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Cretaceous albitization and dequartzification of Hercynian peraluminous granite in the Salvezines Massif (French Pyrénées)

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Abstract

The Salvezines Massif in northern French Pyrénées has undergone extensive albitization. The massif consists of gneisses and a leucogranite hosted in Paleozoic sediments (schists and carbonates). The leucogranite was emplaced at the end of the Hercynian orogeny. The granite underwent monazite fractionation during magmatic stages, which induced lowering of REE and Th contents in the most evolved rocks. Hydrothermal alteration during late magmatic stages is also identified through the development of a tetrad effect in the REE patterns of the granite and through the fractionation of ratios like Zr/Hf out of the CHARAC (CHarge RAdius Controlled) range. The granite underwent partial to complete sub-solidus albitization. Progressive metasomatic overprint induced metasomatic replacement of feldspars into albite and dissolution of quartz (episyenitization) together with new albite formation. Hydrothermal muscovite with a sheaf-like structure sometimes crystallised in albitites. Inherited muscovites from magmatic stage and newly formed muscovites from albitites have distinct chemical compositions with the latter being much more phengitic. The initial peraluminous chemistry of the leucogranite was lost during albitization and composition evolved towards a pure albite one (A/CNK = 1). Albitization induced gains in Na and Al, and losses in Si and K. Leaching of REE and U is also identified during albitization, as well as the non-CHARAC behaviour of some elements. $\delta^{18}O$ values of quartz and muscovite in albitized granites are in the magmatic range (about 12 and 9.5‰, respectively). Feldspars acquired high $\delta^{18}O$ values during albitization (up to 15‰). Muscovite grains from albitites have higher $\delta^{18}O$ values than inherited ones and tend towards isotopic equilibrium with albite. The albitizing fluids have interacted with high-$\delta^{18}O$ rocks (probably local carbonates) prior to alter granite. Muscovites inherited from magmatic stages display very characteristic disturbed ^{39}Ar–^{40}Ar age spectra with saddle-shapes when a muscovite associated with albitization provided a plateau age at 117.5 Ma for this alteration event. Albitization in the Salvezines Massif just preceded the regional talc/chlorite hydrothermal mineralization. Both events might then represent two outward signs of a huge hydrothermal system at the time of the rotation of the Iberian plate around Europe. The North Pyrenean Metamorphism is identified by ^{39}Ar–^{40}Ar analyses at ca. or younger than 100 Ma.

Keywords: Albitization; Sub-solidus hydrothermal alteration; ^{39}Ar–^{40}Ar dating; Stable isotopes; Pyrénées

1. Introduction

Albitization is a very widespread metasomatic phenomenon that occurs in the upper crust of the Earth. It has received relatively limited attention over the past few decades despite the fact that this process might mark the

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circulation of fluids of various origins on a very large scale in a wide variety of contexts. As recently reviewed by Perez and Boles (2005, and references therein), albitization has been described in deuterically altered granitic rocks, alkali–carbonatites complexes, volcanics (tuffs, spilites) and sedimentary basins (diagenetic albitization of feldspars). During mineralization processes, albitic alteration may affect several cubic kilometres of continental crust (Turpin et al., 1988). Albitization is also common in metamorphic environments, associated with regional scale ductile shear zones (Rubenach and Lewthwaite, 2002) and during exhumation of metamorphic terranes (Holness, 2003). The flow of surface derived fluids has been proposed in some instances for the cause of albitization (McLelland et al., 2002).

In diagenetic and metamorphic environments, replacement of K-feldspars and Ca-plagioclase by albite is related to dissolution–precipitation processes (Davisson and Criss, 1995, and references therein). Such phenomena are obvious, for example, when complete albitization of granitic rocks must involve dissolution of quartz and micas. Dissolution induces a transient or definitive increase in porosity and permeability that thus enhances the infiltration of albitizing fluids through altered rocks.

Two extreme types of fluids have been reported as albitizing agents.

1 — Circulation of dilute aqueous fluids along a temperature gradient, close to chemical equilibrium with country rocks, has been invoked (Pascal, 1979; Carten, 1986). An increase in temperature or pressure leads to an increase in the K/Na activity ratio in the equilibrium fluid phase (Orville, 1963; Lagache and Weisbrod, 1977). So, to maintain chemical equilibrium in the rock–fluid system, the rock must lose K and gain Na through exchange with the fluid. This exchange results in albitization of K-feldspars:

$$KAlSi_3O_8 + (Na^+)_{aq} = NaAlSi_3O_8 + (K^+)_{aq}$$

Given that quartz solubility increases with temperature and/or pressure (Anderson and Burnham, 1965), silica enrichment should accompany potassic alteration whereas silica leaching should accompany sodic alteration (see also Dipple and Ferry, 1992). According to this phenomenon, albitization is expected to occur around plutons along up-temperatures fluid flow paths, whereas potassium metasomatism should occur along down-temperature flow paths. Potassium enrichment is indeed reported in the structurally high levels of porphyry copper deposits whereas sodium–calcium metasomatism is observed in the root zones (Carten, 1986).

2 — Highly saline fluids can also serve as albitizing agents because sodium easily complexes with chlorine. This is particularly the case for albitization associated with some iron-rich oxide deposits (Barton and Johnson, 1996) and uranium deposits (Kish and Cuney, 1981; Turpin et al., 1988; Lobato and Fyfe, 1990) or within mid-crustal shear zones (De Jong and Williams, 1995). In the latter case, muscovitization is commonly associated with albitization (McCaig et al., 1990). The high salinity of some albitizing fluids can be a primary magmatic feature (Hall et al., 1988; Aslund et al., 1995) or be acquired either by interaction between aqueous metamorphic/magmatic fluids with evaporite levels (Oliver, 1995; Barton and Johnson, 1996) or represents a primary characteristic of surface-derived brines (McLelland et al., 2002). Such brines can invade continental crust along faults within extensional settings (Battles and Barton, 1995).

From this brief review, it follows that granite albitization can develop either during the hydrothermal activity associated with cooling of the intrusion (Lee and Parsons, 1997) or long after this stage, totally disconnected of cooling (Cathelineau, 1986). In the latter case, granites only play a passive role within an infiltrated lithologic sequence.

In the Pyrénées, many albitites occurrences are reported (Fig. 1a). Some of them developed at the expense of granites; others derive from metamorphic rocks (micaschists, gneisses). The geographical distribution of albitites closely matches that of talc/chlorite ore bodies (Fig. 1a). Talc mineralization is related to a hydrothermal event of regional extent (Boulvais et al., in press) during mid-Cretaceous times (Schärer et al., 1999). Very scarce geochemical information is available for the Pyrenean albitites.

This study presents some geochemical characteristics of albitites in the Salvezines Massif (Fig. 1a and b), which developed at the expense of a peraluminous Hercynian granite. It shows that albitization developed during post-solidus stages. ^{39}Ar–^{40}Ar dating of a muscovite from albitites gives a mid-Cretaceous age for the hydrothermal event when a muscovite from the granite clearly evidence a disturbance related to albitization. As a consequence, albitization and talc mineralization might represent two metasomatic effects of a giant hydrothermal system during mid-Cretaceous times.

2. Geological context

Several occurrences of albitites are recognized in the central and eastern Pyrénées (Pascal, 1979; Clavières, 1990; Fig. 1a). They developed at the expense of