

## **The Late Devonian mass extinction: new geochemical and geochronological insights**

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The Late Devonian marked a time of numerous successive environmental perturbations and biotic crises, including one of the 'Big Five' mass extinctions of the Phanerozoic. The Frasnian–Famennian (FF) boundary Kellwasser crises (~372 Ma) represents the largest and best known of these crises, but numerous smaller scale events (e.g. the Late Famennian Annulata Event: ~363 Ma) also occurred during the 20 million year-long Late Devonian. However, despite representing a time of substantial floral and faunal turnover, there remains little consensus as to the cause of these events, either individually or collectively.

In this study, we present a new precise U-Pb age for the FF boundary at Steinbruch Schmidt (Germany), and osmium-isotope (Os(i)) data from Kowala Quarry (Poland), including the first stratigraphic coverage of the two Kellwasser crises. We determine an age of the FF boundary of  $371.88 \pm 0.12$  Ma, confirming previous age estimates of this horizon, but not coincident with any known Late Devonian meteorite impact or currently dated volcanics from the Viluy Traps Large Igneous Province. The Os(i) values from the FF boundary and Lower Famennian are consistent with those from multiple North American records, suggesting that the record at Kowala documents global osmium-isotope trends. Shifts to very radiogenic Os(i) values are documented at the base of the Kellwasser horizons, with a less pronounced shift also observed across the Annulata level, potentially supporting globally enhanced weathering rates at the onset of those crises. These results support previous proposals for a potentially important role of extreme weathering rates and associated nutrient runoff towards the causes of marine anoxia and extinctions during the Late Devonian biotic crises.