

White D E. Environments of generation of some **basemetal ore** deposits.

Econ. Geol. 63:301-35. 1968.

[US Geological Survey, Menlo Park, CA]

Many copperleadzinc ore deposits were introduced into previously existing rocks by hotwater solutions. Prevailing theory had related ore fluids and metals to underlying crystallizing magma. The chemistry and isotopes of two active geothermal systems and three 'fossil' ore districts all involve chloride brines of different origins. [The *SC*[®] indicates that this paper has been cited over 120 times since 1968]

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"Natural processes that could concentrate base metal sulfides (principally copper, lead, zinc, and iron) of low solubility were enigmatic. Prevailing theory held that ore metals were introduced into older rocks by deep magmatic fluids. My 15 years of research on active geothermal systems provided clues for mercury and goldsilver, but these dilutewater systems yielded nothing on basemetals.

"The enigma hinged on the extremely low solubilities of these metal sulfides in dilute waters. Could metalchlorides or other metal complexes be more soluble? Then, in 1962, a deep well was completed in a hostile environment in SE California – temperatures too high to measure (near 350°C) and chloride eight times higher than sea water.¹ Rich

coppersilver sulfides formed on well casings, and young sedimentary rocks were being actively metamorphosed—both were new events for geologists! This spectacular brine, with its high metal contents, might even be the longsought magmatic ore fluid. My close associate, L.J.P. Muffler, and leading geochemists helped with the challenging problems. However, we soon found that the water was not magmatic but was local ground water that dissolved subsurface evaporites. The resulting dense brine circulated to great depth and, with volcanic heating, dissolved metals from the host sediments during their metamorphism. This system also demonstrated that dissolved sulfide and abundant base metals can coexist in high-temperature chloride brines.

"Another spectacular example of diverse origins and chloride complexing was found in 1964 in heavy hot brines (~ 60°C) that had precipitated base-metal ore deposits in a deep basin of the Red Sea.

"Why has my 1968 paper been frequently cited? It contains comprehensive summaries of these two active brine systems as well as the first three base-metal ore districts whose origins were decipherable from isotopic data. All five had brines, but of diverse origins; only one may have been dominantly magmatic!

"This theme of diverse origins was later expanded to include mercury and gold-silver, as well as many more base-metal systems."²

1. White D E, Anderson E T & Grubbs D K. Geothermal brine well: mile-deep drill hole may tap ore-bearing magmatic water and rocks undergoing metamorphism. *Science* 169:918-22, 1963.

2. White D E. Diverse origins of hydrothermal ore fluids. *Econ. Geol.* 69:954-73. 1974.