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Sr, Nd isotope geochemistry of hercynian granitoids from the Western Massif Central (France)

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ABSTRACT. — Isotopic geochemistry (Sr, Nd) of the two granitic families, i.e. granodiorites-monzogranites and leucogranites, substantiates their dual origin. In the ϵNd-ϵSr and ϵNd-Age plots the two groups exhibit contrasting trends. Leucogranites may be derived from a metasedimentary crustal source. In contrast, a more mafic, less LREE-enriched source, or the contribution of a mantle-derived component in a crust-mantle mixing process appears more likely to account for the origin of the granodiorites and monzogranites.

Key words: Isotopic geochemistry, Sr, Nd, granites, French Massif Central.

RÉSUMÉ. — Une étude isotopique Sr, Nd effectuée sur des granodiorites-monzogranites et des leucogranites hercyniens montre que ces deux familles ne peuvent provenir d'une source identique. Dans les diagrammes ϵNd- ϵSr et ϵNd-Age ces deux groupes présentent en effet des évolutions différentes. Une source métasédimentaire crustale est la plus vraisemblable pour les leucogranites. Pour les granodiorites-monzogranites une source moins enrichie en T.R. légères ou la participation d'un composant dérivé du manteau, semble nécessaire pour expliquer leur origine.

Mots clés: Géochimie isotopique Sr, Nd, granites, Massif Central français.

Introduction

Syn-and post- metamorphic granitoids form nearly 50% of the exposed area of the Hercynian basement in the French Massif Central. They are geographically very widely scattered and occur in various geological settings. Their ages range from 360 to 275 Ma (Rb/Sr total rock isochrons, or U/Pb zircon and monazite dates). They range in composition from quartz diorites through granodiorites and monzogranites to leucogranites. The magmas were formed in a broadly collisional environment, although their precise local tectonic setting is still debated.

The origins of such different granitoids and the nature of their sources is of fundamental importance. The production of large volumes of magma over an approximate interval of 100 Ma (from the late Devonian to the early Permian) is a crucial factor in the growth and differentiation of the continental crust in this region (and many similar regions, worldwide).

As initial isotope ratios obtained by the Rb-Sr method cannot unequivocally constrain the nature of magma sources, Nd isotopes were used as an additional tracer in this study.

Geological background

We present preliminary results of the combined Nd-Sr systematics of some granitoids from the Western French Massif Central (Fig. 1). This region was selected for this study because much previous background work (cartography, petrography, chemistry and isotope geochemistry) has been done on these rocks.

This study focuses on the two main petrographic types of granitoids in this area, i.e. monzogranites/granodiorites and leucogranites, according to the classification of DIDIER and LAMEYRE (1969-1980). Although these two types are sometimes said to be the equivalent to the I- and S- type granites of CHAPPELL and WHITE (1974), it reliationships have been documented; the only exceptions are the Auriat (U-Pb monazite age, GEBAUER et al., 1981) and Chirac granites (Rb-Sr internal isochron data; DUTHOU, 1977). All the studied granites are of Hercynian age (360-300 Ma).

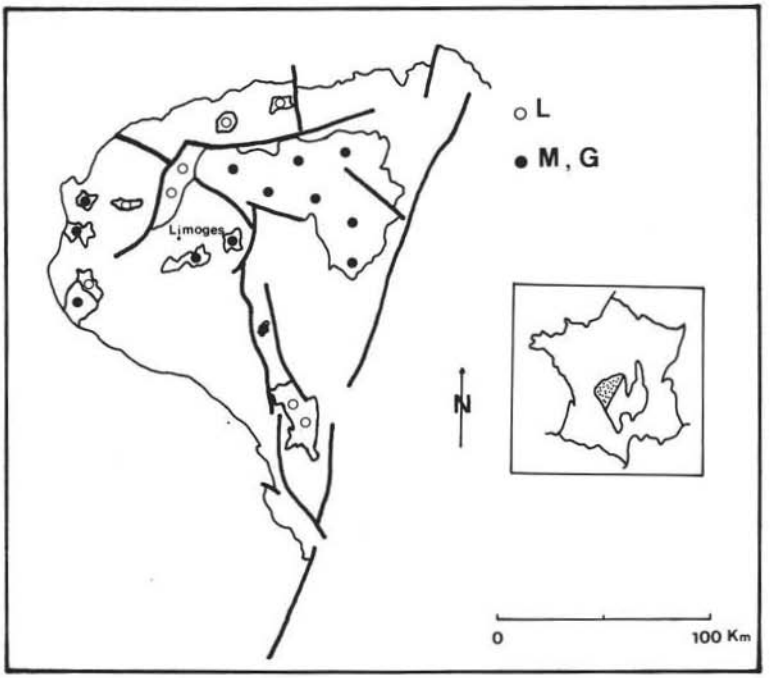

Fig. 1. — Geological sketch map of the studied granitoids. L = Leucogranites, M = Monzogranites, G = Granodiorites. 1: St. Mathieu, 2: Crevant, 3: Crozant, 4: Blond, 5: Chateauponsac, 6: St. Julien, 7: Esse, 8: Piégut, 9: Auriat, 10: Aureil, 11: Gour Noir, 12: Guéret, 13: Chirac.

must be emphasized that the two classification schemes are not strictly equivalent (DIDIER et al., 1982).

Detailed descriptions of the studied granites (7 monzogranites-granodiorites and 6 leucogranites) have been given by DUTHOU (1977), DUTREUIL (1978), BERTHIER et al. (1979), MONIER (1980), PETITPIERRE (1981), ROLIN (1981), and FRIEDRICH (1984).

The analysed samples (one for each massif) were selected among those which had been the subjects of previous Rb-Sr geochronological studies (ref. in DUTHOU et al., 1984). Almost all selected samples belong to larger sets for which good isochron

Strontium results

Initial Sr isotope ratios calculated at the time of emplacement age, vary from 0.7063 to 0.7177 for leucogranites, and from 0.7063 to 0.7113 for monzogranites. Although these results overlap, a trend of increasing initial ratios with younger ages is observed among the leucogranites. The reverse trend appears to exist for the monzogranites.

These isotope ratios support a crustal origin for the magmas. For the leucogranites this origin is quite credible, as no geochemical or geological evidence is opposed to this interpretation (LAMEYRE, 1980). The

TABLE 1

Nd and Sr initial isotopic characteristics of the studied samples

Sample		Age T (M.a.)	87Sr/86Sr(T)	εSr(T)	εNd(T)
1	St Mathieu	315	0.7177	+ 192	- 8.2
2	Crevant	312	0.7068	+ 38	- 8.1
3	Crozant	312	0.7069	+ 40	- 7.8
4	Blond	300	0.7136	+ 135	- 7.6
5	Chateauponsac	348	0.7063	+ 32	- 5.7
6	St Julien	336	0.7074	+ 47	- 5.8
7	Esse	315	0.7065	+ 33	- 3.8
8	Piegut	325	0.7063	+ 31	- 4.8
9	Auriat	323	-	-	- 5.2
10	Aureil	346	0.7113	+ 102	- 5.3
11	Gour Noir	344	0.7097	+ 79	- 6.4
12	Guéret	356	0.7098	+ 80	- 7.0
13	Chirac	300	0.7060	+ 25	+0.6

average initial ratio of monzogranites and granodiorites is also consistent with a similar origin. However, the systematic occurrence of mafic enclaves may suggest a mixed origin with the participation of a mantle component for the rocks. The monzogranites and granodiorites may result from crustal fusion induced by injection of mantle magma (DIDIER et LAMEYRE, 1969), from melting of a lower crust consisting of a mixture of source rock components (MICHARD VITRAC et al., 1980), or from differentiation of contaminated (hybridized) magmas originating in the mantle.

In an isotopic evolution plot (Sr_i vs Age) the data points for all these granites plot below the evolution trend of the older Cambro-Ordovician orthogneisses, which cannot therefore provide a suitable source for the granites (DUTHOU et al., 1984). In contrast, some metasediments may fit the data, and it is inferred that partial melting of similar rocks was involved in the production of some granitoids (work in progress).

εSr varies from + 30 to + 200, but it is noticeable that the range exhibited by the leucogranites (+ 30 to + 200) is nearly twice that for the other granites (+ 30 to + 100).

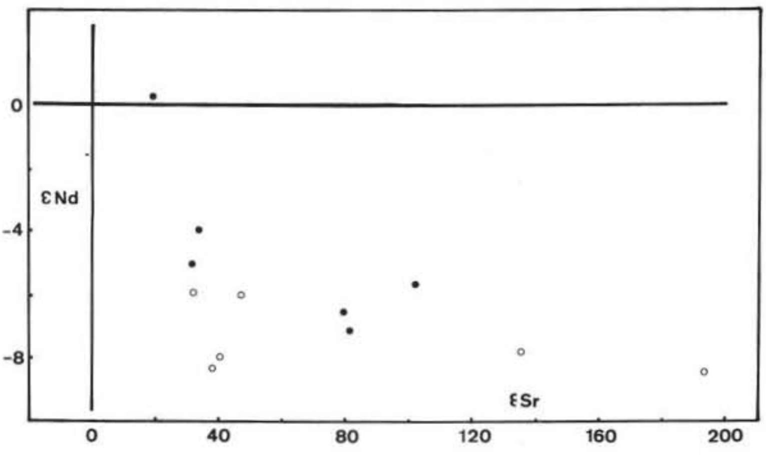

Fig. 2. — Plot of initial εNd, εSr ● Monzogranites - Granodiorites ○ Leucogranites.

Nd results

In the Sm-Nd isochron diagram, no linear trend corresponding to an isochron or a mixing line is observed. However leucogranites and monzogranites-granodiorites plot in two separate fields.

Initial εNd ranges from + 0.5 to —8.4 and the scatter of Nd isotopes is roughly similar for both groups of rocks. However, leucogranites display significantly lower values (—5.9 to —8.4) than the other group (—3.9 to —7.1). With the exception of the Chirac granodiorite (εNd = + 0.5), all εNd values are negative, implying a time — integrated LREE — enriched source, most likely the continental crust (Table 1).

Sr-Nd correlations

In the εSr-εNd plot (Fig. 2), all samples but one (Chirac) plot in the lower right quadrant,

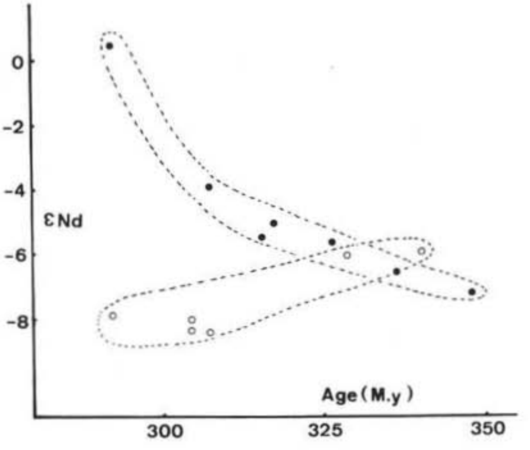

Fig. 3. — Plot of initial εNd vs Age ● Monzogranites - Granodiorites ○ Leucogranites.

typical of the continental crust. This is in agreement with Sr results and also O isotope data (SHEPPARD, 1986); a recycled continental component played a major role in the genesis of the granitoids. Isotopically, the leucogranites may be derived from a metasedimentary source similar to the widespread migmatic gneisses which seem to have had roughly similar εNd (—7 to —10) in Carboniferous times (work in progress). Similar conclusions have been proposed for Hercynian granites in the Armorican Massif (BERNARD GRIFFITHS et al., 1985).

The higher εNd requires a different origin for the monzogranites and granodiorites. They may have originated through mixing processes between crustally derived and mantle derived magmas. Alternatively, a crustal reservoir with a higher time - integrated Sm/Nd ratio prior to the melting episode (intermediate meta-igneous rocks, volcaniclastic greywackes) would also fit the isotope data.

Moreover, as the εNd values are not highly negative and the spread of the strontium isotope ratios is larger compared to the εNd in the two rock families, the crustal component cannot be very ancient. Likewise, chondritic mantle model ages (CHUR) of 600 - 1200 M.a. or depleted mantle model ages (DM) of 1000- 1400 M.a. preclude the involvement of Archean crust. This is in marked contrast with the 3000 Ma old crust that MICHARD et al. (1981) inferred from Pb isotope results.

Although the reliability of this concept is disputable, these model ages agree with previous results. Indeed, the distribution of initial Sr isotopic ratios for the Cambrian meta-igneous rocks suggests that, in this region, major crustal development occurred at the end of the Precambrian.

Nd - age correlations

In an εNd - age plot, the two rock families exhibit contrasting trends (Fig. 3). Whereas the εNd of leucogranites decrease with time (—5.8 at 348 Ma to —8.2 and —8.1 at 312 Ma) those for the monzogranites and granodiorites increase with time (—7 at 356 Ma to —3.8 at 315 Ma up to + 0.6 at 300 Ma). This feature suggests the increasing role of a high εNd component with decreasing age in the genesis of the granodiorites and monzogranites, and the reverse for the leucogranites.

This observation supports a dual origin for the rock families.

— The evolution of granodiorites and monzogranites may be explained by:
  - an increasing amount of mantle-derived component in the crust-mantle mixing process.
  - progressive melting of more mafic, refractory crustal source,
  - or both.

— The leucogranite trend may result from the migration of the melting zone towards more and more mature, isotopically ancient sediments.

To more precisely constrain this dual origin, Nd and Sr studies on the possible metasedimentary and meta-igneous source material of these granidoids are in progress.

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