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Multiple subduction imprints in the mantle below Italy detected in a single lava flow

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ABSTRACT

Post-collisional magmatism reflects the regional subduction history prior to collision but the link between the two is complex and often poorly understood. The collision of continents along a convergent plate boundary commonly marks the onset of a variety of transitional geodynamic processes. Typical responses include delamination of subducting lithosphere, crustal thickening in the overriding plate, slab detachment and asthenospheric upwelling, or the complete termination of convergence. A prominent example is the Western–Central Mediterranean, where the ongoing slow convergence of Africa and Europe (Eurasia) has been accommodated by a variety of spreading and subduction systems that dispersed remnants of subducted lithosphere into the mantle, creating a compositionally wide spectrum of magmatism. Using lead isotope compositions of a set of melt inclusions in magmatic olivine crystals we detect exceptional heterogeneity in the mantle domain below Central Italy, which we attribute to the presence of continental material, introduced initially by Alpine and subsequently by Apennine subduction. We show that superimposed subduction imprints of a mantle source can be tapped during a melting episode millions of years later, and are recorded in a single lava flow.

1. Introduction

Despite its relative rarity, post-collisional potassium-rich magmatism provides important insight into the composition of the subcontinental lithospheric mantle along the Alpine–Himalayan belt, and highlights the role of recycled continental-crust (Guo et al., 2006; Lustrino et al., 2011; Miller et al., 1999; Prelević et al., 2013; Tommasini et al., 2011; Zhao et al., 2009). Extensive studies of Italian mainland volcanics have used Sr–Nd–Pb isotopes to argue for involvement of recycled crustal material (Conticelli et al., 2002; Lustrino et al., 2011; Peccerillo, 1999), but in view of the complex subduction history of the Mediterranean region, the provenances are difficult to resolve using bulk-rock samples. Melt inclusions (MIs) provide direct information about primitive magma compositions in considerably more detail (Jackson and Hart, 2006; Kobayashi et al., 2004; Maclennan, 2008; Nikogosian and van Bergen, 2010; Rose-Koga et al., 2012; Saal et al., 2005; Sobolev et al., 2000; Sorbadere et al., 2012). We use olivine-hosted MIs from Latera, a strategically positioned volcano in Central Italy, to investigate the subcontinental mantle source beneath the Italian peninsula. We demonstrate that their Pb isotope compositions and trace-element signatures are diagnostic in tracing input from both Alpine and Apennine subduction.

1.1. Magmatic and geodynamic setting

Pliocene to present-day magmatism in peninsular Italy has developed in a post-collision setting associated with plate convergence involving continental Europe, the extending western Mediterranean realm and Adriatic–Ionian lithosphere (Fig. 1). The large compositional spectrum of predominantly potassic parental magmas has been attributed to (1) different subducted crustal components, (2) heterogeneous pre-metasomatic mantle or (3) progressive melt-extraction processes (Conticelli et al., 2004; Foley, 1992; Peccerillo, 2005). Further to this, systematic compositional variation in erupted products with geographic location could reflect lateral heterogeneity in mantle sources affected by distinct metasomatic events associated with multiple subduction systems (Peccerillo, 1999). Magmatism in and off the northern

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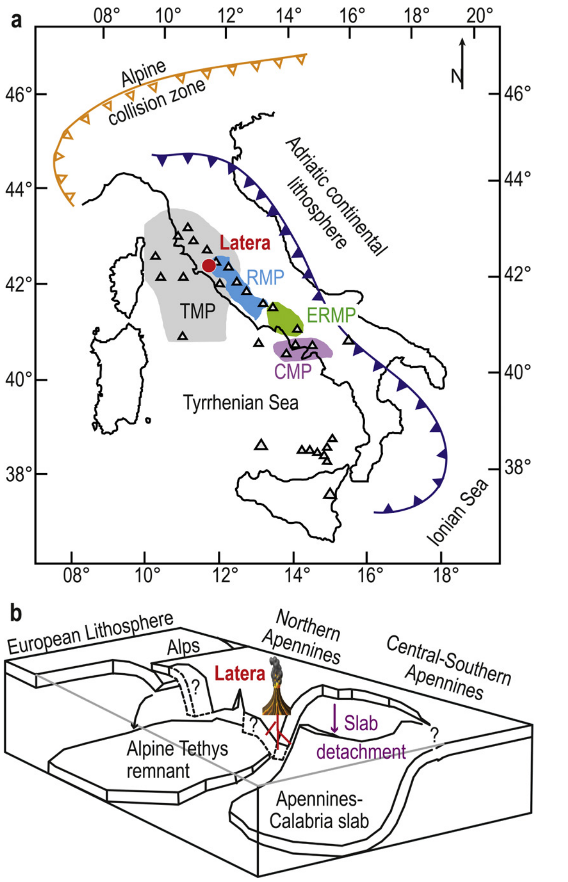

Fig. 1. a: Location of Latera volcano and other volcanic centers of central–southern Italy. Map redrawn after Peccerillo (2005). RMP: Roman Magmatic Province, TMP: Tuscan Magmatic Province, ERMP: Ernici-Roccamonfina Magmatic Province, CMP: Campanian Magmatic province. Orange curve marks Alpine subduction and blue curve marks Apennine subduction, including Calabrian subduction in the southern part. **b**: Schematic representation of tomographic model for mantle structure with subducted slabs beneath Italy and Tyrrhenian Sea, after Spakman and Wortel (2004), and approximate position of the mantle column below Latera volcano. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

part of peninsular Italy (mostly in the Tuscany–Corsica region) has been linked to Cretaceous-Oligocene Alpine subduction (Peccerillo, 1999; Peccerillo and Martinotti, 2006) and is characterized by lamproite (LAM) – shoshonite (SHO) – calc-alkaline (CA) magmatic associations. In contrast, magma sources in Central–Southern Italy developed under the influence of the Miocene to Recent subduction of Adriatic–Ionian lithosphere and produced shoshonite and strongly silica-undersaturated leucite-bearing high-potassium (HKS) and minor subalkaline rock series (Conticelli et al., 2002; Peccerillo, 1999).

Seismic tomography has identified the presence of fossil and still actively subducting slabs below Italy, related to the south- to eastward subduction of Tethyan oceanic lithosphere in the north, and the southwest to westward subduction of Adriatic and Ionian lithosphere, with continental and oceanic affinities respectively, below the central and southern areas (Giacomuzzi et al., 2012; Spakman and Wortel, 2004). These two separate subduction processes are referred to as Alpine and Apennine subduction, respectively (see Fig. 1). The geodynamic influence on magmatism is further complicated by rollback, tearing, and detachment of slabs and lithospheric delamination that accompanied subduction of the Adriatic lithosphere in the Apennine subduction zone (Chiarabba and Chiodini, 2013; Faccenna et al., 2001; Giacomuzzi et al., 2012; Serri et al., 1993; Wortel and Spakman, 2000).

Latera stratovolcano represents the latest stage (0.28–0.15 Ma) of K-rich volcanism in the Vulsini volcanic complex (<0.7 Ma), the northernmost sector of the Roman Magmatic Province (Roman MP) where HKS and SHO rock series prevail (Peccerillo, 2005). In this area, the Roman MP overlaps the neighboring Tuscan Magmatic Province (Tuscan MP) (Fig. 1) where mantle-derived magmas are represented by LAM-SHO-CA associations (Conticelli et al., 2010). Erupted products of Latera comprise SHO as well as HKS rock types (Conticelli et al., 1991). We focus on samples from various locations across a ca. 12 km long shoshonitic flow (Selva del Lamone, SdL) and from a representative HKS lava from nearby Monte Starnina (Conticelli et al., 1991). The SdL samples (4.8–5.8 wt.% MgO) contain olivine phenocrysts together with clinopyroxene, plagioclase, and rare sanidine. The Monte Starnina sample (4.8 wt.% MgO) contains clinopyroxene leucite and olivine as phenocrysts (see Table B.1, Fig. A.1).

2. Methods

2.1. Analytical techniques

Whole-rock compositions of the studied samples were determined by XRF (major elements) and ICP-MS (trace elements) at the Earth Science Department of the Free University (Amsterdam), using a Philips PW1404/10 and Thermo Electron X-series II ICP-MS, respectively.

Each sample was crushed and sieved to separate the olivine phenocrysts. They were embedded in epoxy holders and polished on one side for electron microprobe analysis (EPMA). The most forsterite-rich olivine grains with noticeable melt inclusions were selected to determine compositions and crystallization conditions of the parental melts. Melt inclusion re-homogenization and quenching experiments were performed with a high-T heating/quenching stage (design of Sobolev et al., 1980) at the Free University (Amsterdam), following the experimental procedure described in Nikogosian and van Bergen (2010). Details of melt inclusions homogenization experiments can be found in Appendix A. After quenching, host-olivine grains were polished until the melt inclusions were exposed at the surface for major, trace, and volatile element analysis by EPMA, Secondary Ion Mass Spectrometry (SIMS), and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS).

EPMA analyses were carried out using a JEOL JXA8600 Superprobe at Utrecht University, operated in WDS (wavelength dispersive) mode following the procedure described in De Hoog et al. (2001). Natural minerals, metals, and synthetic oxides were used as calibration standards. Daughter mineral phases in un-homogenized melt inclusions exposed at the surface were identified using semi-qualitative energy dispersive spectrometry (EDS) analysis.

Low-temperature microthermometry on fluid phases was performed on a Linkam TP/91-THMS 600 stage at the Free University (Amsterdam) following a routine as outlined in Nikogosian et al. (2002).

Concentrations of trace elements in most of the quenched melt inclusions were determined by SIMS using a CAMECA IMS4f at the Institute of Microelectronics (Yaroslavl', Russia), following techniques and procedures reported by Danyushevsky and Sobolev (1996) and Portnyagin et al. (2007). Polished, gold-coated olivine mounts were initially sputtered with a 70 µm diameter primary $^{16}O_2^-$ beam for 3 min to remove the coating. Data were obtained using a $^{16}O_2^-$ primary ion beam of 15–20 nA accelerated to 50 kV resulting in a spot size of ca. 10–20 µm. Each MI was analyzed near its center, with 5 data points taken over a 10–15 µm deep vertical profile with an integration time of 40 to 60 min. A calibration curve for glass standards ATHO-Ga (Jochum et al., 2006)