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Pyroclastic chronology of the Sancy stratovolcano (Mont-Dore, French Massif Central): New high-precision $^{40}Ar/^{39}Ar$ constraints

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ABSTRACT

The Sancy (16 km^2) is the youngest of the two stratovolcanoes that constitute the Mont-Dore Massif (Massif Central, France). The restricted number of high precision radio-isotopic ages currently limits our knowledge of the pyroclastic chronology of this edifice which is the source of many tephra layers detected in middle Pleistocene sequences in southeast Europe. To improve our knowledge of the building phases of this stratovolcano, we collected thirteen pyroclastic units covering the entire proximal record. We present $^{40}Ar/^{39}Ar$ single grain laser dating performed in the facility hosted at the LSCE (Gif-sur-Yvette, France). The $^{40}Ar/^{39}Ar$ ages range from 1101 ± 11 ka to 392 ± 7 ka (1σ external). Four pyroclastic cycles lasting on average 100 ka were identified (C. I to C. IV). C. I corresponds to the earlier explosive phase between 1101 ka and 1000 ka and starts about 100 ka earlier than previously thought. The second pyroclastic cycle (C. II) is the main pyroclastic episode spanning from 818 to 685 ka. This cycle is constituted of a minimum of 8 major pyroclastic eruptions and includes a major event that corresponds to a large plinian eruption at 719 ± 10 ka (1σ external) and recorded as a 1.4 m thick layer 60 km south-east of the Sancy volcano. The link between this large eruption and formation of a caldera stays however, hypothetical. The third pyroclastic cycle (C. III) found in the northeastern part of the Sancy (Mont-Dore valley) spanned from 642 to 537 ka. Finally, the youngest pyroclastic cycle (C. IV) starts at 392 ka and probably ends around 280 ka. The age versus geographic location of each pyroclastic cycle indicates three preferential directions of channeling of the pyroclastic events and/or collapse of the volcanic edifice: northwest to west (C. I), southeast (C. II) and finally north to northeast (C. III and IV). The new high precision $^{40}Ar/^{39}Ar$ age for the Queureuilh bas pyroclastic unit (642 ± 9 ka) is identical within error with the U/Pb age obtained by Cocherie et al. (2009) [*Geochimica et Cosmochimica Acta, 73, 1095–1108*] and suggests a short residence time of the magma in a shallow, short-lived, small magmatic chamber. Finally, the source of the t21d tephra layer found in the Pànico Séllere varved sequence (Northern Italy) is not the Rivaux pumice flow as proposed by Brauer et al. (2007) [*Journal of Quaternary Science 22, 85–96*] and neither one of the C. II pyroclastic units as suggested by Roulleau et al. (2009) [*Quaternary International 204, 31–43*]. Accordingly, the source for the t21d layer has yet to be found at Sancy or elsewhere.

1. Introduction

The alkaline intraplate volcanism of the French Massif Central (FMC hereafter) is well known for its dominantly basaltic products. However, differentiated products with wide petrographical ("silica saturated" trachybasalt to rhyolite and "silica unsaturated" tephrite to phonolite) and volcanological/dynamical diversity (lava-flows, intrusions, pyroclastics, lahars, debris-avalanches) are known and associated to large volcanic edifices that were active from 11 Ma to 200 ka (Nehlig et al., 2003). Two large stratovolcanoes are known in the FMC: the Cantal and the Mont-Dore Massif (Fig. 1). The youngest of these edifices (Mont-Dore) covers 500 km^2 and produced a volume of volcanic products between 200 and 220 km^3 (Brousse, 1971; Vincent, 1981) to about 70 km^3 (Cantagrel and Baubron, 1983; Cantagrel and Briot, 1990) (Fig. 1). Long thought to be composed of one single volcano, it was later shown to consist of two main stratovolcanoes the Guéry and the Sancy (Baubron and Cantagrel, 1980).

The Guéry encompasses the lower and the middle series of the Mont-Dore massif and the Sancy the upper series (Glangeaud et al., 1965). Numerous articles were published concerning this massif (*e.g.* Brousse, 1961; Gourgaud and Maury, 1984; Briot, 1988, 1990; Pastre, 1992; Wilson et al., 1995; Pastre and Cantagrel, 2001; Bernth et al., 2002) but only a few geochronological investigation using modern radio-isotopic methods on the pyroclastic products are yet available (Lo Bello et al., 1987; Féraud et al., 1990; Cocherie et al., 2009). As a result, the temporal evolution of the massif remains poorly

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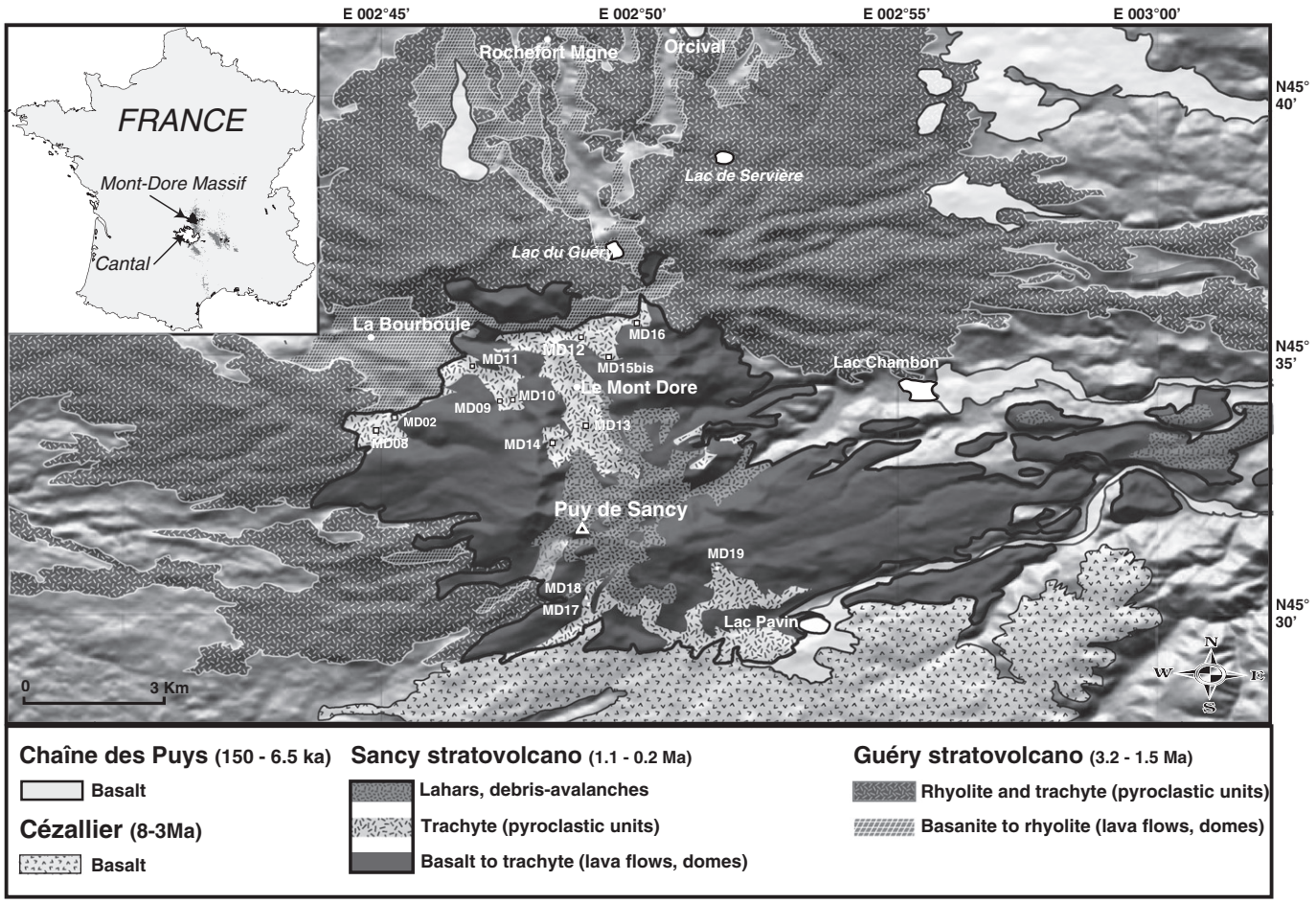

Fig. 1. Digital elevation model (SRTM 3), simplified geological map of the Mont-Dore massif and sample location.

constrained with current data allowing for various hypotheses regarding the explosive history of this edifice (e.g. Cantagrel and Baubron, 1983; Lavina, 1985; Pastre and Cantagrel, 2001). Tephra layers originating from the Mont-Dore massif, and especially the Sancy, are recognized in several peripheral middle Pleistocene maars of South-East France (*e.g.* Roger et al., 1999; Pastre et al., 2007; Nomade et al., 2010), in rivers terraces (Pastre, 1986, 1987, 2005), in karst (e.g. Debard and Pastre, 2008), and probably as far as Northern Italy in the Pianico varved paleolake sequence (t21d ash layer; *e.g.* Brauer et al., 2007; Roulleau et al., 2009). These ash layers constitute valuable chronological markers for continental paleoenvironmental records. Unfortunately, in many cases, direct and accurate dating is difficult and the lack of a tephrochronological database limits any precise correlation of these ash layers with the numerous pumice and ash flow deposits recognized in the Mont-Dore massif (Pastre and Cantagrel, 2001). This problem results for example in conflicting hypothesis on the age of the Pianico varved sequence (*e.g.* Brauer et al., 2007; Roulleau et al., 2009).

In order to constrain the explosive chronology and formation history of the youngest of the Mont-Dore massif volcano, the Sancy, we collected thirteen pyroclastic deposits covering the proximal record of this edifice (Fig. 1). $^{40}Ar/^{39}Ar$ laserprobe sanidine single-grain dating of these samples is presented in detail below. Based on these new and high precision data we build the first numerical age based explosive chronology for the Sancy. The pyroclastic activity, volcanic processes, magma residence time, and products dispersal are discussed in the light of these new ages complemented by recent $^{40}Ar/^{39}Ar$ data obtained on tephra layers found in the Alleret maar sequence, France (Pastre et al., 2007; Nomade et al., 2010). As the dated pyroclastic units represent potential sources for the t21d tephra layer found in the Pianico Sellère sequence, we will review and discuss the two current hypotheses proposed by Brauer et al. (2007) and Roulleau et al. (2009).

2. The Sancy stratovolcano, geological overview

The Sancy stratovolcano s.s. lies on the southeastern flank of the Guéry stratovolcano, north of the Plio–Pleistocene Cézallier volcanic area in the central part of the FMC (Fig. 1). The Sancy covers about 16 km^2. Its activity started about 1.0 Ma ago (Pastre and Cantagrel, 2001). Volcanic products belong to both undersaturated (basanites to phonolites) and saturated (basalts to trachytes) alkaline series. However, with Na_2O-2<K_2O, most are potassic (Maury, 1976). About 75% of the lavas and intrusions have an intermediate composition (shoshonites and latites in the IUGS classification of Le Bas et al., 1986) and are grouped as trachyandesites (Briot, 1990) that including basaltic trachyandesite and acid trachyandesites of the IUGS classification. The Sancy was the most active French volcano during the late Early to Middle Pleistocene period (Julien, 1988; Pastre and Cantagrel, 2001). Its activity ceased around 200 ka ago according to the K/Ar ages obtained by Cantagrel and Baubron (1983), before the beginning of the Chaîne des Puys activity 100 ka ago (Nehlig et al., 2003, Fig. 1). Pyroclastic materials, including pumice-flows/ignimbrite, block-and-ash flows, plinian falls and surges represent about 20–30% of the volcanic products (Brousse, 1963). A global tephrostratigraphy of the Mont-Dore massif was proposed in 2001 by Pastre and Cantagrel who distinguished, based on mineralogical, geochemical as well as field arguments more than thirty pumiceous