

# Geochemistry of the Fluids Related to Epigenetic Carbonate-Hosted Zn-Pb Deposits in the Maestrat Basin, Eastern Spain: Fluid Inclusion and Isotope (Cl, C, O, S, Sr) Evidence

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## Abstract

Epigenetic Zn-Pb deposits in the Maestrat basin (eastern Spain) are hosted by dolostones that replace Aptian limestones. The deposits have morphologies ranging from mineralized breccias to stratiform, massive replacements. Sphalerite and galena cementing breccias precipitated as well-formed crystals; whereas, the stratiform replacements are characterized by textures such as colloform and skeletal or dendritic growths. Two mineralized areas are found: Valdelinares and Mas de la Mina-Cedramán. The highest ore grades (up to 11% Zn) and largest deposits (ca. 30,000 t of sulfides) occur as stratiform deposits in the Valdelinares area (Resurrección and Restauración mines).

In the Valdelinares area, microthermometry of fluid inclusions reveals that ore-stage minerals precipitated by the mixing of two distinct fluids: fluid A, a high salinity brine, with salinity greater than 26 wt percent NaCl equiv and temperatures above 120°C, and fluid B, a low salinity fluid, with less than 15 wt % NaCl equiv and temperatures around 40°C. Fluid A-dominated brines are found in mineralized breccias located in the vicinity of major fracture zones; whereas, more dilute fluids are typical of massive ores. In the Mas de la Mina area, the presence of two fluids is less evident, although the ranges in both temperature and salinity also point to mixing. Na-K-Li-Cl-Br systematics of the inclusion fluids indicates that fluids A and B were evaporated seawater that did not significantly interact with K- and Li-rich sediments. The most diluted mixtures (fluid B) are characterized by relatively heavy Cl ( $\delta^{37}\text{Cl} = 1.11$  and  $1.19\text{‰}$ ) compared to fluid-A dominated brines, which have  $\delta^{37}\text{Cl}$  values close to seawater (0‰). The sulfur isotope compositions range from -10.5 to 13.4 per mil for sulfides and between 16 and 17.8 per mil for barite. Such values are consistent with mixing of a metal-rich brine with small amounts of  $^{32}\text{S}$ -enriched sulfur and a sulfur-rich fluid with a  $\delta^{34}\text{S}$  close to the marine sulfate of Late Cretaceous to early Paleocene age. The C and O isotope compositions of ore-stage calcite ( $\delta^{13}\text{C}$  from 0.6 to -7.8‰;  $\delta^{18}\text{O}$  from 17.2 to 20.9‰) are also explained by the precipitation from different mixtures of fluids A and B.

From the geochemical data, it is inferred that fluid mixing played a key role in the formation of the Zn-Pb deposits in the Maestrat basin. Ore precipitation occurred in places where brines ascending through faults interacted with a dilute, sulfur-rich fluid. Deposits with the highest ore grade and size are related to areas where the most extensive mixing occurred.

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