Controls on the formation of a large Zn-Pb Irish-type deposit: evidence from the Navan halos

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The mainly epigenetic Navan orebody is hosted by the Lower Carboniferous shallow water carbonate Pale Beds. Subordinate mineralization, hosted by submarine debris flows and the lowermost overlying basal rocks, formed during seafloor exhalation and reaches ore grade in the Conglomerate Group Ore. Both deposit styles were fault controlled and likely formed at ~340-345 Ma. Sulphide ores crystallized when relatively hot, metal-rich hydrothermal fluids (positive $\delta^{34}$S) mixed with cooler seawater-sourced brines carrying bacteriogenic sulphide (negative $\delta^{34}$S). Over 90% of ore sulphide at Navan is of bacteriogenic origin.

A Pale Beds-hosted epigenetic halo contains low-grade sulphide mineralization with Zn/Pb <1 up to 2.5 km from the orebody. The dominant sulphide is galena with a hydrothermal signature ($\delta^{34}$S = 0 to 10‰). Locally where grades increase, higher Zn/Pb ratios tend towards those in the Navan orebody and a bacteriogenic signature is present ($\delta^{34}$S = -25 to -5‰). This suggests that mineralization within this halo formed mainly in an environment relatively depleted in bacteriogenic sulphide, supported by relatively high fluid inclusion homogenisation temperatures of 172 ± 35°C. Zn isotope values ($\delta^{66}$Zn = -0.3 to 0.4‰) within the epigenetic halo suggest that precipitation was not from exhaust fluids moving laterally away from the Navan deposit, but from upwelling hydrothermal fluids over a region larger than the Navan orebody. Starved of bacteriogenic sulphide-bearing fluids, sulphide precipitation was very limited.

A second, apparently syngenetic, halo comprises Fe-(Mn-)rich horizons hosted by lowermost Upper Dark Limestone (UDL), stratigraphically overlying the orebody. In the Tara Deep deposit, where these horizons are more abundant, limited data indicate that Pale Beds Zn-Pb mineralization has a dominantly hydrothermal sulphide signature ($\delta^{34}$S = 6 to 16‰), but overlying UDL halo pyrite has a bacteriogenic sulphide signature. Bacteriogenic sulphide-bearing fluid seemingly did not penetrate as efficiently into the Pale Beds, to mix with the hydrothermal fluid, as in the main orebody. This may imply repeated hydrothermal fluid upwelling, or barriers to downward flow of bacteriogenic sulphide-bearing fluids. Zn isotope data are consistent with UDL sphalerite crystallization from Pale Beds exhaust fluid.

From a mineral exploration point of view, the syngenetic halo provides a better opportunity to vector towards high-grade base metal mineralization than the epigenetic halo. Temperatures of ore fluids at the time of ore deposition are poorly known. However, clumped O-C isotope analysis of carbonate minerals in the Navan and other Irish-type deposits is underway, to constrain fluid temperatures. Preliminary analysis of samples from Navan and Lisheen has demonstrated its potential to understand fluid movement and mixing processes during orebody formation and hence act as another vectoring tool towards mineralization.