A Magmatic – Hydrothermal Origin for the Giant Broken Hill Pb-Zn Deposit

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The Broken Hill Pb-Zn-Ag deposit (300 Mt) is the largest known accumulation of Pb on Earth (28 Mt of Pb metal). It occurs in the Palaeoproterozoic Willyama Complex in western NSW, within highly deformed metasedimentary rocks, as stacked ore lenses along a line of lode ~7km long. Metagabbroic sills are common in the district. Although some consensus exists that the deposit and its host rocks formed in a rift setting around 1700-1670 Ma, the origin of this giant ore system remains controversial. Importantly, S isotopic data for the ores are homogeneous, and totally mantle-like, with minimal evidence for seawater-derived S.

Away from the line of lode, the sills are typical rift tholeiites with flat REE patterns and E-MORB compositions. However, as has been noted previously, in the vicinity of the line of lode, sills are strikingly Fe-rich tholeiites, with well-preserved chilled margins having up to 22% total Fe as Fe2O3. No similarly Fe-enriched sills were encountered elsewhere in the region. We believe that the remarkably Fe-rich compositions of sills along the line of lode reflect the operation of extensive synkinematic fractionation of structurally focussed magma batches, during which late stage interstitial Fe-rich melts were pumped out of the crystal-mush pile and up an extensional shearzone. This process is well documented for ultra-slow spread crust on the SW Indian Ridge, where ODP Hole 735B revealed the presence of large volumes of often foliated oxide gabbros.

Fractional crystallisation very effectively separates Cu from Pb and Zn, since Cu partitions strongly into a magmatic vapour phase from the early stages of fractionation, whereas lithophile Pb and Zn remain in the magma as fractionation proceeds. We argue that late magmatic fluid evolution from these Fe-rich magmas transported large amounts of Pb and Zn into a robust hydrothermal system that ultimately formed the ore deposits along the trace of the extensional shear system. Abundant Mn in the alteration halo, a characteristic of the Broken Hill deposit, we ascribe to alteration of ilmenite (0.5-2% MnO), a major phase in oxide gabbros.