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Timing of Interplay between Hydrothermal and Surface Fluids in the Navan Zn + Pb Orebody, Ireland: Evidence from Metal Distribution Trends, Mineral Textures, and $\delta^{34}S$ Analyses

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Abstract

Models of genesis for the Navan orebody are of two distinct types. An early hypothesis that mesothermal (though nonmagmatic) deposition of ore began when a supernatant seawater brine still had access to the host sediments (during the early to mid-Mississippian), has been challenged by recent suggestions favoring a later (mid- to late Mississippian to Pennsylvanian) mineralization derived from cooler fluids traversing either the Mississippian/Pennsylvanian basin or the underlying basement from the south. These models, characterized here as Irish-type and Mississippi Valley-type respectively, are interrogated as to their particular predictions with regard to metal distributions and sulfur isotope patterns associated with various fault geometries.

The basal 5 lens of the Navan Zn + Pb deposit contains ~70 percent of the known tonnage of the ~90 Mt orebody and, thus, is the focus of this examination. Lead distribution patterns suggest that migration of metal-bearing fluids was principally directed up early to mid-Mississippian, near vertical north-northeast, northeast, and east-northeast minor normal faults. These faults predate or are coeval with the major extensional, partly listric, east-northeast faults which now control the general disposition of the deposit. Only where these major east-northeast faults cross putative deep-seated northeast (Caledonoid) and northwest structures are they associated with lead enrichments.

A systematic $\delta^{34}S$ survey in the 5 lens across five minor north-northeast– through to east-northeast–trending faults associated with distinct lead enrichments, and one east-northeast–trending, partly listric, major extensional fault adjacent to that trend, revealed positive $\delta^{34}S$ values (1–18‰) for galena, sphalerite, and marcasite sampled within 3 m of all the faults on the profile. Sulfides with positive $\delta^{34}S$ values associated with the deep-seated, metal-bearing fluid generating the Navan deposit have been highlighted by previous workers (Anderson et al., 1998). The evidence reported here strongly suggests that the metal-bearing fluids rose through all the fractures. Conversely, negative $\delta^{34}S$ values (–1 to –26‰) were returned in galena and sphalerite sampled 3 m or more from these faults. These negative values indicate that locally derived bacteriogenic sulfide, reduced from seawater sulfate, dominated away from these faults. Pyrite $\delta^{34}S$ values suggest a background level of –29 ± 3.0 per mil across the profile. However, pyrite $\delta^{34}S$ values as low as –34 ± 2.7 per mil were recorded in one sample collected from within 1 m of a fault. Thus, fluids containing highly fractionated, bacteriogenic sulfide also gravitated into these faults on at least one occasion. There is also evidence suggesting that the metal-bearing solutions periodically displaced the locally derived bacteriogenic sulfide-bearing fluid in and near the faults.

Mineral sulfide petrography is used to contextualize the sampling and to give a qualitative indication of the degree of chemical disequilibrium of the system. Mineral textures demonstrating comminution and dissolution are revealed by this study that, when coupled with evidence of isotopic overprinting, force the conclusion that mineralizing fluids first invaded the host lithologies during mid-Lower Mississippian times, coincident with active faulting. There is no evidence of reactivation of the minor fault sets encountered in the study area during post-Chadian tectonism, though the major, partly listric, east-northeast extensional faults were reactivated at that time.

Ore deposition was effected by bacteriogenic sulfide (reduced from Mississippian seawater sulfate) reacting with rising, metal-bearing mesothermal fluids. Thus any model invoking an onset of mineralization later than the mid-Lower Mississippian does not stand up to this scrutiny.