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Lamprophyres of Italy: early Cretaceous alkaline lamprophyres of Southern Tuscany, Italy

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ABSTRACT

Alkaline lamprophyres from southern Tuscany are early Cretaceous, ultrabasic, primary mantle melts that have not undergone significant magmatic differentiation. New mineralogical, geochemical and Sr, Pb and Nd isotopic evidence shows contrasting geochemistries with "crustal-like" and mantle geochemical features. High Mg#'s, however, coupled with high compatible elements, rule out any notable mantle melt dilution by bulk crustal contamination. Variations of Zr/Hf and Ta/Nb indicate a source containing residual titanates while their REE geochemistry suggests low degrees of partial melting and possible metasomatism of their source by carbonatitic melts. Arrays in isotope ratio diagrams are consistent with mixing between two distinct mantle end members. One is FOZO-like in character, and supports the involvement of asthenosphere, while the second has $^{87}Sr/^{86}Sr$ initial values that are much higher than FOZO (>0.70641). High $^{87}Sr/^{86}Sr$ signatures are present in the other Italian alkaline lamprophyres as well as other potassic–ultrapotassic and carbonatitic rocks of Italy. Our preferred model involves melting of a two component, metasomatised mantle, which can be tied into plume-related magmatism.

1. Introduction

Lamprophyres are genetically related to lamproites, kimberlites and carbonatites which establish a firm link with deep-seated melts derived from metasomatised mantle (Rock et al., 1991; Mitchell, 1994; Rock, 1987, Tappe et al., 2008). All of these rocks represent volatile-rich magmas rapidly emplaced at crustal levels during regional stages of lithospheric relaxation. Alkaline lamprophyres (AL) in Italy form dyke swarms that cut across different structural domains commonly showing a large spatial and temporal distribution. There are eleven major early Cretaceous to Oligocene AL occurrences reported from the Eastern and the Western Alps, Southern Tuscany, Sardinia, and the Puglia Region (Fig. 1a). Similar repetitions are observed in Africa (Bailey and Woolley, 1995), where four different magmatic cycles correspond with those found in the Mediterranean area: early Cretaceous (130–110 Ma), late Cretaceous (85 Ma), Eocene (40 Ma), and Miocene to Recent (<23 Ma). Their occurrence seems to be independent of the geodynamic evolution of the Tethyan–Mediterranean area and none correlates with the main Tethyan tectonic events (Dercourt et al., 1986).

The lamprophyres found in Southern Tuscany mark one of the oldest events of K-alkaline magmatism in the history of the Italian magmatism. Their present spatial distribution is shown in Fig. 1b. These rocks were known by the local name "selagite" and were previously considered to be mafic differentiates from granitic or syenitic magmas (Debenedetti, 1958). Faraone and Stoppa (1990) classified them as lamprophyres and linked their emplacement to within-plate continental extension during a mature stage of the Ligurian basin development. In this paper we discuss the mineralogy and geochemistry of the Southern Tuscany lamprophyres, including new Nd, Sr and Pb isotopic data.

2. Geological setting

The Southern Tuscany alkaline lamprophyres (STALs) are Albian in age (ca. 110 Ma) and occur in the Lower Cretaceous sequence of distal flysch that extends over an area of about 3000 km^2 in the provinces of Grosseto and Siena, Central Italy (Fig. 1b). This flysch is located between the subsiding margin of the Adria sector of the Africa plate and the Ligurian branch of the Tethys Ocean. Even though they are not strictly associated with Jurassic ophiolites they were probably located on oceanic lithosphere (Fig. 1c). To the east lies the subsident Tuscany domain marked by Triassic evaporites and Jurassic–Cretaceous limestones overlying the Palaeozoic crystalline basement belonging to the African sub-plate Adria (Brogi et al., 2000). To the north, the

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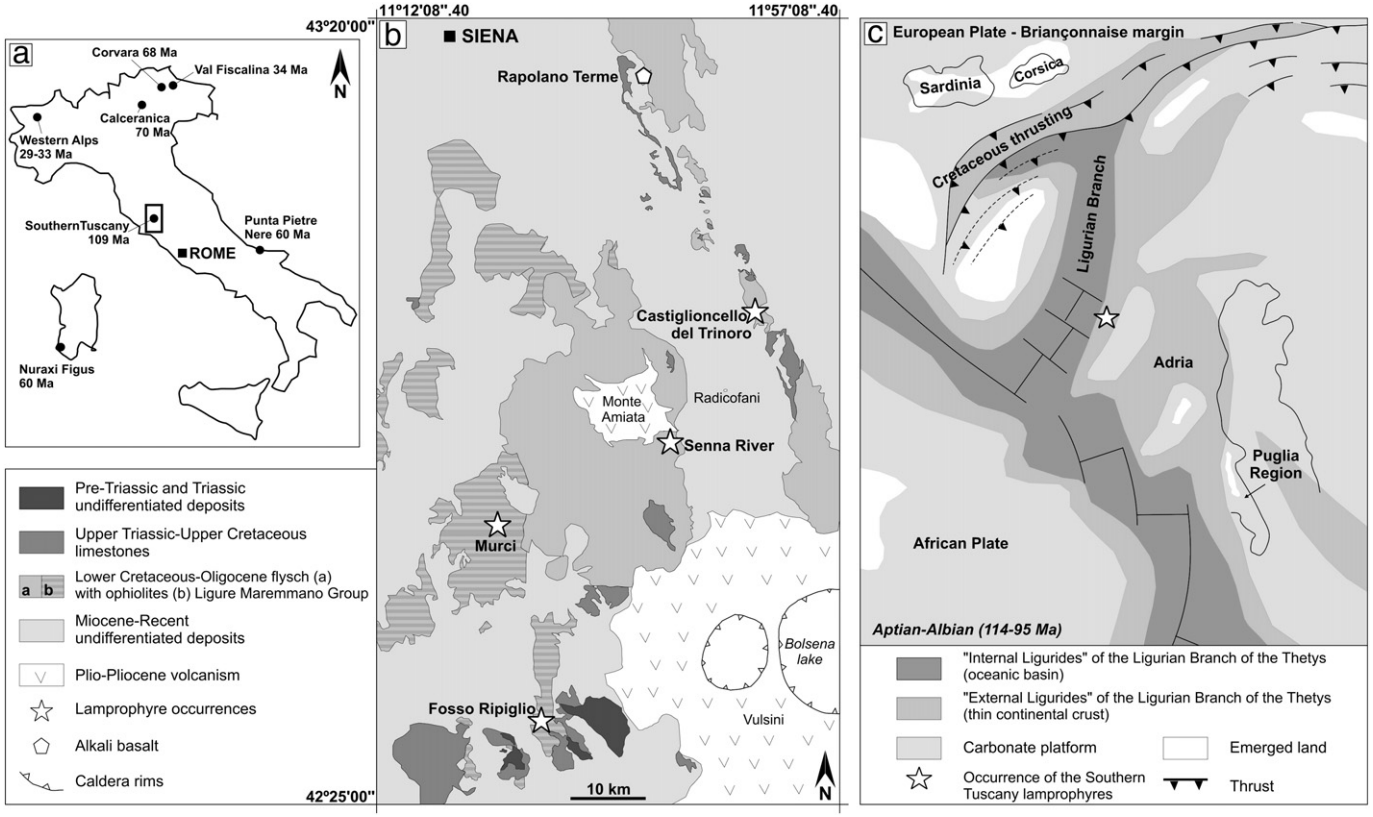

Fig. 1. (a) Location of Italian alkaline lamprophyres; (b) geological map and location of the Southern Tuscany alkaline lamprophyres at Siena and Grosseto, Italy; (c) early Cretaceous (Aptian–Albian) palaeogeographic restoration of the Ligurian Branch of the Tethys Ocean with the location of the lamprophyres shown.

Table 1
Modal compositions (vol.%) of the Southern Tuscany lamprophyres.

Location	Sample name	Lithology	Olivine[a]	Diopside[b]	Biotite[c]	Kaersutite[d]	Alkali feldspar[e]	Calcite	Apatite	Accessory minerals[f]	
Senna River	SF29	Dyke/sill									
	SF30	Dyke/sill	3	20	12	4	46	6	2	7	
	SF9	Dyke/sill									
	SF11	Dyke/sill									
	SF12	Dyke/sill									
	SF23	Dyke/sill	3	20	15	–	38	18	2	4	
Murci	PMT3a	Dyke/sill									
	PMT7a	Dyke/sill	4	18	20	–	35	16	2	5	
	PMT2	Dyke/sill									
	PMT4b	Pillow-lava	14	63	–	–	–	15	2	6	
Fosso Ripiglio	FR5	Dyke/sill									
	FR9	Pillow-lava	18	72	–	–	–	2	2	6	
	FR1b	Dyke/sill									
	FR2b	Dyke chilled margin	12	57	Total 12		9	–	2	8	+ trevorite
	FR6	Dyke/sill									
	FR8	Dyke/sill									
Castiglioncello del Trinoro	S5	Dyke/sill									
	S15	Pillow-lava	12	57	Total 12		9	–	2	8	
	S16	Dyke/sill									
	S4	Dyke/sill	3	16	12	4	42	15	3	5	

[a] Phenocrysts pseudomorphed with pennite, chrysotile and carbonate.
[b] Phenocrysts and euhedral groundmass grains (up to 6 wt.% TiO_2, 9 wt.% Al_2O_3, and 0.9 wt.% Cr_2O_3, Mg# = 0.7–1.0) rimmed with aegirine–augite (up to 5 wt.% TiO_2, <1 wt.% Al_2O_3, Mg# = 0.1–0.2).
[c] Zoned phenocrysts and euhedral groundmass crystals with eastonite–siderophyllite core and annite-rich rim (up to 10 wt.% TiO_2 and 3 wt.% BaO, Mg# = 0.7–0.5 and 0.5–0.2 for core and rim, respectively). Unzoned biotite occurs in samples FR1b, FR2b, FR6, FR8, S5, S15, S16, and PMT2.
[d] Phenocrysts with up to 7.7 wt.% TiO_2.
[e] Interstitial, branched and spherulitic groundmass crystals of sanidine and subordinate anorthoclase and albite with <0.1 wt.% SrO and <0.4 wt.% BaO.
[f] Additional accessory phases found in all of the studied samples except PMT4b, FR5 and FR9 include: Ti–magnetite, chromite, rutile, ilmenite, pyrite, and chalcopyrite.