Decoding Devonian Dynamics: Carbon Isotopes from the Jefferson Formation in Montana

Alyssa Card, Page Quinton, and Michael Rygel

Department of Earth and Environmental Sciences, SUNY Potsdam, 44 Pierrepont Ave., Potsdam NY 13676

Abstract

The Devonian Period was a dynamic interval in Earth's history marked by significant changes in the terrestrial biosphere and a shift to icehouse conditions. Using stable carbon isotopes to document perturbations to the global carbon cycle during this interval of time, especially the regional expression of that record, can help us to better understand the connection between the biosphere and climate. For the Late Devonian of Montana, that record is preserved in the Jefferson Formation. However, the extensive dolomitization of the Jefferson Formation has led some to argue that the geochemistry of these rocks has been altered and cannot provide an accurate depiction of the ancient carbon cycle. To better understand the carbon isotopic record of the Jefferson Formation this study focused on the Baker Mountain section. The Baker Mountain section is exposed along the eastern flanks of the Beartooth Mountains in south central Montana. We measured and described 84.5 meters of exposure and collected samples for geochemical and petrographic analysis. In total we present 178 carbonate carbon isotopic values, 27 organic carbon values, and TOC estimates paired with a detailed sedimentological framework for the Baker Mountain section. Using this new dataset we explore the relationship between depositional environment, sea level, dolomitization, and carbon isotopes

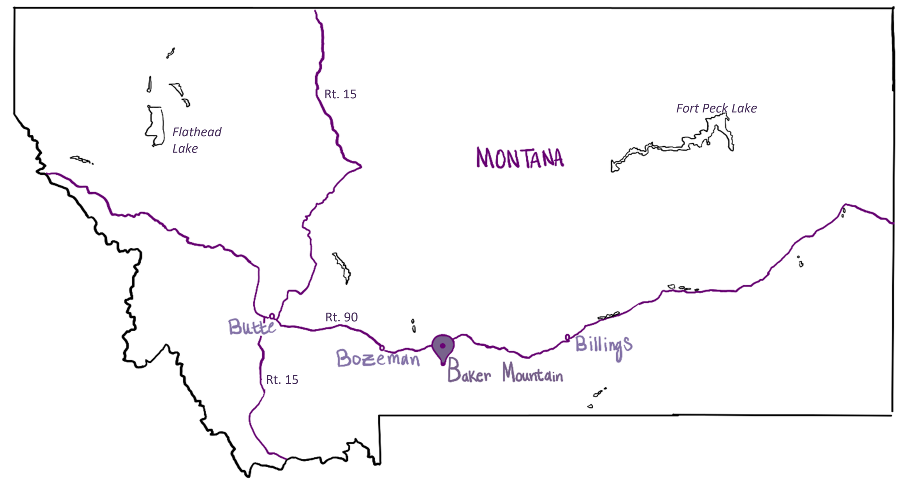


Figure 1. *Map of Montana with the location of the Baker Mountain study section.*

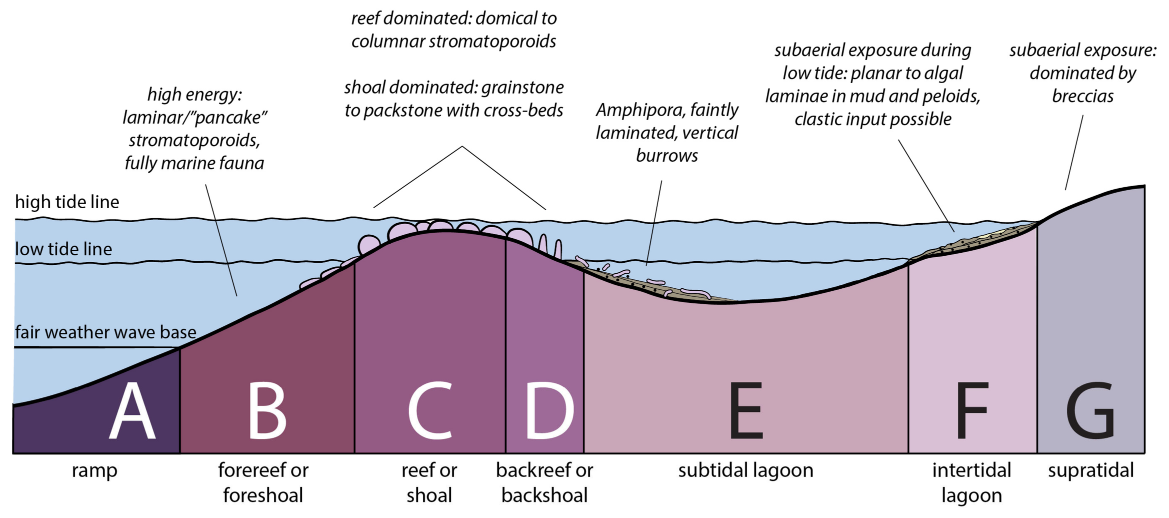


Figure 2. *Depositional environments of the Jefferson Formation. Facies associations used in this study are indicated with letters and are modified from Da Silva and Boulvain (2004).*

Methods

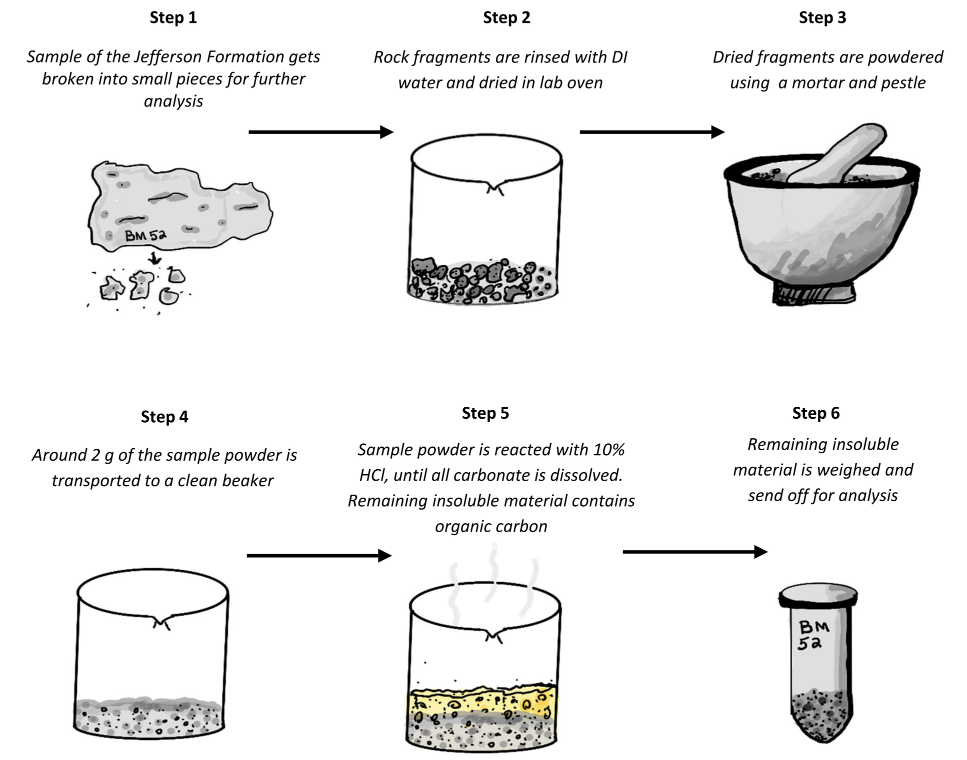


Figure 3. *Illustration of the six-step process utilized to decarbonate samples prior to geochemical analysis for organic carbon isotopes.*

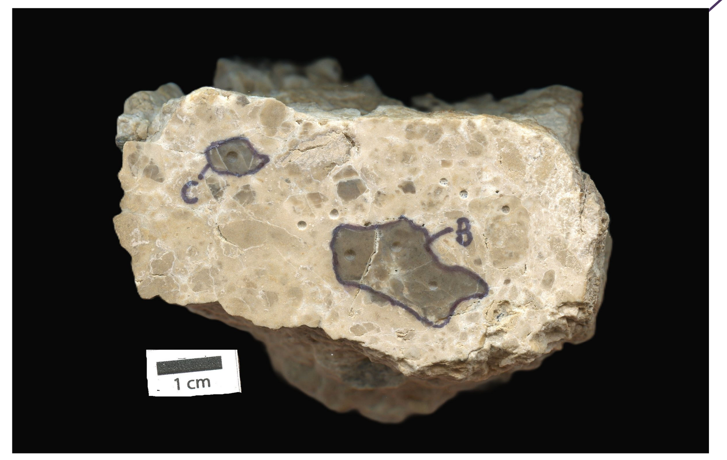


Figure 4. *Hand sample of a brecciated horizon. Geochemical samples were taken for different clasts in the breccia*

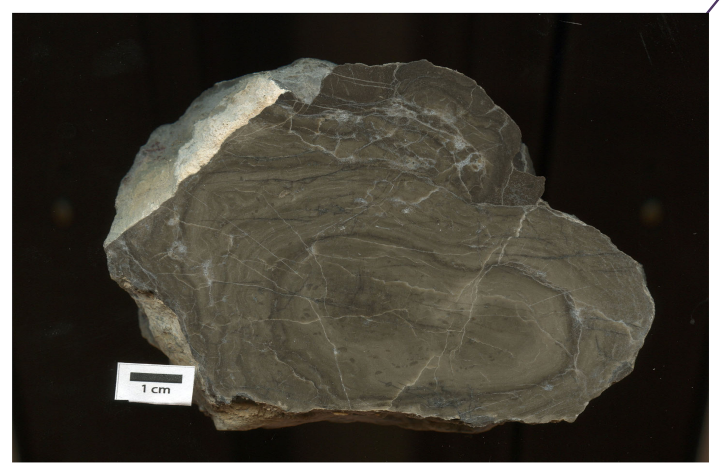


Figure 5. *Hand sample of a stromatoporoid that has been cut and polished*

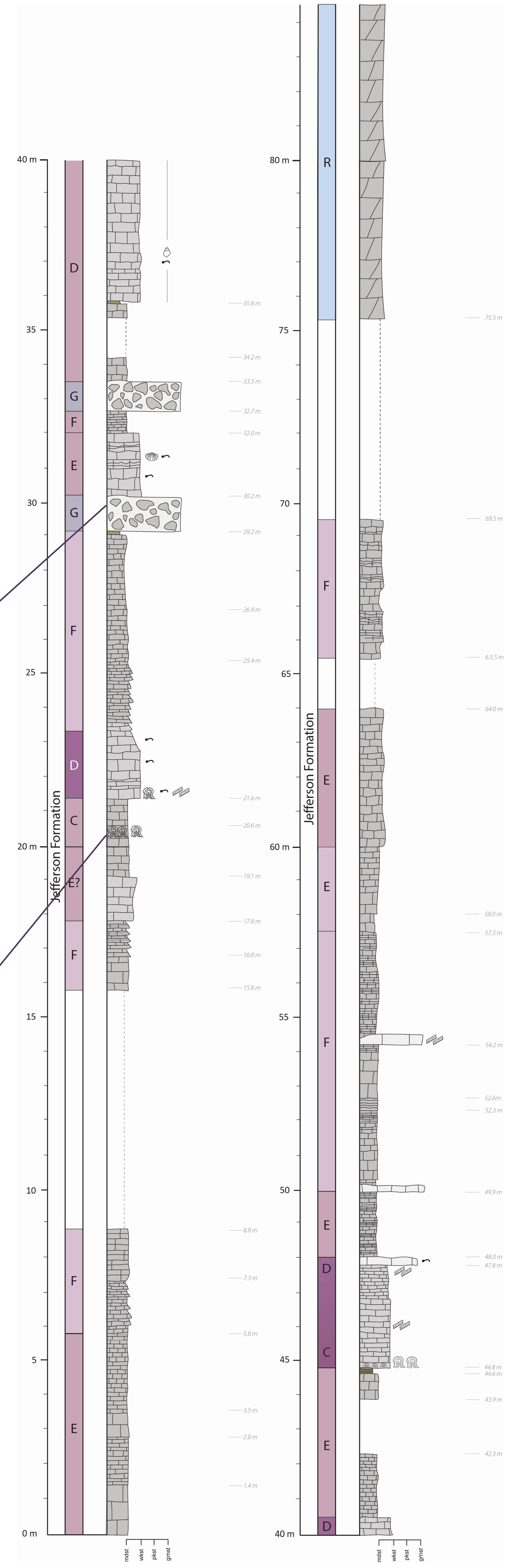


Figure 6. *Measured section showing 85+ meters of the Jefferson Formation at the Baker Mountain section. Interpreted facies associations are indicated with letters and colors from Figure 2.*

Test 1: Dolomite vs Calcite

If dolomitization influenced the geochemical signal, we would expect dolomite samples to record systematically distinct carbon and oxygen isotopic values.

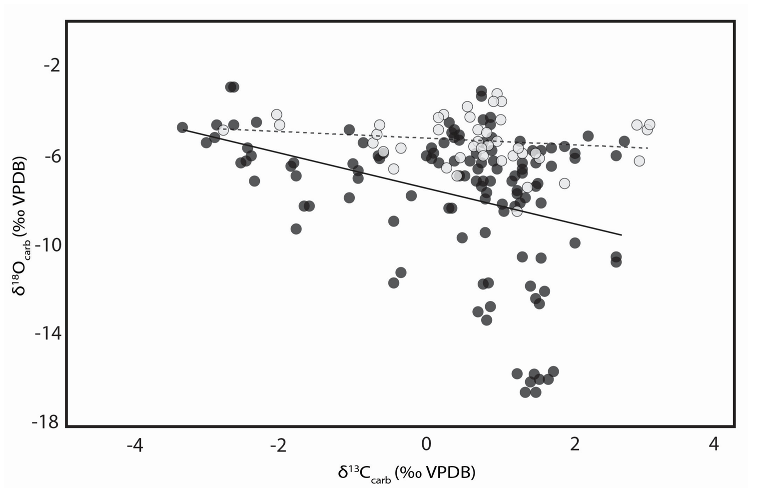


Figure 7. *Cross-plot of carbonate carbon and oxygen. There is a very weak statistically significant negative correlation between carbon and oxygen isotopic values (Pearson's r = -0.27, p-value <0.001). ANOVA analysis indicates that there is a statistically significant difference in the oxygen isotopic values of dolomite vs. calcite (p-value <0.001) but not in the carbon isotopic values (p-value = 0.181).*

Test 2: Carbonate and Organic Carbon

If carbonate carbon isotopic values are altered, we might expect little to no relationship with organic carbon isotopic trends.

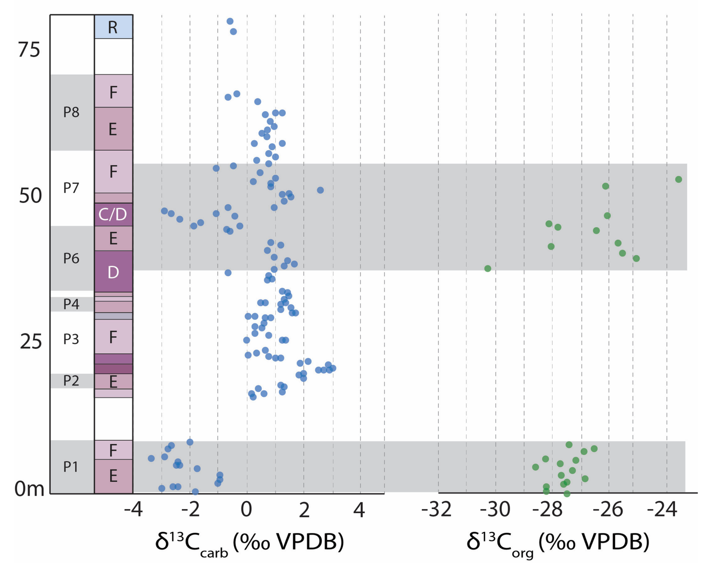
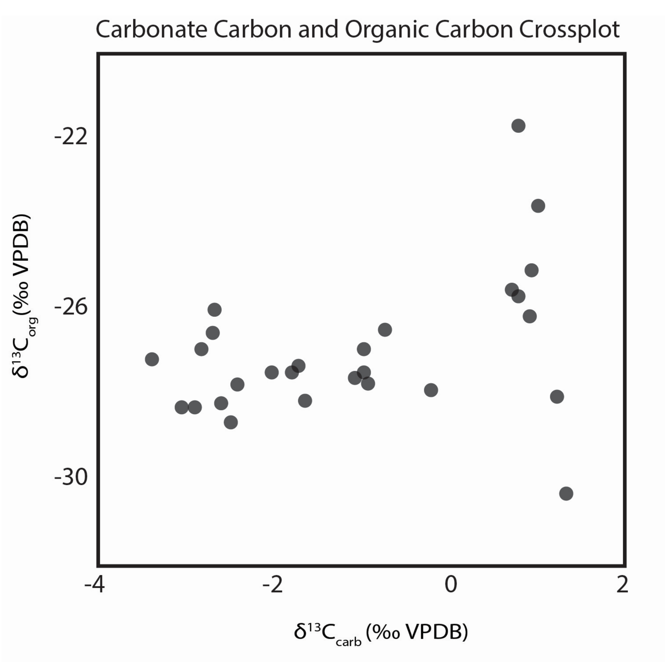


Figure 8. *Geochemical results from this study plotted with facies associations and shallowing upwards cycles. Zones of overlapping carbonate and organic carbon isotopic results are highlighted with grey boxes.*

Test 3: Organic Carbon and TOC

If carbonate carbon isotopic values are altered, we might expect little to no relationship with organic carbon isotopic values.

If organic carbon isotopic values are altered, we might expect to be correlated with total organic carbon (TOC) values.



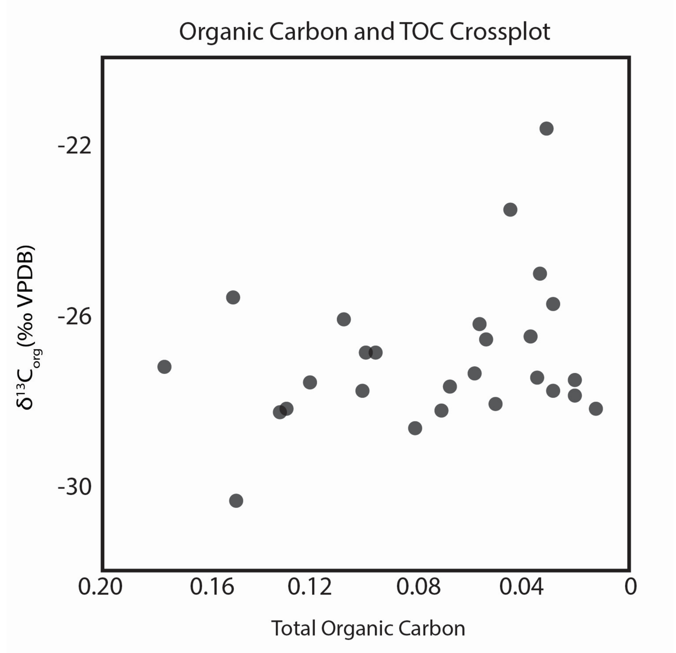


Figure 9. *Our results indicate that there is a weak statistically significant correlation between carbonate carbon and organic carbon isotopic values (Pearson's r = 0.381, p-value = 0.05). Secondary processes that typically alter organic carbon isotopic values can result in a negative correlation between organic carbon isotopic values and total organic carbon (Knoll et 1986). We found no evidence for a correlation between organic carbon isotopic values and total organic carbon (Pearson's r = -0.029, p-value = 0.142). Total organic carbon was calculated using the method described in Quinton et al. (2016).*

Conclusions

Test 1: Our results are consistent with a relationship between carbonate oxygen isotopic values and dolomitization but not for carbon isotopes.

Test 2: Our results indicate that carbonate carbon and organic carbon isotopic trends are similar.

Test 3. We found no correlation between organic carbon isotopic values and total organic carbon as one would expect if diagenetic processes occurred and altered that carbon.

Interpretation: this preliminary study on Baker Mountain suggests that primary carbonate carbon isotopic values remain intact.

References

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- Quinton, P.C., Herrmann, A.D., Leslie, S.A. and MacLeod, K.G., 2016. Carbon cycling across the southern margin of Laurentia during the Late Ordovician. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 458, p. 63-76.

Acknowledgments

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Field photograph from northwest Montana