The compositions and origins of ore-forming brines

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Many metals form soluble chloride salts, and base metal concentrations can reach percent levels in chloride-rich fluids. As a result, brines are extremely potent vehicles for hydrothermal concentration of a wide range of metals including Fe, Pb, Zn, Cu, Co, Ni, Mn, PGE and REE, and they have also been implicated in the formation of gemstones, such as emeralds. Over the past 25 years fluid inclusion studies in particular have revolutionised our understanding of the distribution of brines in the geological record and of their chemical composition.

Many brines are linked to sedimentary evaporite sequences, but brines can also be of magmatic origin. In some cases however, magmatic brines arise by recycling of original sedimentary concentrations. Sedimentary brines may be the residua after halite has begun to precipitate (bittern brines) or can arise through dissolution of halite beds. They are readily distinguished by their Br/Cl ratios and these signatures can survive extended crustal residence and involvement in deep geological processes. Although bitterns have much higher metal contents initially, both types have been implicated in the formation of MVT deposits.

Compilation of brine analyses from a wide range of settings shows that their base metal load varies systematically with Cl concentration and temperature. The metal:chloride ratio can increase by 6 orders of magnitude between brines present at surface conditions and those formed at magmatic temperatures. It appears that in deep sedimentary basins there may be large quantities of brine with moderate base metal contents, while magmas may give off much smaller amounts of brine that have much higher metal levels; hence both may have ore-forming potential.

It appears that salt is very difficult to wash out of rock sequences, and there are a number of examples of shelf sequences with evaporites which have gone on to develop hydrothermal ores through an extended geological history. In the Pyrenees, bittern brines that originated during deposition gave rise to low grade veins formed in the Mesozoic and subsequently lubricated Alpine thrusts. The Capitan pluton of New Mexico has associated magmatic hydrothermal veins formed from wet salt melts that originated as Triassic salt beds, melted and remobilised by the intrusion. In areas such as central Queensland, the link between distinct deposits is less clear, but a wide range of ore deposits formed from brines occur in a sequence that included originally halite-rich formations.

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