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Middle Carboniferous crustal melting in the Variscan Belt: New insights from U–Th–$Pb_{tot.}$ monazite and U–Pb zircon ages of the Montagne Noire Axial Zone (southern French Massif Central)

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ABSTRACT

In France, the Devonian–Carboniferous Variscan orogeny developed at the expense of continental crust belonging to the northern margin of Gondwana. A Visean–Serpukhovian crustal melting has been recently documented in several massifs. However, in the Montagne Noire of the Variscan French Massif Central, which is the largest area involved in this partial melting episode, the age of migmatization was not clearly settled. Eleven U–Th–$Pb_{tot.}$ ages on monazite and three U–Pb ages on associated zircon are reported from migmatites (La Salvetat, Ourtigas), anatectic granitoids (Laouzas, Montalet) and post-migmatitic granites (Anglès, Vialais, Soulié) from the Montagne Noire Axial Zone are presented here for the first time. Migmatization and emplacement of anatectic granitoids took place around 333–326 Ma (Visean) and late granitoids emplaced around 325–318 Ma (Serpukhovian). Inherited zircons and monazite date the orthogneiss source rock of the Late Visean melts between 560 Ma and 480 Ma. In migmatites and anatectic granites, inherited crystals dominate the zircon populations. The migmatization is the middle crust expression of a pervasive Visean crustal melting event also represented by the "Tufs anthracifères" volcanism in the northern Massif Central. This crustal melting is widespread in the French Variscan belt, though it is restricted to the upper plate of the collision belt. A mantle input appears as a likely mechanism to release the heat necessary to trigger the melting of the Variscan middle crust at a continental scale.

1. Introduction

Crustal melting is a common phenomenon observed in many collision belts, such as Himalaya, Variscan, Appalachian, Qinling–Dabie–Sulu, etc. This feature is often interpreted as the response to thermal relaxation during syn-, or late-collisional unthickening of previously thickened continental crust (e.g. Le Fort, 1981; Harris and Massey, 1994; Faure et al., 2003; Guillot et al., 2003; Whitney et al., 2004; Brown, 2005; Faure et al., 2008).

The Variscan Belt of Western and Central Europe is a Paleozoic collisional orogen that involved large continental masses, such as Gondwana, Baltica and Laurussia, and several Gondwana-derived microcontinents, such as Avalonia, Armorica, Mid-German Crystalline Rise (e.g. Paris and Robardet, 1990; Matte, 1991; Tait et al., 1997; Franke, 2000; Matte, 2001; Von Raumer et al., 2009; Johnston and Gutierrez-Alonso, 2010; Melleton et al., 2010a,b). The detail paleogeographic and geodynamic reconstructions of the Variscan Belt remain controversial, nevertheless, there is a wide agreement that most of continent amalgamation was completed in the Early Carboniferous. Since the Late Visean, intracontinental deformation, namely wrenching, thrusting and normal faulting was coeval with intense crustal melting. However, the timing and tectonic setting of these late-collisional events is not clearly settled yet. This paper deals with age constraints on the Middle Carboniferous (Visean) migmatites and granitoids exposed in the Axial Zone of the Montagne Noire in the southern French Massif Central. New U–Th–$Pb_{tot.}$ ages on monazite using Electron Probe Microanalyzer (EPMA) method and U–Pb ages on zircon using High Resolution Secondary Ion Mass Spectrometry (HR-SIMS) were determined to date migmatites, anatectic granitoids and late to post-migmatitic granitic plutons are provided. These data are combined with the available ages of crustal melting known in other Middle Carboniferous migmatitic complexes recognized in the French Massif Central, Massif Armoricain, Vosges and Variscan Pyrénées. A possible geodynamic interpretation of the crustal melting experienced by this segment of the Variscan Belt is discussed.

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2. An outline of the Variscan French Massif Central

It is now well accepted that the French Massif Central, which is one of the largest pieces of the Variscan belt of Western Europe, belongs entirely to the northern Gondwana margin. Its bulk architecture results of the stacking of several tectonic–metamorphic units. From bottom to top, and from South to North, five main tectonic–metamorphic units are recognized, namely (Fig. 1): 1) the late Visean foreland basin; 2) the fold-and-thrust belt; 3) the para-autochthonous unit; 4) the Lower Gneiss Unit; 5) the Upper Gneiss Unit (for detail, see Faure et al., 2005, 2009a and enclosed references).

The French Massif Central experienced several tectonic–metamorphic events (e.g. Pin and Peucat, 1986; Ledru et al., 1989; Faure et al., 1997, 2005, 2009a,b). From Late Silurian to Middle Devonian, the northward continental subduction of the Gondwana margin beneath the Armorica microplate is coeval with the formation of high (or ultra-high) pressure rocks, called D0 event (Lardeaux et al., 2001). Around 380 Ma, the D1 event, referred to as the Eo-Variscan event, is responsible for nappe stacking, exhumation of the high-pressure rocks and the first crustal melting (cf. Faure et al, 2008 and enclosed references). A NE–SW-trending stretching lineation associated with a top-to-the-SW shearing develops during D1 (Roig and Faure, 2000). The stack of nappes is reworked by a D2 event, dated around 360–350 Ma (Late Devonian to Early Carboniferous), and characterized by a top-to-the NW shearing, and coeval with an intermediate pressure–temperature metamorphism (Roig and Faure, 2000; Bellot, 2001; Duguet et al., 2007; Melleton et al., 2009). A Middle Carboniferous thrusting event, called D3, and dated at 340–330 Ma, characterized by South to SW-directed ductile shearing develops only in the southern part of the French Massif Central (e.g. Arthaud and Matte, 1977; Ledru et al., 1989; Faure et al., 2005). At the same time, in the northern part of the Massif, the onset of the syn-orogenic extension took place. During the early Late Carboniferous times, around 320–310 Ma, the entire belt experienced extensional tectonics characterized by a pervasive NW–SE striking stretching well recorded by the architecture and emplacement mechanisms of the syn-kinematic granitoids (Faure, 1995).

The French Massif Central exhibits a large amount of magmatic rocks (e. g. Duthou et al., 1984; Pin and Duthou, 1990 and enclosed

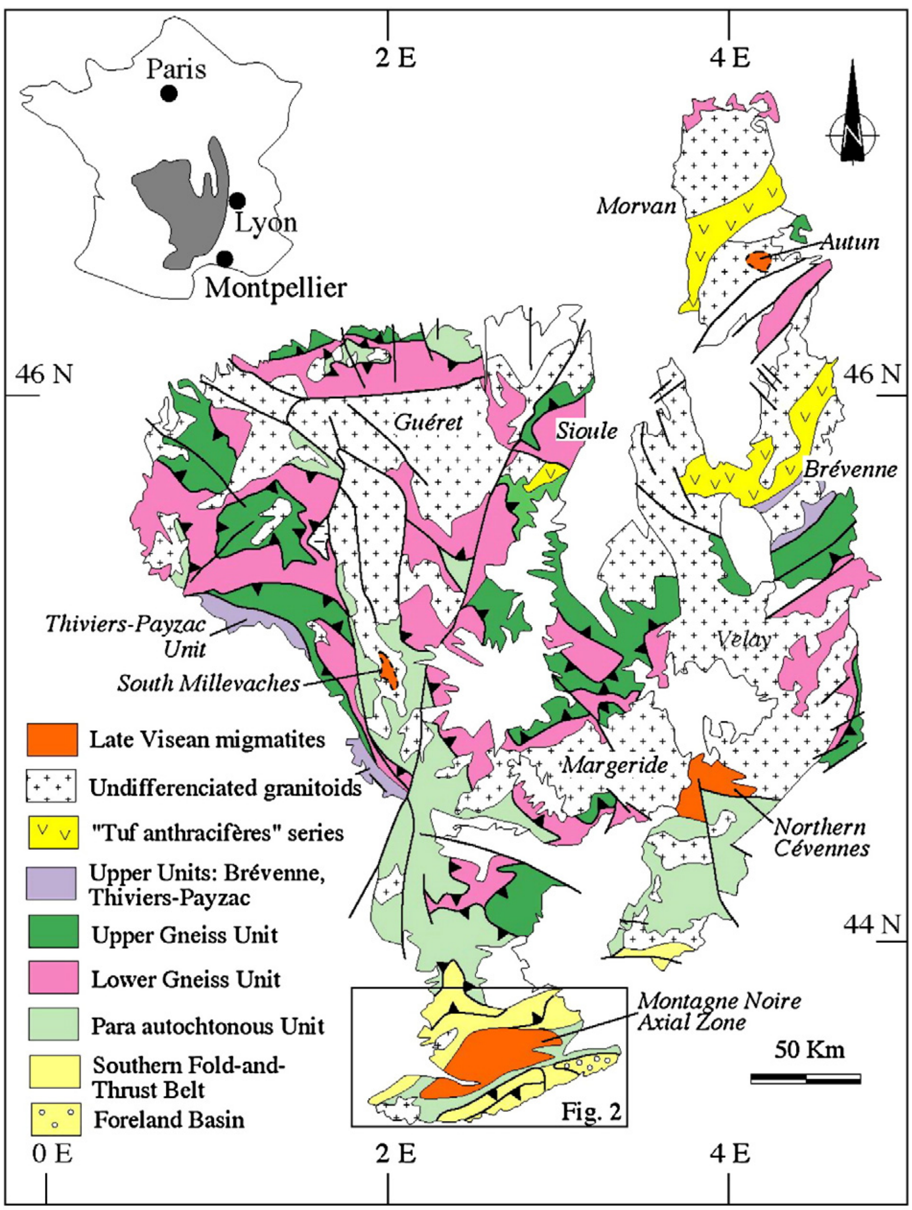

Fig. 1. Structural map of the Variscan French Massif Central (modified from Ledru et al., 1989, and Faure et al., 2005, 2009a,b) showing the location of the Montagne Noire in the southern part of the massif.