Coupled transfer properties and geochemical fractionation in shear and fracture systems

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The permeability of sheared and fractured systems is assumed to be significantly higher than that of host rocks. In addition to physical modifications, such rocks are known to constitute a common type of geochemical water/rock interaction. The aim of this study is to couple (1) a study of strain as well as transfer properties of the porosity network in such rocks (Géraud *et al.*, 1995) with (2) study of subsequent water/rock interactions tracing using a geochemical approach (*REE*, Sr and O isotopes). Both approaches were applied to two different systems. The first system consists of a mylonitic shear zone in granite, in the northwestern French Massif Central (Géraud *et al.*, 1995). The second one is a normal fault deeping 70° east in Triassic sandstone of the western border of the Rhinegraben (Maurin, 1995). In both cases a serie of samples was collected along a profile across the fractured area.

The physical approach shows clearly that the granites of the mylonite zone are porous and that porosity varies with shear strain. Porosity is heterogeneous at two different scales: on the one hand, it is higher at the meter scale in the highly strained axial part of the shear zone (up to 8%) than at the less deformed margin (1–2%) and increases with decreasing grain size; there is a shift between the highest porosity value and the highest strain value. On the other hand porosity is heterogeneous at the centimeter scale in the mylonite, where it is higher in the feldspar-mica ribbons than in the quartz ribbons. Porosity is variable, because it is composed of pores with two different shapes: cracks and tubes. Cracks occur principally in the mildly deformed margins, whereas tubes are developed in the more strongly deformed central mylonite. The porosity network is anisotropic: cracks and especially tubes are preferentially oriented parallel to the C-surfaces. This preferred orientation is best developed in the central mylonite, where it tend to parallel the major finite strain axis. Common granite contains about 50-60 % quartz, 10–15% feldspar and 25–30% plagioclase, whereas strained areas are quartz enriched. The fractured zone itself consists only of small quartz grains. Towards the fracture, common granite exhibits ^{18}O depletion from 10.0 to 8.7 on one side of the fracture and from 8.2 to 7.4‰ SMOW on the other side. In the fracture, $\delta^{18}O$ of quartz ranges between 10.0 and 10.4‰ SMOW. Thus depletion of the samples on the sides of the fractures may correspond to a thermal effect, related to strain or fluid circulation in the fracture. Further isotopic analyses carried out on separate minerals allow us to estimate the temperatures. From a mineralogical point of view, the fracture system is also characterised by low alkaline (Sr range between 6.91 and 22.1 ppm, Ba range between 28.4 and 73.2 ppm) and alkaline earth contents (Rb range between 109 and 341 ppm) compared to common granite (Sr: 20.7–43.1 ppm, Ba: 79.8–181 ppm, Rb: 289–454 ppm).

Preliminary porosity measurements of the sandstone samples across the normal fault are consistent with higher porosity values of the down lifted block rocks (ranging between 8.9 and 12.0%) compared to the rocks from the other block (block B) (porosity ranges between 6.2 and 9.9%). Sandstones exhibit little mineralogical variety. They contain detrital and diagenetic quartz, with around 10% feldspa together with clays. The mineralogy of the clays depends widely on the location of the sample. Thus samples belonging to the block A contain more kaolinite (60–75%) than illite compared to the samples from block B which are illite rich (75–90%). Rare Earth Element patterns of samples from block B exhibit Light *REE* enrichment (La/Yb range between 1.1 and 2.4), compared to patterns from samples from block A (La/Yb range between 1.0 and 1.5). Furthermore, the negative Ce anomaly decreases as the distance to the major fault decreases. Alkaline and alkaline earth element concentrations of samples from block B (Sr: 46–1816 ppm, Ba: 235–271 ppm, Rb: 50.1–70.8 ppm) is higher than for samples from block A (Sr: 270–353 ppm, Ba: 140–195 ppm, Rb: 31.8–43.4 ppm).

Conclusion

In both granites and sandstones, the behaviour of elements follows the porosity variations which are not directly related to the variations of the strain. This effect shows clearly the relationship between element transfer and the porosity network of the system. Both type of data allow us to make differences between the block which moved and in which fluid flow occurred and the immobile block where no fluid circulated.

References

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