A New Genetic Model for Mineralization in the Irish Zn-Pb Orefield

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The carbonate-hosted zinc-lead deposits of the Irish orefield are stratigraphically and structurally controlled. Ore deposits are restricted to two stratigraphic units of lower Carboniferous (Tournaisian and Visean) age: (1) the Waulsortian Limestone Formation in southern and central Ireland, and (2) the Navan Group of north-central Ireland. The Waulsortian-hosted deposits occur largely in the complexly faulted hanging walls of large (>150-m offset) normal faults within relay-ramp systems formed during transtensional fault movement. The giant Navan deposit occurs broadly within a complexly faulted, horst-related anticlinorium that was also subject to syndepositional, submarine mass wastage which removed a significant thickness (>300 m) of sedimentary cover above the mineralized zone. Ore-controlling faults in the Irish orefield formed in response to extensional tectonism in the Tournaisian and early Visean, but their location and orientation were probably controlled by preexisting faults within the lower Paleozoic basement.

Fluid inclusion studies indicate that the presence of two fluids was critical for the formation of major deposits: (1) a moderate-temperature (mostly 130°–240°C but locally up to 280°C), low- to moderate-salinity (8–19 wt % NaCl equiv), reduced and sulfur-poor, metal-bearing fluid (the “principal ore fluid”); and (2) a relatively low temperature (50°–130°C), high-salinity (>20 wt % NaCl equiv), Br-enriched bittern brine. Sulfur, lead, and strontium isotope data and fluid geochemistry indicate that fluid 1 originated as partially evaporated seawater that derived metals and sulfur from lower Paleozoic (±Precambrian) basement during deep circulation. Fluid geochemistry suggests that fluid type 2 was reservoired within the Carboniferous sequence and never interacted with siliciclastic rocks. A connected permeability structure linking feeder faults with permeable sedimentary horizons was important for allowing the two fluids to mix efficiently. A number of studies have suggested that the second fluid acquired reduced sulfur derived from bacteriogenic reduction of seawater sulfate proximal to hydrothermal upflow zones of the principal ore fluid. It is proposed that bacterial productivity was linked to hydrothermal leakage into subseafloor sediments, providing a positive feedback between zones of focused metalliferous fluid flow and sulfide generation.

Detailed petrographic work demonstrates that the majority of sulfides at the major deposits formed by replacement of carbonate wall rocks during burial. The balance of evidence from geological relationships and geochronology of ore minerals suggests that ore formation occurred episodically over an extended period of time (10–15 m.y.), within a few hundred meters of the paleoseafloor. The intimate relationship between mineralization and volcanic activity in the Limerick province supports a model involving magmatic heat as a key driver for fluid circulation that was enhanced by downward flow of cool, dense, seawater-derived brines. Episodic fluid flow, linked to pulses of extension-related alkaline igneous activity, primarily occurred within the wedge of fractured lower Paleozoic rocks that lay beneath the basin sequence. From these rocks, metals were easily leached and transported upward into receptive carbonate host rocks, where mixing with sulfidic brines occurred.