[PS]A Hydrocarbon Seep Model of Large Bedded Barite Deposits in the Devonian Slaven Chert of Central-North Nevada*

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Abstract

Barite ($BaSO_4$) deposits are crucial to economic geology, paleoceanographic, and paleotectonic studies, yet the genesis of the megaton-scale beds is still being debated. The mineral is an economic commodity because its inert properties, low solubility, and high specific gravity of 4.5 g/cm^3 allow it to act as a weighting agent in drilling fluid. In addition, the isotopic compositions recorded in barite could be used to demonstrate chemical and biological changes in seawater over time. This study is focused on large barite beds and limestone deposits located at the Clipper, Northumberland, Greystone, Dana, Mountain Springs, and Shasta open pit mines of the Roberts Mountain Allochthon in north-central Nevada. These deposits formed on a continental slope along an active tectonic margin before the Antler orogeny. Preliminary data support a model where barium is removed from seawater as organic flux to the sea bed, buried and remobilized in organic-rich and highly reducing sediments, transported by methane flow, and precipitated as barite at and below the seafloor.

Evidence of methane seepage is based on anomalous limestone lenses with depleted delta 13C values (-27.31 to -31.65 per mil; n=13) and fossils of Dzieduszyckia - a brachiopod known to have inhabited seeps. Preliminary sulfur isotope data (n=34) show elevated delta 34S values up to 20 permil above contemporaneous Devonian seawater (23 permil). The low delta 13C of seep associated limestone point to a carbon source that is influenced by subsurface anaerobic oxidation of methane, while the enriched sulfur isotope signals of barite indicate a sulfate source linked to bacterial sulfate reduction. Initial petrographic analysis shows a variety of barite fabrics ranging from 1.1-3.4 mm rosettes of euhedral acicular crystals to inequigranular xenotopic mosaics (76 µm avg). Poikilotopic frameworks of subhedral barite (.8 mm avg) enclosing smaller euhedral crystals (22 µm avg) are also common. The limestone is composed of small to large subhedral calcite crystals with extensive thin twinning. Brachiopod shells are recognizable and some shell fabric is preserved. Ongoing research is aimed at linking the geographical and stratigraphic occurrences of barite and limestone with specific petrofabrics and isotopic trends. The goal of this project is to detail the various pathways by which the barium, carbon, and sulfur cycles influenced barite formation and drove the localized chemosynthetic ecosystems across the continental slope in the Devonian.

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Introduction

Large, sedimentary barite deposits comprise the major economic source for this mineral at a global scale, yet the genesis of the beds is still being debated. Barite ($BaSO_4$) is an economic commodity because its inert properties, low solubility, and high specific gravity of 4.5 g/cm^3 allow it to act as a weighting agent in drilling fluid. In addition, the isotopic compositions recorded in barite could be used to demonstrate chemical and biological changes in seawater over time.

My M.S. research focuses on barite and limestone from open pit mines in the Devonian Slaven Chert of central-north Nevada. Preliminary data support a model where barium is remobilized in organic-rich sediments and transported by methane seeps to the seafloor.

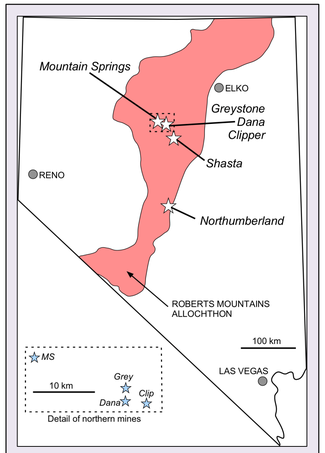

Figure 1: Locations of mines used in this study. Red swath denotes outcrops of the Devonian Roberts Mountains Allochthon.

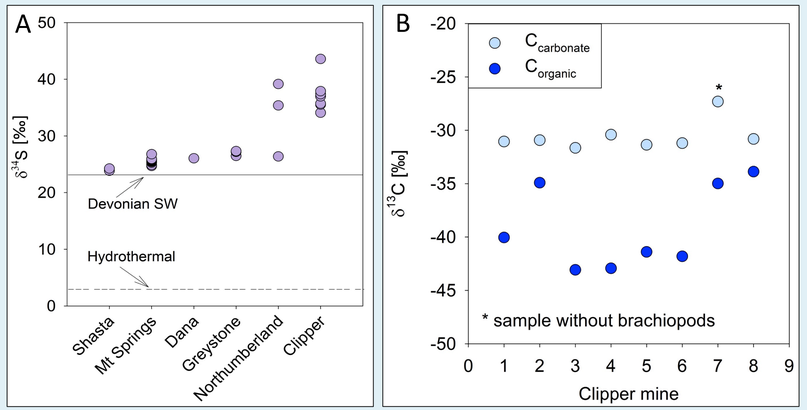

Figure 3: (A) Preliminary $\delta^{34}S$ data from barite (n=34). Note that the sulfur values are enriched relative to contemporary seawater, signaling bacterial sulfate reduction. (B) Preliminary $\delta^{13}C$ data from limestone (n=8) sampled from Clipper Mine. Carbon values are depleted in regards to Devonian seawater (2-4‰). Samples containing brachiopod fossils are more depleted than the sample without fossils. (C) A model of the impact of methane seepage rate on $\delta^{34}S$ values of barite.

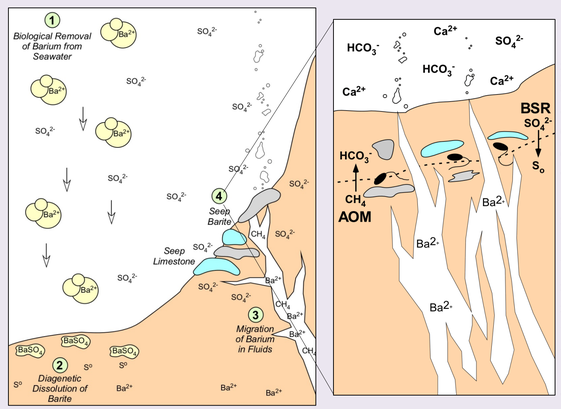

Figure 2: A model for barite and limestone formation at methane seeps along an active continental slope. (1) Seawater barium associated with organic material/ celestine decomposes in the water column. The free barium combines with seawater sulfate to form barite. (2) Barite dissolves in a sulfate-reduction zone. (3) Barium is transported with methane-rich fluids along fractures towards the seafloor. (4) Barium combines with sulfate to form barite at or near the seafloor. A mix of bicarbonate from anaerobic oxidation of methane and seawater combines with calcium to form limestone.

Research Questions

- How did barite and limestone form in the Devonian Slaven Chert of central-north Nevada?
- What role did chemosymbionts play in the formation of the barite and limestone?
- Is there a relationship between barite/limestone formation and petrofabric?

Methodology

- Sulfur Isotope Analysis
  - Delta+XL with Thermo Elemental Analyzer
- Inorganic and Organic Carbon Isotope Analysis
  - Picarro $\delta^{13}C$-CO_2 Analyzer
- Petrography
  - Olympus SC30 Petrographic Microscope

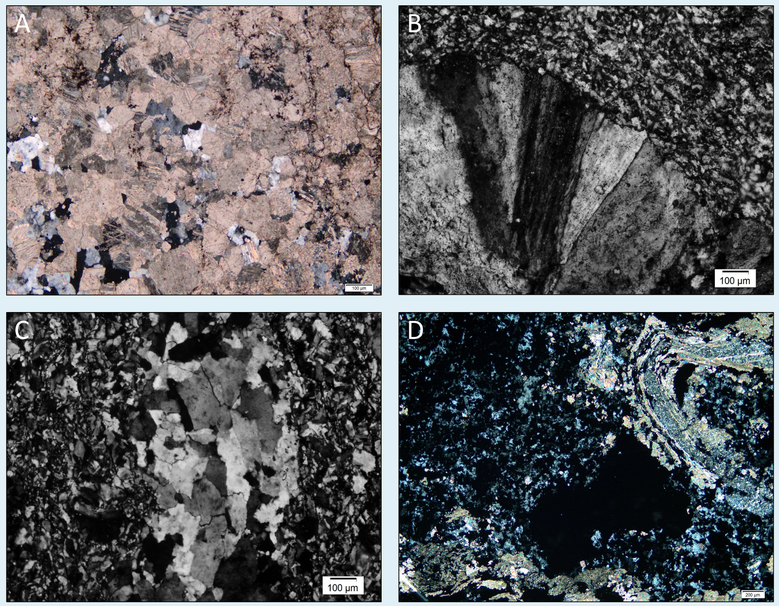

Figure 4: Petrographic images of barite samples. (A) Euhedral, twinned calcite with barite. Clipper, $\delta^{13}C$=31.65‰ (B) Large rosette in hypidiotopic matrix. Northumberland, $\delta^{34}S$=35.39‰ (C) Vein of coarse subhedral barite through small barite splays. Greystone, $\delta^{34}S$=27.18‰ (D) Brachiopod shell, preserved in calcite, with euhedral calcite in barite matrix. Clipper, $\delta^{34}S$=35.10‰

Results and Conclusion

- Preliminary sulfur isotope values are elevated relative to Devonian seawater[5] and hydrothermal[3] sources. *The barite formed at a hydrocarbon seep with both sulfate from seawater and residual sulfate from sulfate reduction.*
- Sulfur isotopes show a spread of values of 20‰. *This suggests that multiple processes, such as flux rate and ocean chemistry, affected barite formation.*
- Limestone carbon isotopic composition is significantly depleted in comparison to seawater, which is about 2-4‰[5]. *The bicarbonate is sourced from a combination of anaerobic oxidation of methane ($\delta^{13}C$=-75‰ to -125‰ biogenic or $\delta^{13}C$=-35‰ to -65‰ thermogenic), seawater ($\delta^{13}C$ =2-4‰), and sulfate reduction ($\delta^{13}C$ =-25‰)[1].*

Ongoing Research

- Sulfur and carbon isotope analysis will be done on additional samples to form a more complete picture of barite and limestone formation.
- $\delta^{18}O$ will be measured to better understand fluid source and temperature.
- Petrographic, scanning-electron, and cathodoluminescence microscopy will be used to classify petrofabrics and compile a barite atlas.
- Isotope data will be analyzed to potentially determine the affect of methane flux rate on barite formation and distribution.
- Trends between petrofabrics and sulfur fractionation will be studied.

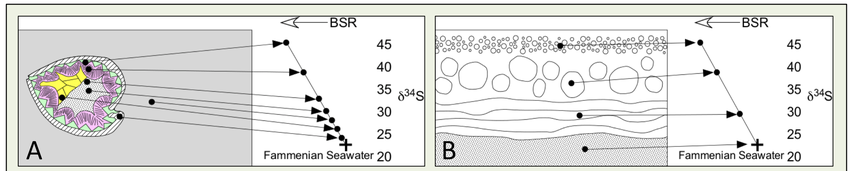

Figure 5: Models of potential impacts of paragenesis on $\delta^{34}S$ values of barite. (A) Different textures within a brachiopod fossil. (B) Various petrofabrics present in sedimentary sequences.

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