Characterization of meteoric water infiltration in Variscan shear zones

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Crustal-scale shear zones are sites of significant fluid circulation. The Armorican Massif (AM) and the French Massif Central (FMC) are part of the internal zones of the Variscan Belt, where leucogranites were emplaced within ductile shear zones during the Late Carboniferous. Combining structural, microstructural, hydrogen (δD) and oxygen ($\delta^{18}O$) isotope and geochronology of syntectonic granite, we determined the mechanisms of fluid flow and fluid-rock interaction in these fossil hydrothermal systems.

The δD values of muscovite (δD_{Ms}) allowed us to determine the source of fluids that infiltrated different types of shear zones in the AM. Combined with temperatures of hydrogen isotope exchange deduced from quartz microstructures, EBSD and Ti-in-Ms thermometry, we calculated the δD values of water (δD_{water}) present during high-temperature deformation. A 41‰ difference in δD_{water} values from deep to shallow crustal levels reveals a mixing relationship between D-enriched metamorphic/magmatic fluids (δD_{water} ~ -33‰) and that of meteoric fluids with δD_{water} values as low as -74‰. This is further supported by fluid inclusions in quartz grains that contain very low salinity water (0 to 7 wt% eq. NaCl) and which have intermediate δD and $\delta^{18}O$ values.

In the FMC, syntectonic leucogranites from the Millevaches massif yield δD_{Ms} values as low as -116‰ that indicate an incontestable signature of meteoric fluids. The penetration of meteoric fluids occurred between ~320 and 300 Ma ($^{40}Ar/^{39}Ar$ and U/Th-Pb) through brittle fractures in the upper crust while the emplacement of high-grade metamorphic rocks sustained fluid convection at depth.