Sequence stratigraphic and stable isotopic expressions of over-filled and balanced-filled transitions within the Tipton Member of the Green River Formation, WY

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Eocene Lake Gosuite

TECTONIC SETTING
- Cordilleran Foreland
- Laramide-style uplifts impound basin

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

Sediment + H₂O > Accommodation

Sediment + H₂O ≈ Accommodation

Sediment + H₂O < Accommodation

Over-Filled

Balanced-Filled

Under-Filled

Potential Accommodation

Sediment Fill + H₂O

Fluvial

Over-Filled

Balanced-Filled

Under-Filled

Eolian
Over-Filled
Sediment + H₂O > Accommodation

Balanced-Filled
Sediment + H₂O ≈ Accommodation

Under-Filled
Sediment + H₂O < Accommodation

- **Low-quality oil shale**
  - Fluvial-Lacustrine lithofacies assemblage

- **High-quality oil shale**
  - Fluctuating-Profundal lithofacies assemblage

- **Limited oil shale development**
  - Evaporative lithofacies assemblage

Lake Type and Source Potential - Bohacs et al., 2000
Green River Formation, Wyoming

A - South

- Over-filled
- Balanced-filled
- Under-filled
- Alluvial Fan
- Fluvial
- Palustrine
- Coal Stringer
- Dated Tuff

A' - North

- Wilkins Peak
- Farson
- Sand Butte Bed

Wasatch Fm.

Lumon

Tipton

Bishop Conglomerate (Oligocene?)

Scheggs

Uplift

Continental Fault

Greater Green River Basin

Balanced-filled

Under-filled

Alluvial Fan

Fluvial

Palustrine

Coal Stringer

Dated Tuff

100m

30 km

100 km

Modified from Pietras, 2006
Constraining the Tipton Transitions: METHODS

- 3 core, 6 field sections described at cm-scale resolution
- Represent N-S transect of >150km, from deep profundal to marginal depositional environments
- 13 lithofacies grouped into 2 lithofacies assemblages:
  - FLUVIAL-LACUSTRINE
  - FLUCTUATING PROFUNDAL
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
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; number of sequences and ratio of coarse-grained to fine-grained sediments decrease

- Lateral migrations of a deltaic system
- Lithofacies and associated sedimentary structures indicate rapid deposition
Fluctuating Profundal Assemblage: **BASIN-WARD EXPRESSION**

- 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 kerogen-saturated.

- 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.
Fluctuating Profundal Assemblage: **SHOREWARD EXPRESSION**

- Coarse-clastic, biogenic, and fine-grained, organic rich lithofacies
- Fish “debris”, stromatolite, burrows, and ostracode accumulation
- 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
BASIN-WARD

Fluvial-Lacustrine Facies Assemblage
Fluctuating Profundal Facies Assemblage

SHORE-WARD

Fischer Assay Data from Roehler, 1991; Whitehorse Creek Field Section modified from Pietras, 2003

Spring Deposit
Sand Package
Stromatolite
Core
Higher quality oil shales are associated with *Fluctuating Profundal* intervals

Low quality oil shales are associated with *Fluvial-Lacustrine* intervals

Fischer Assay Data from Roehler, 1991;
Fluvial-lacustrine intervals: CALCITIC
Fluctuating profundal intervals: DOLOMITIC

Biogenic Model of Dolomite Distribution
Mg preferentially concentrated by blue-green algae
Desbourough, 1978
Fischer Assay Data from Roehler, 1991; Whitehorse Creek Field Section modified from Pietras, 2003
$\delta^{13}C$ influenced by:

1) Primary productivity
   \[ \text{Prod} \uparrow^{13}C \uparrow \]

2) Rate of organic decomposition
   \[ \text{Decomp} \uparrow^{13}C \downarrow \]

3) Dissolved inorganic carbon from limestone bedrock
   \[ \text{Lime} \uparrow^{13}C \downarrow \]

Fluvial-lacustrine lower productivity, higher rates of decomposition

Fluctuating Profundal high productivity, lower rates of decomposition
\( \delta^{18}O \) influenced by:

1) Climate / Evaporation
   \[ \text{Temp} \uparrow \quad ^{18}O \uparrow \]

2) Elevation
   \[ \text{Elev} \uparrow \quad ^{18}O \downarrow \]

3) Residence Time
   \[ \text{Time} \uparrow \quad ^{18}O \uparrow \]

Fluvial-lacustrine waters had shorter residence time in the lake

Fluctuating Profundal waters had longer residence in the lake
**Tipton Stable Isotopic Signature**

**Fluvial-Lacustrine Facies Assemblage**
**Sand Package**
**Fluctuating Profundal Facies Assemblage**
**Stromatolite**
**Spring Deposit**
**Core**

Fischer Assay Data from Roehler, 1991; Whitehorse Creek Field Section modified from Pietras, 2003

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BASIN-WARD

SOUTH

NORTH

SHORE-WARD
The Scheggs-Rife contact represents the initial impoundment of Eocene Lake Gosuite, and is represented by a trend towards heavier $^{18}$O and $^{13}$C, an increase in organic content, cessation of the Farson Sandstone, and a trend towards dolomitic mineralogy.

3 distinct lake-type transitions are preserved within the Tipton Member, representing an oscillation between over-filled and balanced-filled lake conditions.

These transitions are thought to result from the diversion, re-capture, and terminal diversion of significant drainage network away from the basin.
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

Lisa Lesar, Field Assistant

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