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Invited review article

The role of carbon from recycled sediments in the origin of ultrapotassic igneous rocks in the Central Mediterranean

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ABSTRACT

The Central Mediterranean region is one of the most important areas on Earth for studying subduction-related potassic and ultrapotassic magmatism, derived from partial melting of the metasomatised lithospheric mantle wedge. In this region, leucite-free (i.e., lamproite) and leucite-bearing (i.e., kamafugite, leucitite, and plagioleucitite) ultrapotassic rocks closely occur, in a time-related progression, linked to the evolution of both the mantle source and the regional tectonic regime. Time- and space-related magmatism migration followed the roll-back of the subducting slab and the anticlockwise drift of the Italian Peninsula. Leucite-free silica-rich lamproites are restricted to the early stage of magmatism and are associated with ultrapotassic shoshonites and high-K calc-alkaline volcanic rocks. Leucite-bearing (i.e., *Roman Province*) rocks are erupted consistently later than lamproite-like and associated shoshonitic rocks, with post-leucititic volcanism occurring in the late stage of volcanic activity with eruption of alkali-basaltic to latitic and trachytic rocks, often after major caldera-forming events. Present-day ultrapotassic volcanism is restricted to the Neapolitan area. Central Mediterranean potassic and ultrapotassic rocks are extremely enriched in incompatible trace elements with variable fractionation of Ta, Nb, and Ti in comparison to Th and large ion lithophile elements (LILE). They are also variably enriched in radiogenic Sr and Pb and unradiogenic Nd. The main geochemical and isotopic signatures are consistent with sediment recycling within the mantle wedge via subduction. A twofold metasomatism, induced by the recycle of pelitic sediments and dehydration of lawsonite-bearing schists generates the early metasomatic events that enriched the mantle wedge from which leucite-free ultrapotassic rocks (i.e., lamproite) were generated. Recycling of carbonate-rich pelites played an important role in the shift to silica-undersaturated ultrapotassic rocks (kalsilite- and leucite-bearing) of the classic 'Roman province'.

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1. Introduction

Despite their scarcity, ultrapotassic volcanic rocks are the most studied igneous rocks on Earth because of their peculiar mineralogy, geochemistry, geologic settings and economic value (e.g., Mitchell, 2006; Mitchell and Bergman, 1991). Ultrapotassic igneous rocks originate from partial melting of metasomatised upper mantle sources, in which K-bearing phases have been stabilised by the reaction of surrounding peridotite with K-rich metasomatic melts (e.g., Edgar, 1987, and references therein; Foley, 1992a, 1994). These rocks were initially considered related to intraplate continental settings (e.g., Cundari, 1980), although potassium enrichment is considered an important characteristic of arc-related magmas (e.g., Cawthorn et al., 1981; De Astis et al., 2000; Francalanci et al., 2004, 2007; Ninkovich and Hayes, 1972; Tommasini et al., 2007). Experimental geochemical studies have shown that silica- and potassium-rich magmas can originate at depth, from the recycling of sediments at depths within the upper mantle (e.g., Avanzinelli et al., 2012a; Elliott, 2003; Elliott et al., 1997; Plank and Langmuir, 1993, 1998; Skora and Blundy, 2010). Geochemical and isotopic studies have also shown that several potassic and ultrapotassic igneous rocks are related to the continental collision, which occurred after closure of the Tethys Ocean, with recycling of upper crust within the sub-continental lithospheric mantle wedge playing a major role (e.g., Conticelli and Peccerillo, 1992; Conticelli et al., 2002, 2007; Cox et al., 1976; Duggen et al., 2005, 2008; Guo et al., 2006, 2013; Peccerillo, 1985, 1999; Peccerillo et al., 1987; Prelević and Foley, 2007; Rogers et al., 1985, 1987).

Despite this large body of work made, limited attention has been paid to the origin of the different types of ultrapotassic magmas ranging from leucite-free, leucite-bearing and kalsilite-bearing ultrapotassic rocks (e.g., Edgar, 1987; Foley et al., 1987; Yoder, 1986). In Italy all these ultrapotassic rock types cluster together in space but not in time, providing a unique opportunity to investigate the mechanisms that control the formation of ultrapotassic magmas with different degrees of silica saturation (Conticelli et al., 2002, 2007).

In this paper we review the trace element geochemistry, the isotopic characteristics, and the petrological constraints of the Central Mediterranean ultrapotassic and associated rocks, in order to better understand: i) the evolution of the mantle source ii) the possible geochemical and isotopic relationships with changes in the geodynamic system and iii) the shift from silica-saturated (leucite-free) to silica-undersaturated (leucite- and kalsilite-bearing) magmatic rocks.

2. Chronological and geologic outline

In a pioneering study Washington (1906) grouped the potassic and ultrapotassic volcanic rock associations occurring in Italy into three different magmatic '*regions*' on the basis of mineralogical and petrographic characteristics: the Tuscany, Roman, and Apulian regions. The author did not use any temporal constraints, nor did he include or describe the scattered potassic rock cropping out in Corsica, in Tuscany Archipelago, and in intra-pennine areas (Fig. 1). Avanzinelli et al. (2009) recently proposed a classification of Central Mediterranean potassic to ultrapotassic igneous associations, in four magmatic events (i.e., *provinces*; Table 1) based on their timing, petrography, and spatial constraints, according to criteria suggested by Turner and Verhoogen (1960) and Conticelli et al. (2004).

The westernmost and oldest outcrops of ultrapotassic leucite-free (i.e., lamproitic) to high-K calc-alkaline volcanic rocks are found in the so-called *Corsica magmatic province* (Fig. 1), along with igneous rocks of Cornacya, Sisco, and Capraia Island (e.g., Chelazzi et al., 2006; Gagnevin et al., 2007; Mascle et al., 2001; Peccerillo et al., 1987, 1988). These rocks were emplaced during the Miocene and yields radiometric ages of 14.3–7.1 Ma (Fig. 2; Civetta et al., 1978; Mascle et al., 2001; Gasparon et al., 2009).

Between the Lower Pliocene (Zanclean) and Lower Pleistocene (i.e., 4.5–0.88 Ma; see Peccerillo, 2005, and references therein) volcanism shifted eastward to the western shoreline of the Italian Peninsula (Fig. 1). This maintained a close spatial association of ultrapotassic leucite-free (lamproitic) with shoshonitic and calc-alkaline suites (e.g., Clausen and Holm, 1990; Conticelli and Peccerillo, 1992; Conticelli et al., 1992, 2001, 2009a, 2011, 2013; Peccerillo, 1999, 2005; Peccerillo et al., 1987, 1988). This Plio-Pleistocene magmatic event produced the *Tuscany magmatic province* (e.g., Avanzinelli et al., 2009; Conticelli et al., 2004, 2010; Washington, 1906).

Coeval intrusive to volcanic silicic rocks, which were ultimately derived by anatexis of continental crust, were emplaced in southern Tuscany and within the Tuscany archipelago (Fig. 1) between 6 and 2 Ma. These rocks were kept isolated from the subcrustal igneous rocks of the classic *Tuscany magmatic province* due to their different sources. However, in some cases, hybridisation between mantle and crustal derived magmas has been recorded (e.g., Conticelli et al., 2013; Peccerillo et al., 1987; Poli, 1992).

Following a brief hiatus, magmatism resumed in the Central Mediterranean region during the middle Pleistocene (0.7–0.2 Ma). Ultrapotassic kalsilite- to leucite-bearing igneous rocks were produced at several silica-undersaturated volcanoes of the *Roman magmatic province* (e.g., Avanzinelli et al., 2009; Conticelli et al., 2004, 2010; Peccerillo, 2005; Washington, 1906). This province extends from Monte Amiata to the Neapolitan area (Fig. 1). It runs along as a narrow volcanic belt between the western Italian Peninsula shoreline and the Apennine chain (Fig. 1), showing a broad southeastward migration with time (Fig. 2). At about 400 ka, magmatic activity jumped to a more central region of the Apennine chain, in the Umbria region, marked by the eruption of strongly silica-undersaturated kalsilite-bearing rocks (i.e., kamafugites; Fig. 1). However, no further activity has been recorded in this region (e.g., Conticelli and Peccerillo, 1992; Conticelli et al., 2004, 2010; Gallo et al., 1984; Peccerillo, 2005; Peccerillo et al., 1987, 1988; Stoppa and Cundari, 1998).

The most abundant rocks of the *Roman magmatic province* are silica-undersaturated leucitites and plagio-leucitites (Table 1). When present kalsilite-bearing ultrapotassic igneous rocks are confined to early