Sedimentology and Carbon Isotopes of the Jefferson Formation (Late Devonian), Bridger Mountains, Montana

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Abstract

The Devonian Period (419.2-358.9 million years ago) was an interval of significant change in the Earth's history with the proliferation of land plants and a shift to icehouse conditions. Many of these global changes impacted the carbon cycle. One primary method for identifying perturbations to the global carbon cycle is by using carbon isotopes. However, these records can potentially be influenced by local environmental factors and/or altered by diagenetic processes. In Wyoming and Montana, the Jefferson Formation (Frasnian) was significantly dolomitized. The goal of this study is to better understand the relationship between dolomitization, depositional environments, and carbon isotopes in the Jefferson Formation. These results will have implications for our ability to distinguish between primary carbon isotopic trends and those that have been influenced by dolomitization. To accomplish this task, we focused on the Jefferson Formation exposed in the Bridger Mountains of southwestern Montana. We measured and described 185.1 meters of rock exposed on the flank of Sacagawea Peak. Samples were collected forth in sections, polished slabs, and geochemical analysis. Based on these observations, we identified the presence of four facies associations at Sacagawea Peak that range from intertidal lagoon to reef. We present 189 new carbon isotopic values that range from -4.44‰ to 3.68‰ with an average -0.12‰. These values are similar to those seen in other basins for the Late Devonian. Values generally decrease at the base of the section (0-20m), followed by an ~2‰ increase in average values from 35–75 m in the section. There are no discernible trends and significant scatter from 75-115 m. Values show much less scatter near the top of the section (115-185.1 m) and record an ~1‰ decrease. With these identifiable trends, we explore the relationship between carbon isotopes, facies associations, and dolomitization.

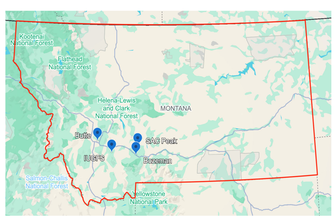

***Figure 1**: Map of Montana highlighting the study section (Sacagawea Peak: SAC). IUGFS refers to the Indiana University Geologic Field Station.*

***Figure 2**: Exposure of the Jefferson Formation at Sacagawea Peak.*

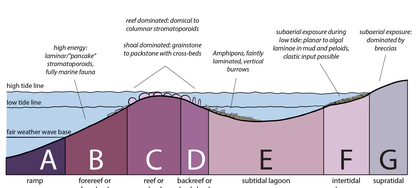

***Figure 2:** The seven facies association that are present in the Jefferson Formation in Montana; four of the seven are present at Sacagawea Peak. Facies associations used in this study are indicated with letters and are modified from Da Silva and Boulvain (2004).*

Symbol	Environment	Description	Example Slabs
F	Intertidal lagoon	Planer to wavy laminations, clastics, peloids, rip-up clasts	
E	Subtidal lagoon	*Amphipora*, minor brachiopods, gastropods. Vertical burrows, can be faintly laminated to internally massive, peloids	
D	Back reef or Back shoal	**Reef Dominated:** *Amphipora* common, columnar stromatoporoids, corals **Shoal Dominated:** Wackestone to packstone, rip-up clasts, possible *Amphipora*, corals, gastropods, brachiopods	
C	Reef or Shoal	**Reef Dominated:** Boundstone, bulbous stromatoporoids, corals (rugosa), oolds, skeletal grainstones, cross-beds **Shoal Dominated:** Grainstones to packstones	

***Figure 4**: Depositional environments and facies associations used in this study are modified from Da Silva and Boulvain (2004). Example hand samples representing the four facies associations present in the Sacagawea Peak section.*

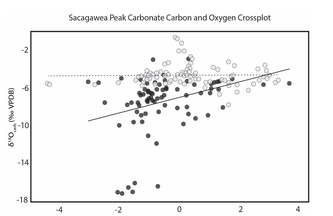

***Figure 5**: Cross-plot of carbonate oxygen and carbon isotopic values. The grey dots indicate dolomitic samples, and the black dots indicate calcitic samples. If there is a relationship between dolomitization and geochemical values, we would expect the dolomite samples to be systematically different from calcite. ANOVA analysis indicates that there is a statistically significant difference in the carbon and oxygen isotopic values of dolomite and calcite samples (p-value <0.001). We also observe a very weak but statistically significant correlation between oxygen and carbon isotopic values (Pearson's r = 0.291, p-value = <0.001)*

***Figure 6**: Scan of a slab with Amphipora*

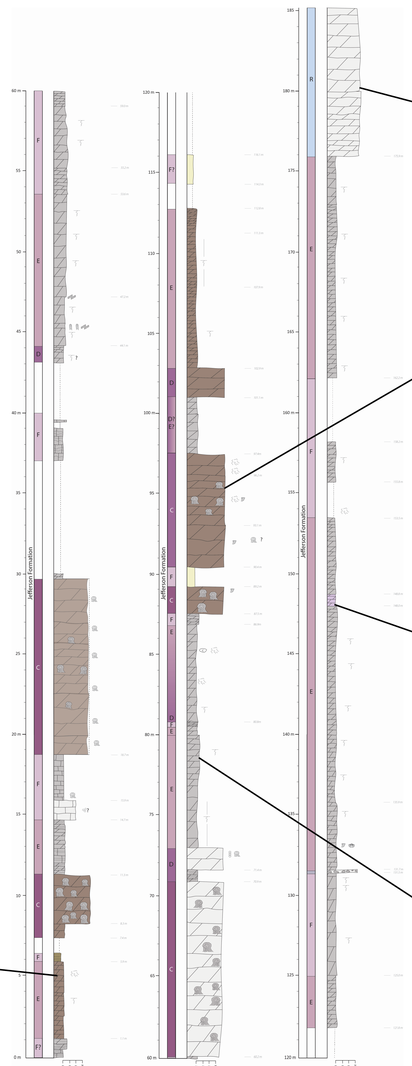

***Figure 7**: Measured section of Sacagawea Peak. Facies associations are indicated with letters and colors*

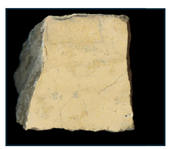

***Figure 8**: Recrystallized "Bird Bear" member at the top of the Jefferson Formation.*

***Figure 9**: Domal stromatoporoids in a reef boundstone.*

***Figure 10**: Distinctive "lavender bed" that is completely dolomitized.*

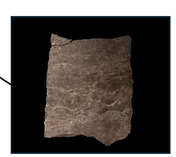

***Figure 11:** Burrowed dolomudstone.*

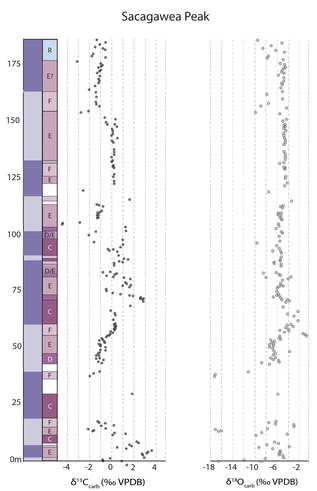

***Figure 12:** Carbon and oxygen isotopic trends for the Sacagawea Peak section. Facies associations are indicated with color and letters and shallowing upward cycles are identified by alternating colors and transparency based on facies associations. Black circles represent carbon isotopic values and grey circles represent oxygen isotopic values. No systematic relationship is observed between the shallowing sequences and the geochemical signals.*

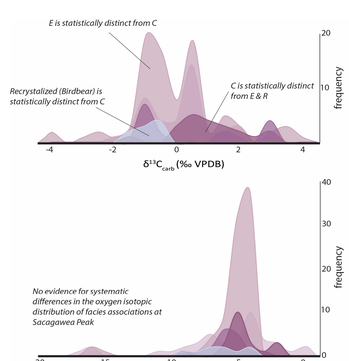

***Figure 13**: Frequence distribution curves for oxygen and carbon isotopic values as a function of facies association. ANOVA tests indicate that there is a statistically significant difference in the carbon isotopic values of facies associations (p-value = 0.001) but not for the oxygen isotopic values of facies associations (p-value = 0.301)*

Conclusions

Is there a relationship between geochemical record and dolomitization, sea-level change, or depositional environment in the Jefferson Formation at Sacagawea Peak?

1. If dolomitization led to systematic alteration of the geochemical signal, we would expect to observe dolomitic samples to record statistically significant differences in the oxygen and carbon isotopic values when compared to calcite samples.

   We do observe statistically significant differences between dolomite and calcite samples.

2. If sea-level change influenced geochemical signals, we would expect to observe systematic patterns in carbon and oxygen isotopic values in shallowing-upward cycles.

   We do not observe systematic patterns within shallowing-upward cycles.

3. If depositional environment influenced the geochemical signal, we would expect to observe statistically significant differences in the carbon and oxygen isotopic values of facies associations.

   We do observe statistically significant differences in the carbon isotopic values of some facies associations. To determine the mechanism, we need to look at more sections.

References

- Da Silva, A.C. and Boulvain, F., 2004. From palaeosols to carbonate mounds: facies and environments of the middle Frasnian platform in Belgium. Geological Quarterly, v. 48(3), p. 253-266.
- Smith, T.M. and Dorobek, S.L., 1989. Dolomitization of the Devonian Jefferson Formation, south central Montana. The Mountain Geologist, v. 26, p. 81-96

Acknowledgments

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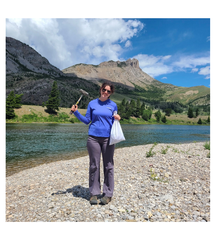

Field work photograph from Montana.