[PS]Chemostratigraphy, Mineral Association and Water Chemistry Modeling of the Green River Formation, Piceance Basin, Northwestern Colorado: An Integrated Method to Unveil the Evolution of the Uinta Lake*

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Abstract

The Eocene Green River Formation (GRF) of Colorado in the Piceance Basin (PB) is estimated to contain the largest oil shale deposits in the world, and is a well-documented classic example of a lacustrine depositional system. The GRF provides an opportunity to define the chemical evolution of its rich source rock. Understanding the chemistry of these sedimentary rocks across the basin can give us an insight into the interaction of clastic input, carbonate mineral sedimentation, saline mineral precipitation, and organic matter deposition. A systematic profile of major and trace elements was generated by handheld X-ray Fluorescence (XRF) measurements made on the Douglas Pass area and cores "Shell 23X-2" and "John Savage 24-1", which represent the two end members of the PB, the basin margin and the basin center, respectively. Quantitative mineral identification was completed by X-ray Diffraction (XRD). Integrating these data, mineral stability diagrams have been constructed and the chemistry under which these minerals formed is simulated via Geochemistry Workbench. Boak et al. (2013) defined three mineralogic units in the Piceance Basin: 1) the Lower Mineralogic Unit, with illite in the basin center and multiple clay types in the basin margin, reflecting less saline, alkaline conditions; 2) the Middle Mineralogic Unit, defined by the appearance of dawsonite in the basin center, indicating increased salinity, alkalinity and CO_2 concentration; 3) the Upper Mineralogic Unit, characterized by the disappearance of dawsonite, and the appearance of analcime in the basin margin, corresponding to increased silica activity, and possibly lower CO_2. Trace metal redox indicators (U, Mo, V, Cr, Ni, Cu, Zn, etc.) provide support to the interpretation of Lake Uinta as stratified, with a deep suboxic, and periodically anoxic zone in the basin center, underlying a shallow, less persistently suboxic zone in the basin margin. The distinct mineral association between the basin margin and the basin center shows the variation in water chemistry of Lake Uinta in terms of silica activity, alkalinity, salinity, and CO_2 concentration. The integration of XRF, XRD, and water chemistry modelling is critical to reveal the evolutionary history of Lake Uinta in the Eocene era.

References Cited

Boak, J., S. Poole, J.F. Sarg, and K. Tänavsuu-Milkeviciene, 2013, Evolution of Lake Uinta as Defined by Mineralogy and Geochemistry of the Green River Formation in Colorado: Unconventional Resources Technology Conference (URTEC), Denver, Colorado, USA, 12-14 August 2013, URTeC 1578649.

Tänavsuu-Milkeviciene, K., and J.F. Sarg, 2012, Evolution of an Organic-Rich Lake Basin – Stratigraphy, Climate and Tectonics: Piceance Creek Basin, Eocene Green River Formation: Sedimentology, v. 59/6, p. 1735-1768.

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1. Abstract

The Eocene Green River Formation (GRF) of Colorado in the Piceance Basin is a well-documented classic example of a lacustrine depositional system. The GRF provides an opportnity to definie the chemical evolution of its rich source rock. Understanding the chemistry of these sedimentary rocks across the basin can give us an insight into the interaction of clastic input, carbonate mineral sedimentation,saline mineral precipitation, and organic matter deposition.

A systematic profile of major & trace elements was generated by handheld XRFmeasurements made on Douglas Pass area and core “Shell 23X-2”, which represent the two end members of the PB, the basin margin and basin center,respectively. Three mineralogic units can be identified by quantitative XRD analysis, which can also be reflected in the geochemical profiles. The lower mineral unit, reflects less saline, and alkaline conditions; the middle mineral unit, definied by the appearance of dawsonite in the basin center, indicating increased saliity; the upper mineral unit, corresponded to increased slica activity, and lower CO_2.

Based on hierarchical clustering analysis, chemofacies were generated to characterize the rocks.

Trace metal redox indicators (U, Mo, Ni, Cu) were used to evaluate the water condition and redox conditions in the lake Uinta, further support the stratified lake. The distinction between the basin margin and basin center shows the variation in water chemistry of Lake Uinta. The integration of XRF, XRD and mineral stability modeling is crtical to revealing the evolutionary history of the Lake Uinta in the Eocene time.

2. Objectives

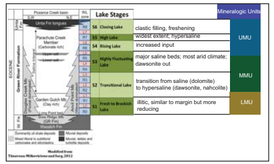
1) To extract the chemofacies generated by hierachical clustering analysis based on the data from the handheld XRF and test the feasibility in the PB;

2) To identify the most appropriate trace metal proxies to evaluate the redox conditions of the paleolake;

3) to stimulate the mineral stability corresponding to the variations in water chemistry across the basin.

3. Geologic Setting

Early Tertiary Paleogeography Map



4. Datasets and Methods

Datasets:

Douglas Pass area: HHXRF data and XRD data (Basin Margin area)

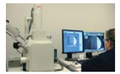
Shell 23X-2 core: HHXRF data and Quantitative XRD data (Basin center location)

CR-2 semi-quantitative, XRD data for comparison

Some of the SEM images from thin sections

HHXRF (Bruker IV-SD)

XRD analysis

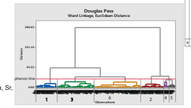


SEM analysis

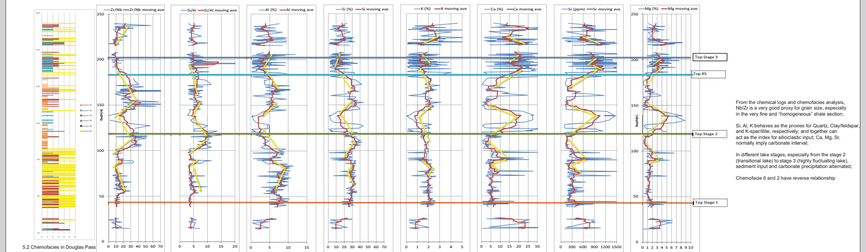
5. Basin Margin

Hierarchial clustering analysis (HCA) in minitab is used to identify the appropriate variables and clusters.

6 clusters used to characterize the dataset in Douglas Pass area:
Cluster #1: high Zr/Nb, high Si and Si/Al, low Al and Ca, Mg;
Cluster #2: High Ca, Sr, Mg;
Cluster #3: relatively high Si, K, low Al;
Cluster #4: high redox enrichment factors V (EF), Ni (EF), Zn (EF), and high Si/Al, Mg, Ca, Sr;
Cluster#5: high redox enrichment factors Zn (EF), Ni (EF), high Mg, Ca, Sr, and low Si/Al;
Cluster#6: high Al, Si, K



5.1 HCA Dendrogram of Douglas Pass



5.2 Chemofacies in Douglas Pass

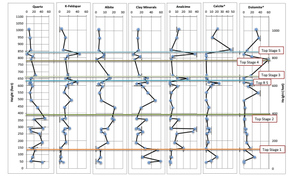
From the chemical logs and chemofacies analysis, Ni/Zr is a very good proxy for grain size, especially in the very fine and “homogeneous” shale section;

Si, Al, K behaves as the proxies for Quartz, Clay/feldspar and K-spar/illite, respectively; and together can act as the index for silicclastic input; Ca, Mg, Sr, normally imply carbonate interval;

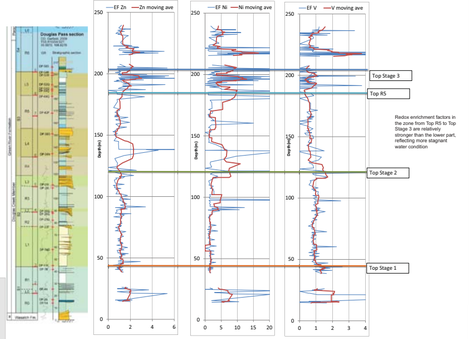
In different lake stages, especially from the stage 2 (transitional lake) to stage 3 (highly fluctuating lake), sediment input and carbonate precipitation alternated;

Chemofacie 6 and 2 have reverse relationship

5.3 Chemical logs of Douglas Pass



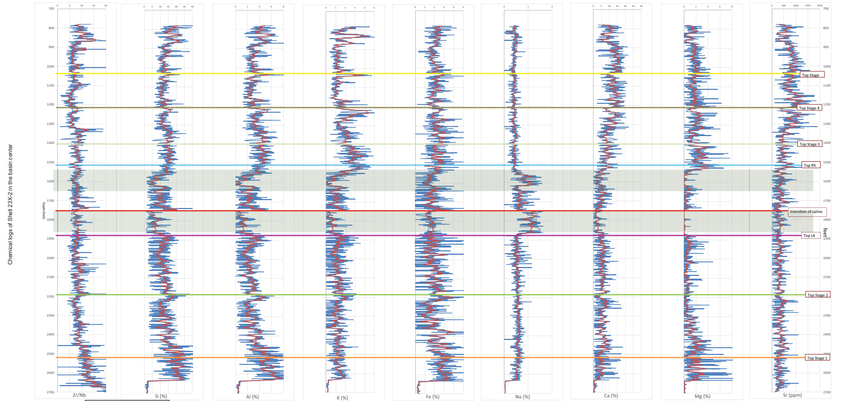
5.5 XRD data of the Douglas Pass area

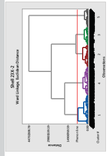


Redox enrichment factors in the core from Top R5 to Top Stage 3 are relatively stronger than the lower part, reflecting more stagnent water condition

5.4. The trace metal proxies in the Douglas Pass

6. Basin Center (Shell 23X-2)





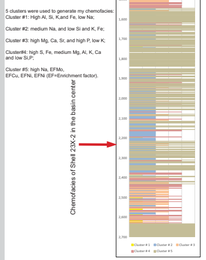
5 clusters were used to generate my chemofacies
Cluster #1: High Al, Si, K,and Fe, low Na;

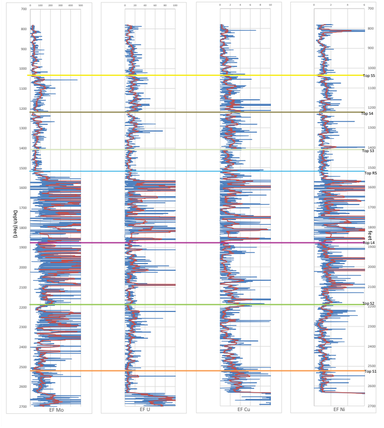
Cluster #2: medium Na, and low Si and K, Fe,

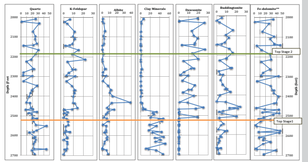
Cluster #3: high Mg, Ca, Sr, and high P, low K;

Cluster#4: high S, Fe, medium Mg, Al, K, Ca and low Si,P;

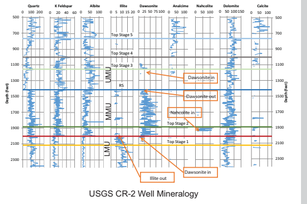
Cluster #5: high Na, EFNi, EFCu, EFNi, EFNi (EF=Enrichment factor).







Shell 23X-2 XRD Mineral logs



USGS CR-2 Well Mineralogy

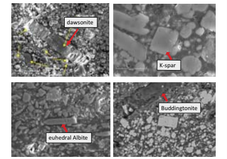
From the Chemical logs of Shell 23X-2, between the Top L4 and transition of saline, and below the Top R5, there exists two saline zone, based on Na log as a proxy for salinity, above R5, the salinity becomes very low, combined with the CR-2 mineralogy log, the saline zone could be teached out;

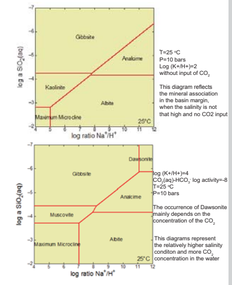
From the chemofacies, especially from the middle zone, where high Na, EFCu, EFMo, EFNi and EFU exist, Si and K was very low, implying a saline and reducing water condition;

From CR-2 mineralogy log, based on the relationship of thesetypical minerals, like dawsonite, nahcolite and illite, a mineralogical classification can be identified and a possible mineral reaction equation could be:

$KAlSi3O10(OH)2+2Na++2H2O+2CO2 = KAlSi3O8+2NaAl(OH)2CO3+2H+$

K-illite K-feldspar + dawsonite





Conclusions

Chemofacies derived from handheld XRF data proves to be valuable in analyzing the detailed sedimentary process of the lacustrine system;

The Ni,Cu trace metal proxies are found to be very consistent and reliable in evaluating the depositional environment of the paleolake;

Combined with XRD mineral analysis,simulating the mineral stability in different water conditions in terms of Silica activity, Salinity and PH, can extract the evolutionary signal of the paleolake system, but further research needs to be done on the index minerals of the system.

Acknowledgement

Oklahoma Geological Survey

U.S.Geological Survey

Total

Shell