Journal of Geochemical Exploration 153 (2015) 79–87

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/jgeoexp

Reinforcing the origin of volcanic rocks from the Massif Central through the isotopic composition of lead and strontium

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ARTICLE INFO

Article history:
Received 1 August 2014
Accepted 14 March 2015
Available online 28 March 2015

Keywords:
Lead isotopes
Strontium isotopes
Basalts
French Massif Central volcano

ABSTRACT

The Massif Central in France hosts a large volume of Tertiary to Recent continental alkaline volcanism, with evidence of crustal contamination of the differentiated magmas. Detailed investigations on feldspathic basalts and basanite rocks from the Cantal Volcano exposed in the Allanche basin by lead and strontium isotopes i) reveal the role of the mantle components Depleted Mantle (DM) and Low Velocity Component (LVC, corresponding to the European asthenospheric reservoir) end-members based on $^{208}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ isotopic ratios, and ii) show contamination by meta-igneous granulites from the lower crust when using $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ ratios, as only part of the samples plot along the Northern Hemisphere Reference Line (NHRL) mixing line between DM and HIMU (High U/Pb Mantle) end-members. Cross plotting of Pb–Sr isotopes rules out recycled sediment and/or igneous granulite as potential crustal contaminant for the Cantal basalts, but suggests mixing between the low-velocity component (LVC) and EMI (Enriched Mantle I)-pelagic sediments. Replaced in the regional context of the Massif Central, we confirm the existence of several mantle sources and different crustal contaminations in the magmas of the Cantal Volcano.

1. Introduction

During the Cenozoic, Africa and Europe converged, seafloor spreading took place in the Atlantic and, as a direct result of the convergence, numerous microplates in the Mediterranean area collided. This resulted in an intense igneous activity either related to subduction or to intraplate geodynamics (Lustrino and Wilson, 2007). Consequently, Tertiary–Quaternary volcanic fields are found throughout Southern, Western and Central Europe (Lustrino and Wilson, 2007; Wilson and Downes, 1992), corresponding to the later phases of the Alpine orogeny and the Neogene collapse of the Mediterranean and Pannonian basins (Wilson and Downes, 1992). The main phases of volcanic activity occurred during the Miocene and Pliocene, with Pleistocene activity restricted only to specific areas. A possible geodynamic origin has been evoked for explaining diapiric mantle upwellings beneath the European lithosphere (Granet et al., 1995; Kolb et al., 2012). Hoernle et al. (1995) proved, using seismic tomography, the presence of a low S-wave-velocity anomaly, named Low Velocity Zone (LVC), extending from the eastern Atlantic to Central Europe. The LVC I interpreted as a common lithospheric mantle reservoir named European Asthenospheric Reservoir (EAR; Granet et al., 1995).

Here, we studied the central eastern part of the Cantal Volcano, located in the French Massif Central. This area is one of the largest volcanic provinces in the country, whose volcanic forms include Strombolian cones aligned along fissures (Chaine des Puys), extensive basaltic plateaus (Aubrac and Devès), and two large central volcanoes (Cantal and Mont Dore). The Cantal Volcano, equivalent in size of the Etna, was active between 13 and 3 million years ago. Numerous outcrops and the diversity of rocks emitted during its activity make it an ideal study site to investigate different magmatic processes affecting the composition of the volcanic rocks. Basalts from the Cantal stratovolcano are characterized by a significant change in their chemical composition over time, comparable to that observed for most intraplate basalts known on the Earth's surface. The volcanic rocks of the Massif Central consist of silica-saturated alkali rocks (olivine basalt, trachyandesite, trachyte, and rhyolite) and alkali-rich nepheline-normative rocks (basanite, tephrite and phonolite). Geochronological dating and lithostratigraphic studies linked the changes recorded in chemical composition to a change in their mantle source during spreading, which occurred however during a short geological period of 3 to 4 million years. Niobium (Nb), thorium (Th) and tantalum (Ta) and their respective ratios are key elements, and changes in Nb or Th contents reflect the gradual change in chemical composition between

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http://dx.doi.org/10.1016/j.gexplo.2015.03.005
0375-6742/

infra- and supra-Cantal basalts, i.e., changes in the composition of the underlying mantle during the construction of the volcano. This led to the development of several models of heterogeneous mantle source to explain the Massif Central basalts (Downes, 1987; Downes et al., 2003; Granet et al., 1995; Hoernle et al., 1995; Stettler and Allègre, 1979).

For several decades, the use of geochemistry comprising trace elements and/or radiogenic isotopes as natural tracers for investigating geological phenomena has been readily accepted by scientists scrutinizing processes that occur within the Earth (Allègre, 1982). In that way, numerous Tertiary–Quaternary volcanic fields have been investigated in Southern, Western and Central Europe (Bosch et al., 2014; Dautria

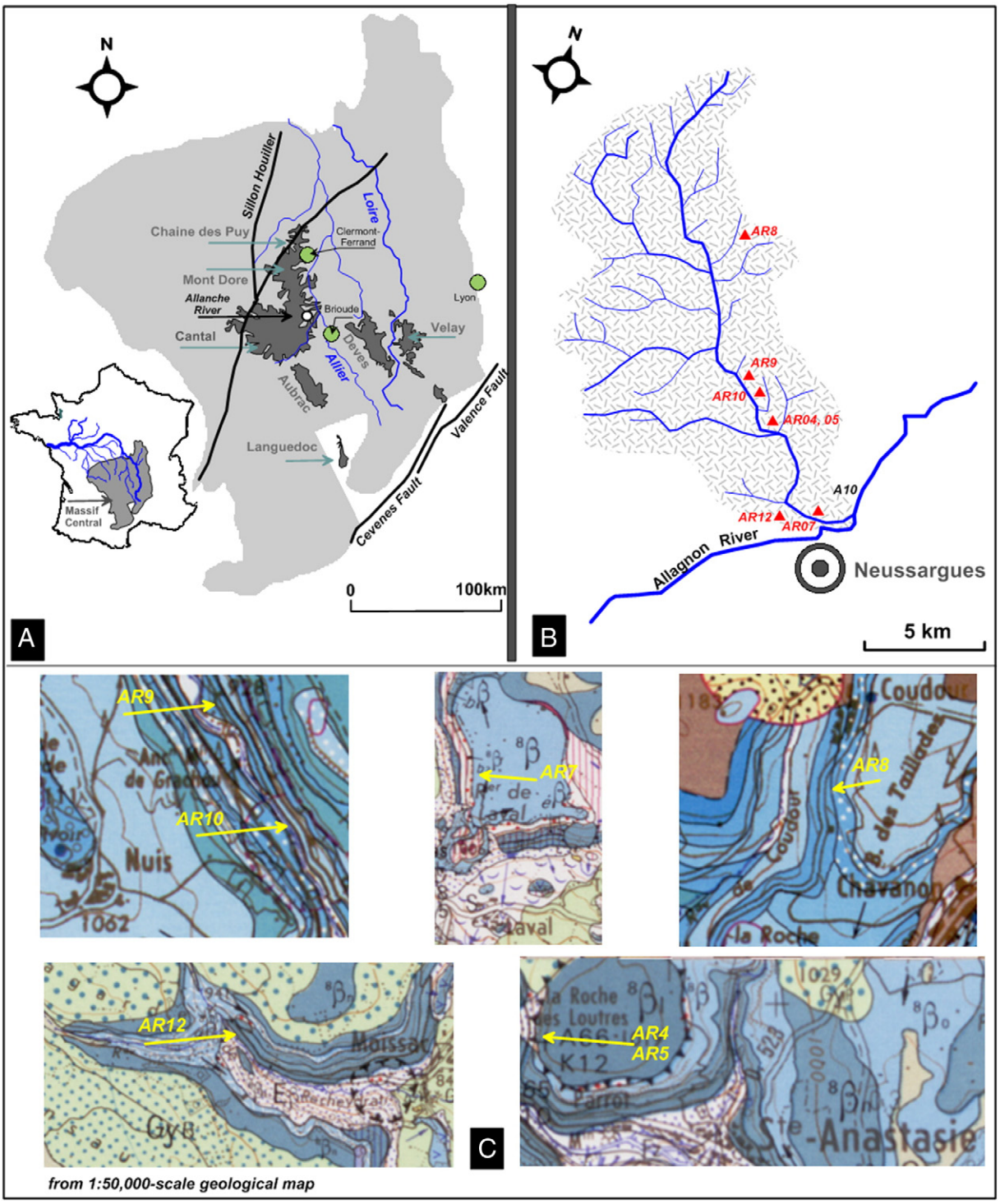

Fig. 1. (A) Map of the Massif Central with the location of the volcano areas (dark gray) Chaine des Puys, Cantal, Aubrac, Deves, Velay and Languedoc. The bright gray area corresponds to the extension of crystalline basement rocks of the Massif Central. (B) Local map of the Allanche River basin with bedrock sampling points. (C) Detailed geological maps of the sampling locations plotted on the 1:50,000-scale geological map from http://infoterre.brgm.fr. The three types of bedrock correspond to the labels 8βi (basanite nepheline–leucite), 8βn (basanite nepheline) and 8β (feldspathic basalt), defined in De Goër De Hervé and Tempier (1988).