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Genesis of the Eugui sparry Magnesite deposit, Western Pyrenees, Spain

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The origin of carbonate-hosted sparry magnesite deposits is a matter of intense debate. Detailed petrography, fluid inclusion and isotopic analyses were applied to unravel the genesis of the Eugui magnesite deposit (Western Pyrenees, Spain), which is one of the largest and best-known sparry magnesite occurrences in the World. The Eugui deposit is hosted by the Devonian-Carboniferous metasedimentary succession of the Aldudes-Quinto Real basement massif, which is subdivided into two major Groups (Irurita and Eugui). The Irurita Group is mostly composed of siliciclastics, whereas the overlying Eugui Group comprises Namurian carbonates with siliciclastic intercalations overlain by a Westphalian flysch unit. The sparry magnesites are hosted by the Namurian dolomites. The successions were deformed during the Hercynian and Alpine Orogenies and were intruded by mafic igneous dykes, which are associated with Late-Triassic Keuper evaporite facies.

In a paragenetic order, the following main diagenetic phases were identified: fine-crystalline organic-rich host rock dolostone, sparry magnesite, coarse-crystalline Fe-poor and Fe-rich dolomites, authigenic quartz and minor Fe-rich calcite. Fine-grained disseminated pyrite and coarse-crystalline pyrite in nodules were often observed. The sparry Magnesite replaces the Namurian host rock dolomite and occurs in alternating thin dark and white layers with coarse-grained crystals (up to 8 cm) often growing perpendicular to stylolite planes. The Fe-poor and Fe-rich dolomites occur in veins crosscutting magnesite, in zebra features and as massive precipitates associated with or replacing magnesite. Primary fluid inclusions in the sparry magnesites display homogenisation temperatures (T_h) that vary between 125° and 200°C and a high salinity of 22.4 to 26.5 wt.% $CaCl_2$, with the highest temperatures reported from the dark and cm-size magnesite crystals. Primary fluid inclusions in the host rock dolomite and the different Fe-poor and Fe-rich dolomite phases display a progressive decrease in temperature and salinity with T_h values that range between 90° and 145°C and salinities between 14.2 and 23.2 wt.% $CaCl_2$. Fluid inclusions with a slightly lower T_h (85°-125°C) and a similar salinity (16.5-21.5 wt.% $CaCl_2$) were observed in the authigenic quartz. Primary aqueous mono-phase all-liquid fluid inclusions with a salinity of 0 to 0.7 wt.% NaCl were reported in the Fe-rich calcite.

The sparry magnesites display $\delta^{13}C$ values of +3.5‰ to +4.8‰ and $\delta^{18}O$ values between −14.1‰ and −12.9‰ V-PDB. The calculated $\delta^{18}O_{fluid}$ values range between −2 and +5‰ V-SMOW. The different Fe-poor and Fe-rich dolomite generations display a wide range of $\delta^{13}C$ and $\delta^{18}O$ values that overlap with or are progressively depleted relative to the magnesite values. The host rock dolomite displays a wide range of $\delta^{18}O$ values that overlap with or are significantly depleted from the $\delta^{18}O$ signature of marine Carboniferous carbonates, suggesting recrystallization. The late calcite displays $\delta^{13}C$ (−3.3‰ to −0.1‰) and $\delta^{18}O$ (−12.5‰ to −8.9‰) values that confirm its meteoric origin. The Sr isotopic compositions of the sparry magnesites and the different dolomite and calcite generations display a wide range ($^{87}Sr/^{86}Sr$ = 0.70824 to 0.71127) that fall in a mixing trend between the Carboniferous Sr marine signature and the

high radiogenic Sr signatures of the siliciclastic rocks ($^{87}Sr/^{86}Sr$ = 0.71266 to 0.74403) intercalating with and underlying the magnesite body. In contrast, the Triassic mafic intrusions display a significantly lower Sr isotope signature (0.70649 to 0.70709). The fine-grained pyrite displays $\delta^{34}S$ values (−15.8‰ to −0.8‰ V-CDT) that typically reflect bacterial sulphate reduction, whereas the $\delta^{34}S$ values of the coarse-crystalline pyrite (−1.3‰ to +14.5‰ V-CDT) suggest remobilization of sulphur and a new sulphur input from thermochemical sulphate reduction.

Results suggest that the Eugui sparry magnesite is related to a hydrothermal high salinity fluid, likely of Late Triassic marine origin, which became heated by downward migration and progressively enriched in heavy O and radiogenic Sr by interaction with the basement siliciclastic rock units.