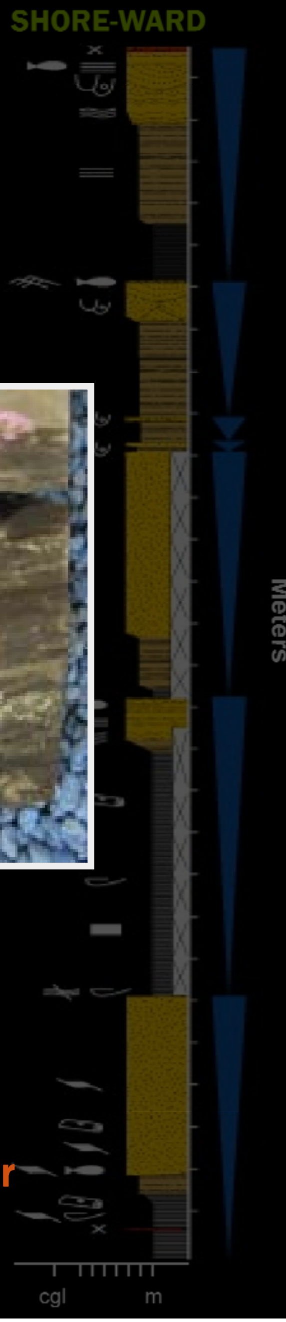
Fluvial-Lacustrine Assemblage: SCHEGGS BED



Fluvial-Lacustrine Assemblage: BASIN-WARD EXPRESSION

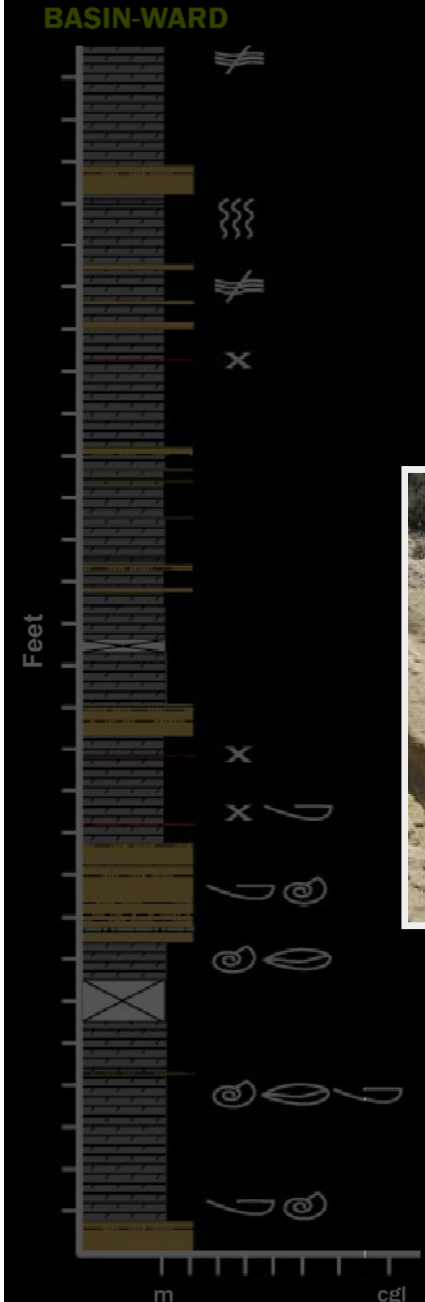


- Massive Mudstone with cm- to decimeter-scale interbeds of fining-upward siltstone and, less frequently, coquina
- Low organic content, ranging from 2-16 Gal./ton
- Freshwater bivalves, gastropods, ostracodes, burrows
- Absence of parasequences and thick tuff laminations



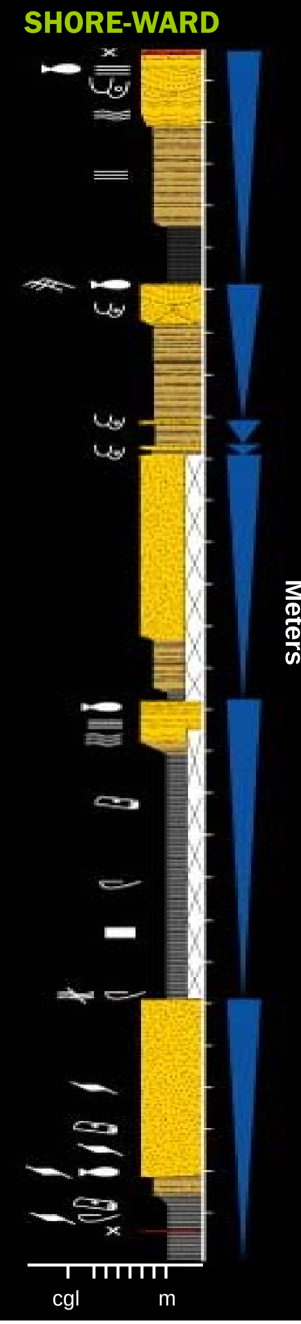
- Sustained high-stand conditions
- Oxygenated lake waters with limited to non-existent chemical and thermal stratification
- Clastic dilution, chemical degradation, biologic consumption or a combination thereof

Fluvial-Lacustrine Assemblage: SHOREWARD EXPRESSION

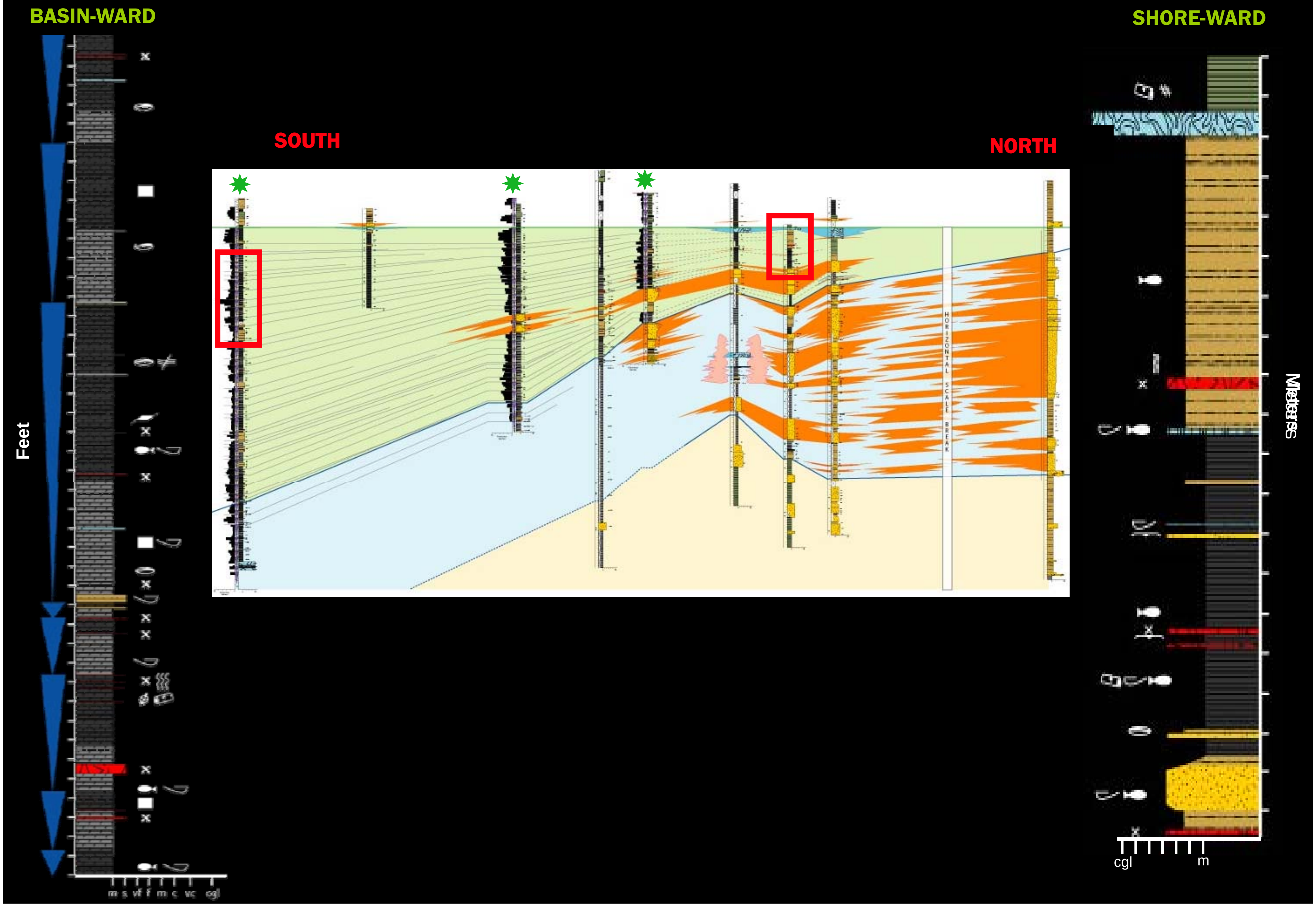


- Stacked, coarsening upward cycles of laminated mudstone, siltstone, and well-sorted sandstone lithofacies
- Imprints of terrestrial flora, silt rip-ups, and loading features are abundant throughout
- Cycle thickness decreases basin-ward, while number of sequences and ratio of fine-grained to coarse-grained sediments increase

- Lateral migrations of a deltaic system
- Lithofacies and associated sedimentary structures indicate rapid deposition

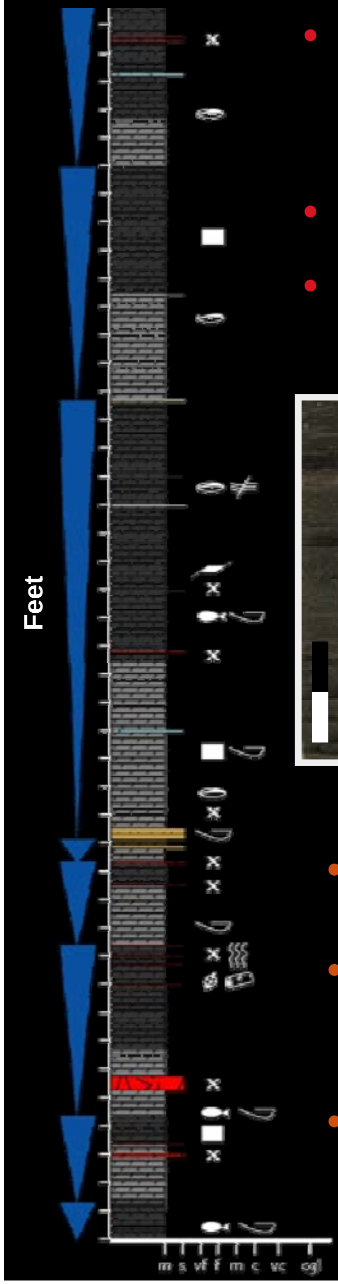


Fluctuating-Profundal Assemblage: RIFE BED



Fluctuating Profundal Assemblage: BASIN-WARD EXPRESSION

BASIN-WARD



- Alternating intervals of organic-rich (20-26 Gal./ton) and less organic-rich (9-22 Gal./ton) finely-laminated mudstone form meter-scale parasequences
- Fish and ostracodes are the primary-preserved organisms
- Tuff laminations (3mm - 15cm) are frequent and often saturated by kerogen

- Oscillations between low- and high-stand lake conditions
- High rate of organic preservation suggests a chemically and thermally stratified lake system
- The replacement of bivalves/gastropods with fish suggests a shift towards more saline conditions

SHORE-WARD

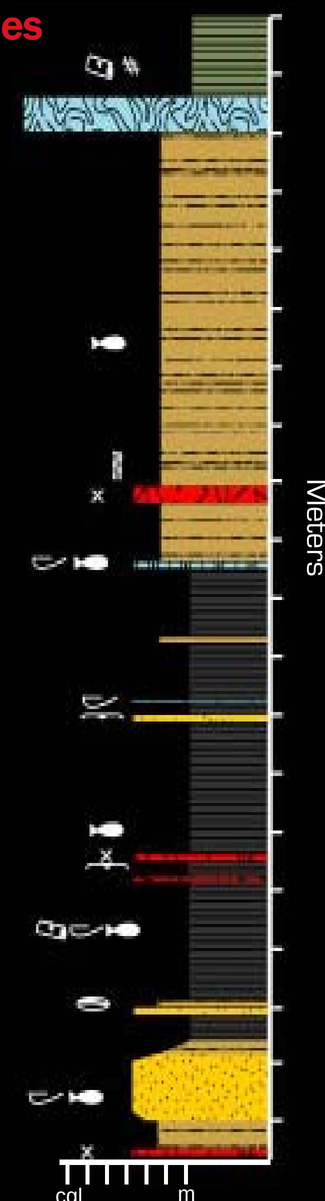
Fluctuating Profundal Assemblage: SHORE-WARD EXPRESSION

BASIN-WARD

- Coarse-clastic, biogenic, and fine-grained, organic rich lithofacies
- Fish “debris”, stromatolite, burrows, and ostracodes
- Mud cracked horizons and thick tuffs (>20 cm)
- Vertically grades into green, evaporative-mineral bearing siltstone and mudstone lithofacies of the Wilkins Peak Member

- Oscillations between high- and low-stands
- Larger regressive trend towards under-filled conditions of the overlying Wilkins Peak Member
- Thick tuff laminations indicate quiet hydrologic conditions in which suspended deposits are preserved

SHORE-WARD

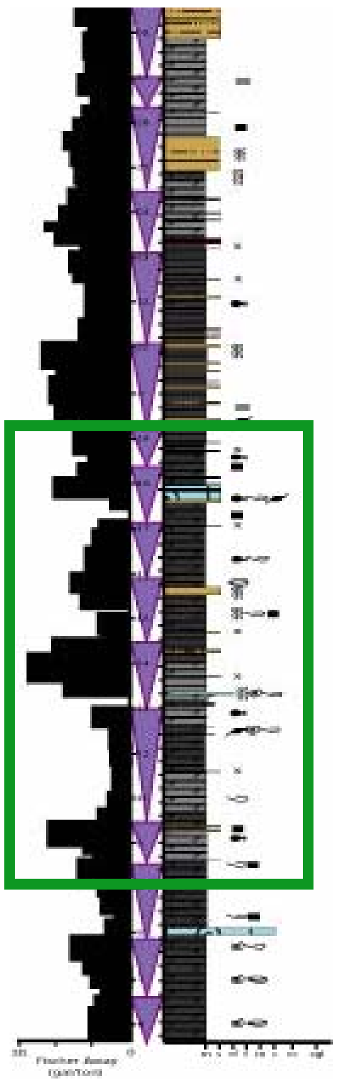


Scheggs-Rife Transition Zone: Lithology

SOUTH
Currant Creek Ridge
No. 1 Core

64 km OFFSET

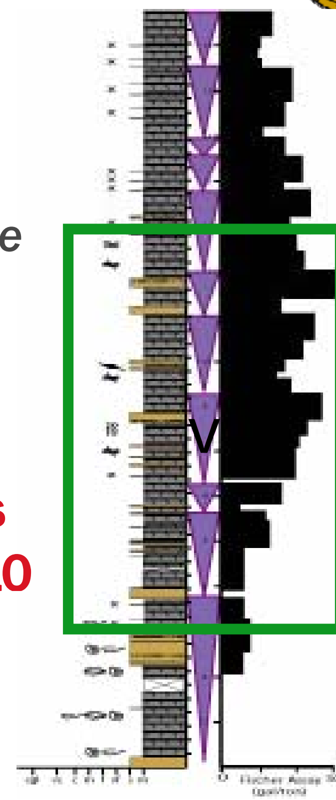
NORTH
White Mtn.
No. 1 Core



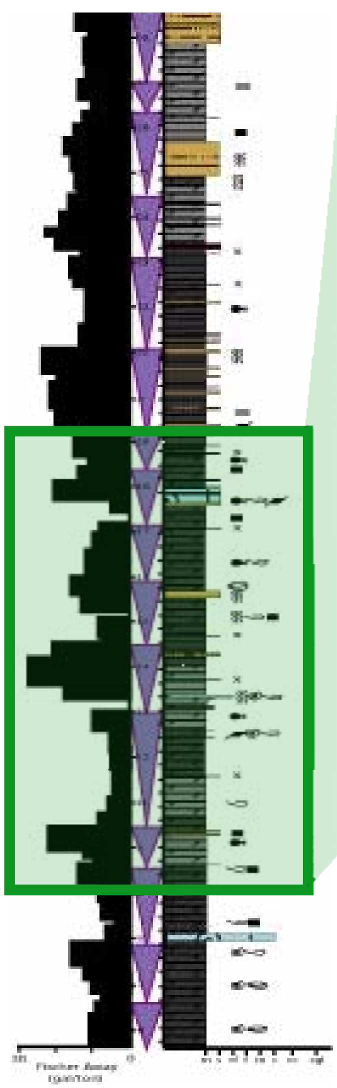
- *Above the transition window is planar-parallel, relatively organic-rich (12 - 22 Gal/ton) mudstone that bears abundant tuff interlaminations and fish fossils*

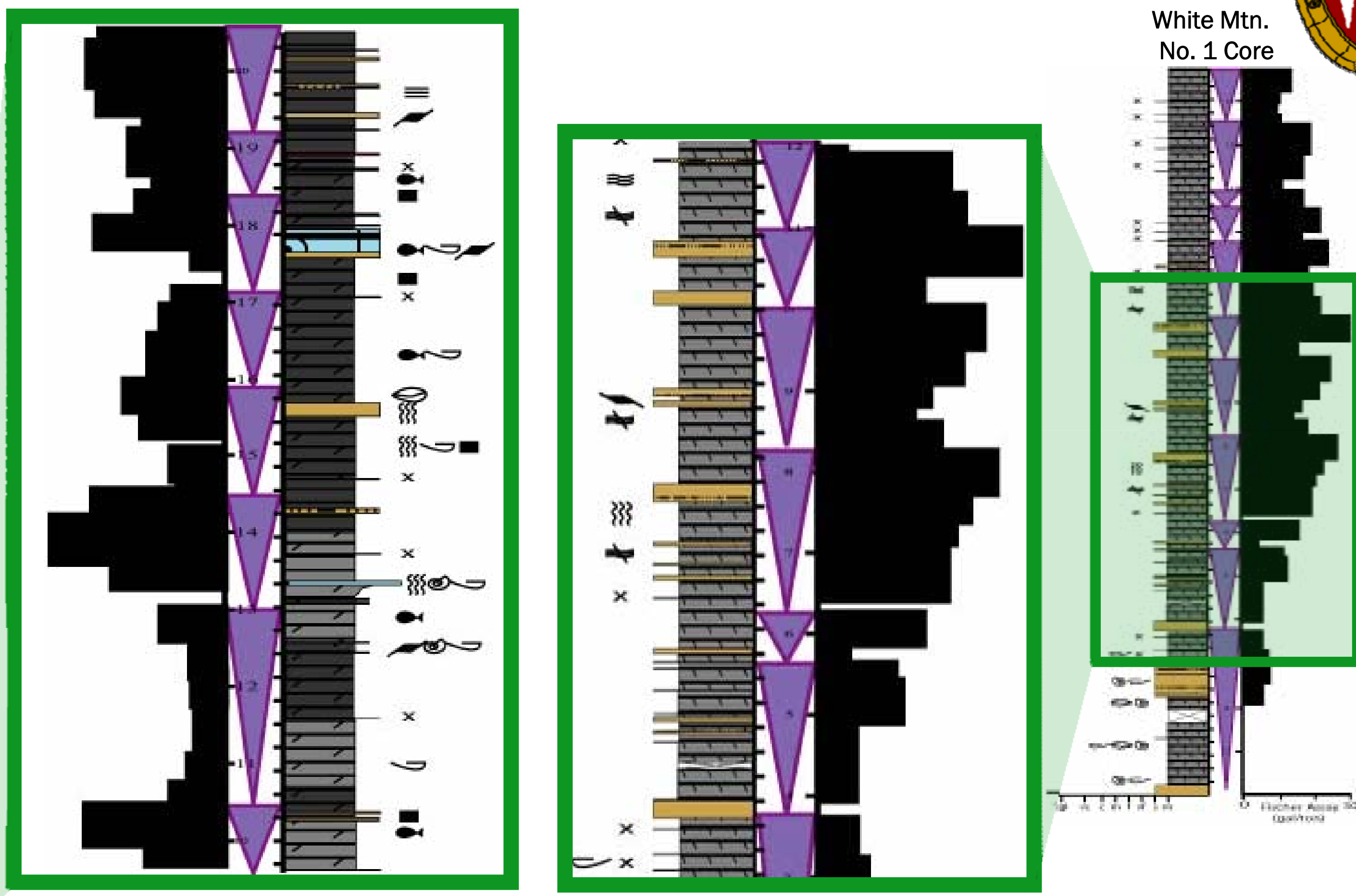
- **Transition from Scheggs to Rife deposition is gradual and represented by approximately 10 meters of section**

- *Below the transition window is massively-bedded, organically-depleted (0 - 13 Gal./ton) mudstone that bears bivalves and gastropods*



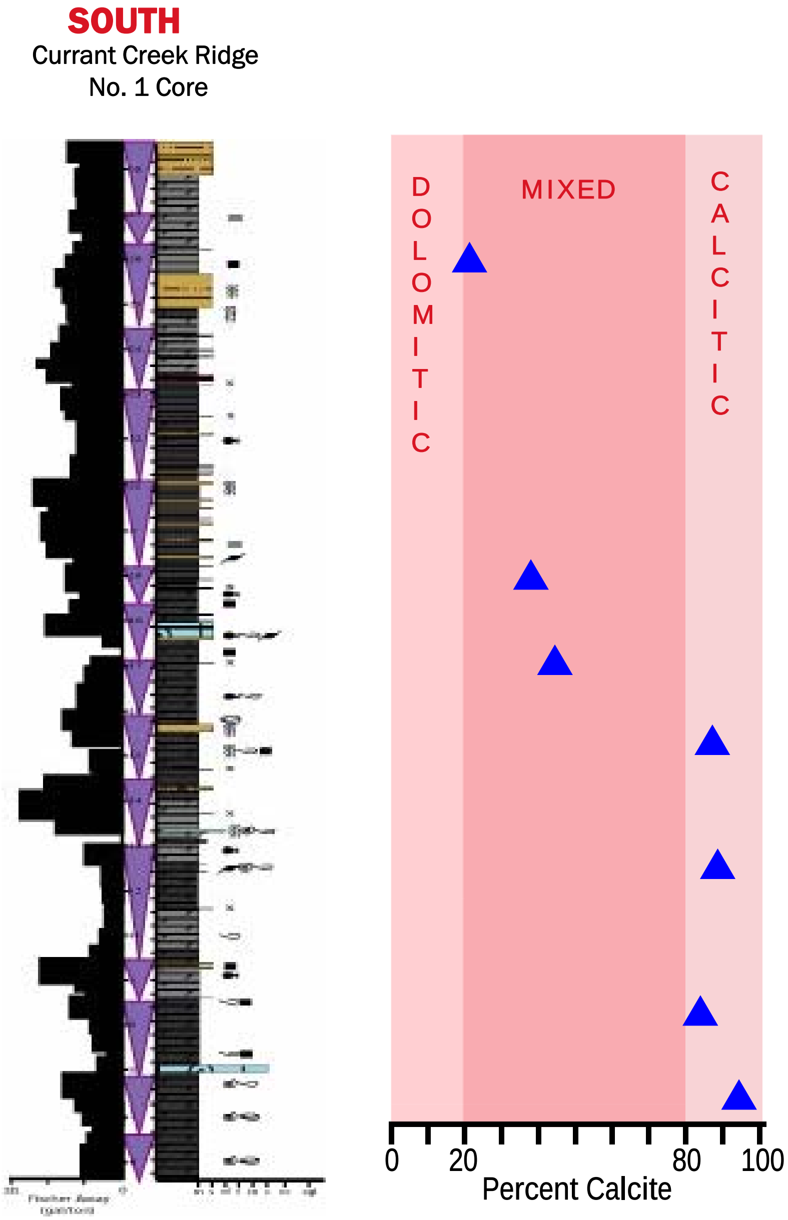
Scheggs-Rife Transition Zone: *Lithology*

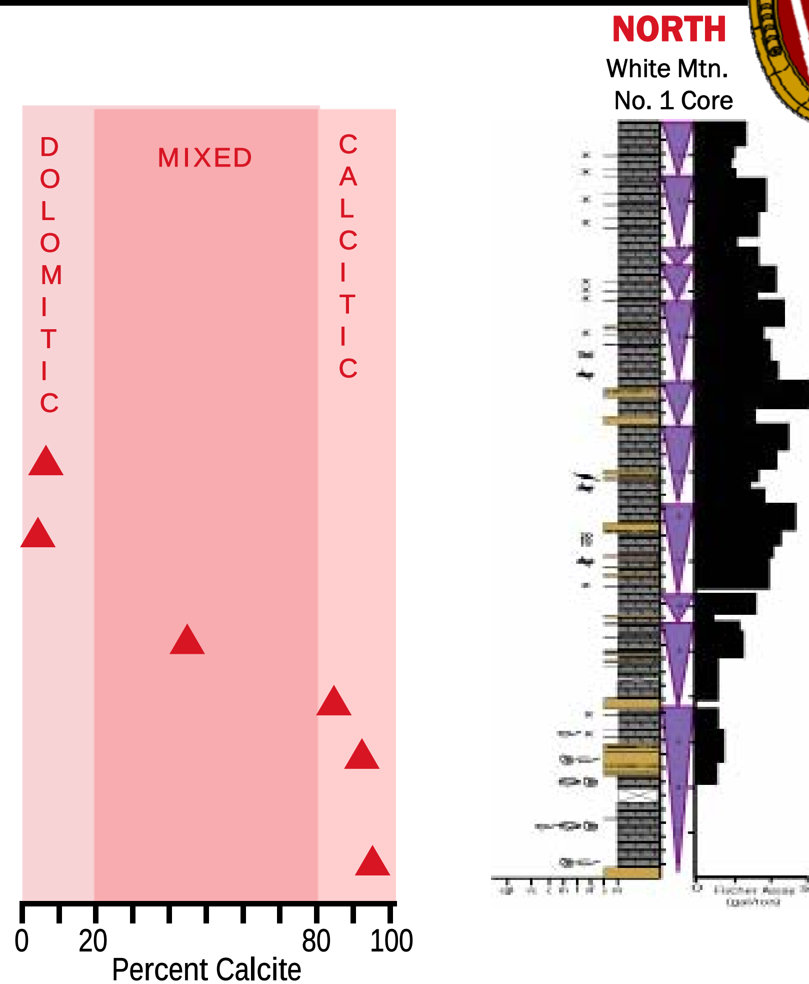




- Suspensional (tuffs) and high-enery deposition (rip-ups)
- Freshwater (bivalves/gastropods) and saline (fish) fauna
- Variable organic content, ranging from 0 to 29 Gal./ton

Scheggs-Rife Transition Zone: XRD Mineralogy



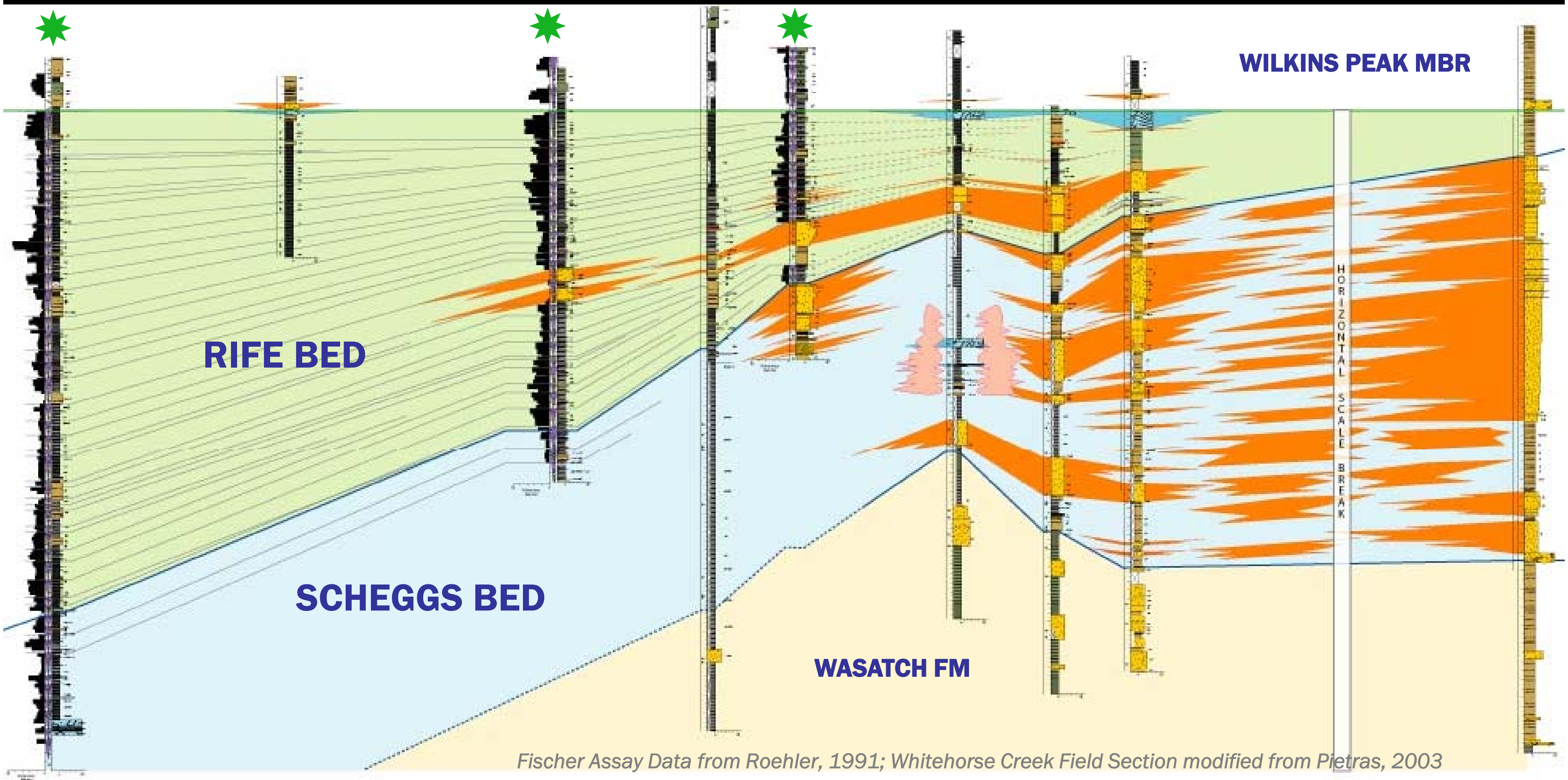


- ***Within transition zone, there is a pronounced shift in relative carbonate content, from dominantly calcitic mineralogy towards dolomitic***

Tipton Member Across the GGRB

SOUTH **NORTH**

BASIN-WARD ***SHORE-WARD***



Fluvial-Lacustrine Facies Assemblage

Fluctuating Profundal Facies Assemblage

Sand Package

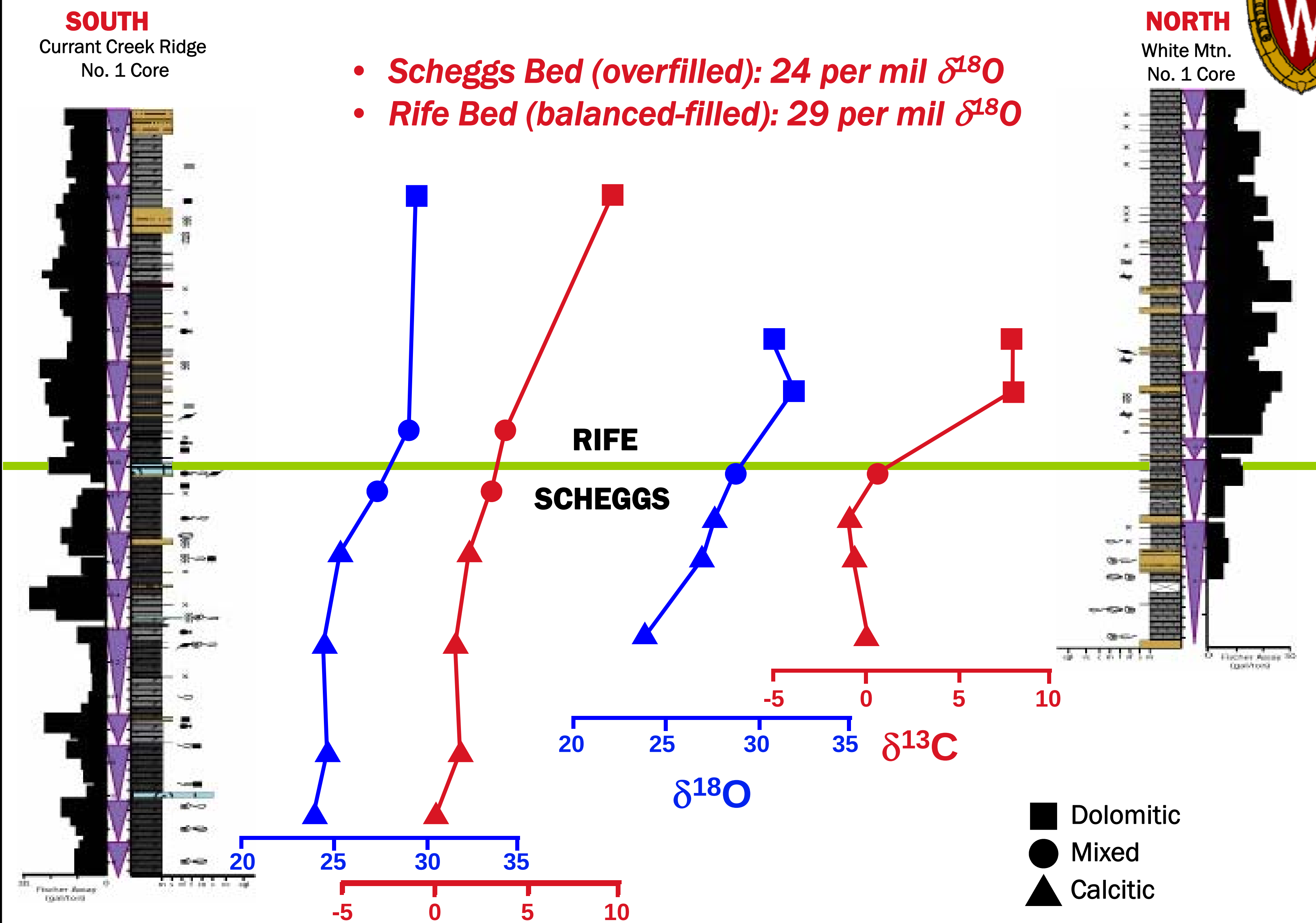
Stromatolite

Spring Deposit

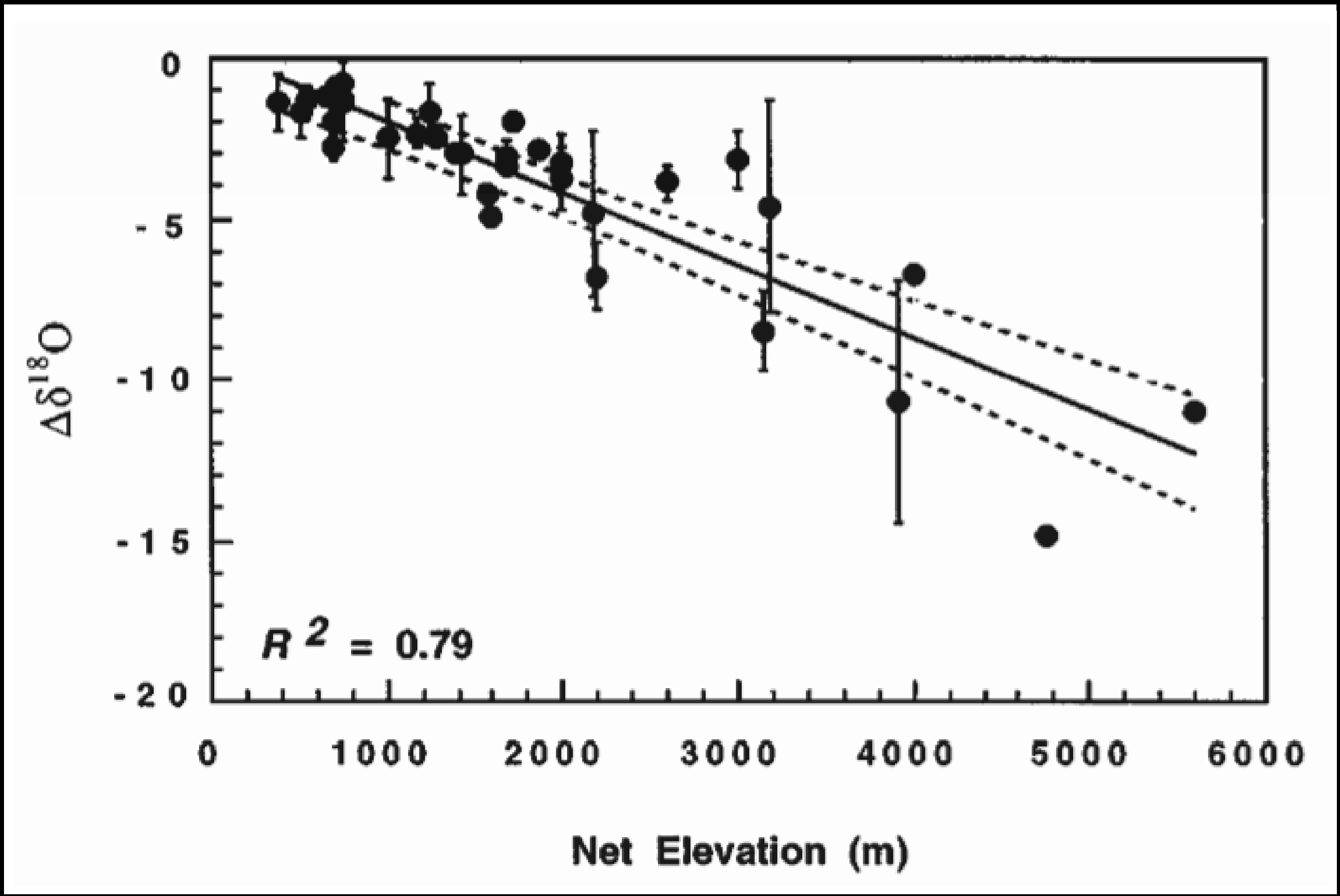
Core

Scheggs-Rife Transition Zone: Geochemistry

- *Scheggs Bed (overfilled): 24 per mil $\delta^{18}O$*
- *Rife Bed (balanced-filled): 29 per mil $\delta^{18}O$*



$\delta^{18}O$ and Elevation Connection: Chamberlain and Poage, 2000



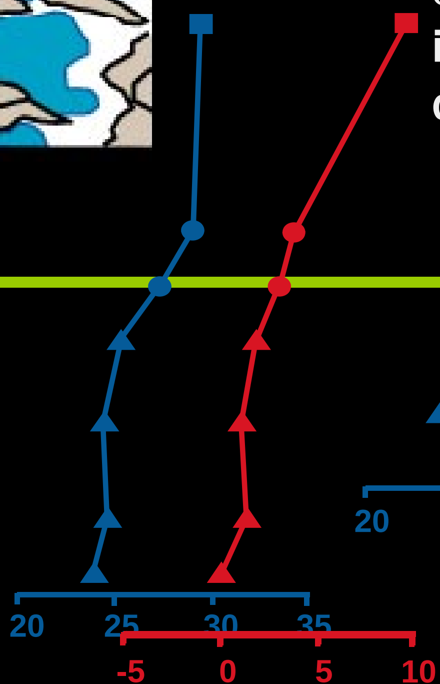
- *$\delta^{18}O$ values decrease where elevation increases*

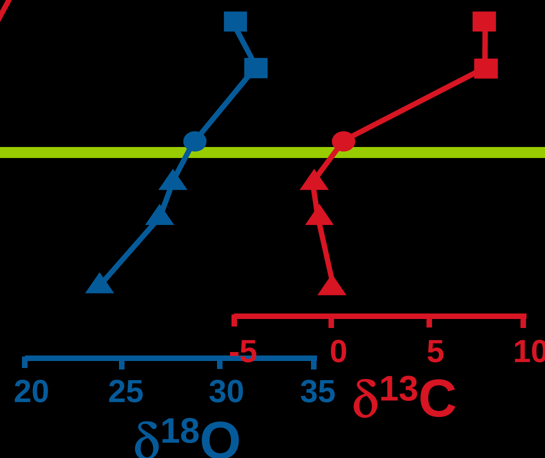
Scheggs-Rife Transition Zone: Highland Source Diversion

- Highland drainage network is tectonically diverted
- In the absence of highland sources the $\delta^{18}O$ signature of the lake water increases to reflect lower-elevation drainage sources

RIFE

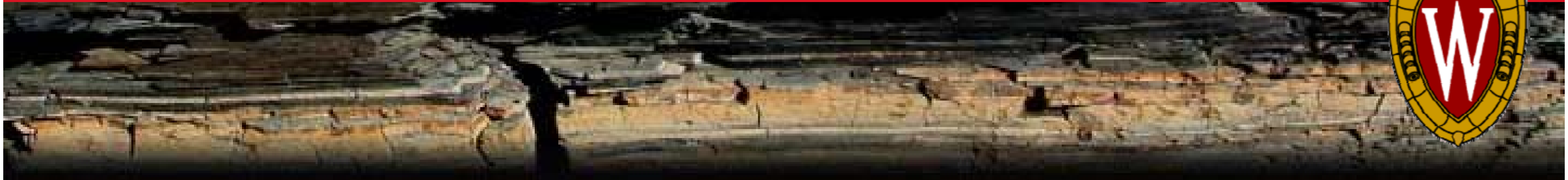
SCHEGGS





- Highland drainage network sources light $\delta^{18}O$ water
- Correspondingly, lake water has a light $\delta^{18}O$ value

Conclusions on the Tipton Member



TIPTON STRATIGRAPHY

Scheggs Bed and Rife Bed are distinguished by two distinct lithofacies assemblages, fluvial-lacustrine (over-filled) and fluctuating profundal (balanced-filled), respectively

SCHEGGS-RIFE CONTACT

Lithologic transition is gradual, but shift from calcite to dolomite and a 5.0 per mil increase in $\delta^{18}O$ clearly define Scheggs-Rife contact

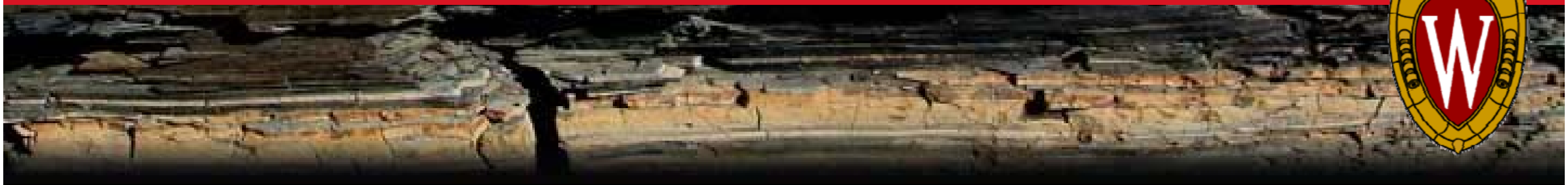
CAUSES OF LAKE-TYPE CHANGE

The transition from over-filled to balanced-filled is thought to have resulted from a diversion of an isotopically light drainage network away from the basin

APPLICATION TO OIL SHALE EXPLORATION

Identification of allogenic drivers, such as paleo-geomorphic drainage networks, can yield more accurate assessments of oil shale reserves

Acknowledgements



UW-Madison Lacustrine Basins Research Team

Eric Williams, Amalia Doebbert, Meredith Rhodes-Carson, M. Elliot Smith, Lauren Chetel, Jana Van Alstine, Wasinee Aswasereelert, Jeff Pietras, Andrew Trzaskus

S.W. Bailey X-ray Diffraction Laboratory at UW-Madison

Huifang Xu, Jason Huberty, Hiromi Konishi

The University of Michigan Stable Isotope Laboratory

USGS Core Repository, Denver, Colorado

Lisa Lesar, Field Assistant

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