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Miocene shoshonite volcanism in Sardinia: Implications for magma sources and geodynamic evolution of the central-western Mediterranean

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ABSTRACT

In this paper we document the existence of a Miocene shoshonite (SHO) volcanism in Northern Sardinia (Anglona). This occurrence completes the spectrum of orogenic magmas related to the subduction process which developed from the Eocene along the Palaeo-European continental margin, in concert with the opening of the Ligurian–Balearic back-arc basin and southeastward drift/rotation of the Sardinia–Corsica continental block. K–Ar ages show that the oldest volcanics of the area are calcalkaline (CA) basalts and andesites (~21 Ma), overlain by 19.7–18.4 Ma-old more potassic products such as high-potassium calcalkaline (HK-CA) and SHO lavas. CA, HK-CA and SHO suites include basalts and differentiated lavas of andesite and latite composition, respectively, that (according to the PELE software modelling) represent ~40–45% residual liquid fraction after shallow fractional crystallization. Application of the "Arc Magma Simulator" software suggests that the generation of primary melts of the distinct suites may occur at similar degrees of partial melting (5–8%) and melting pressures (2–2.2 GPa, ~60–70 km depth) in the mantle wedge. By contrast, the potassic character of parental melts of CA, HK-CA and SHO suites is controlled by 1) the amount of subducted continental components (possibly terrigenous sediments) and 2) the pressure (depth) at which these metasomatic agents are released from the slab. Results suggest that the slab depth beneath the volcanic district increased from ~80–100 to 100–120 km for CA and SHO magmas, respectively. Accordingly, the evolution from CA to SHO magmatism in the same plumbing system could be related to slab deepening and increase of the subduction angle of ~5–10° in the time span of 2–3 Ma. This tectono-magmatic scenario conforms to the major anticlockwise rotation (~30°) event of the Sardinia block (between 20.5 and 18 Ma). This geodynamic evolution preludes the development of the volcanism in the Apennine–Tyrrhenian domains, where the final collisional/post-collisional stages of subduction were characterized by accentuated slab retreat and roll back, inter-arc extension and eruption of highly potassic magmas in the frontal arc (Roman and Aeolian Provinces).

1. Introduction

The Oligocene–Miocene orogenic volcanism of Sardinia is fundamental for the reconstruction of the Cenozoic evolution of the Western Mediterranean area. It represents an important marker for Eocene subduction of the Ionian oceanic lithosphere beneath the Palaeo-European continental margin (Beccaluva et al., 1989, 1994; Wilson and Bianchini, 1999). This subduction system migrated southeastward in connection with the Sardinia–Corsica drift and rotation away from the European margin (Faccenna et al., 2001; Gattacceca et al., 2007; Montigny et al., 1981; Vigliotti and Langenheim, 1995) and was accompanied by the diachronous opening of the Ligurian–Balearic and the Tyrrhenian back-arc basins. The igneous orogenic activity initially developed with tholeiitic/calcalkaline (CA) magmas in Provence and Sardinia, whereas High-K calcalkaline (HK-CA) products, associated with CA volcanics, appeared since Burdigalian (Beccaluva et al., 1989, 1994, 2005, 2011; Brotzu, 1997; Conte et al., 2010; Downes et al., 2001; Guarino et al., 2011; Lustrino et al., 2009, 2011; Mattioli et al., 2000; Morra et al., 1997), following Latest Eocene/Early Oligocene continental collision in the Corsica–Apennine sector (Molli and Malavieille, 2011).

In this framework, shoshonite (SHO) products have been occasionally reported in Anglona (Beccaluva et al., 1994, 2005), but the existence of a genuine SHO series has been so far overlooked in the literature, despite its importance as a marker of highly metasomatized suprasubduction magma sources. In this paper we document the occurrence of a SHO volcanism in the Anglona district of northern Sardinia, closely associated with calcalkaline (*s.l.*) products. The following sections report new field observations, K–Ar ages, and an exhaustive major and trace element dataset on the Anglona volcanic district. The new findings are discussed in the framework of the whole orogenic volcanism of the Island, in order to provide fresh insights on the significance of this peculiar magmatic association in terms of magma source evolution and causative geodynamic processes.

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2. Geological outlines

In Sardinia, magmatic activity developed between 38 Ma (Lustrino et al., 2009) and 26 Ma with tholeiitic/calcalkaline basaltic and andesite lavas (Beccaluva et al., 1989, 1994, 2005). Subsequently, in the time span 23–13 Ma, eruptions of rhyodacitic ignimbrites alternated with basaltic–andesitic lavas and marked the last period of volcanic activity in Sardinia (Beccaluva et al., 1985, 1989). Between 21 and 18 Ma extensive rhyodacite ignimbrite eruptions took place together with the occurrences of highly primitive CA basalts (~18 Ma; Morra et al., 1997), suggesting paroxysmal extensional tectonics and deep lithospheric rifting which accompanied the opening of the Ligurian–Balearic basin and the related drifting and anticlockwise rotation of the Sardinia–Corsica block (Gattacceca et al., 2007; Martí et al., 1992; Montigny et al., 1981; Vigliotti and Langenheim, 1995).

The appearance of more potassic lavas in northern Sardinia during this period conforms to advanced stages of orogenic magmatism (Beccaluva et al., 1989, 1994, 2005), as confirmed by recent findings of coeval HK-CA/SHO products recovered offshore in the Ligurian Sea between southern Corsica and northern Sardinia (Réhault et al., 2012; Rossi et al., 1998). More recent potassic products also occur offshore in the Sardinia Channel (SHO ~13–12 Ma; Mascle et al., 2001) and as lamproites at Sisco in the Alpine Corsica (~14 Ma; Civetta et al., 1978; Conticelli et al., 2009).

The Anglona volcanism, which is the object of this study, represents a unique aspect of the Sardinia Oligo-Miocene magmatism showing the presence of CA, HK-CA, and SHO products associated in the same stratigraphic sequence (Fig. 1). The basic and intermediate lavas from these suites, extending over an area of ~300 km^2, were erupted from a number of volcanic centres mostly aligned in a N–NW/S–SE direction. The new K–Ar radiometric ages, integrated with those available in the literature (Table 1), allow us to delineate the general stratigraphy of the volcanism in the area. The oldest products, dated at ~20.9 Ma, are represented by thick lava flows or domes (CA basaltic andesites and andesite) mostly buried below younger volcanics and/or sedimentary deposits, and correspond to the andesite A1 unit dated at 22–21 Ma

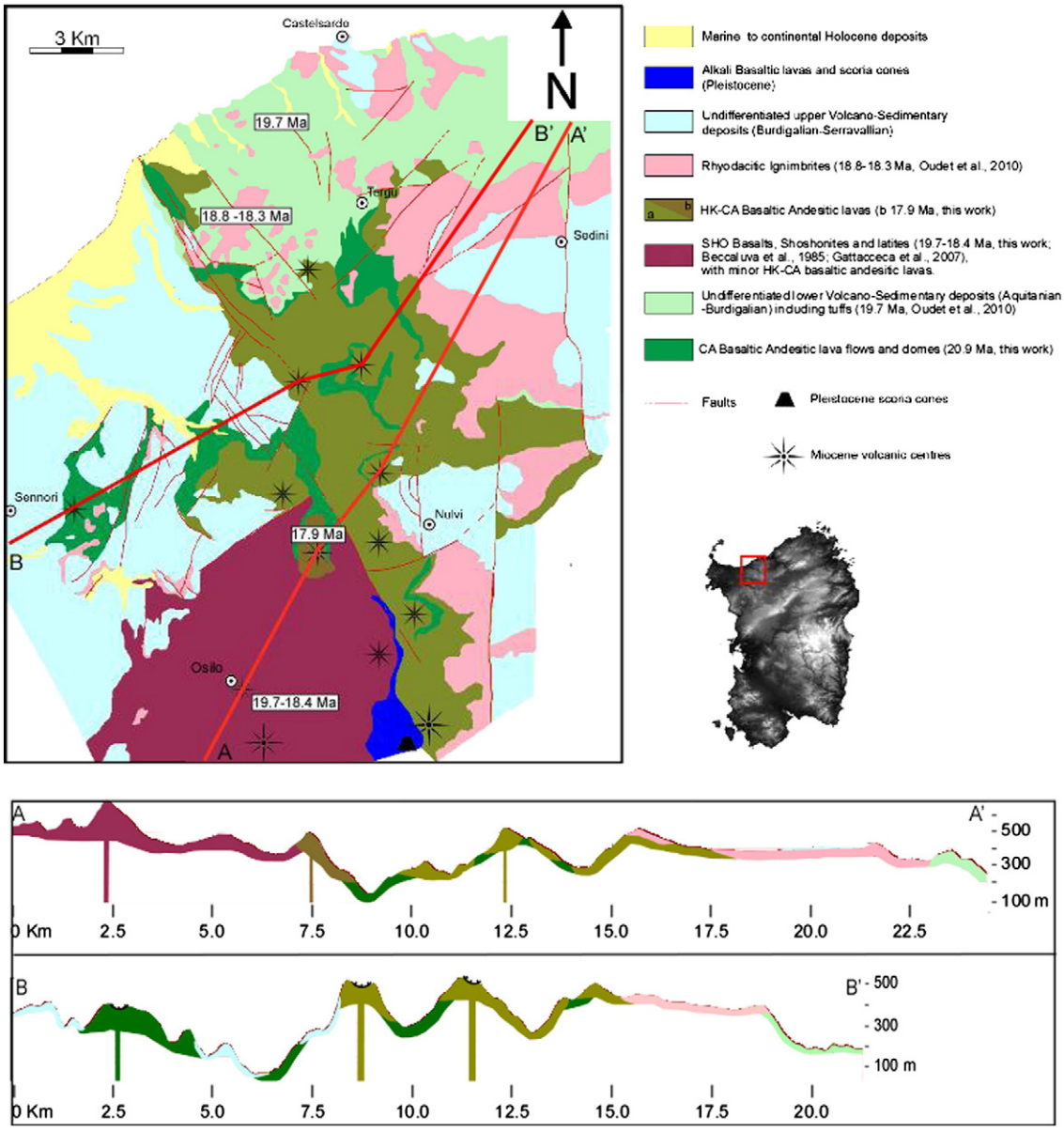

Fig. 1. Geological map of the Anglona volcanic area (after Carmignani et al., 2008 modified and integrated with data from this work), reporting the main volcanic lineaments and the location of the dated samples. Interpretative cross sections and an index map of Sardinia are also reported.