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Electron microprobe monazite geochronology of magmatic events: Examples from Variscan migmatites and granitoids, Massif Central, France

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Abstract

U–Th–Pb dating of monazite with the electron probe microanalyser (EPMA) is increasingly documented as a reliable geochronological method offering high spatial resolution. This method has been applied on monazite from the Cévennes migmatites and granitoids from the southeast of the French Massif Central. Measurements were performed on separated grains after systematic back-scattered electron (BSE) imaging. Monazites from migmatites record two main ages: (i) a protolith age of about 550–543 Ma obtained on inherited cores, and (ii) a migmatization event between 329 ± 5 and 323 ± 3 Ma recorded by monazite rims and all other monogenetic grains. Monazite from the peraluminous Rocles pluton yields a 318 ± 3 Ma age. Finally, three granite dykes are dated at 333 ± 6, 318 ± 5 and 311 ± 5 Ma; the older dyke is the most deformed of them and is interpreted as linked to the migmatization event; the two other dykes are geochronologically, petrologically and structurally coeval with the Rocles pluton. The data constrain the timing of crustal melting following Variscan thickening in the northern Cévennes area. Migmatization of Ordovician protoliths took place at 329–323 Ma and was shortly followed by intrusion of leucogranite at 318–311 Ma. The study shows that EPMA dating of monazite can be successfully used to resolve a close succession of regional melting events.

Keywords: Monazite; Electron microprobe; Geochronology; Massif Central, France

1. Introduction

Monazite is a suitable chronometer for studying magmatic and polymetamorphic events due to its high Th and U contents and negligible common Pb content (Parrish, 1990). U–Th–Pb dating of monazite with the electron microprobe microanalyser (EPMA) has been

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recently developed into an alternative, accurate, and truly in situ means of geochronology, providing valuable constraints on the timing of metamorphic assemblages at a μm scale (Williams and Jercinovic, 2002). This new approach shed new light on the U–Th–Pb systematics in this mineral. It has thrown several earlier beliefs into question by showing that: the closure temperature of the system is significantly higher than 900 °C (Braun et al., 1998); inheritance in monazite is rather common as shown by Cocherie et al. (1998, 2005); if no fluid interacts with monazite (Townsend et al., 2000), Pb diffusion is negligible (Cocherie et al., 1998; Crowley and Ghent, 1999; Zhu and O'Nions, 1999).

In the present study, we dated specific monazite crystals from migmatites, granitic plutons and dykes in the Cévennes area of the French Massif Central. The main geological questions concern the genetic relationships between the migmatites, the Rocles pluton and leucogranite dykes. The occurrence within a relatively small area of several generations of plutonic and migmatitic rocks, probably formed during a short time span, provided an ideal opportunity for using the EPMA monazite dating method, in order to distinguish the succession of melting events, and to assess the ability of the method to establish the ages of the protoliths. As shown in the following sections, EPMA U–Th–Pb dating on monazite suggests distinct timing for migmatization and leucogranite plutonism.

2. Geological setting

The analysed samples come from the Cévennes area in the southeastern part of the Variscan French Massif Central (Fig. 1, with sample locations). A continental collision between two large continental masses, Gondwana and Baltica, and several intervening microcontinents marked the pre-Permian tectonic evolution of France. In the southern Massif Central, top-to-the-south ductile shearing caused nappe stacking (e.g., Ledru et al., 1989; Faure et al., 1997; and references therein). After the continental collision, the Variscan belt underwent major crustal melting from Late Devonian to Late Carboniferous times, at the expense of metapelites and metagranites (e.g., Duthou et al., 1984; Pin and Duthou, 1990).

The Cévennes area is a circa 5-km-thick stack of thrust sheets with metapelite, metagraywacke and quartzite belonging to the Parautochtonous Unit that was transported southward over an underlying augen orthogneiss and biotite–muscovite paragneiss units (Faure et al., 2001). South of the study area, synmetamorphic shearing was dated around 340–335 Ma by $^{40}Ar/^{39}Ar$ method on micas and amphiboles (Caron, 1994; see review in Faure et al., 2001).

Thrusting was followed by crustal melting producing biotite–sillimanite migmatite and granite that

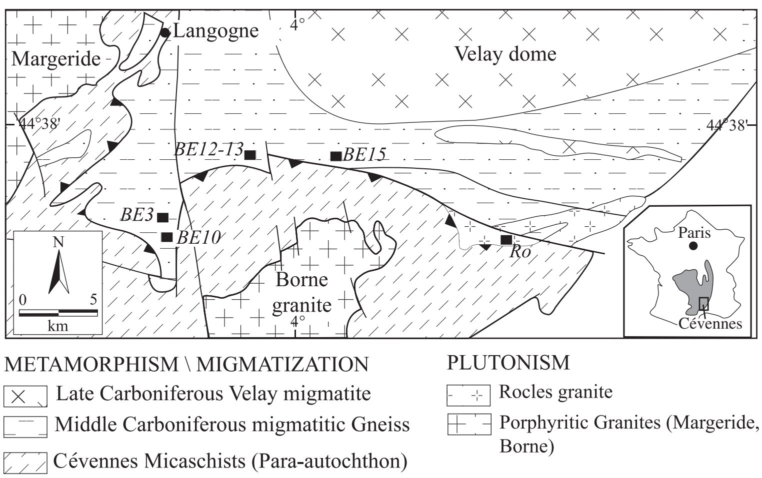

Fig. 1. Structural map of the North Cévennes area with the location of investigated samples (dark squares). Insert locates the study area in the French Massif Central.