Stratigraphic Reconnaissance of the Helderberg Group near Moorefield, West Virginia

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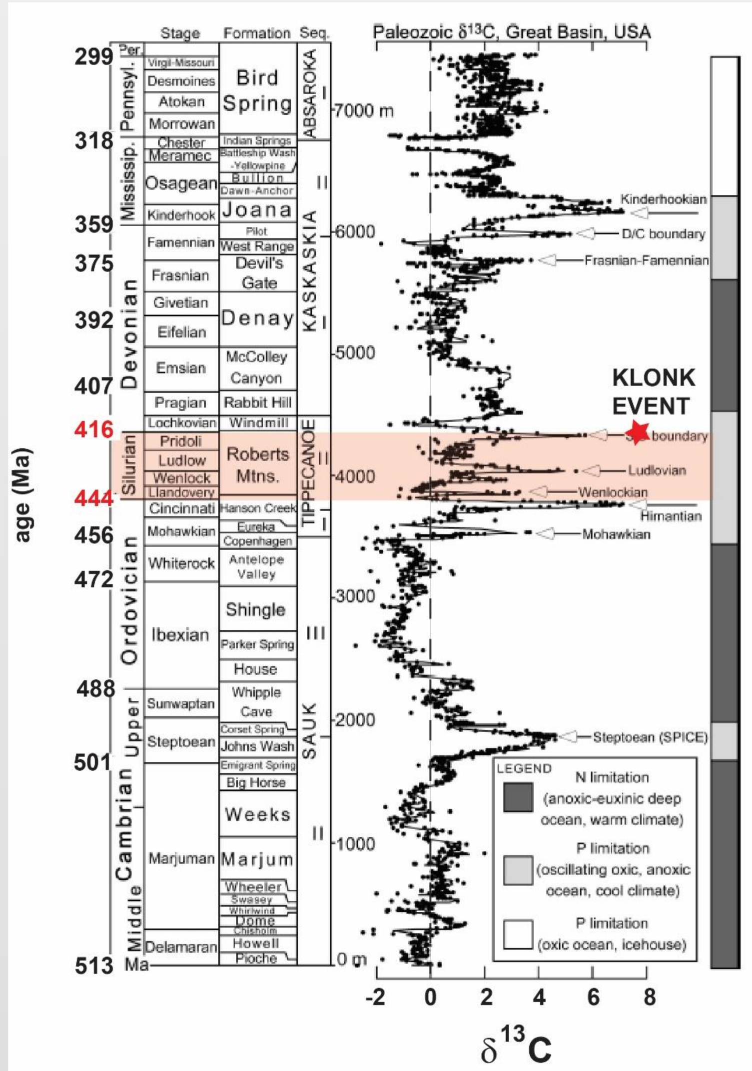
Abstract

A stratigraphic reconnaissance of the Helderberg Group limestones near Moorefield, West Virginia has provided new geochemical information about the Silurian-Devonian boundary, suggesting that enhanced weathering drove organic carbon burial and high rates of microbial sulfate reduction.

Introduction



The Klonk Event at the Silurian-Devonian boundary (Fig. 1) is a minor global extinction event that coincides with a global positive carbon isotope excursion (Figs. 1 & 2), making it one of the largest carbon cycle anomalies of the Paleozoic (Malkowski and Racki, 2009). The most likely driving factor of changes in the carbon isotope composition of seawater is organic carbon burial, which may have been stimulated by enhanced weathering inputs of nutrients to the shallow marine environment. In 2007, Gill et al. found a negative sulfur isotope excursion in carbonate associated sulfate (CAS) associated with the carbon cycle anomaly. These authors suggested that pyrite oxidation on exposed continents and delivery to seawater as ^{32}S enriched sulfate was the consequence of an oxidizing atmosphere.

Figure 1: Paleozoic carbon isotope variations recorded in the Great Basin, USA. The Silurian (highlighted) ends with a positive $\delta^{13}C$ anomaly, which is preserved in the Helderberg Group of West Virginia (Modified from Saltzman et al., 2005).

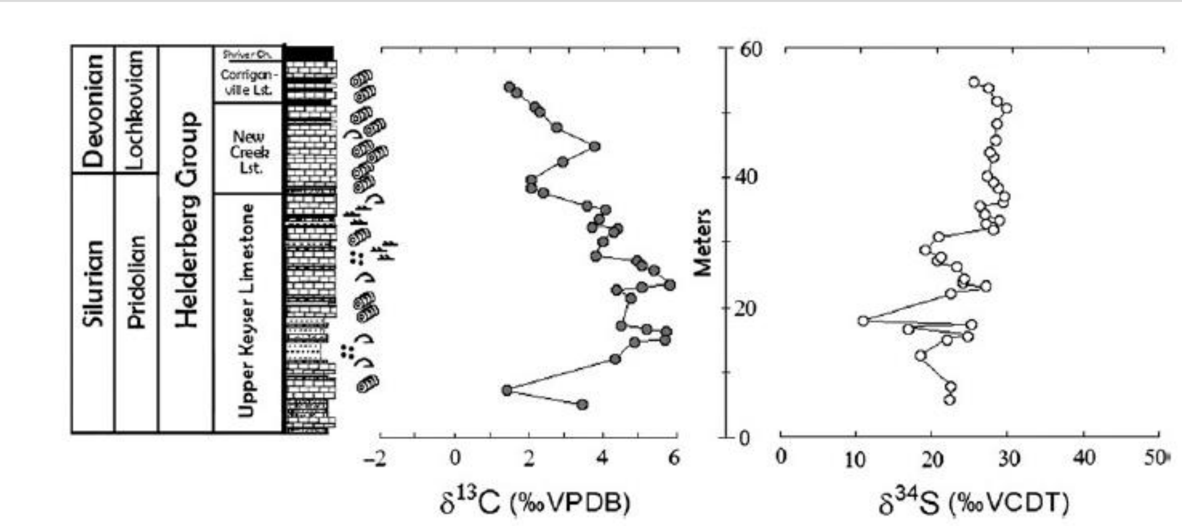


Figure 2: Carbon and sulfur isotopes in the Helderberg Group carbonates at Strait Creek, Virginia (From Gill et al., 2007).

Enhanced weathering in the Silurian is supported by the significant rise of $^{87}Sr/^{86}Sr$ of marine proxies through the period with the peak at the boundary with the Devonian. This suggests an increase in weathering insofar as radioactive decay of ^{87}Rb from weathered igneous continental rocks is the main source of ^{87}Sr in the oceans (Burke et al., 1982; Kaufman et al., 1993).

In much of Virginia and West Virginia, the Silurian-Devonian boundary outcrops in the Helderberg Group, a series of limestones deposited in a shallow passive margin setting (Dorobek and Read, 1986). In 2010, a new section of highway opened near Moorefield, West Virginia that includes road cuts though the Helderberg Group (West Virginia Division of Highways). An investigation of these outcrops has revealed new information about the Silurian-Devonian boundary.

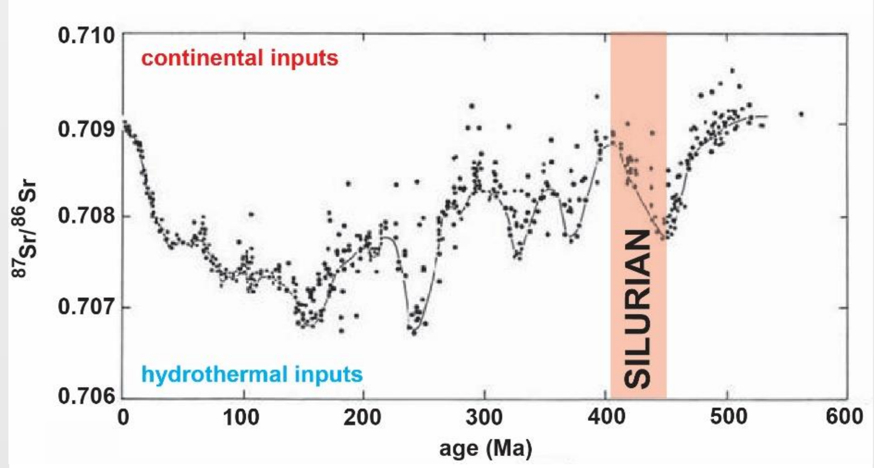


Figure 3: $^{87}Sr/^{86}Sr$ variations over Phanerozoic time, with the significant rise from 0.7080 to 0.7090 in the Silurian Period highlighted (Modified from Burke et al., 1982).

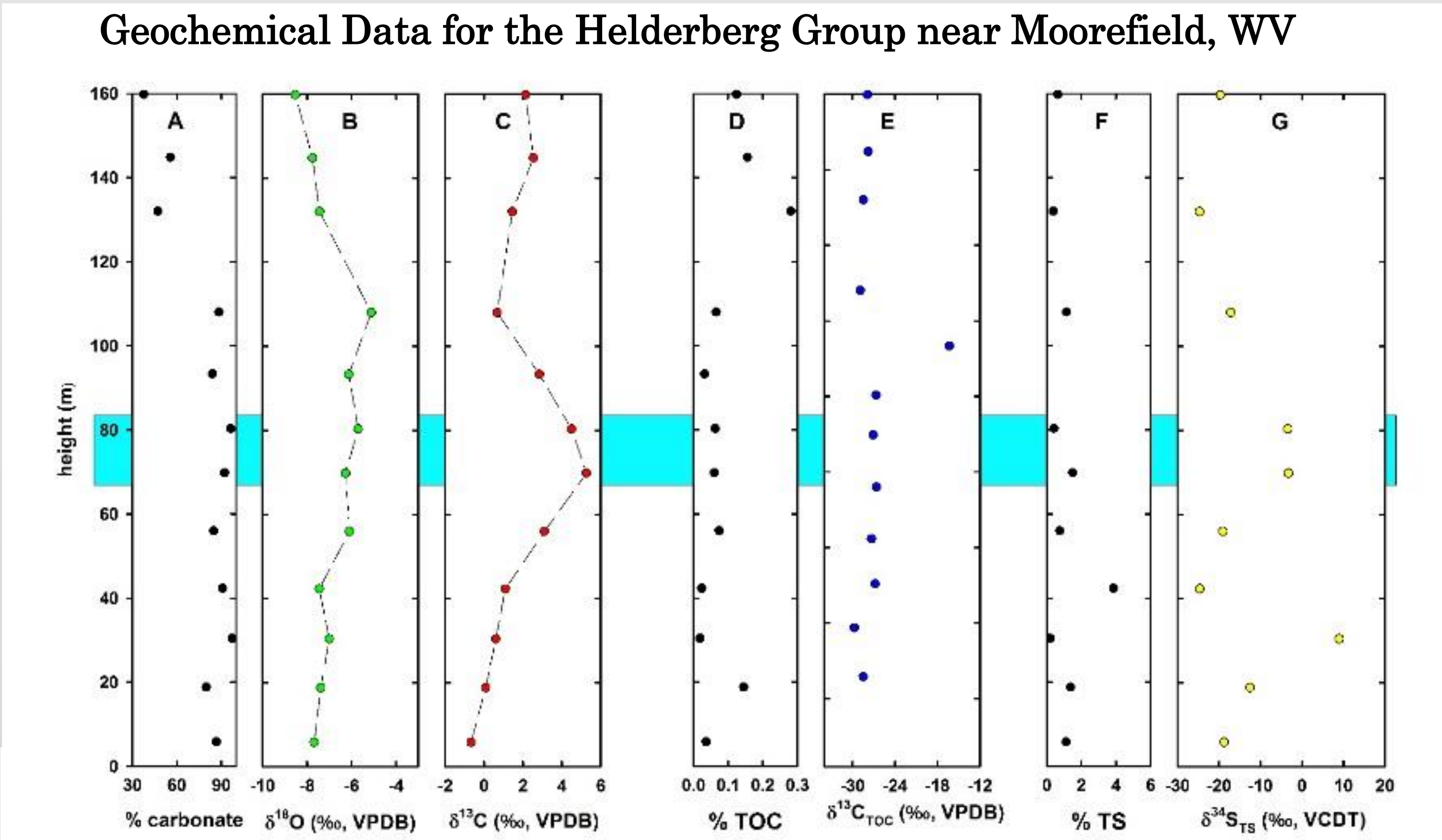


Figure 4: Data collected from samples near the Silurian-Devonian boundary; interval of $\delta^{13}C$ and $\delta^{34}S$ peaks highlighted. Note similar trends in bulk carbon (C) and pyritic sulfur (G), but not organic carbon (E).

Conclusions

Figure 4 shows the time-series data from this study that directly captures the positive carbon isotope excursion at the Silurian-Devonian boundary. There is, however, little change in organic carbon isotopes. This is possible if the presence of a large reservoir of organic carbon in the ocean buffers the organic carbon isotopic value of seawater (McFadden et al., 2008), or if weathering of fossil organic matter buffered the seawater system. With the Sr isotope trend through the Silurian, these data support the likelihood of increased weathering and organic carbon burial as the cause of the carbon isotope anomaly.

The positive pyrite sulfur isotope excursion measured here contrasts with the negative excursion measured in CAS (Figs. 2 & 4). The pyrite ^{34}S enrichment may be the result of rapid microbial sulfate reduction in pore fluids enhanced in nutrients through weathering (Rudnicki et al., 2001), although other scenarios are possible.

With high rates of organic carbon burial and anoxia that promoted microbial sulfate reduction, the water column was most-likely stratified (Gomes and Hurtgen, 2015; Cao et al., 2016). A higher resolution study of this outcrop is warranted to confirm these trends and further understand the driving forces for the carbon and sulfur cycle excursions.

Figure 5: Interval where $\delta^{13}C$ and $\delta^{34}S$ values peak is between lighter bands of carbonates in this photo; 70 m height indicated

Acknowledgements

I thank both of my advisors, Dr. Alan J Kaufman and Dr. John Merck, for the tremendous amount of help they have given me in the course of this project. I must also thank Rebecca Plummer for her abundant guidance and assistance relating to the mass spectrometric measurements.

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