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Constraining fluid mixing processes at the Irish-type Lisheen Zn-Pb orebody: preliminary evidence from clumped C-O isotopes

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Irish-type Zn-Pb ore deposits are the mainstay of the Irish mining industry. In the last 50 years, five orebodies have been developed (Tynagh, Silvermines, Navan, Galmoy and Lisheen) and over twenty sub-economic deposits discovered. There is now a consensus that these deposits are mainly epigenetic ores formed by carbonate replacement of Lower Carboniferous (Courceyan to lower Chadian) limestones. Conditions required for their formation include dense networks of normal faults that allowed ascending, warm, metal-bearing fluids equilibrated with Lower Palaeozoic basement to mix with sinking, cooler, hypersaline brines that carried bacteriogenically reduced dissolved sulphide of ultimate seawater origin [1]. Deposits exhibit strong structural and stratigraphic controls, with all major Irish mineral occurrences within 50 km of the likely position of the Iapetus Suture Zone.

It is well established that the crystallization of carbonate minerals from aqueous fluids causes temperature-dependent mineral-fluid C and O isotope fractionations. Mineral C-O isotope compositions are therefore controlled by crystallization temperature and fluid isotope compositions. However, the heavy isotopes of these two elements are now known to bond in carbonate minerals measurably more frequently than expected by stochastic distribution. The extent of this “clumping” is also temperature dependent, but crucially is independent of fluid isotope composition and carbonate mineral chemistry [2]. Measuring the deviation from a stochastic distribution allows the mineral growth temperature to be estimated, with temperature differences of ~5°C resolvable up to at least 200°C. Furthermore, the C-O isotope ratios of the fluid can simultaneously be determined [3].

Our research has applied the clumped O-C isotope technique to the Irish Zn-Pb ore field. Preliminary clumped C-O data will be presented from the Lisheen Zn-Pb orebody (22.3 Mt mined at 11.7% Zn and 2.0% Pb) [4] along with fluid inclusion data. Samples were analysed from all main carbonate generations across the deposit [5], including: regional dolomite (D_1), dark grey to black pre-ore hydrothermal dolomite (D_2; also known as black-matrix breccia), medium- to coarse-grained ore-stage white ferroan dolomite (D_3; white-matrix breccia), late veins of ferroan dolomite (D4) and white calcite (C4), post-ore crosscutting pink saddle dolomite (D_5), and post-ore white blocky calcite (C_6). We will discuss existing metallogenetic models for the Lisheen deposit and the potential for clumped C-O analysis to constrain fluid flow pathways and mixing processes, and as a tool for mineral exploration.

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