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Petrography and C and O stable isotope composition of ophicalcites in the Western Pyrenees/Eastern Cantabrian Mountains: geodynamic implications

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This work presents a petrographic, geochemical and C and O isotopic study of the westernmost outcrop of mantle rocks present in the Pyrenean-Cantabrian belt. The outcrop is located near the village of Ziga, close to the Paleozoic Basque Massifs of Cinco Villas and Aldudes. Our aim is to gain insight into the exhumation history of these rocks in relation to the Mesozoic crustal extension episode between Iberia and Eurasia, and the subsequent Pyrenean inversion.

The Ziga peridotites crop out as allochthonous blocks, together with fragments of different types of granulites, marbles, Buntsandstein facies rocks and basic subvolcanic rocks, embedded in a gypsum-clay matrix defining a deformation band in the junction between the Leiza fault (which has other associated outcrops of high-grade metamorphic rocks along its E-W trending trace) and the Pamplona fault (with a NNE-SSW orientation marked by the alignment of several Keuper-facies salt diapirs). The deformation band has the same orientation of the Pamplona fault and a comparative study between this matrix and the Keuper-facies Estella diapir associated to that fault reveals a similar mineralogy (gypsum, quartz, kaolinite-montmorillonite, muscovite, carbonates and chlorite) and geochemistry (standing out the high values of Ca and Sr).

The ultramafic rocks are highly serpentinized lherzolites, with a primary association consisting of clinopyroxene+orthopyroxene+olivine+spinel±amphibole; secondary antigorite and chrysotile as serpentine varieties; and calcite with minor aragonite and dolomite as late carbonate phases. Calcite occurs mainly as veins crosscutting all other minerals, as a result of low-temperature alteration of serpentinized ultramafic rocks in contact with fluids (ie. ophicalcites). In order to infer the nature of these fluids we analysed the carbon and oxygen isotopic signature of the Ziga veins. For comparison, we also analysed calcite veins from the Col d'Urdach ophicalcites (French Western Pyrenees), whose exhumation to the seafloor in mid-Cretaceous times is well documented by field evidences. Coherently, values of $\delta^{13}C_{PDB}$ for the Col d'Urdach samples lie in the range of -1.23 to +1.30 ‰ (n=8), typical of marine carbonates, and only one anomalous sample seems to reflect the presence of mantle-derived carbon ($\delta^{13}C_{PDB}$ = -5.24 ‰). On the contrary, very negative values of $\delta^{13}C_{PDB}$ are found in Ziga (-9.79 to -12.39 ‰ n=9), reflecting the presence of light carbon originated most probably by oxidation of methane released during the serpentinization process, mixed with variable quantities of mantle-derived CO_2 and/or seawater. These negative $\delta^{13}C$ values and the presence of antigorite suggest a deeper alteration process than in Urdach (ie. incomplete extensional exhumation). $\delta^{18}O_{PDB}$ results allow calculating the temperatures at which the veins formed. A preliminary estimation for Ziga samples ($\delta^{18}O_{PDB}$ = -4.79 to -4.47 ‰), considering a deep fluid with a $\delta^{18}O_{SMOW}$ between 1 and 2 ‰ yields temperatures of 40-48 ºC, although the effect of different fluid compositions and fluid/rock ratios need to be analysed with care. In the case of Urdach, assuming a seawater origin for the fluid ($\delta^{18}O_{SMOW}$ = 0 ‰) and excluding the anomalous sample, estimated temperatures range from 50 to 78ºC ($\delta^{18}O_{PDB}$ = -10.99 to -7.16 ‰).