Hydrothermal remobilisation of Sm-Nd isotopes at the mineral scale in granites

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Introduction

Very little is known about the behaviour of isotopic systems at the mineral scale during fluid-rock interactions (Halliday *et al.*, 1991). In order to investigate this, we have made a Sm-Nd isotope mineralogical study of two examples of granites. It appears that although some minerals retain their magmatic signature, others can be severely affected by hydrothermal events, as is apparent from their peculiar chemical zonations and isotopic signatures.

Samples and procedure

The two examples studied are from the Late Palaeozoic Corsican Anorogenic Province (SE France), mainly consists of granites. The first example is a hypersolvus fayalite-bearing granite from the Punta di Mantelluccio intrusion, a part of the Cauro-Bastelica complex. The second one is a hypersolvus peralkaline granite from the Evisa complex. Details about petrology, sample preparation and the Sm-Nd isotopic procedure used are presented elswhere (Poitrasson *et al.*, 1994).

Results and discussion

Alkali-feldspar, ferrobaroisite, zircon, fluorite and fergusonite yield a statistically good isochron (M.S.W.D. = 0.28) at 331 ± 10 Ma for the hypersolvus fayalite-bearing granite of Mantelluccio; arfvedsonite, fluorite, sphene and fergusonite of the hypersolvus peralkaline granite of Evisa yield an age of 258.5 ± 5.8 Ma (M.S.W.D. = 0.88) (Poitrasson mes-i" > et al., 1994). These Sm-Nd dates are in agreement with other geochronological determinations (e.g. amphiboles ^{39}Ar–^{40}Ar for Mantelluccio), with field relationships, and they probably record the magmatic crystallization age of the granites. The large spread in $^{147}Sm/^{144}Nd$ ratios in both cases allows the age to be constrained with a reasonable uncertainty, which makes these geochronological determinations useful for geological studies. However, a hydrothermal overprint is apparent on the Sm-Nd systematics of some minerals that do not plot on the above mentioned isochrones. For example, allanites plot above the isochron that yields the magmatic crystallization age of the Mantelluccio granite. The complex chemical zonations observed in allanites strongly suggest a hydrothermal recrystallization which would have perturbed the Sm-Nd radiometric system in these phases. This isotopic disequilibrium of allanites compared with the five minerals yielding the isochron can be explained either by a decrease of their Sm/Nd ratio at the time of the hydrothermal alteration, provided that this process occurred several tens million years after the emplacement of the granite because of the long half-life of ^{147}Sm decay, or by a supply of Nd with high $^{143}Nd/^{144}Nd$ ratio to allanites by hydrothermal fluids.

Epidotes are the minerals that plot the furthest off the five mineral isochron of the Mantelluccio granite. This observation, together with the very small size fraction in which epidotes were found during mineral separation and their anhedral shape, suggests that these phases (re)crystallized late, perhaps under hydrothermal conditions, as it is often the case in unmetamorphosed rocks (see e.g. Deer *et al.*, 1986). Epidotes have a very low $^{143}Nd/^{144}Nd$ ratio compared to the other phases of the granite studied. Such a low Nd isotopic signature is unlikely to be found within the granite of Mantelluccio. In contrast, it is likely that the Nd in by the epidotes came from its basement, at 1km at least from the sampling locality. Indeed, low $^{143}Nd/^{144}Nd$ ratios have been measured in these country-rocks (Cocherie *et al.*, 1994). This implies that they (re)crystallized from a fluid which carried lanthanides over 1 km at least, probably through fractures.

Also, it appears that the Nd isotopes of alkali-feldspars and malacons of the Evisa granite were reequilibrated with respect to their Nd isotopes at *c.* 200 Ma. These two minerals plot off the four

mineral isochron that gives the magmatic crystallization age of this granite, and this alkali-feldspars-zircons pair yields 198 ± 28 Ma. Although no direct evidence for a hydrothermally driven isotopic reequilibration between these two phases has been found, several features favour this assertion: (1) Alkali-feldspars and malacons have peculiar Sm, Nd concentrations and Sm/Nd ratios from a magmatic point of view; (2) Alkali-feldspars and metamict zircons have crystal lattices that are weakly resistant to hydrothermal processes; (3) In contrast to what is usually observed in zircons, the malacons do not present any chemical zonation (This is, following experimental studies (Sinha *et al.*, 1992), another argument favouring the hypothesis of a hydrothermal recrystallization); (4) This age of *c.* 200 Ma has been already obtained in Corsica by several authors, using various methods (Bonin *et al*, 1972; J.C. Baubron, J.M. Cantagrel, reported in Vellutini, 1977; F. Poitrasson, unpublished). All these dates were interpreted by the quoted authors to be rejuvenated. Interestingly, this age correspond to an important hydrothermal event that affected Western Europe during Early Jurassic times. This suggests that, like K-Ar and Rb-Sr, the Sm-Nd method on minerals that present a weak resistance to post-magmatic processes may be used to date hydrothermal events.

Conclusions

It has been shown that hydrothermal events have perturbed the Sm-Nd systematics of allanites. Epidotes from the granite of Mantelluccio have probably also (re)crystallized under hydrothermal conditions. Their very low $^{143}Nd/^{144}Nd$ ratio leads us to conclude that *REE* were carried from the basement of Mantelluccio, over more than 1 km, probably through fractures. Finally, the likely reequilibration of Nd isotopes between alkali-feldspars and malacons from the granite of Evisa allows us to date the reactivation of hydrothermal systems at *c.* 200 Ma in Corsica, in agreement with previous Rb-Sr and K-Ar determinations.However, experimental data on the behaviour of different mineral phases with regard to their Sm and Nd content under hydrothermal conditions are necessary if quantitative values are required from studies of natural examples. This will indicate which fluid-rock conditions (e.g. fluid temperature, pressure and composition; mineral composition, surface and metamictization; fluid–rock ratio, etc.) are important for a given element or isotopic system to be remobilised. Alternatively, such data may also indicate if a given mineral pair has been at isotopic equilibrium during a given hydrothermal process (and thus can yield a date for this hydrothermal process), provided the thermodynamic conditions have been obtained by other means.

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