

# Metallogenesis of Zn-Pb Carbonate-Hosted Mineralization in the Southeastern Region of the Picos de Europa (Central Northern Spain) Province: Geologic, Fluid Inclusion, and Stable Isotope Studies

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## Abstract

The Zn-Pb deposits of the southeastern area of the Picos de Europa province display an epigenetic hydrothermal mineralization of moderate temperature hosted by intensely dolomitized limestones of Carboniferous age. They are structurally and lithologically controlled since the three phenomena of fracturing, dolomitization, and mineralization are interrelated. Two types of mineralization have been found: type I, granular dark brown-colored sphalerite, galena, and dolomite, and type II, toffee-colored sphalerite, galena, and calcite. Type II mineralization is later than type I.

The Aliva and Andara deposits are the two largest in the Picos de Europa area, and both contain type I and type II styles of mineralization. Fluid inclusion studies indicate that the mineralizing solutions for both stages were similar and had trapping temperatures between 170° and 200°C and salinities around 15 wt percent NaCl equiv. However, microthermometric data from sphalerite (I and II), dolomite I, calcite II, and fluorite samples show various stages of circulation and trapping of brines with spatial and temporal variations in salinity and temperature.

Calcite and dolomite from the mineralization have  $\delta^{13}\text{C}_{\text{PDB}}$  values between 1 and 2.9 per mil ( $\delta^{13}\text{C}^{\Sigma\text{CO}_2} = -0.8$ – $1.1\%$ ), and  $\delta^{18}\text{O}_{\text{SMOW}}$  values between 11.5 and 16.2 per mil ( $\delta^{18}\text{O}^{\text{H}_2\text{O}}$  varied from 0.7– $1.9\%$ ). Sulfides show  $\delta^{34}\text{S}$  values between 12.9 and  $-16.8$  per mil ( $\delta^{34}\text{S}_{\text{fluid}}$  for the Aliva deposit ranged between 13.4 and  $-2.5\%$ ). The combined stable isotope data indicate evolved marine waters. Isotope evidence suggests that the mineralizing fluids were probably formation waters of the Palentine zone and the Picos de Europa province sediments. During the Permian, possibly during extensional tectonic phases, these brines moved toward and through the Picos de Europa province along late Hercynian fractures giving rise to the Zn-Pb mineralization.