between crust and mantle (Hall, 1989), and celadonite may be a minor participant in this process.

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Mixing between lamproitic and dacitic components in Miocene volcanic rocks of S.E. Spain

THE Miocene magmatic province of S.E. Spain is characterized by calc–alkaline/shoshonitic and lamproitic rocks which, during the last decade, have been reconsidered by several authors (Lopez Ruiz and Rodriguez Badiola, 1980; Munksgaard, 1984; and Venturelli *et al.*, 1988). The lamproitic rocks have a mantle origin, whereas the calc–alkaline and shoshonitic associations have a more complex origin involving both mantle and crust anatexis (Zeck, 1970; Toscani *et al.*, 1990).

Phlogopite is the typical magmatic mica of lamproites. In places, however (e.g. at Zeneta, province of Murcia), rocks with lamproitic affinity contain both stable phlogopite and biotite as phenocrysts and in the groundmass. This feature led Venturelli *et al.* (1984; p. 15) to interpret these rocks as the product of mixing between lamproitic and shoshonitic components which occurred just before or during magma emplacement. A similar hypothesis, based on the same line of evidence, was proposed by Fuster (1956; p. 86) for the origin of the biotite + phlogopite-bearing trachytes ('dellenites' in Fuster, 1956) occurring in the area of Vera (province of Almeria).

Further petrographic and geochemical evidence is given in the present paper which supports the mixing hypothesis. The study is concerned with a small outcrop (about 150 m long) of autobrecciated trachytic latites (Table 1), located 6.5 km W of Mazarron (province of Murcia), close to Caserio Fuente de Meca (1°23′11″W, 37°35′40″N, about 180 m above sea-level), and resting on penecontemporaneous autobrecciated

Table 1. Average compositions of potassic dacites and of trachytic latites (nomenclature after Le Bas et al., 1986) occurring near Caserio Fuente de Meca, Mazarron, SE Spain

	Potasssic dacites			*Trachytic latites*		
	Whole rock [3]	*a*	Glass [3]	Whole rock [5]	*b*	Glass [5]
%						
SiO_2	63.90		75.26	60.04		70.75
TiO_2	0.57		0.12	0.83		0.59
Al_2O_3	15.97		13.68	14.02		15.13
Fe_2O_3t	4.61		1.94	5.05		2.77
MnO	0.06		0.00	0.06		0.01
MgO	2.19	<5	0.26	5.95	>8	0.89
CaO	2.57		0.96	2.41		1.41
Na_2O	2.48		2.97	2.59		3.36
K_2O	3.67		4.81	4.14		5.13
P_2O_5	0.34			0.76		
L.O.I	3.66			4.15		
ppm						
Sc	17			15		
V	97			95		
Cr	116	<270		387	>400	
Co	17	≤ 20		27	≥ 20	
Ni	35	≤ 90		219	≥ 360	
Cu	19			24		
Zn	67			69		
Ga	22			21		
Rb	201			372		
Sr	403			447		
Ba	1166			1663		
Y	25			30		
Zr	216	≤ 390		397	≥ 440	
Nb	19			27		
Pb	97			94		
Th	46			88		
Ni/Co	2.1	≤ 6.5		8.1	≥ 12.5	
MgO/FeOt	0.53	≤ 0.9		1.31	≥ 1.5	
Zr/Y	8.6			13.2		

For glass, the microprobe analyses have been normalized to 100% ; [ ] = number of analyses; *a* and *b* are typical limit values for Miocene cordierite-bearing calc-alkaline/shoshonitic rocks and lamproites, respectively, from SE Spain.

potassic dacites (Table 1) of probable Late Tortonian age (see detailed description in De Larouzière and Bodet, 1983).

Petrography and chemistry

The *potassic dacites* consist of orthopyroxene, biotite (TiO_2 3.1–4.1 wt.%, Al_2O_3 16.6–17.1 wt.%, Mg# 52–54), frequently spongy or dusty plagioclase (47–79 An), abundant rhyolitic glass, and accessory apatite, zircon, ilmenite and graphite, which is present both in silicate phases and in the groundmass. They contain also crustal xenoliths, consisting of cordierite, orthopyroxene (Mg# 89 core $\rightarrow$ 53 rim), biotite ($TiO_2 \simeq$ 3.1 wt.% $Al_2O_3 \simeq$ 17.0 wt.%, Mg# $\approx$ 55), hercynitic spinel, andalusite, sillimanite and graphite, and xenocrysts of lobated quartz. The crustal xenoliths may be fragmented to give xenocrysts and are restitic, since they underwent thermometamorphism and partial melting. Dacitic rocks with shoshonitic affinity are abundant in S.E. Spain, particularly in the area of Mazarron, and have been carefully described by Zeck (1970) at Cerro de Hoyazo (Nijar depression, ENE of Almeria).

The *trachytic latites* contain olivine phenocrysts ($\leq$0.8 mm, Mg# 86.7–93.6) mostly altered to serpentine, phlogopite ($\leq$0.8 mm, TiO_2 3.1–4.1 wt.%, Al_2O_3 12.4–13.3 wt.%, Mg# 83–88.5),

Table 2. Test of mixing between lamproitic and dacitic components (least squares method)

0.500 F + 0.497 D = L

	SiO_2	TiO_2	Al_2O_3	FeOtot	MgO	CaO	Σalk	P_2O_5
F	59.33	1.41	11.62	5.54	9.43	2.90	8.97	0.80
D	66.67	0.59	16.66	4.33	2.29	2.68	6.42	0.35
L (obs)	63.01	0.87	14.71	4.77	6.24	2.53	7.06	0.80
L (calc)	62.84	1.00	14.10	4.92	5.85	2.79	7.68	0.58

	Rb	Ba	Sr	V	Cr	Ni	Th	Zr
F	594	1637	531	113	629	428	91	634
D	210	1217	420	101	121	37	48	225
L (obs)	390	1745	469	100	406	230	92	417
L (calc)	402	1424	475	107	375	232	70	429

F, D and L represent the average compositions of the lamproites from Fortuna, potassic dacites and trachytic latites respectively (obs=actual data, calc=data calculated according to the mixing model). All major element data are on L.O.I.-free basis and have been normalised to 100% with the exception of L (calc).

biotite (≤1.5 mm, TiO_2 3.0–3.6 wt.%, Al_2O_3 16.2–17.5 wt.%, Mg# 46.0–58.3), Cr-rich spinel (Al_2O_3/Cr_2O_3 0.05–0.16, Cr_2O_3 up to about 60 wt.%) included in the olivine phenocrysts, spongy and dusty plagioclase (31–63 An), accessory apatite (≤0.15 mm) and abundant rhyolitic colourless glass. Spherules of anisotropic greenish material (devitrified glass?) are a characteristic feature of the matrix. The rocks also contain xenocrysts of cordierite, orthopyroxene, hercynitic spinel, andalusite, sillimanite and lobated quartz as described for dacites. Graphite may be present in some silicate phases (e.g. biotite and cordierite) and in the greenish spherules of the matrix, but is absent in the colourless glass of the groundmass. Representative analyses of minerals may be requested from the authors. Owing to the very small size of Cr-spinel crystals, the results of the analyses were always affected by the host olivine.

As evidenced in Table 1, the geochemistry of the trachytic latites and dacites at this outcrop differ significantly; this contrasts with what was reported by De Larouzière and Bordet (1983) who proposed similar compositions for 'rhyodacites' and 'lamproites' (potassic dacites and trachytic latites respectively in this paper).

Evidence of lamproitic and dacitic components in trachytic latites

The role of lamproitic and dacitic components is suggested by mineralogical evidence and is in agreement with the geochemical features.

As reported above, the trachytic latites contain phlogopite, olivine with high Mg# and Cr-rich spinel included in olivine. These mineralogical features are typical of the Spanish lamproites, where olivine with Mg# 86–94 and Cr-spinel with $Al_2O_3/Cr_2O_3 \leq 0.05$ and Cr_2O_3 up to 64 wt.% occur (Venturelli *et al.*, 1988). Comparable Cr-spinels are absent, whereas olivine is a rarity in the calc–alkaline/shoshonitic rocks of S.E. Spain. The trachytic latites also exhibit petrographic features which are typical of the coexisting potassic dacites, i.e. they contain biotite, plagioclase and crystal xenocrysts/xenoliths. The hybrid feature of trachytic latites may be explained through the mixing of dacitic and lamproitic magmas; the presence of stable phlogopite and biotite microcrysts in the glassy groundmass of latites supports this hypothesis rather than assimilation of country rocks by superheated lamproitic magma. In the latites the homogenization of the two mixing components was not complete. This is indicated by the presence of the glassy spherules which contain graphite and probably represent the glassy portion of the dacitic component.

Geochemically the trachytic latites are intermediate between typical Spanish lamproites (MgO > 8%) and the cordierite-bering calc–alkaline (Mar Menor) and shoshonitic volcanic rocks (La Union-Cartagena, Mazarron, Vera, Cerro de Hoyazo) of Miocene age (Zeck, 1970; Lopez Ruiz and Rodriguez Badiola, 1980; Munksgaard, 1984; and our unpublished data). Their high contents of MgO (*c.* 6%). Cr (*c.* 390 ppm), Ni (*c.* 220 ppm), Zr (*c.* 400 ppm) and Th (*c.* 90 ppm) and the high Ni/Co (*c.* 8) and MgO/FeOtot (*c.* 1.3) are compelling evidence of lamproitic parentage.

Whereas the potassic dacites coexisting with latites may be taken as one of the end-members of the mixing series, the lamproitic component is more difficult to define. Taking into account the available geochemical data on the lamproites occurring in S.E. Spain (Venturelli *et al.*, 1984), the best fit for mixing is obtained considering the rocks from Fortuna and some from Barqueros (province of Murcia) as the lamproitic end-member. The results of the test of mixing are reported in Table 2 and suggest that the trachytic latites represent the product of mixing of equal amounts of dacitic and lamproitic components. The model is satisfactory for most elements but not for TiO_2, P_2O_5, Ba and Th which result lower than observed. This discrepancy, however, is not surprising since the outcrops of lamproitic rocks in S.E. Spain show wide compositional variation and some are richer in TiO_2, P_2O_5, Ba and Th (Venturelli *et al.*, 1984).

Our petrogenetic interpretation conflicts with what was proposed by De Larouzière and Bordet (1983) who regard trachytic latites and potassic dacites as heteromorphic expressions of the same magma.

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