

The Geology and Isotope Geochemistry of the Talc Deposits of Puebla de Lillo (Cantabrian Zone, Northern Spain)

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Abstract

The talc deposits of Puebla de Lillo (Cantabrian zone, Variscan belt of Iberia) are hosted by hydrothermal dolostones replacing Carboniferous limestones and are generally located adjacent to Ordovician quartzites. The talc orebodies occur as metasomatic replacement zones of the dolostones near faults or lithologic contacts and, to a lesser extent, as replacements of the nearby quartzites or slates. These rocks are affected by a very low grade regional metamorphism but occur in a highly deformed setting with abundant thrusts and faults. Dolostones similar to those hosting the talc deposits are widespread in the Cantabrian zone; most of them are barren, although a few host epithermal sulfide mineralization.

Four hydrothermal events are recognized. The first two formed gray (I) and beige (II) hydrothermal dolostones (\pm quartz), very similar to the regional barren dolostones. The third, a white coarse-grained dolomite (III) is directly associated with the talc. The final episode is characterized by late-stage vuggy dolomite (IV), calcite, and quartz.

Fluid inclusion studies in dolomite and quartz suggest that the dolomitizing fluids were aqueous NaCl-CaCl₂ brines of variable salinities (0-23 wt % NaCl equiv) and a low CO₂ content (0.003-0.01 X_{CO2}). Thermodynamic considerations, fluid inclusion data, and comparison to regional studies suggest that dolomite (events I and II) formed at temperatures between 100° and 280°C, the talc-forming event (III) was between 280° and 405°C, and the postore carbonates and quartz (IV) precipitated between 65° and 170°C. Fluid pressure during the hydrothermal event was low, probably between 165 and 450 bars.

The $\delta^{18}\text{O}$ value of the dolomite reflects the interaction of an infiltrating ¹⁸O-depleted fluid with the country-rock limestones having $\delta^{18}\text{O}_{\text{SMOW}} = 22.5$ to 33.2 per mil and leading to a concomitant lowering of the average $\delta^{18}\text{O}$ value to 19.9 ± 4.0 (dolostone I), 17.2 ± 6.2 (dolostone II), and 16.8 ± 1.9 per mil (dolomite III) during the different dolomitization events. The talc replacing the dolostone has a monotonous $\delta^{18}\text{O}$ signature of 10.7 to 12.7 per mil and a $\delta\text{D}_{\text{SMOW}}$ composition of -64 to -62 per mil. However, the talc replacing quartzites, slates, or impure dolostones has more variable and lower $\delta^{18}\text{O}$ values (8.1 , 9.0 , and 11.5% , respectively). The late dolomite IV has a $\delta^{18}\text{O}$ composition of 14.7 ± 3 per mil, whereas the associated quartz has a $\delta^{18}\text{O}$ of 13.0 to 15.7 per mil. The oxygen isotope results are indicative of a systematic oxygen isotope disequilibrium between the hydrothermal minerals.

The combined $\delta^{18}\text{O}$ - $^{87}\text{Sr}/^{86}\text{Sr}$ data support a complex hydrothermal evolution involving the mixing of two fluids. Fluids related to the dolomitization of the limestones were dominated by deep brines equilibrated with the underlying siliciclastic rocks ($\delta^{18}\text{O} > 5\text{-}7\%$; $^{87}\text{Sr}/^{86}\text{Sr} = 0.7090$). They gradually mixed with a meteoric fluid with incomplete equilibration with the basement. The hydrothermal fluid during talc formation had an isotopic signature of $\delta^{18}\text{O} = 5.0$ to 7.9 per mil and δD close to -70 per mil, whereas the postore hydrothermal fluids were mostly meteoric in origin ($\delta^{18}\text{O} < 0\%$; $^{87}\text{Sr}/^{86}\text{Sr} = 0.7086$). The $\delta^{13}\text{C}$ values of all hydrothermal carbonates investigated (-2 to $+4.9\%$) are indicative of carbon being buffered by the host limestones, in agreement with the observed low X_{CO_2} of the fluid.

The isotopic composition of sulfur in pyrite ($\delta^{34}\text{S}_{\text{CDT}}$; -3.8 to $+10.2\%$) also indicates derivation from two different sources, the host limestones containing sulfides with high $\delta^{34}\text{S}$ formed by the abiogenic reduction of seawater sulfates and siliciclastic rocks from the basement having isotopically light sulfur of bacteriogenic origin.

The talc mineralization of Puebla de Lillo resulted from a regional-scale episodic hydrothermal activity related to early Alpine wrench faulting. The mineralization is located along tensional structures adjacent to the deep-seated Cofiñal strike-slip fault, a major structure of the Cantabrian zone. These extensional faults acted as conduits for large amounts of hydrothermal fluids. Upwelling silica and Mg-rich brines reacted with the carbonate rocks, producing the dolomitization and superimposed talc mineralization. The critical factor in the formation of the talc instead of the regional dolostones (+stable quartz) was a local increase in temperature. This localized high-heat flow cannot be solely explained by normal geothermal gradients and suggests the existence of a deep igneous intrusion near the fault, which provided heat that drove the hydrothermal system. The role of the nearby quartzites was probably to saturate the hydrothermal fluids in silica as they were most likely SiO_2 undersaturated due to heating after equilibration with the basement.