Cyclostrophy of the Parachute Creek Member: Analysis of Vertical and Lateral Facies and Inorganic Geochemical Variability in the Green River Formation of the Uinta Basin, Utah

Abstract:
Detailed lithofacies description of the Parachute Creek Member of the Green River Formation deposited in Lake Uinta reveals a history of cyclicity. Decameter-scale cycles of organic-rich and organic-depleted facies are separated by mm-scale laminations of siltstones and mudstones. Organic-rich facies are deposited during times of high lake levels, whereas organic-depleted facies are deposited during times of low lake levels. These cycles are interpreted to have formed in response to changes in the lake level, which are controlled by climatic variations. The paratabular limestones and marls of the Parachute Creek Member are interpreted to have formed in a shallow, warm, and hypersaline environment, similar to modern lake systems.

Geologic Background and Regional Stratigraphy:
During the Cretaceous, the Uinta Basin of northeast Utah was part of the foreland basin that formed east of the Sevier Orogenic Belt, which was subsequently divided during the Laramide orogeny by basement-cored uplifts. The Uinta Basin is one in a series of basins, including the Greater Green River Basin in WY, and the Parachute Creek Basin in CO, that were filled by long-lived lakes during the Eocene, recorded by deposition of the Green River Formation.

Large-Scale Sediment Packaging:
Organic lean zone (L6) from Parachute Creek Member:
Organic rich zone (R5) from Parachute Creek Member:

Current Correlations of the R4/L4 and R5/L5 Zones:

Location of basins containing the Green River Formation and cores studied in this project. The location of the Uinta Basin (U), Parachute Creek Basin (P), Greater Green River Basin (G), Uinta Mountains (UM), and Douglas Creek Arch (DCA) are noted.

Magnified Facies and Sedimentary Structures:

Geologic and lithologic descriptions of the Parachute Creek Member were obtained from cores analyzed in this study. Palynologic and geochemical analyses were performed on selected samples to determine the paleoenvironmental conditions during deposition.

Magnified Facies and Sedimentary Structures:

Sedimentary Structures:

Other features observed in the Parachute Creek Member (Skyline 16 and PR 45 Tc core):

Methodology:
Detailed sedimentologic core descriptions will serve as a template to investigate changes in elemental concentrations based on hand-held X-ray fluorescence (XRF) spectroscopy using a Bruker Tracer III-XL XRF Handheld Spectrometer. Petrographic analysis of thin sections will aid in facies recognition and mineral identification.

XRF spectroscopy is a process whereby elements are excited from their atomic orbitals by incident X-rays. As a result, electrons from a higher orbital drop down and release an X-ray that is detected by the spectrometer; the energy of these fluorescent X-rays is characteristic for each element. The raw spectrum can be converted to concentrations for each element based on calibration to known standards (Rome et al., 2012). For this study, data was collected at the scale of 7.62 mm per meter increments (3 inches), which is smaller than the average thickness of individual lake expansion-compression cycles. Certain intervals were targeted for high-resolution data collection (0.5-3.4 mm) to investigate variability within facies and across facies boundaries.

Potential chemical changes that can be observed from XRF spectroscopy include:
1) Proton for siliciclastic input such as Na2O, TiO2, Al2O3, K2O, and Zr
2) Carbonate content based on Ca concentrations
3) Variations in the Mg/Ca ratio as a proxy for dolomite and calcite abundance which may relate to lake water chemistry or diagenesis
4) FeKα, Mn, and Al as mineral proxies
5) Ti/Al and Al as a proxy for clay mineralogy/content

Tobischl (et al., 2006; Rome et al., 2008; Binghouse & Vander Berg, 2009; Keigley, 2013; Sabaté, 2014)

Lithofacies:
Facies observed in Parachute Creek Member (Skyline 16 and PR 45 Tc core):
a) laminated kerogen-rich mudstone;
b) massive kerogen-rich mudstone;
c) massive kerogen-poor mudstone;
d) laminated kerogen-poor mudstone;
e) siltstone/sandstone;
f) unoxidized/oxidized pyrite;
g) interbedded carbonate mud and sand (local potential chemical or biological conditions).

- Within organic rich zones, laminated oil shales, waxy-bioleached carbonates and siliciclastic sandstones, and mudstones containing desiccation cracks stack into vertical packages which comprise meter and sub-meter-scale lake expansion-contraction cycles.

Skylite Ash (400 ft) from Parachute 14 core dated at 49.80.12 Ma (Smith & Carroll, 2015). Note the interbedded nature of facies.
Lake expansion-contraction cycles are typically thinner in organic-rich zones than those in organic-lean zones. Cycles in organic-rich zones are typically thinner than those in organic-lean zones. Cycle boundaries are commonly marked by a transgressive lag overlain by kerogen-rich mudstone or other deeper water facies. The transgressive lag can be composed of (but is not limited to):

- Graded and planar lags,
- Mud rip-up clasts,
- Subaqueous desiccation cracks.

### References:


### Future Work:

- Finalize stratigraphic correlations at various scales including rich-lean zone couples, individual lake expansion-contraction cycles, and marker tuffs.
- Correlate time lines (cyclical boundaries and tuffs) with rich-lean zone boundaries to investigate the potential chronostratigraphic significance of these units.
- Fully integrate sedimentological descriptions with geochemical proxy data to better understand the history of lake water evolution and provenance change.
- Conduct Fourier analysis on the XRF dataset to investigate potential aquatic cycles. This cyclicity can then be combined with future geochemistry studies of interbedded tuffs to investigate the periodicity of these cycles.

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### Sedimentological Descriptions and XRF Synthesis:

Lake expansion-contraction cycle on the order of 50 cm (~2.0 ft) within an organic-rich zone (LS) of the Parachute Creek Member from Skyline 16 Core (~1,410-1,400 ft). Lake expansion-contraction cycle on the order of 50 cm (~2.0 ft) within an organic-lean zone (LS) of the Parachute Creek Member from PR-15 7c Core (~500-550 ft).

Lake expansion-contraction cycles occur on the order of 10 cm (~0.4 ft) within an organic rich zone (R5) of the Parachute Creek Member from Skyline 16 Core (~1,410-1,400 ft).

Lake expansion-contraction cycles occur on the order of 10 cm (~0.4 ft) within an organic-lean zone (L5) of the Parachute Creek Member from PR-15 7c Core (~500-550 ft).

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Lake expansion-contraction cycles occur on the order of 10 cm (~0.4 ft) within an organic rich zone (R5) of the Parachute Creek Member from Skyline 16 Core (~1,410-1,400 ft).