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# Climatic variability during the Late Devonian Kellwasser Crisis on astronomical and millennial timescales

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The Late Devonian (ca. 379–359 Ma) was characterised by a series of widespread marine anoxic events, documented in the rock record by black shales and limestones. The greatest of these, the Kellwasser Crisis at the Frasnian-Famennian boundary, was associated with one of the "Big five" Phanerozoic mass extinctions. Despite decades of research, it remains controversial what triggered the Kellwasser Crisis and why the Late Devonian ocean was particularly sensitive to widespread anoxia. De Vleeschouwer et al. (2017) hypothesised that the exact timing of tipping the Devonian system into oceanic anoxia could have been related to a particular sequence of astronomical forcing configurations. First, a long-term eccentricity minimum (or "node") creates relatively stable climate conditions for several tens of thousands of years, during which thick continental regoliths are formed. Then, a rapid increase in eccentricity intensifies climate variability and triggers the release of nutrients from the continents into the oceans. To test this hypothesis, we have generated high-resolution elemental records of the Winsenberg roadcut (eastern Rhenish Massif, Germany), employing a number of different X-Ray Fluoresence (XRF) methods. The Winsenberg section is 12 m thick and reflects a deeper outer shelf environment just southeast of the Brilon Reef Complex. It features well-expressed Lower and Upper Kellwasser black shales/limestones (LKW and UKW) that are 150 and 80 cm thick, respectively. While rhythmically bedded carbonates crop out in between the two Kellwasser intervals, the 72-cm thick Usseln Limestone occurs directly below the LKW. This limestone bed contains strongly-expressed cm-scale rhythmical variations in carbonate content and can be traced through much of the Rhenish Massif (Gereke, 2007). Lithologic cyclicity is smaller in scale but also more evident in the Usseln Limestone, compared to the stratigraphic interval in between the two Kellwasser shales. This distinction dictates a difference in XRF analytical approach: while the interval between the LKW and UKW was analysed at a cm-scale using a portable XRF analyser, the Usseln Limestone was XRF-imaged at mm-scale resolution using µXRF elemental mapping. These combined methods allow for a detailed investigation of Winsenberg's environmental response throughout the Kellwasser Crisis, on both astronomical and millennial timescales. On astronomical timescales, the stable 405-kyr eccentricity 'metronome' cycle defines an astrochronological framework that is largely in line with other globally-distributed astrochronologies. The Winsenberg floating chronology will form the basis for testing the eccentricity minimum hypothesis, which is a work in progress. The µXRF images of the Usseln Limestone are combined with petrographic thin-section analysis to show that diagenetic processes did not superimpose the primary rhythm of millennial-scale climate variability. Our results indicate that the Late Devonian Earth system was highly variable on short timescales immediately prior to the Kellwasser Crisis, and the Usseln Limestone provides a unique sedimentary archive to analyse the imprint of these rapid climatic fluctuations in the rock record.

Reference

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