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Lead isotopes tracing weathering and atmospheric deposition in a small volcanic catchment

Philippe Négrel [a,b,c,*], Emmanuelle Petelet-Giraud [d], Catherine Guerrot [a,b,c], Romain Millot [a,b,c]

[a] BRGM, ISTO, UMR 7327, BP 36009, 45060 Orléans, France
[b] CNRS/INSU, ISTO, UMR 7327, 45071 Orléans, France
[c] Université d'Orléans, ISTO, UMR 7327, 45071 Orléans, France
[d] BRGM, Laboratory Division, 45060 Orléans, France

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ABSTRACT

Lead isotopes were studied in soil and sediments of the small volcanic catchment in the Massif Central (France), a large area of Tertiary to Recent continental alkaline volcanism. The comparison of Pb and K (normalized to Zr) shows a linear evolution of weathering processes, whereby lead enrichment from atmospheric deposition is a major contributor explaining the deviation of several points from this line. A box model simulates the lead evolution in sediments from soil production on the hillslopes due to bedrock weathering and from anthropogenic input through atmospheric deposition and constrains the dynamics of sediment transfer. Lead isotope ratios decrease from bedrock to sediment and soil without any clear relationship when compared to lead contents. Pb isotopic compositions showed that most of the lead budget in sediment and soil results from bedrock weathering with influence of gasoline-additive-lead and past mining activities derived inputs, but no lead input from agricultural activity.

1. Introduction

The chemical weathering of rocks involves consumption of CO_2, a greenhouse gas with a strong influence on climate. Among rocks exposed to weathering, basalt plays a major role in the carbon cycle as it is more easily weathered than other crystalline silicate rocks, whether at ocean-island scale (Louvat and Allègre, 1997), at high latitudes (Gislason et al., 1996), or in large tropical basaltic provinces like the Deccan Trap (Das et al., 2005; Taylor and Lasaga, 1999). This means that basalt weathering acts as a major atmospheric CO_2 sink (Dessert et al., 2003). In the wider framework of the study of erosion mechanisms, the soils and sediments of the Loire Basin have been studied over a decade, using geochemical tools and isotope tracing (Négrel, 1997; Négrel and Grosbois, 1999; Négrel and Petelet-Giraud, 2012; Négrel and Roy, 2002; Négrel et al., 2000).

The present study investigated the lead isotopes in soil and sediment for constraining the life cycle of a catchment, covering erosion processes and products, and anthropogenic activities. For this, we investigated the Allanche river drainage basin in the Massif Central (France), flowing over the recent lava flows of the Cantal volcano as part of the Loire Basin, which offers opportunities for selected geochemical studies since it drains a single type of volcanic rock in a virtually unpolluted catchment, with only few agricultural activity increasing downstream (Négrel and Deschamps, 1996). Soil and sediment are derived exclusively from basalt weathering, and their chemistry,

* Corresponding author at: BRGM, ISTO, UMR 7327, BP 36009, 45060 Orléans, France.
E-mail address: p.negrel@brgm.fr (P. Négrel).

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coupled to isotope tracing, should shed light on the behavior of chemical species during weathering from parental bedrock.

Lead isotopes are commonly used in environmental studies of catchments, lakes and urban areas (e.g., Bird et al., 2010; Emmanuel and Erel, 2002; Graney et al., 1995; Petit et al., 2015), and of erosion processes (Allègre et al., 1996; Hemming and McLennan, 2001; Millot et al., 2004), soils and tree rings (Reimann et al., 2012; Schucknecht et al., 2011; Stille et al., 2012). Isotopic investigation on the weathering products generally offer important information on the chemical reactions taking place during such processes, as studies on the Pb isotope systematics of granitic rock weathering demonstrate (Erel et al., 1994; Harlavan et al., 1998; Peng et al., 2014). Our data present evidence for processes and mechanisms that can be beneficial to other large-scale continental weathering studies, but they also have a wider-ranging value in ascertaining the use of isotope systematics and in interpreting isotope studies in a large volcanic province for deciphering natural and anthropogenic influences.

2. General features of the catchment and sampling strategy

The Allanche drains part of the Massif Central (Fig. 1a), one of the largest volcanic areas in France, whose volcanic forms include Strombolian cones aligned along fissures (Chaîne des Puys), extensive basaltic plateaus (Aubrac and Devès), and two large central volcanoes (Cantal and Mont Dore). The Allanche river is 29 km long and the catchment area is 160 km^2 (Fig. 1a and b). From its origin in the

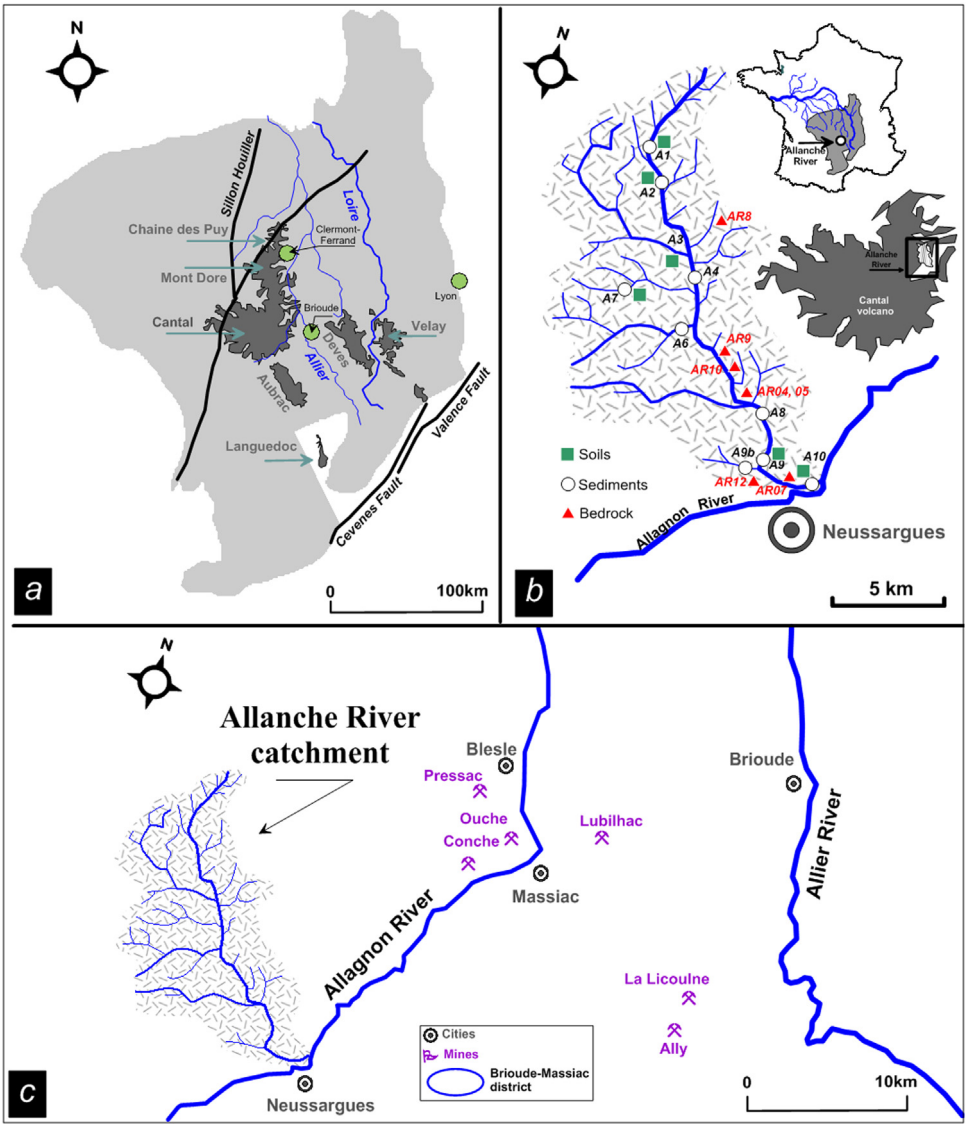

Fig. 1. (Color online.) Location map of the Massif Central region (a) with the location of the main volcanoes areas (Chaîne des Puys, Cantal, Aubrac, Deves and Velay) and (b) detailed map of the Allanche catchment and the different sampling points. Map showing the location of mines in the Brioude–Massiac district (c) in the Massif Central (Pressac, Ouche, Conche, La Licoulne and Ally) and the location of processing plants (Blesle and Massiac).