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The lamprophyres of Afyon stratovolcano, western Anatolia, Turkey: description and genesis

Les lamprophyres du stratovolcan d'Afyon, Anatolie de l'Ouest, Turquie : description et genèse

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Abstract

The Afyon stratovolcano exhibits lamprophyric rocks, emplaced as hydrovolcanic products, aphanitic lava flows and dyke intrusions, during the final stages of volcanic activity. Most of the Afyon volcanics belong to the silica-saturated alkaline suite, as potassic trachyandesites and trachytes, while the products of the latest activity are lamproitic lamprophyres (jumillite, orendite, verite, fitztroyite) and alkaline lamprophyres (campto-sannaite, sannaite, hyalo-monchiquite, analcime–monchiquite). Afyon lamprophyres exhibit LILE and Zr enrichments, related to mantle metasomatism.

Résumé

Le strato-volcan d'Afyon (Anatolie de l'Ouest, Turquie) présente des roches lamprophyriques sous forme de produits phréatomagmatiques, coulées de laves aphanitiques et dykes, en fin de cycle éruptif. Les produits du volcan sont essentiellement des trachy-andésites et des trachytes, appartenant à la série alcaline saturée en silice et potassique. Les produits tardifs sont des lamprophyres lamproïtiques (jumillite, oréndite, vérite, fitztroyite) et des lamprophyres alcalins (campto-sannaite, sannaïte, hyalo-monchiquite, analcime–monchiquite). Ces lamprophyres montrent un fort enrichissement en éléments incompatibles, attribué à la métasomatose du manteau.

Keywords: Afyon; Anatolia; Turkey; volcanism; alkaline; dykes; lamprophyre; metasomatism

Mots-clés : Afyon ; Anatolie ; Turquie ; volcanisme ; alcalin ; dyke ; lamprophyre ; métasomatisme

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1. Introduction

Les lamprophyres sont présents dans divers environnements : zones de subduction, arc insulaire, marge continentale, rift, craton [13]. La mise en place des lamprophyres d'Afyon coïncide avec la fin de l'activité du strato-volcan d'Afyon. Ce volcan est édifié dans un bassin lacustre d'âge Miocène moyen. La série volcanique, alcaline et potassique [9,10], caractérise la subduction associée au fossé hellénique [10]. Les âges du volcanisme d'Afyon sont entre 8,5 et 14,5 Ma [4]. Le strato-volcan couvre une superficie de 550 km^2 (Fig. 1). Son histoire est marquée par deux grands stades d'évolution, séparés par l'effondrement d'une caldéra. Dans cette note, la géologie et la pétrologie des lamprophyres d'Afyon sont présentées et leur origine est discutée.

2. Géologie des lamprophyres

Les lamprophyres apparaissent sous forme de coulées de laves aphanitiques et de dykes, associés ou non à des édifices phréatomagmatiques (maars et diatrèmes, Fig. 1).

2.1. Coulées de lave

Elles sont de couleur grise ou noire, sans phénocristaux. Les laves noires présentent des plans de fluidalité bien développés et sont très vitreuses. Ces coulées sont parfois interstratifiées dans des dépôts sédimentaires au nord-nord-ouest du volcan [8].

2.2. Intrusions

Deux types d'intrusions ont été observés : dykes associés à des maars et diatrèmes, et dykes indépendants.

2.2.1. Les dykes associés aux maars et diatrèmes

Ils sont localisés à l'ouest et au nord-ouest du volcan (Fig. 1). L'édifice le plus à l'ouest a 100 m de diamètre, un bouchon de lave de 30 m de diamètre et quatre dykes associés. Les tufs phréatomagmatiques reposent sur des sédiments lacustres.

Les diatrèmes sont localisés dans le même secteur. Les produits correspondants sont des pépérites, de 30 m d'épaisseur maximale.

2.2.2. Les dykes indépendants

Les dykes sont nombreux, parfois groupés en essaims. À l'affleurement, ils peuvent atteindre 50 m de long pour quelques mètres de large. Nous avons distingué les dykes aphanitiques, les dykes porphyriques et les dykes de brèche intrusive.

Les dykes aphanitiques sont constitués d'une lave identique à celle des coulées. Les dykes porphyriques sont riches en phénocristaux de mica. Deux dykes de brèches intrusives sont également présents. La brèche est constituée de fragments de lamprophyres et de substratum, dispersés dans une matrice fine. Ce type de brèche intrusive est classique dans les zones à lamprophyres [13].

3. Pétrographie

La pétrographie, plutôt que la géochimie, permet de classer les lamprophyres. Nous avons utilisé la terminologie proposée par Rock et al. [13].

3.1. Coulées de laves lamprophyriques

Deux groupes de lamprophyres ont été distingués d'après l'assemblage minéralogique : lamprophyres lamproïtiques (LL) et lamprophyres alcalins (AL).

3.1.1. Lamprophyres lamproïtiques (LL)

Ils sont composés d'olivine, de diopside, de sanidine, d'albite, de leucite, de micas (phlogopite et biotite), d'oxydes et de verre volcanique. Olivine et diopside sont dominants et constituent la phase phénocristalline. La mésostase contient les autres phases minérales. Le type pétrographique correspondant est la « jumillite ».

3.1.2. Lamprophyres alcalins

Les assemblages minéralogiques permettent de définir quatre groupes : (*i*) *campto-sannaïtes* (olivine, diopside, phlogopite, sanidine, ± plagioclase, ± analcime, ± népheline, ± apatite), (*ii*) *sannaïtes* (phlogopite, diopside, sanidine, olivine, verre volcanique), (*iii*) *hyalo-monchiquites* (phlogopite, diopside, verre volcanique), (*iv*) analcime–monchiquites (olivine, phlogopite, diopside, analcime).

3.2. Dykes (lamprophyres lamproïtiques)

Nous avons distingué trois groupes : (*i*) *jumillites* (*orendites*) (phlogopite, sanidine, diopside, olivine, leucite, oxydes, ± verre volcanique), (*ii*) *vérites* (olivine, diopside, leucite, phlogopite, ± sanidine, apatite, oxydes, verre volcanique), (*iii*) *fitztroyites* (phlogopite, leucite, verre volcanique).

4. Géochimie

Une sélection représentative d'analyses chimiques (éléments majeurs et traces) des laves alcalines du volcan d'Afyon et des lamprophyres associés est présentée dans le Tableau 1.

4.1. Éléments majeurs

Dans le diagramme TAS (Fig. 2), les laves d'Afyon appartiennent à la série alcaline saturée en silice. Il s'agit essentiellement de trachyandésites et trachytes, alors que les lamprophyres sont globalement plus basiques. Les variations en fonction de la silice confirment les deux ensembles : saturé (trachytique essentiellement) et lamprophyrique (Fig. 3).

4.2. Éléments en traces

On note un net enrichissement en LILE, et en Zr, surtout pour les lamprophyres (Fig. 4). Les diagrammes multi-éléments montrent aussi la similarité des deux séries, nettement enrichies (Fig. 5). Nos données analytiques (en particulier la faible teneur en Nb et la teneur élevée en Zr) et les données de la littérature [7,10] montrent une affinité orogénique liée à une ancienne subduction pour les laves d'Afyon.

5. Discussion et conclusion

D'après la chimie, les deux séries semblent issues de la même source, et ont ensuite évolué séparément. La mise en place des lamprophyres d'Afyon coïncide avec la fin de l'activité volcanique dans la région. Ils contiennent du phlogopite et de la leucite. Ce volcanisme s'est développé dans un bassin lacustre au Miocène moyen, en régime extensif. Les lamprophyres sont génétiquement associés à la série trachytique. Leurs caractères minéralogiques, pétrographiques et géochimiques, ainsi que le contexte extensif, nous amènent à proposer pour leur genèse la fusion partielle d'une source hydratée (manteau métasomatisé), avec des taux de fusion variable.

1. Introduction

Lamprophyres occur in various tectonic settings: subduction zones (oceanic arcs, continental margins), rifts and stable cratons [13]. In the Afyon area, lamprophyre emplacement occurred during the final stage of volcanic activity. The central volcano is built on a lacustrine basin of Middle Miocene age. The actual west Anatolian crust is 35–40 km thick and exhibits a negative Bouguer anomaly similar to that observed in the Basin and Range Province in the USA [1]. Such anomalies in extensional zones indicate crustal thinning [6]. The Afyon volcanics belong to the alkaline series [9,10], with the volcanism being mainly potassic and ultrapotassic in character, due to mantle metasomatism caused by lithospheric subduction from the Hellenic trench [10]. The age of this volcanism ranges between 8.5 and 14.5 Myr [4].

The volcanism of Afyon, in western Anatolia, is represented by a small stratovolcano, which covers 550 km^2 (Fig. 1). Volcanic activity developed in two stages, separated by a caldera collapse. The products of the first stage are lava flows and domes, lahars and block-and-ash flows. Following caldera collapse, and the formation of related ignimbrites, the volcano witnessed extrusions of megasanidine-bearing (up to 5 cm) trachytic lava domes and dome flows, associated with block-and-ash flow, debris avalanches and autobrecciated lava flow deposits. Hydrovolcanic activity, lamprophyric lava flows and phlogopite-bearing dyke intrusions occurred at the end of this stage. The volcanological evolution of the Afyon stratovolcano was detailed previously [2,3]. In this paper, we present the geology and petrology of the lamprophyres and address the question of their genesis.

2. The geological setting of the Afyon lamprophyres

Lamprophyres occur as lava flows and intrusions, in the Afyon area. Most of the dykes are well preserved within the ignimbritic and sedimentary deposits.

2.1. Lamprophyric lava flows

Lamprophyric lava flows are either interstratified with the sedimentary deposits, to the north-northwest

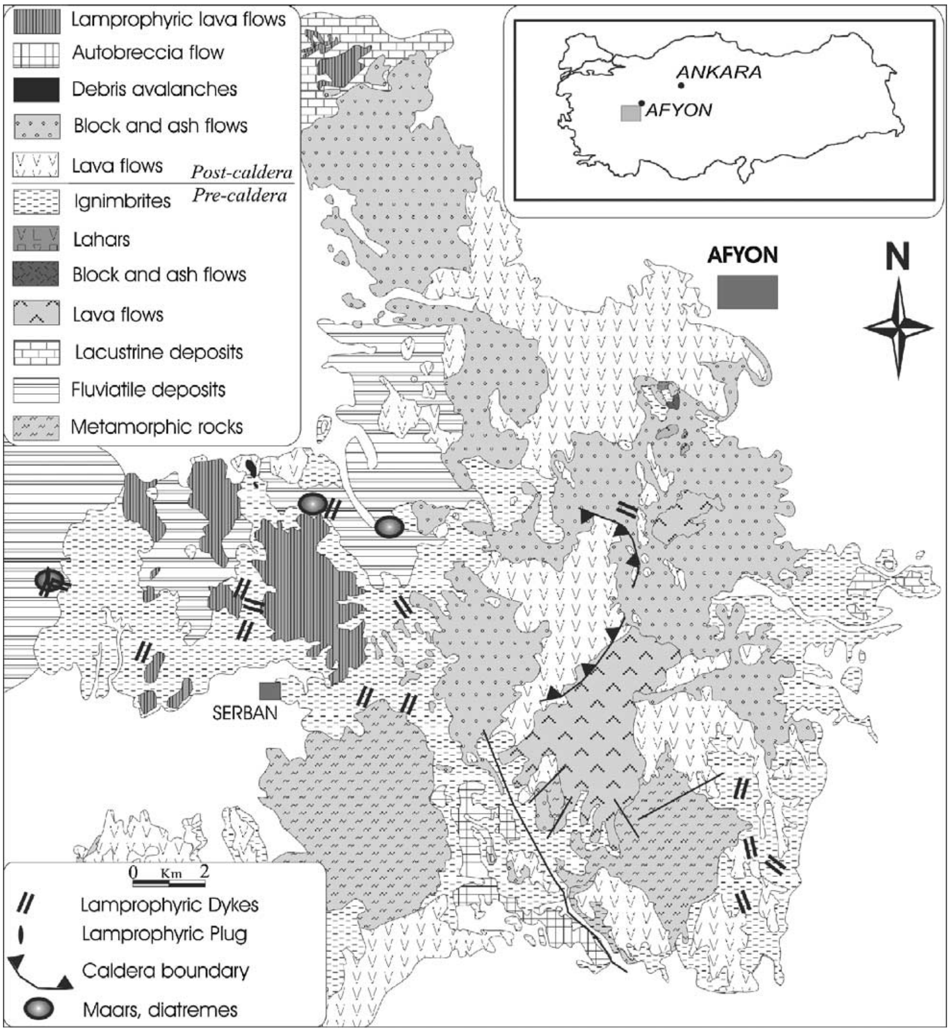

Fig. 1. Geological sketch map of Afyon stratovolcano (western Anatolia).

Fig. 1. Carte géologique du strato-volcan d'Afyon (Anatolie de l'Ouest).

of the volcano [8] or overly lacustrine deposits. Lamprophyres are dark grey or black coloured, fine-grained and aphyric. The grey lamprophyres exhibit more vesicles than the black ones. The black lavas are vitreous and exhibit thin laminae related to their fluidal texture.

2.2. Lamprophyric lava intrusions

Two kinds of intrusion were observed in the fields: maar-related intrusions and independent dykes (or dyke swarms).

2.2.1. Maar-related intrusions

A small maar crater (100 m in diameter) occurs in the western part of the Afyon volcano (Fig. 1). A lamprophyric lava plug (30 m width) occupies the central part of the crater. Moreover, four small crosscutting dykes outcrop within the crater. Phreatomagmatic products are represented by tuffs with abundant lithic fragments showing jigsaw cracks. The pillow-like surface morphology of the plug and the stratigraphical position of the explosive products overlying the lacustrine deposits, lead us to suggest that the magma intruded a lacustrine environment.

Two peperite diatremes can be seen in the north-western part of the volcano. These are blocky deposits, with a maximum thickness of 35 m. They contain aphanitic magmatic fragments with jigsaw cracks and vitrified surfaces.

2.2.2. Dykes

Numerous independent dykes or dyke swarms outcrop in the investigated area. The dykes are made of aphyric or porphyritic lava or intrusive breccias.

The aphyric dykes outcrop as dyke swarms and resemble aphyric lava flows. They exhibit some silicification that progresses outwards from the core to the margin of the dykes.

The porphyritic dykes contain abundant mica phenocrysts. They reach 50 m in length, and several metres in width. They occasionally outcrop as small stocks with cooling joints similar to those of granitoids. However, the surface of the stocks exhibits abundant vesicles, suggesting a subsurface emplacement.

Two intrusive breccia dykes were observed, containing fragments of the basement scattered within a fine-grained matrix. Such dykes are very common in lamprophyric areas [13].

3. Petrography

Mineralogy and petrography are the main tools used to describe and classify lamprophyric rocks. We used the terminology and classification of Rock et al. [13].

3.1. Lava flows

There are two groups of lamprophyres randomly distributed in the investigated area: lamproitic lamprophyres (LL) and alkaline lamprophyres (AL).

3.1.1. Lamproitic lamprophyres

LLs are fine-grained and exhibit a porphyritic texture. They are composed of olivine, diopside, sanidine, albite, leucite, micas (phlogopite and biotite), oxides and lesser amounts of volcanic glass. Olivine and diopside are the main euhedral phenocryst phases. Olivine is usually transformed into pilite pseudomorphs (carbonate + silica + chlorite). Although sanidine is sometimes observed as phenocrysts, with inclusions of leucite and diopside, it is usually found in the groundmass as the dominant salic phase. The groundmass contains abundant phlogopite–biotite microcrysts; with the exception of some samples, they form the phenocryst phases that represent sagenite net. Leucite is generally euhedral or, sometimes, rounded in shape. Such mineral properties correspond with the '*jumillite*' type of lamprophyre.

3.1.2. Alkaline lamprophyres

There are four AL groups, distinguished according to their mineralogical compositions:

(i) *campto-sannaites*, composed of olivine, diopside, phlogopite, sanidine, ± plagioclase, ± analcime, ± nepheline, ± apatite;
(ii) *sannaites*, composed of phlogopite, diopside, sanidine, olivine, volcanic glass. There is no salic mineral apart from sanidine in these rocks. Phlogopite is the essential phase;
(iii) *hyalo-monchiquites*, composed of phlogopite and diopside – no felsic mineral was observed within this glassy rock;
(iv) *analcime–monchiquites* are composed of olivine, phlogopite, diopside and analcime.

3.2. Dykes (lamproitic lamprophyres)

We saw jumillite (orendite), verite and fitztroyite.

Jumillites (*orendites*) are composed of phlogopite, sanidine, diopside, olivine, leucite, and oxides ± volcanic glass. The phlogopite phenocrysts contain sagenite nets. Sanidine occurs as ophitic arrangements. Olivine is commonly altered to pilite pseudomorphs. The groundmass contains small, rounded leucites.

Verites contain olivine, diopside, leucite, phlogopite, ± sanidine, apatite, oxides and volcanic glass. The phenocrysts are olivine, diopside, rarely phlogopite, while leucite, sanidine, apatite, most of the phlogopite and oxides are found in the groundmass together with abundant glass.

Fitztroyites are very glassy and composed mainly of phlogopite and leucite. Apatite and oxides are scattered within the glassy groundmass.

Table 1
Selected major and trace element analysis of the Afyon stratovolcano, including lamprophyres. Complementary analyses are available upon request

Tableau 1
Sélection d'analyses chimiques (éléments majeurs et en traces) du strato-volcan d'Afyon, lamprophyres compris. Les analyses complémentaires sont disponibles sur demande

	Central vent products						Lamprophyres													
%	**S-13**	**S-23**	**S-90**	**S-96**	**S-81**	**S-82**	**S-1a**	**S-77**	**S-78a**	**S-92a2**	**S-101**	**S-98**	**Z-36**	**Z-59**	**B70b**	**B-69b**	**B-125a**	**B-125b**	**G-27**	**G-32**
SiO_2	57.79	57.86	57.64	58.10	62.30	61.95	55.50	62.11	53.76	61.52	52.39	60.36	58.28	55.83	55.64	55.27	53.94	52.42	49.39	51.51
Al_2O_3	13.87	13.97	15.00	13.75	16.59	17.31	11.60	12.79	12.28	12.34	11.40	12.75	11.46	11.78	10.70	12.14	12.38	11.16	11.86	10.37
TiO_2	0.98	0.96	1.05	0.93	0.78	0.82	2.11	1.84	2.00	1.90	1.45	1.78	2.19	2.05	2.21	1.34	1.36	1.19	1.51	1.81
$Fe_2O_3^*$	6.26	6.27	5.76	6.14	4.58	4.92	7.12	3.76	7.81	4.29	7.31	5.03	5.12	4.39	6.75	5.99	5.78	5.77	7.57	6.44
CaO	5.49	5.49	6.63	5.86	4.08	4.15	5.81	2.93	7.03	3.16	6.16	3.37	4.02	7.81	5.73	5.03	6.69	10.58	7.86	4.76
MgO	3.42	3.44	3.26	3.69	1.29	0.95	4.52	1.90	4.53	2.32	9.59	4.60	5.80	5.53	5.43	7.10	6.51	3.60	6.55	7.82
MnO	0.12	0.09	0.10	0.10	0.05	0.04	0.05	0.04	0.10	0.04	0.12	0.06	0.05	0.05	0.05	0.08	0.08	0.16	0.16	0.11
Na_2O	2.80	2.79	2.95	2.78	4.12	4.23	2.74	2.09	3.27	1.97	1.79	1.96	0.88	1.99	2.19	1.07	0.75	1.93	3.45	3.65
K_2O	6.06	5.97	5.22	5.85	3.99	4.03	4.57	5.31	4.05	5.47	5.91	7.47	10.01	3.59	6.44	7.37	7.02	6.50	2.34	2.34
P_2O_5	0.80	0.81	0.71	0.78	0.29	0.31	1.01	0.50	0.93	0.31	0.94	0.16	0.77	1.09	0.84	0.82	1.13	0.89	0.80	0.79
LOI	0.47	0.83	0.83	0.55	0.56	0.66	3.54	4.58	2.55	5.39	2.07	0.80	1.32	3.78	2.71	2.66	2.69	5.72	7.34	8.73
Total	**98.05**	**98.48**	**99.15**	**98.52**	**98.62**	**99.36**	**98.58**	**98.10**	**98.31**	**98.71**	**99.13**	**98.33**	**99.90**	**97.89**	**98.69**	**98.90**	**98.33**	**99.92**	**98.84**	**98.35**
mg***	0.35	0.35	0.36	0.38	0.22	0.16	0.39	0.34	0.37	0.35	0.57	0.48	0.53	0.56	0.45	0.54	0.53	0.38	0.46	0.55
ppm				**T**	**R**	**A**	**C**	**E**		**E**	**L**	**E**	**M**	**E**	**N**	**T**	**S**			
Rb	259	255	209	257	151	153	800	1413	557	1044	251	367		394	289	205	287	190		
Sr	1148	1159	1079	1082	928	1029	1056	766	1033	803	759	767		1413	1082	1427	1322	1082		
Ba	3218	2874	2148	2435	1340	1415	892	1361	958	1503	1350	1639		1249	1460	1484	1715	1460		
Nb	23	24	24	21	35	35	27	18	29	25	26	31		42	31	39	34	31		
Zr	349	352	358	349	290	312	1183	1152	962	1136	615	896		1371	539	591	711	539		
Y	30	27	32	34	27	29	58	73	50	55	31	26		55	28	52	32	28		
Ga	19	18	20	18	21	21	27	31	25	30	17	26		32						
Ni	57	64	34	62	22	20	227	16	146	19	286	68		120	164	102	107	164		
Co	35	34	29	35	20	15	50	15	33	15	46	19		16	24	46	31	24		
Cr	190	241	231	249	34	43	695	172	617	279	760	415		766	480	478	608	480		
V	129	131	153	121	82	82	170	172	175	170	178	165		185	121	144	149	121		
										C	**I**	**P**	**W**							
Qz	5.59	5.90	6.14	5.92	13.61	12.46	9.27	22.24	4.27	20.85	0.00	9.28	3.95	12.72	5.13	4.25	5.17	0.00	0.00	4.60
Ne	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00
Fo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00
Fa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00

4. Geochemistry

Major and trace element analysis was carried out on selected lamprophyres using Philips PW-1480 XRF (X-Ray fluorescent spectrometer) equipment in Hacettepe University (Turkey). Selected analyses are listed in Table 1.

4.1. Major elements

25 samples from the central volcano and 19 samples of lamprophyres were analysed. The TAS (Total Alkalis-Silica) diagram (Fig. 2) shows a complete series between trachybasalt and trachyte, in a silica-saturated alkaline suite. The SiO_2 content of lamprophyres ranges between 49 and 62%. Although the fluctuation of *mg** (magnesium number: $MgO/MgO + Fe_2O_3$, ranging from 0.57 to 0.31) versus SiO_2 suggests that all lamprophyres are affected by different degree of differentiation, it also indicates heterogeneous compositions of the starting magmas with their different mg^* for similar SiO_2 (for 55% SiO_2, mg^* ranges between 0.38 and 0.55). The lamprophyres are mainly ultrapotassic (K_2O/Na_2O: max. 11.37) or potassic (K_2O/Na_2O: min 0.64 with $K_2O > 2\%$).

The $MgO–SiO_2$, $TiO_2–SiO_2$, $Al_2O_3–SiO_2$ and $Fe_2O_3^*–SiO_2$ variation diagrams (Fig. 3) exhibit two distinct trends: the lamprophyre series, on the one hand, and other lavas, mainly trachytic, called here the trachytic series, on the other hand. The main differences between both series are related to TiO_2, $Fe_2O_3^*$ and Al_2O_3 contents. Correlation between $TiO_2–SiO_2$ is weak (TiO_2 content is almost constant, about 2%) for the lamprophyre series, while TiO_2 decreases with increasing SiO_2 for the trachytic series. Based on the chemical analysis and the oxide–silica variations, it can be concluded that some lamprophyres constitute the more mafic terms of the trachytic series, completing each other to design a genetically related suite. This dominantly trachytic series probably evolved independently within the crust, in shallow magma chamber(s). In comparison to the trachytic series, the lamprophyric series exhibits lower Al_2O_3 contents that increase with increasing SiO_2 (Fig. 3). Moreover, K_2O contents of ultrapotassic lamprophyres mostly increase with increasing mg^*, while the potassic ones have no correlations. Such enrichment was also observed in Mascota lavas, western Mexico, related to

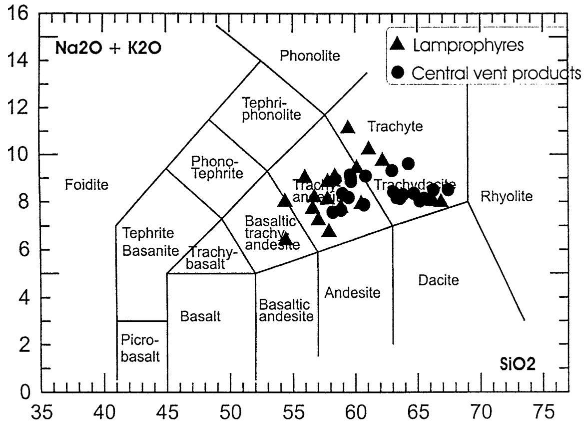

Fig. 2. Plots of volcanics from the Afyon stratovolcano in the Total Alkali-Silica diagram of [11].

Fig. 2. Diagramme TAS (somme des alcalins en fonction de la silice), d'après [11].

the presence of phlogopite within the partially melted source area [5].

A problem is that both series are silica-saturated and most lamprophyres exhibit normative quartz. Paradoxically, the observed minerals may be either leucite or olivine. This is probably linked to the rapid ascent of magma towards the surface, leaving leucite crystals no time to break off.

4.2. Trace elements

Fourteen samples from the trachytic series and 12 samples from the lamprophyres were analysed. All the samples are enriched in LILE (Large Ion Lithophile Elements) (Fig. 4). The trachytic series exhibits high Ba (1115–3218 ppm) and Sr (710–1522 ppm) contents, with variable Cr (9–249 ppm) and Ni (5–64 ppm) contents.

The lamprophyres however are much more enriched than the trachytic group, except for Ba, e.g., Rb contents of the lamprophyres were sometimes very high, ranging between 81 and 1413 ppm. Zr contents of lamprophyres (521–1371 ppm) are higher than in the trachytic series (Zr: 211–388 ppm) (Fig. 4). In addition, Nb contents of lamprophyric and trachytic series are low (< 42 ppm) which is a characteristic feature of subduction-related volcanic rocks. Furthermore, lamprophyric Cr (172–760 ppm) and Ni (16–286 ppm) contents are also higher than in the trachytic series. A MORB normalized spidergram confirms both

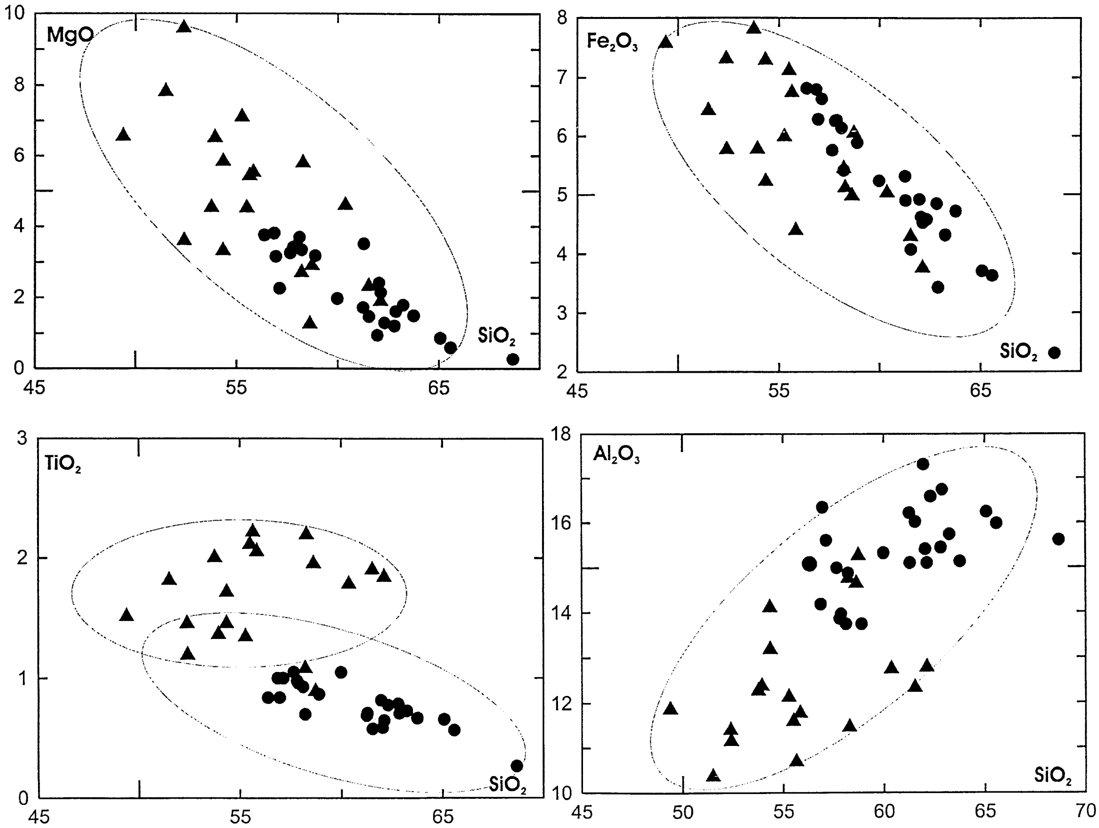

Fig. 3. Oxides versus silica variation diagrams. Symbols are as in Fig. 2.

Fig. 3. Diagrammes de variation de quelques oxydes en fonction de la silice. Les symboles sont ceux de la Fig. 2.

this general enrichment (Fig. 5) and also the similarity of both series.

5. Discussion and conclusion

The lamprophyres were emplaced at the end of the volcanic activity in Afyon area. The Afyon stratovolcano was built on a lacustrine basin, in an extensional tectonic regime, during the Middle Miocene. The distributions of the different petrographic types of lamprophyres are not related to geological features and, at the same locality, different types occur. Some lamprophyres are related to a mainly trachytic series, while others evolved independently. Although the lamprophyres contain phlogopite and leucite, they are quartz normative. On the other hand, K_2O values of ultrapotassic lamprophyres are positively correlated with mg^*. The positive correlation between Al_2O_3 and SiO_2 contents of the lamprophyres is also observed. Geochemical data suggest that phlogopite occurred in the partially melted source area. The incongruent melting of alumina-bearing mineral phases, in addition to potassic minerals, rather than magma-crust interaction, is considered to be responsible for the positive correlation of alumina versus silica. The glassy textures and leucite bearing mineralogy (no pseudoleucite) of most of the lamprophyres also indicate that no major magma-crust interaction occurred. Both series, trachytic and lamprophyric, are rich in incompatible elements, especially in LILE (Ba, Rb, Sr) and HFSE (Zr), suggesting that they were produced from the same metasomatised mantle source. Similar results have been noted in previous works based on major oxides, trace elements, especially REE, and isotopic contents. The potassic

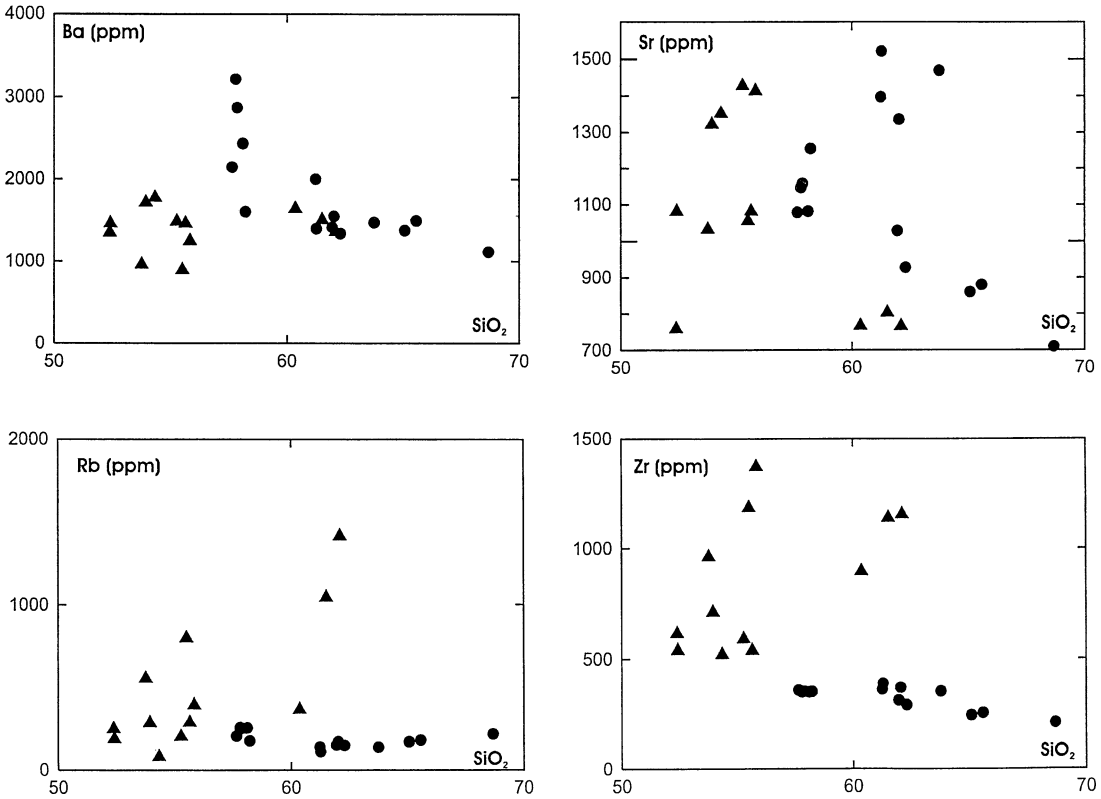

Fig. 4. Some selected trace element versus silica diagrams. Symbols are as in Fig. 2.

Fig. 4. Diagrammes de variation de quelques éléments en traces en fonction de la silice. Les symboles sont ceux de la Fig. 2.

and ultrapotassic rocks of Afyon have relatively high Sr isotope ratios (0.703 88–0.706 15 for the potassic rocks, 0.706 61–0.707 90 for the ultrapotassic rocks) [7,10]. However, medium to high Zr contents against medium to low Nb contents of lamprophyric and trachytic series strongly suggest a subduction effect. On the other hand, high LILE/HFSE, LILE/REE ratios indicate orogenic affinity and a subduction-related tectonic setting for Afyon rocks [7]. It is generally considered that lamprophyres originate from the partial melting of metasomatised lithospheric mantle under H_2O-rich conditions and the wide variations in modal mineralogy and bulk compositions show that the mantle source of the lamprophyres was affected by different metasomatic processes related to subduction [7]. In conclusion, we can say that the emplacement of small volumes of hydrous lamprophyric magmas requires ascent paths favoured by a tectonic regime, related to an extensional basin.

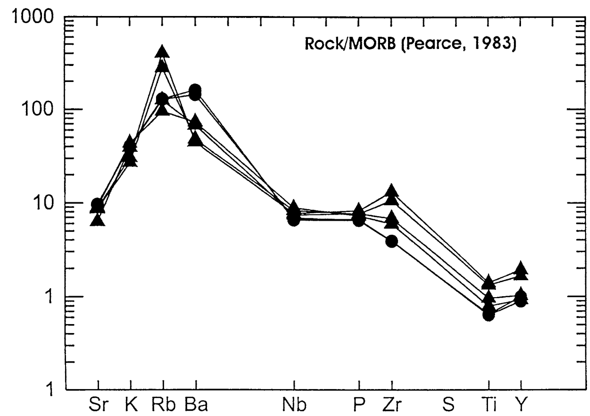

Fig. 5. Spidergram of selected Afyon lavas, including lamprophyres, normalized to MORB, according to [12].

Fig. 5. Diagramme multi-éléments d'une sélection de laves d'Afyon, lamprophyres compris, normalisé aux MORB selon [12].

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