

Geochemistry of lamprophyres in Karakaya (İscehisar, Afyon), Western Anatolia, Turkey

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Abstract. The geochemical characteristics of the volcanism, occurred in the western Anatolia, display calc-alkaline (Oligocene-Lower Miocene) and alkaline (Upper Miocene-Pliocene) affinities. These two different volcanism have an important role to understand the geodynamic evolution of the western Anatolia during the Neogene time. The Karakaya lamprophyres, one of the products of these volcanism lying in the western Anatolia, comprises alkaline basaltic rocks extruded into the ignimbrites. Petrographically, they have mostly hyalopilitic, trachytic, intersertal, vitrophyric porphyritic, pilotaxitic and glomeroporphyritic texture. Olivine (mostly altered to iddingsite and resorbed by carbonate), clinopyroxene (diopside, augite) and phlogopite (partly transformed into Fe-Ti oxide) as phenocryst phase, and apatite, quartz, garnet and opaque minerals as accessory phase defined. In some thin sections, quartz phenocrysts are surrounded by clinopyroxene needles that evuluted as evidence of magma mixing. These lamprophyres are characterized by low concentrations of SiO₂, TiO₂ and total Fe₂O₃, high concentrations of Mg#, enriched in LREE and LILE but variably depleted in HFSE. In the total alkali silica diagram, Karakaya lamprophyres mainly plot in the fields of trachyandesite, basaltic trachyandesite. According to mineral chemistry results, olivines show normal zoning by increasing of CaO and decreasing of Fo contents from core to the rim. Pyroxenes are classified as diopside and augite compositions. The mica minerals are generally phlogopite. The overall data about the petrographic and mineral chemistry exhibit that these lamprophyres appear to derived by fractional crystallization of a magma mixing which formed by melting of the continental crust with effect of the uprising lithospheric mantle during in a extensional tectonic regime after the Middle Miocene.

1. Introduction

Lamprophyres represent volatile-rich magmas, which form as dykes, sills, pipes or small intrusions in various geodynamic settings [1,2,3]. These rocks are considered to be the products of mantle-derived magmas so they can provide significant data on the evolution of ancient continental lithosphere [4]. The study area is located in the approximately 25 km northeast of the city of Afyon, lies between western Anatolia and central Anatolia. Western Anatolia where has an important role in Turkey's geodynamic evolution shows the traces of widespread magmatic events that occurred in the past. In the current research, the aim was to determine the petrographical and geochemical characteristics of the lamprophyres from the Afyon area (Turkey) which display alkaline affinity.



2. Geological Settings and Previous Works

The study area is covered by metamorphic, sedimentary and volcanic rocks. The oldest rocks are Devonian metamorphics (İscehisar Marbles and Doğanlar Schists) which constitute the basement rocks in the study area. The metamorphic basement is unconformably overlain by Early Miocene Seydiler Ignimbrites which is product of explosive volcanism. Middle Miocene Karakaya Lamprophyres, formed by effusive eruption, overlies onto the ignimbrites. These volcanic units are discordantly overlain by Late Miocene-Early Pliocene Gebeciler Formation and Quaternary alluvium (figure 1).

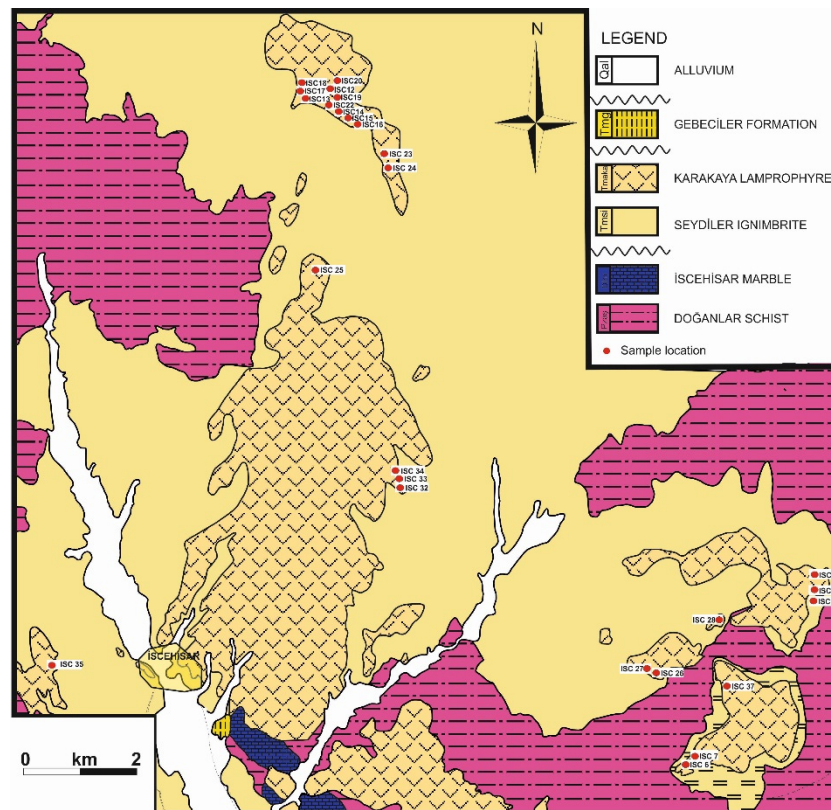


Figure 1. Geological map of the study area (modified after [5])

Study area has been previously studied in order to clarify the stratigraphy, mineralogy and the relation between magmatism and tectonism by [5-19].

3. Analytical Methods

Fifteen rock samples were collected from the study area. Mineral analyses were undertaken at the Potsdam University, Potsdam, Germany by electron probe micro analyser (EPMA). Major element abundances were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES) and trace element abundances were determined by inductively coupled plasma-mass spectroscopy (ICP-MS) in ACME Laboratory, Canada.

4. Results

4.1. Petrography and mineral chemistry

Petrographically, the volcanic rocks investigated are mainly andesite, basaltic andesite. They show mostly hyalopilitic, trachytic, intersertal, vitrophyric porphyritic, pilotaxitic and glemoroporphyrific texture. In Karakaya lamprophyres, clinopyroxene (diopside, augite), olivine and mica (phlogopite) as

phenocryst phase, and apatite, quartz, garnet and opaque minerals as accessory phase defined. Some of olivine phenocrysts have been partially transformed to iddingsite and in some cases, the carbonate clearly replaces olivine. In samples, most of micas are rimmed by iron-oxide. Vesicles in these rocks are filled by carbonates and zeolites. In some thin sections, quartz phenocrysts are surrounded by clinopyroxene needles that evolved as evidence of magma mixing.

Forsterite (Fo) contents of olivines range from 55.0 to 84.0%. They show normal zoning by increasing of CaO and decreasing of Fo contents from core to the rim (figure 2). Pyroxenes are classified as diopside and augite composition (En40-52 Fs05-13Wo40-48). The mica minerals are generally classified as phlogopite on the basis of their low Al and high Mg# contents. And their Al_2O_3 and TiO_2 contents are 11.23-15.68 wt % and 3.08-5.78 wt %.

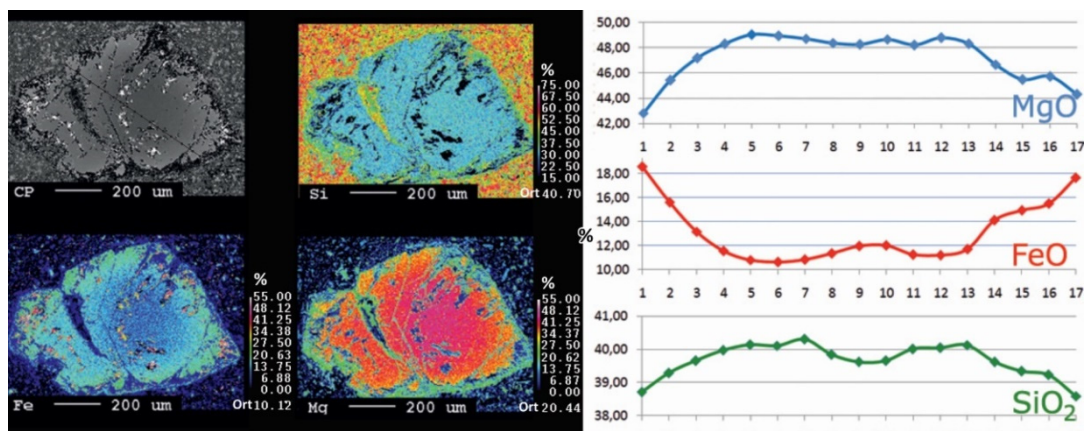


Figure 2. Olivine phenocryst which shows normal zoning

4.2. Whole rock chemistry

Geochemically, the Karakaya Lamprophyres have SiO_2 contents of 50.46-60.00 wt.% and total alkali ($\text{Na}_2\text{O}+\text{K}_2\text{O}$) contents of 6.91-9.31 wt.%. Al_2O_3 ranges from 11.65 to 14.89 wt.% and averages 13.60 wt.%. TiO_2 rather constant and averages 1.36 wt.%. CaO is between 4 and 8 wt.% in most samples (table 1). The Karakaya Lamprophyres are classified as basaltic-trachyandesite and trachyandesite on a Total Alkalies vs. Silica (TAS) classification diagram and exhibit alkaline characteristic (figure 3).

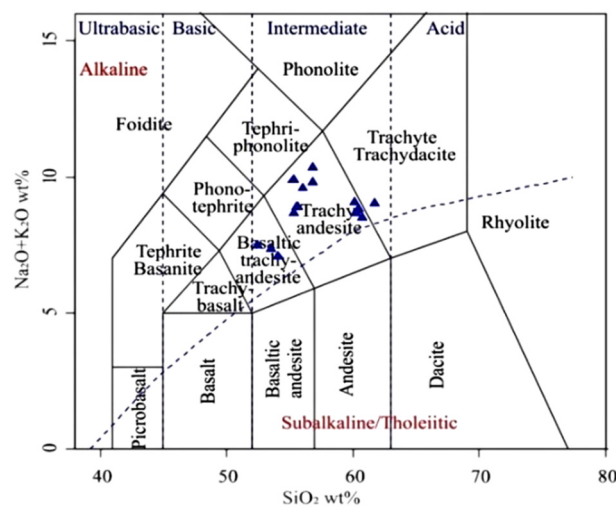
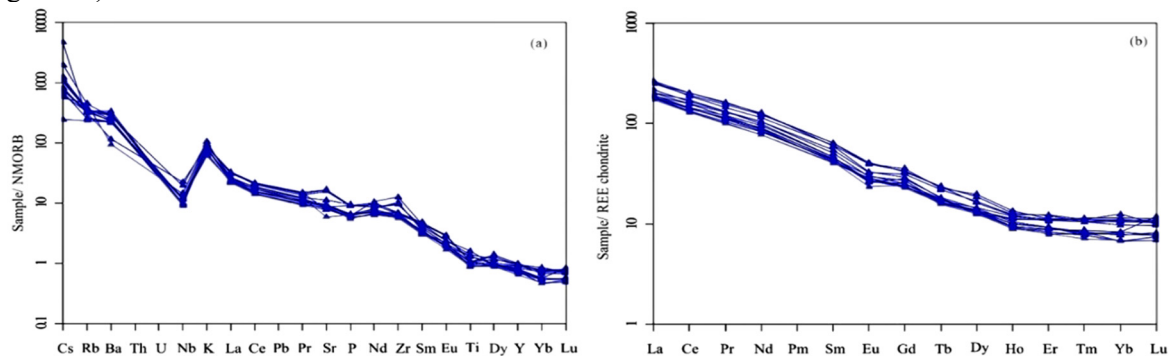


Figure 3. Total alkalis vs. SiO_2 diagram for the Karakaya Lamprophyres [20]

Table 1. Representative whole-rock major (wt %) and trace element (ppm) data for samples of Karakaya lamprophyres

Sample No	ISC 3	ISC 12	ISC 14	ISC 15	ISC 25	ISC 33	ISC 34	ISC 7	ISC 16	ISC 20	ISC 22	ISC 23	ISC 24	ISC 35	ISC 37
SiO ₂	53.1	53.82	53.86	53.61	52.8	50.46	52.28	55.43	59.33	59.4	58.28	60	59.81	54.35	54.15
TiO ₂	1.67	1.34	1.32	1.35	1.2	1.32	1.3	1.64	1.11	1.12	1.15	1.09	1.12	2.01	1.73
Al ₂ O ₃	11.65	13.19	13.22	13.17	14.52	14.08	14.89	11.25	14.31	14.49	14.49	14.82	14.24	12.62	13.48
Fe ₂ O ₃	6.16	7.11	7.21	7.36	7.25	7.28	7.2	6.43	5.05	4.95	5.23	5.14	5.08	6.48	7.66
MnO	0.1	0.12	0.13	0.13	0.11	0.12	0.12	0.1	0.07	0.09	0.05	0.06	0.08	0.1	0.12
MgO	7.85	5.14	5.38	4.98	7.88	8.5	6.83	8.92	3.09	3.36	3.4	2.64	3.72	5.13	3.91
CaO	6.3	7.37	7.68	7.26	6.76	6.75	7.52	4.46	5.27	5.39	5.88	4.77	5.08	5.75	5.89
Na ₂ O	1.69	2.07	2.04	2.08	2.5	2.31	2.65	1.6	2.66	2.69	2.66	2.86	2.68	2.89	2.14
K ₂ O	7.52	6.37	6.26	6.34	4.41	4.84	4.52	7.71	6.02	5.93	5.95	5.84	5.93	6.71	6.98
P ₂ O ₅	0.74	1.04	1.05	1.07	0.64	0.69	0.67	1.07	0.76	0.72	0.77	0.74	0.74	0.72	1.11
LOI	2.7	1.8	1.2	2	1.4	3.1	1.5	0.8	1.9	1.4	1.7	1.6	1	2.7	2.1
SUM	99.65	99.38	99.41	99.4	99.58	99.57	99.57	99.49	99.56	99.57	99.56	99.57	99.54	99.57	99.42
Ba	593	2157	1934	1988	1355	1435	1428	1749	1420	1456	1498	1470	1573	724	1794
Cs	13.9	5.6	4.4	8.8	4.9	32.7	1.7	4	7.3	8.2	5.3	7.8	8.5	5.9	5.3
Nb	33.6	21.8	21.3	22.5	27.1	28.8	27.2	45.4	21.7	21.3	22.8	22.9	23.6	52.5	26.9
Sr	527.4	1484.3	1428	1506.5	759.3	699.6	770.1	764.9	855.1	806.9	803.5	830.6	846	702.4	1005.4
Zr	754.9	496.9	490	513.4	414.7	452.5	421.5	722.5	455.5	436.1	449.5	453.2	493.6	941.4	701.1
Y	21.8	26.5	27.5	27.6	25.1	23.3	25.3	21.1	20.9	18	19.4	20.6	20.1	22.8	26.6
La	63.2	82.7	81.4	77.9	57	54	56	58.7	59.3	56.8	59.6	57.6	63	78.6	67.9
Ce	138.5	163.9	151.4	156	107.7	104.9	106.8	126.9	115.9	115.2	117	114.6	128.6	163.2	135.6
Pr	16.14	19.9	17.69	18.76	12.72	12.12	12.26	15.73	14.67	13.79	13.48	14.05	14.42	19.73	16.17
Nd	59.7	75.2	68.9	73.5	49.4	46.4	46.3	62.5	57.3	52.5	50.5	53.9	53.2	76.8	63.2
Sm	9.15	12.55	11.83	12.54	8.37	7.85	8.01	9.93	9.12	8.09	8.5	8.67	8.73	11.63	10.66
Eu	1.94	3	2.93	2.89	1.98	2.1	2.09	2.17	1.98	1.73	1.98	1.91	2.23	2.42	2.39
Gd	7.32	8.57	9.27	8.68	6.05	5.9	6.23	6.98	6.23	6.18	6.02	6.54	6.5	7.53	8.15
Tb	0.86	1.12	1.07	1.12	0.8	0.77	0.77	0.78	0.75	0.74	0.83	0.78	0.83	0.85	1.03
Dy	4.57	5.96	6.37	5.21	4.66	4.35	4.15	4.44	4.27	4.06	3.99	4.36	4.23	4.21	5.37
Ho	0.75	0.92	0.97	0.87	0.86	0.81	0.8	0.71	0.72	0.64	0.67	0.68	0.66	0.64	0.89
Er	1.93	2.56	2.38	2.31	2.22	2.26	2.31	1.95	1.95	1.69	1.64	1.88	1.73	1.85	2.59
Tm	0.27	0.34	0.36	0.36	0.37	0.34	0.34	0.26	0.25	0.23	0.26	0.27	0.25	0.28	0.36
Yb	1.6	2.04	2.21	2.25	2.38	2.17	2.3	0.04	1.4	1.43	1.63	1.4	1.73	1.74	2.62
Lu	0.26	0.31	0.33	0.35	0.36	0.33	0.34	<0.02	0.22	0.22	0.25	0.24	0.38	0.25	0.32

Mid-ocean ridge basalt (MORB) normalized multi-element patterns display especially significant enrichment in large-ion lithophile elements (LILEs) (Ba, Rb, and Th) and depletions in some of high field-strength elements (HFSEs) (Ti, Y, Yb etc.) (figure 4a) Based on the spider diagrams for Karakaya Lamprophyres, all of the samples show more enrichment in LREE relative to the HREE (figure 4b).

**Figure 4 a)** MORB normalized multi-element patterns for the Karakaya Lamprophyres; **b)** Chondrite normalized REE patterns of the Karakaya Lamprophyres

The samples analyzed in this research plot in the field of alkaline lamprophyres in the ternary diagram Al_2O_3 - MgO - CaO (figure 5a). Similarly, their trace element data classification diagram indicate that they fall within the alkaline lamprophyres (figure 5b).

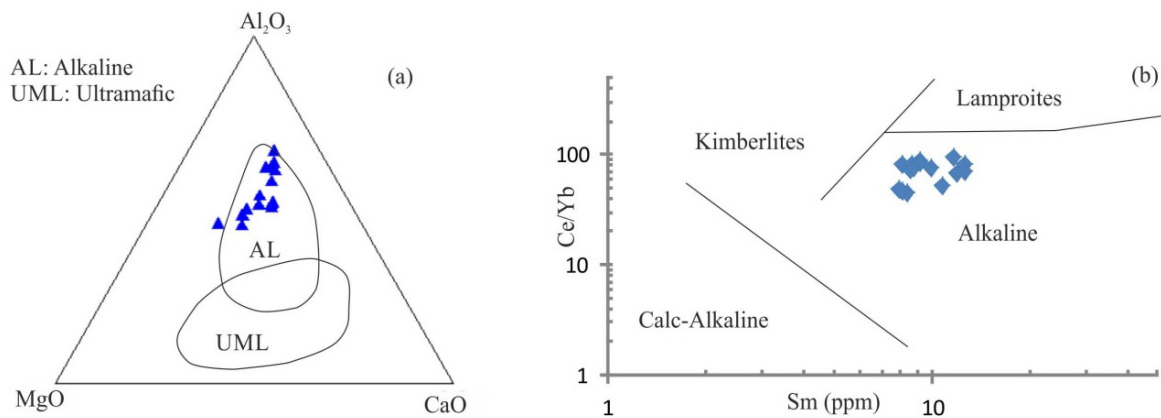


Figure 5 a) Ternary diagram Al_2O_3 - MgO - CaO for Afyon lamprophyres [3]; **b)** Classification of lamprophyres by whole rock chemistry [3]

5. Conclusions

Based on the all petrography and geochemistry, the studied lamprophyres are considered to belong to the alkaline lamprophyre group, in general. These rocks appear to be derived from fractional crystallization of a magma mixing which formed by melting of the continental crust with effect of the uprising lithospheric mantle during in an extensional tectonic regime after the Middle Miocene.

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