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 Tongue 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.
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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INTRODUCTION
Eocene Lake Gosuite
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TIPTON MEMBER
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Lithology
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Stable Isotope Geochemistry

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CONCLUSIONS
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)

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

Smith et al., 2003, 2008
Marwick, 1994; Wilf, 2000
Lake Type Model - Carroll and Bohacs, 1999

- **Over-Filled**: Sediment + H₂O > Accommodation
- **Balanced-Filled**: Sediment + H₂O ≈ Accommodation
- **Under-Filled**: Sediment + H₂O < Accommodation

Diagram with axes:
- Potential Accommodation
- Sediment Fill + H₂O
- Fluvial
- Eolian

Legend:
- Red arrows indicating flow or deposition patterns.
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

A - South

LANEY

Sand Butte Bed

Bishop Conglomerate (Oligocene?)

Over-filled

Balanced-filled

Under-filled

Alluvial Fan

Fluvial

Palustrine

Coal Stringer

Dated Tuff

Unita Mountain Fault

100m

30 km

A' - North

WILKINS PEAK

FARSON

TIPTON

Wasatch Fm.

Greater Green River Basin

Rock Springs Uplift

Modified from Pietras, 2006
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
Fischer Assay Data from Roehler, 1991; Whitehorse Creek Field Section modified from Pietras, 2003

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

- 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
Fluctuating Profundal Assemblage: SHORE-WARD EXPRESSION

- 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
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-energy deposition (rip-ups)
- Freshwater (bivalves/gastropods) and saline (fish) fauna
- Variable organic content, ranging from 0 to 29 Gal./ton
Within transition zone, there is a pronounced shift in relative carbonate content, from dominantly calcitic mineralogy towards dolomitic.
Fischer Assay Data from Roehler, 1991; Whitehorse Creek Field Section modified from Pietras, 2003

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

• 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.
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