

# **Clumped isotope of carbonate minerals in the Tara Deep Zn-Pb orebody: re-equilibration and limitations for the study of ore genesis geochemistry**

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Understanding fluid temperatures associated with the development of an orebody provides critical insights into the processes that drive metal transport and deposition. Tara Deep (Ireland) is the most recent major ore discovery connected to the Navan giant orebody, which supports the largest underground Zn mine in Europe. The location provides an early opportunity to explore the systematics of clumped isotope palaeothermometry in paragenetically well-defined calcite and dolomite within Irish-type mineralization, in a deposit where conventional fluid inclusion microthermometry has proven notoriously difficult. The orebody was formed ~345Ma ago and has been heated by burial and geothermal activity to temperatures of 120-150°C for millions of years, which has the potential to re-distribute isotopes in the carbonate lattice of minerals.

We found calcite samples within Tara Deep have apparent temperatures based on carbonate clumped isotopes that range from 90 to 175°C, with no grouping with sample petrology, which points to the role of both re-distribution of isotopes in the carbonate lattice and recrystallisation. Detailed petrography of textures support this, highlighting, for example, that it is unlikely for early diagenetic cements to record apparent temperature of 150°C. The use of  $TD_{47}$  as a measure of the primary hydrothermal temperature during ore deposition is thus inhibited. Redistribution has been achieved without inducing visible changes in crystal microstructure and trace element concentrations, metrics commonly used to gauge preservation quality. Because re-equilibration during exhumation and cooling will draw the  $T\delta_{47}$  towards lower values, the temperatures recorded in our samples place a lower bound on the peak paleotemperatures at 175°C.

Dolomites associated with the mineralisation record lower apparent temperatures compared to calcites, consistent with previous studies showing a higher threshold for re-equilibration in dolomite, although recrystallisation may still be a concern. Overall, what emerges is a cautionary tale, calcite at Tara Deep does not preserve the primary depositional temperature and has undergone significant reordering, meaning that they should not be considered as primary ore depositional temperatures.