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GEOLOGY AND GEOCHEMISTRY OF THE KARADAĞ VOLCANIC SUCCESSION, POLIOCENE - QUATERNARY, CENTRAL ANATOLIA, TURKEY

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ABSTRACT

The Karadağ volcanic succession of Pliocene and Quaternary represents typical continental volcanisms of central Anatolia. It consists of mainly lava flows and pyroclastic deposits. Overall, they were produced by magmato-phreatic explosions in four periods through the pliocene and Quaternay times. The product of each period can be easily distinguished by weathering surfaces and locally eroded surfaces. Petrographical and geochemical analysis show that they are mostly andesitic and dacitic rocks, originated from partial melting of continental crust.

INTRODUCTION

The volcanic activity, developed in Anatolia (Turkey) during Neogene and Quaternary periods represents one of the most outstanding examples of arc volcanism, related to continental collision (Pasquare et al., 1988), and it has been investigated in several previous works, mainly dealing with its petrographical characteristics (e.g. Jung and Keller, 1972; Innocenti et al., 1975; Keller et al., 1977; Baseng et al., 1977; Baş, 1985; Tankut, 1985). In few studies, this volcanism from stratigraphical and tectonical points of view were discussed (Savaşçın, 1982; Ercan, 1983; Pasquare et al., 1968). The main difficulty to explain the volcanic evolution of Anatolia is the lack of a complete volcanic succession developed during Neogene and Quaternary. Volcanic fields are quite away from each other. Additionally, characteristics and products of volcanism differ from area to area. There is only one locality in Anatolia, where volcanism of Neogene and Quaternary were superimposedly developed: Karadağ volcanic succession, which is described in this paper. It provides a unique axemple in order to examine the complete volcanic activities of these times. Generally, it is thought that the volcanism has been related to moving of Afro-Arabian plate to the northward direction.

In this paper, the Pilocene and Quaternary volcanic evolution in Konya-Karaman region (central Anatolia, Turkey) is reported, with particular reference to the stıatigraphy and geochemical analysis of Karadağ volcanic succession.

THE KARADAĞ VOLCANIC SUCCESSION

The Karadağ volcanic succession, situated in the northwest of Karaman city, covers an area of approximately 600 km^2. It rests on alluvial sediments and fresh-water carbonates of Miocene, howerer, it is largely underlain by Upper Jurassic and Lower Cretaceous limestones (Birand, 1950; Koç and Kılıç, 1987). Recent alluvium and soils locally superimpose the volcanic wits.

The Karadağ volcanic succession forms an important topographic relief in the large Konya-Karaman plain. The elevations are 1100 m at the plain and 2288 m at the highest point. Deep recent valleys, incised the succession radially, provide good cross-sections. Overall, the Karadağ volcanic succession consists of four volcanic sequences (VS), each of which represents separate volcanic periods (Fig. 1 and 2). The volcanic sequences are distinguished from each other by plaeosoil layers and/or intensely weathered surfaces. Erosive surfaces are locally developed. In general, the volcanic sequences are two-partite, comprising volcaniclastic and lava units. They are described below separately.

Volcanic Sequence 1 (Mercik Sequence):

This is the basal sequence which is situated in Mercik area, some 3 km for away from the volcanic body. It has a core-like geometry and represents monogenic volcanic center. This sequence consists of mainly lava flows and subordinate pyroclastics. Units of lava flows are 1 to 3 m thick. Microscopically, they comprise some phenocrists of plagioclase, biotite and hornblende in a porphyric texture. According to radiometric dating of Besang et al., (1977) lavas emplaced 3, 2 Ma ago. Probably, it cocurred with effusive explosions. The other volcanic centers might be capped by later explosions.

Volcanic Sequence 2 (Sızak Sequence):

This is one of the main sequences of the Karadağ volcanic succession. It emplaced largely in NE side of the sucession, around Sızak, Kar-

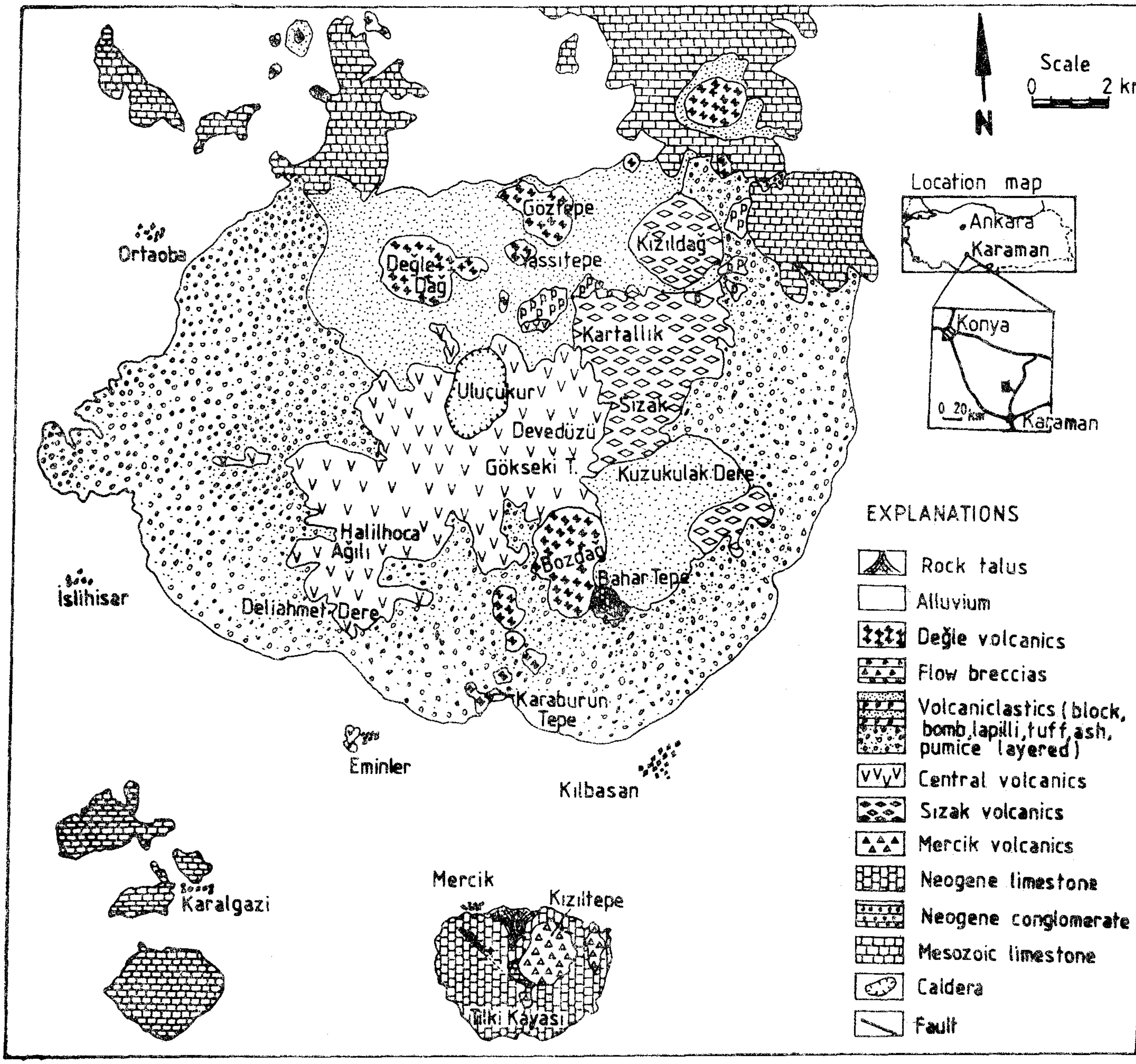

Fig 1. Geological map of the Karadağ area.

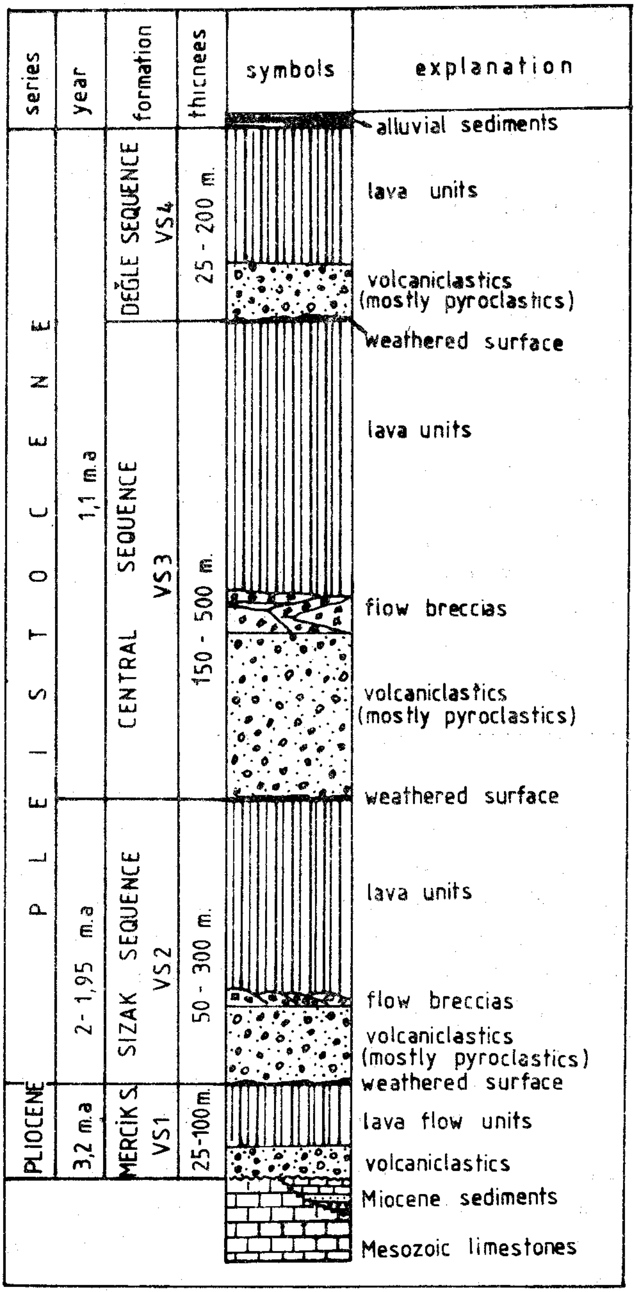

Fig. 2. Generalized columnar section of the Karadağ volkanic succession.

tallıkdağ and Kızıldağ areas. Volcanic sequence 2 is composed of at least three monogenic centers which have two subsequences as volcaniclastics in its lower section and lawa flows in its upper section.

Stratigraphically, the lowermost part of the first subsequence is composed of pumice-rich deposits, which indicates sedimentary structures of bare surge deposits. Pumice layers are also included. There, relatively finer-grained layers are overlain by very thick, up to 100 m. block-and-ash flow deposits. Average size of blocks is 45 cm. Welding is locally present. All pyroclastics are superimposed and/or interfingered by reworked pyroclastic deposits, such as lahars and volcanic mudflows. Thicknesses of the reworked pyıoclastic units increase relatively towards the flanks of the VS2.

The second subsequence of VS2 is lava flows with assymetric dome-like geometries. Units of the subsequence, 1 to 3 m thick, are inclined towards the south, probably due to original topography. Unit thicknesses decrease also in the same direction dating indicates that they emplaced within 2.05–1.95 Ma ago (Besang et al., 1977). Petrographically, lava flow units are composed of augitehornblende-biotite types of andesite.

Volcanic Sequence 3 (Merkez Sequence):

Rocks of this sequence form the main body of the succession, emplacing in the central areas, particularly around Bahar Tepe and Bozdağ. Rock facies and their stratigraphical pattern are similar to VS2, however, volcaniclastics are much more spreaded than VS2's. Pyroclastic surge deposits are typical at the base of the sequence, and they pass laterally and vertically into pyroclastic flow deposits. Pumice-rich and ignimbritic layers are interbedded with coarse-grained, pıobably block-and-ash flow units. Non-erosional to erosional bases of coarse-grained beds and irregularities in bed geometries suggest that block-and-ash flow units had been deposited as mass flows.

Vertically, pyroclastic units grade up to the flow breccias in addition to lava flows. Lawa flow thicknesses reach occasionally up to 5.8 m. Breccias are very coarse-grained and mean size of individual grains is 35 cm in diameter. Lava flow units are in homogene texture, however, flowage structures are locally observed. Radiometric dating of Besang et al., (1977) indicated they occurred 1.1 Ma ago.

Volcanic Sequence 4 (Degle Sequence):

This is the youngest sequence of the Karadağ volcanic succession, mostly situated in SW of VS3, around Bozdağ and Değle dağ. It includes some dome-like relief, suggesting monogenic volcanic centers.

Pyroclastic units of the sequence are dominantly fine-grained, and locally welded. They are covered by flow breccias and lava flows. The lava units have radial distribution with inclination sometimes up to 45°.

VS4 is not only the youngest sequence, but also the highest level of the Karadağ volcanic succession, creating pictoresque morphology due to modern erosion. According to stratigraphic position, lava lows of the sequence (SS4) emplaced at the end of Pleistocene time.

Overall, the four volcanic sequences seem to have been formed by magmatophreatic eruptions, containing abundantly coarse grained pyroclastics. Block, cobble and pebble size fragments are volumetrically dominated with the sequences, Neogene volcaniclastics of central Anatolia, which occurred near and/or in lacustrine environments are relatively finer-grained resulted by phreatic explosions, as tuff or igrimbrites of Ürgütp-Göreme area. Consequently, this type of volcanism might to be related to Neogene pleogeography of central Anatolia.

GEOCHEMISTRY

Petrographically, the rocks of the Karadağ volcanic succession have rather homogeneous composition. In particular, autoclastics and lava flow units of the four sequences are composed of andesite and dacite. Totally 21 rock samples (Tab. 1), collected from the lava units and flow breccias, were analyzed and their C.I.P.W. norms was Fe_2O_3/FeO = 0,15 and the results were checked and interpreted by various methods.

As it is seen in Table 2, the rocks of the succession are generally silisium-rich volcanics and their SiO_2 contents are between 59–66 %. According to Pecerillo and Taylor (1975)'s classification, 6 samples are potassium-rich andesites, 12 samples are identified as dacite, 3 samples are andesites (Fig 3). According to another interpretation of this diagram, 7 samples are silisium-rich andesite (SiO_2 = 59–62 %), while the 14 ones are silisium-rich dacite (SiO_2 = 62–66 %), and all of them are in calc- alcaline category. Moreover, according to Streckeisen (1967)'s classification (Fig 4), 17 samples are described as dacite while three are referred to latite-andesite and one sample latite.

Table 1. Location and petrographical description of the studied samples.

Sample No	Location	Volcanic sequence	Rocky Tpe
57	Karaburun Tdpee	VS4	Dacite
58	Deliahmet Dere	VS3	Dacite
63	Kızıltepe	VS1	Dacite
68–a	Kızıltepe (SE of Mercik)	VS1	Dacite
68–b	Kızıltepe (SE of Mercik)	VS1	Dacite
72	Bahar Tepe	VS4	Andesine
74	Kuzukulak Dere	VS2	Dacite
75	Mahlaç Tepe-Ulu Çukur	VS3	Andesite
77	Deve Düzü-Şimşirlik Tepe	VS3	Andesite
78	South of Sızak Tepe	VS2	Andesite
79	Kartallık Tepe-Sivri Tepe	VS2	Dacite
80	East of Değle Dağ	VS4	Dacite
81	Yassı Tepe	VS4	Dacite
82	North of Kartallık Tepe	VS2	Andesite
85–a	Around Bahar Tepe	VS3	Andesite
85	” ” ”	VS3	Andesite
85–d	” ” ”	VS3	Dacite
86–a	” ” ”	VS4	Andesite
90	South of Uluçukur	VS3	Andesite
103	North of Halilhoca Ağılı	VS3	Dacite
104	South of Halilhoca Ağılı	VS3	Dacite

The charges in total alcaline content of the rocks against SiO_2 content are illustrated in Figure 5. Kuro (1966) classifies the rocks into 3 groups as pigeonitic (tholeitic) -, hiperstenic (high Al) - and alcaline rocks by using the above mentioned changes. Except one sample of Karadağ volcanics, all the others are in calcalcaline fields (Fig. 5). The same results are also obtained by using McDonald (1968); and Irwinand Baragar (1971)'s criteria (Fig. 5).

Table 2. Major element analyses and CIPW normes of volcanic rocks.

	Sample No	57	58	63	68	68.c	72	74	75	77	78	79	80	81	82	85.a	85.c	85.d	85.a	90	103	104
MAJOR ELEMENT	SiO_2	63.20	74.00	63.20	64.90	63.30	60.50	62.30	60.00	60.30	60.10	63.50	62.80	66.40	62.00	60.10	62.00	64.30	61.10	59.00	62.20	63.40
	Al_2O_3	15.00	15.00	14.70	14.90	15.00	16.30	16.00	16.50	17.00	15.20	14.50	15.70	15.50	16.50	16.50	15.70	16.10	15.00	17.00	16.30	17.00
	Fe_2O_3	4.11	3.66	4.40	3.66	2.54	3.97	6.70	5.20	4.43	4.41	3.87	3.13	2.09	5.28	4.41	5.33	2.30	4.40	6.22	4.05	4.15
	FeO	1.29	1.94	0.50	1.44	2.36	2.13	1.00	0.70	2.17	0.89	1.47	1.77	0.91	0.72	1.89	0.57	2.00	1.86	0.58	1.95	0.6
	MgO	2.15	2.86	2.65	2.20	2.07	3.01	2.86	3.72	3.41	3.07	2.32	2.47	1.55	3.30	3.45	3.20	1.87	2.86	3.86	2.54	2.24
	CaO	5.53	5.37	5.72	5.19	5.55	5.55	5.15	5.712	5.83	6.15	5.02	4.49	3.62	5.37	5.67	5.39	4.27	5.72	5.72	5.37	5.22
	Na_2O	3.17	3.38	3.70	3.62	3.70	3.46	3.32	3.45	3.38	3.14	3.46	3.62	3.78	3.34	3.22	3.27	3.62	3.40	3.55	3.74	3.40
	K_2O	2.02	2.36	2.22	2.52	2.46	2.19	2.42	2.86	2.11	2.57	2.73	2.98	2.66	2.16	2.28	2.22	3.13	4.20	2.92	2.60	2.43
	TiO_2	0.50	0.40	0.40	0.50	0.40	0.50	0.50	0.60	0.50	0.50	0.50	0.40	0.30	0.20	0.20	0.30	0.40	0.60	0.30	0.30	0.20
	P_2O_5	0.30	0.30	0.40	0.40	0.20	0.30	0.20	0.40	0.30	0.30	0.30	0.20	0.20	0.50	0.60	0.60	0.40	0.60	0.60	0.50	0.50
	MnO	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	H_2O	1.04	0.48	0.74	0.44	0.36	0.80	0.78	0.66	0.62	1.04	1.02	0.51	0.72	0.44	0.54	0.68	0.40	0.48	0.36	0.60	0.66
CIPW NORMS	IL	0.95	0.76	0.76	0.95	0.76	0.95	0.95	1.14	0.95	0.95	0.95	0.76	0.57	0.38	0.38	0.57	0.57	1.14	0.57	0.57	0.38
	OR	11.94	13.95	13.42	14.89	14.54	12.94	14.30	16.90	12.47	15.19	16.31	17.61	15.72	12.76	13.47	13.12	18.50	24.82	17.25	15.36	14.36
	AB	26.82	28.60	31.31	30.63	31.31	29.28	28.09	29.19	28.60	26.57	29.28	30.63	31.98	28.28	27.24	27.67	30.63	28.77	30.04	31.64	28.77
	AN	20.73	18.79	16.95	16.96	17.06	22.48	21.61	21.09	24.98	19.79	15.97	17.99	17.47	23.65	23.83	21.60	18.44	13.26	21.83	20.01	23.97
	TN	3.72	5.53	8.06	6.19	7.38	3.56	2.78	5.14	2.78	7.55	6.30	3.16	0.34	2.11	3.73	3.62	1.93	10.65	4.62	4.67	1.37
	MT	2.71	5.09	0.45	3.19	3.68	5.42	1.77	0.52	5.54	1.42	3.16	4.54	2.06	1.74	5.38	0.97	3.33	4.26	1.00	5.41	1.39
	HY	1.54	2.05	1.90	1.57	4.95	2.15	2.05	2.66	2.44	2.20	1.66	1.77	1.11	2.36	9.27	2.29	2.61	2.05	2.74	1.82	1.60
	Q	25.79	24.36	22.35	24.12	20.08	19.99	22.40	16.79	19.55	19.91	23.19	20.71	26.01	22.32	16.72	22.76	21.42	15.12	14.78	19.42	22.69
AFM	A	40.73	40.42	43.95	45.68	46.81	38.28	35.21	39.61	35.42	40.55	44.82	47.24	58.60	37.83	36.06	37.62	52.24	45.34	37.83	42.60	45.44
	F	42.38	19.43	36.37	37.94	37.32	341.37	47.24	37.03	42 58	3764	38.37	35.07	27.29	40.54	41.21	40.44	33.28	37.59	39.76	40.32	37.10
	M	16.78	20.14	19.67	16.37	15.20	20.39	17.54	23.35	22.00	21.80	16.79	17.68	14.10	22.29	22.62	21.93	14.47	17.06	22.40	17.07	17.46

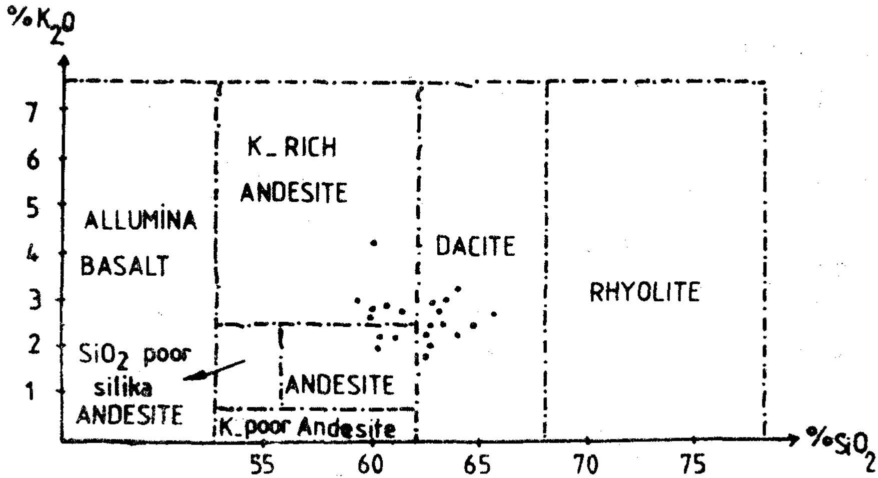

Fig. 3. Classification of the Karadağ volcanic rocks in K_20—$Si0_2$ diagram of Peccerillo and Taylor (1976).

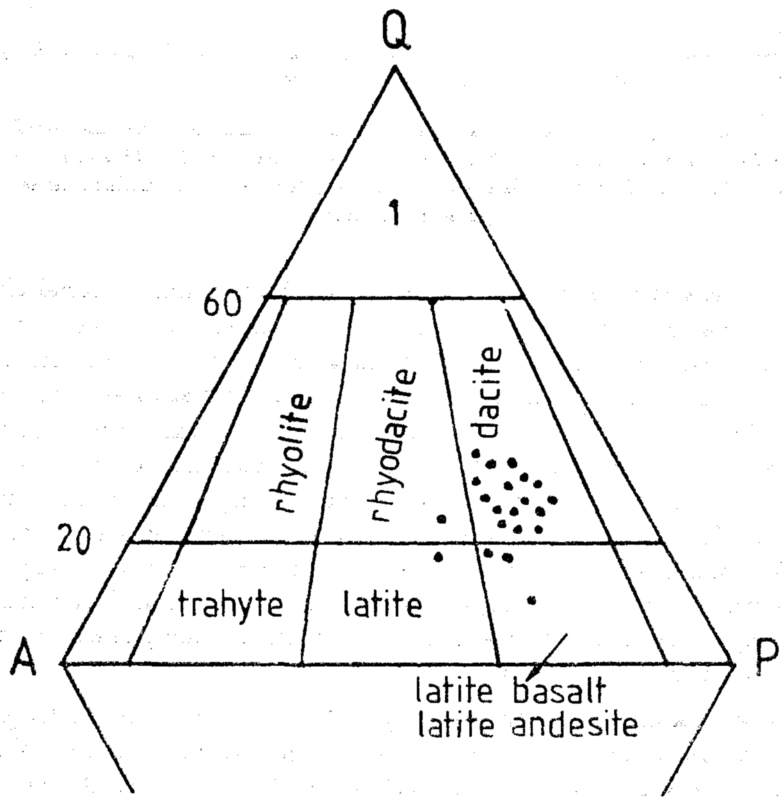

Fig. 4. Classification of the Karadağ volcanic rocks according to Streckeisen (1967).

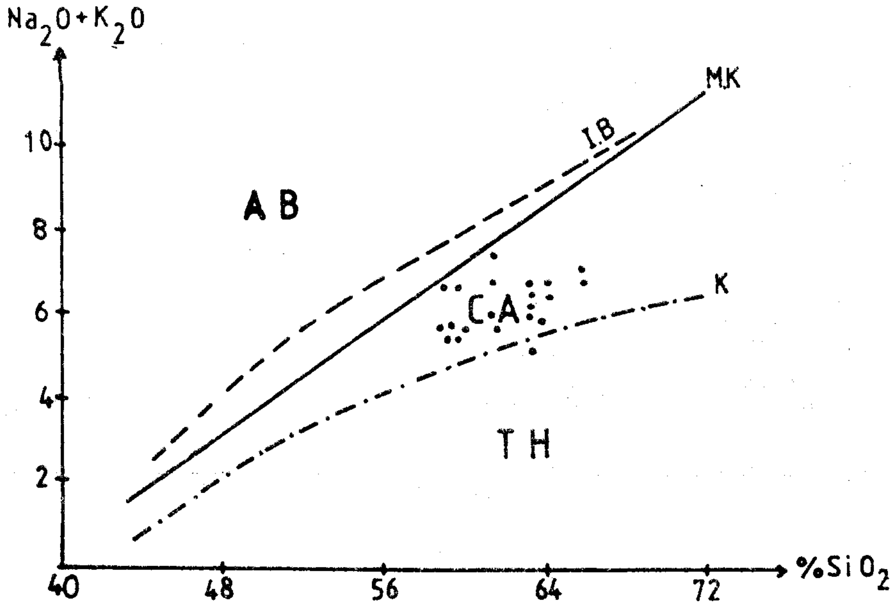

Fig. 5. Alcali—SiO_2 diagram for the samples. The heavy line and the dashed-line classify the alcaline fields (AB) and the subalcaline fields (CA) [After MacDonald, 1968 and Irwine and Baragar, 1971]. The dotted-line classifies also high Al. Series (CA) and tholeitic series (TH) [After Kuno, 1966].

No rock samples of the succession, which are found in subalcaline field of Figure 5, show any increase in the content and hence they are in calcalcaline fields in AFM diagram (Fig. 6). The correlation of normative color index (NCI) and normative plagioglase composition (NPC) [the diagram of Irwin and Baagar (1971)] indicates that the studied samples are grouped on the line of andesite-dacite and particularly 11 samples are referred as dacite and 10 samples on andesite field (Fig. 7). Here, in the Ab'-An-Or triangle diagram, concluded from CIPW normes, all rocks are seen mostly potassic composition (Fig. 8). According to Irwin and Baragar (1911)'s classification based on normative plagioclase composition and Al_2O_2 contents, the samples are mostly in calc-alcaline area (Fig. 9).

The τ values ($\tau = Al_2O_2 - Na_2O / TiO_2$) of rocks are generally greater than 10, hence, they indicate sialic origin (Rittman, 1968). What is more ,the same results is emphazised by the log τ - log δ diagram (Fig. 10).

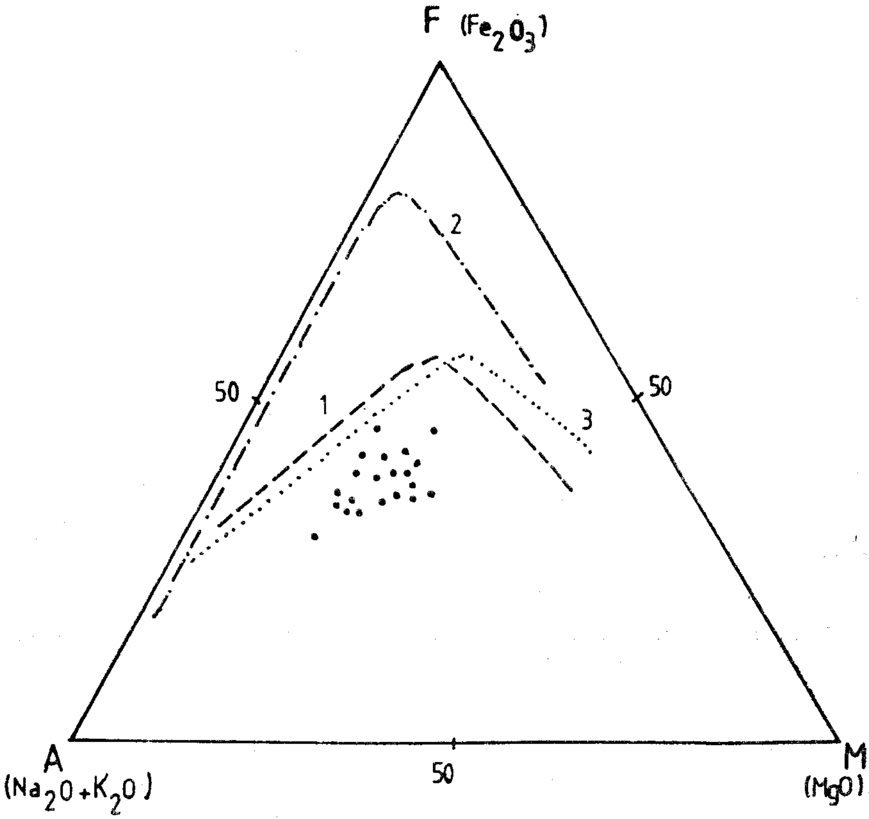

Fig. 6. The AFM triangle diagram of Karadağ volcanics.
Line 1: Division line for tholeitic (upper side) and calcalkaline (lower side) rocks Irwine and Baragar, 1971).
Line 2: Skaergaard Intrusion area [Wager, 1960).
Line 3: Hawaiian alcaline area [MacDonald and Katsura, 1974].

DISCUSSIONS AND CONCLUSIONS

a) Petrogenesis of the Karadağ Volcanics:

From geochemical point of view, the rocks of Karadağ succession have an intermediate acidic calc-alcaline characteristics and they are sialic origin. Adiditionally, some of them are andesite and some are dacite in petrographical definitions. Similar results are also reported by some previous works on the different volcanic areas of Turkey (e.g. Keller and Villari, 1972; Baş, 1979; Ercan, 1983; Terzioğlu, 1986).

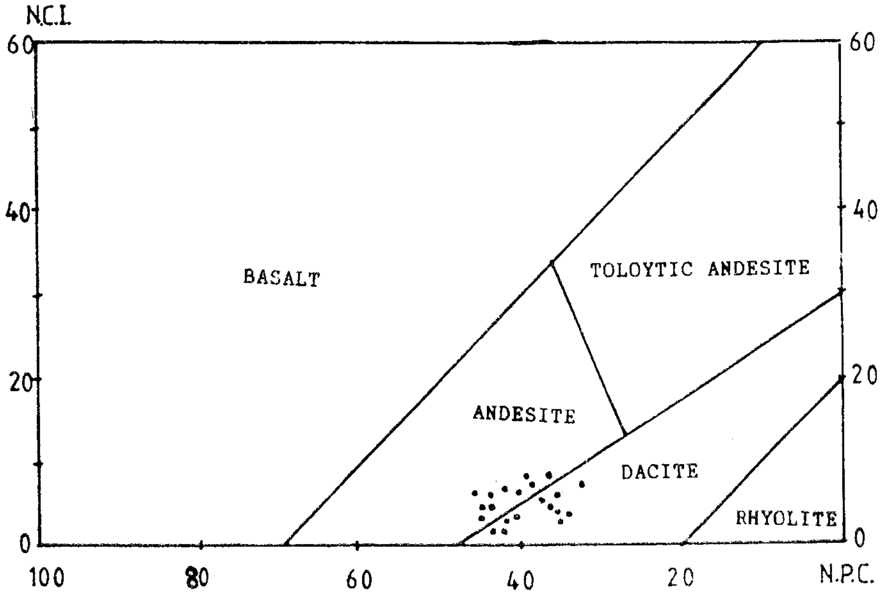

Fig. 7. The distribution of Karadağ volcanic rocks in B.C.I.-N.P.C. diagram plotted according to the diagram of Irwine and Baragar (1971).

Acidic volcanics may be originated by various ways, for example, by the contamination of bacis magma with crustal material (Kuno, 1950) or by differentiation of basic magma (Kuno, 1968), or by anatexis of crustal material (Winkler, 1974), or also by partly melting of upper mantle components in high-water phase (Kuso, 9170). Origin of the Karadağ volcanic rocks seem to be rather complex. Both their mineralogical and geochemical compositions match to crustal rocks (granite, granodiorite). Consequently, this concordance may suggest partial melting of continental crust. On the other hand, presence of lamprophirized Ti-augite minerals within the studied rocks may also indicate a magmatic contamination .However, no basic magmatic rock is observed in hybridisation in the study area. Their presence in the crust may have been masked by the complex tectonic regime, at least since Late Miocene. So far, hybridisation was mentioned for volcanics emplaced in northern part of central Anatolia (Tankut, 1985; Terzioğlu, 1986). Further systematic studies on thin sections are necessary to clarify the view.

b) Volcanic evolution:

On the basis of stratigraphy of the Karadağ volcanic sucession, four main periods can be distinguished in the Pliocene and Quaternary

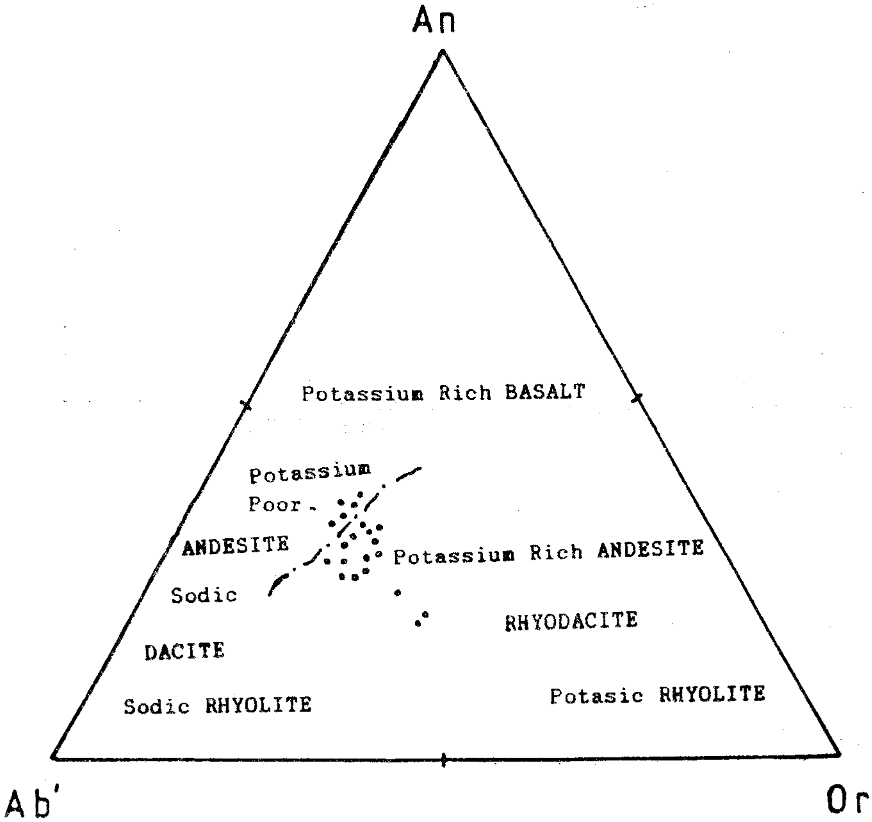

Fig. 8. An-Ab' -Or projections of Karadağ volcanics in Irwine and Baragar (1971) diagram.

volcanic activity of Konya-Karaman region, separated by paleosoil layers and local erosion surfaces Figure 2 illustrates a possible serial evolution of the volcanic activity in this area. The internal stratigraphy of individual sequences are typical with the comprising pyroclastics at the base as explosive products and lava units at the top as effusive products.

The oldest period of volcanism is manily represented by Mercik volcanic sequence (VS1), predominantly formed by lava flows. This period, before 3,2 Ma (Besang et al, 1977), is characterized by mostly effusive activity. It has a mesogenic center placed at the southmost tip of the succession (Fig. 1).

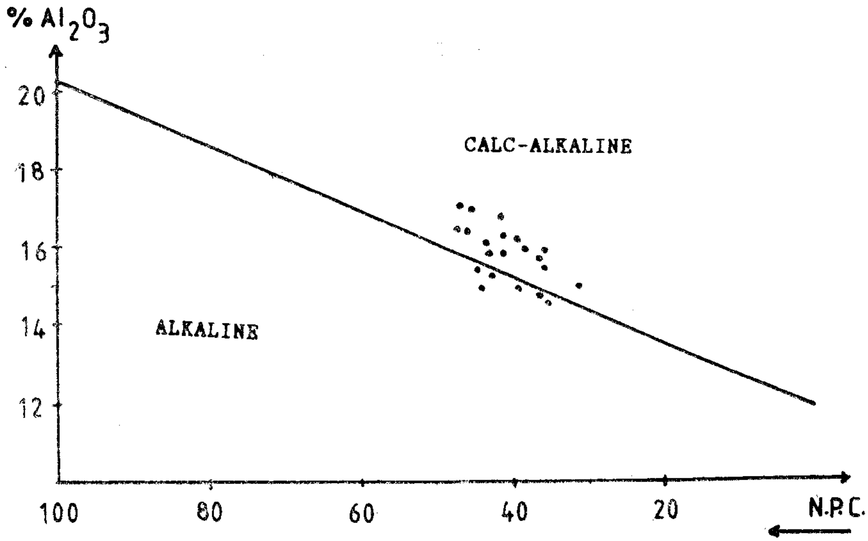

Fig. 9. Plots of wt % Al_2O_3 — normative plagioclase compositions of the Karadağ volcanic succession [Irwine and Baragar, 1971].

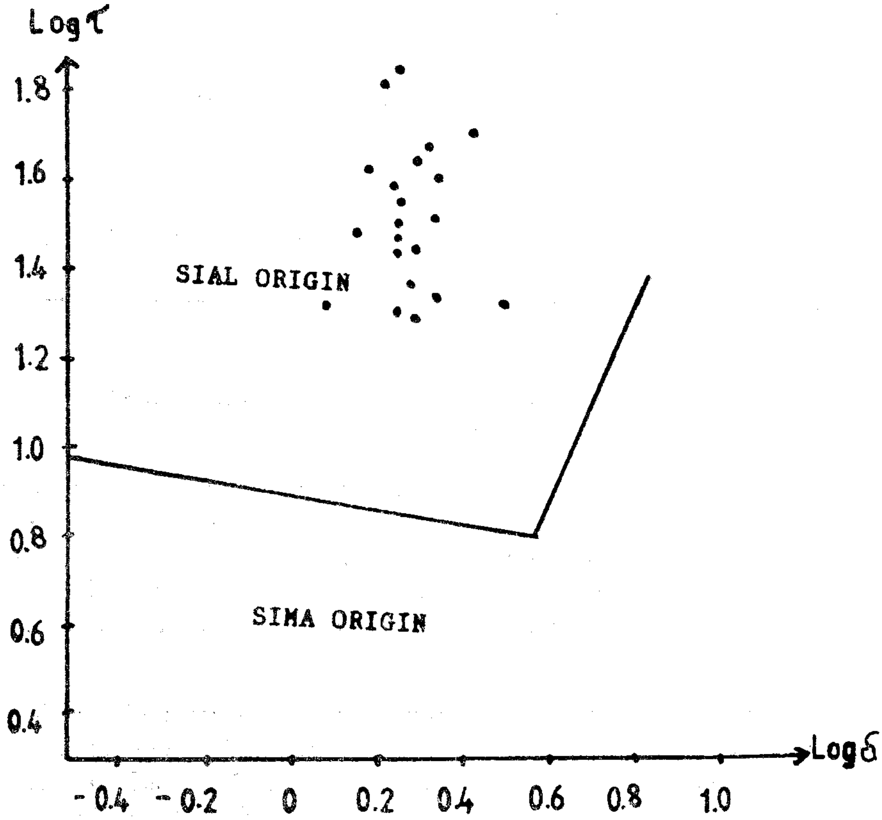

Fig. 10. The Logσ-LogT diagram of Karadağ volcanic rocks.

The second period has occurred about 2,05 to 1,95 Ma ago (Besang et al. 1977). It has mostly explosive characteristics. At least three monogenic centers developed representing present Kartallık dağ, Sızak dağ and Kızıldağ elevations (dağ. in Turkish means hill, mountain) The third period (1,1 Ma ago) was probably the greatest volcanic activity, giving a caldera 2 km long and 1,5 km wide in the Merkez area (Fig. 1). This monogenic center produced mainly pyroclastic deposits (Fig. 2). The last period (late Pleistocene) is represented by the formation of Bozdağ and Değledağ volcanics which include very thick units of lava flows and flow breccias. The volcanics of this period were produced by at least two monogenic centers at the northern side of the sucession (Fig. 1).

Begginning of the volcanic activity in Konya - Karaman region should be related to geological setting of the central Anatolia, possibly collision of Afro-Arabian plate and Anatolian plate (Pasquare et al, 1988). However, its evolution varies locally. The characteristics of the Karadağ volcanic succession is the presence of large lava flow units (Fig. 2). During each period, pyroclastic deposits were predominantly produced by explosive activities, and then lava emplaced. This sequential development suggests that volcanic activity of each period has been extinguished in time and resumed in the next period. We suggest that this two-partite stratigraphy and /or extinction of volcanism might be related to not only regional tectonics, but also to paleogeography. In areas of central Anatolia where pyroclastics are common deposits, syncronous lacustine deposits are also widespread and volcanism seems to have been influenced by large Neogene lakes. The lack of Plio-quaternary lacustine environment around the study area (Fig. 1). suggests effusive magmatophreatic eruptions giving thick lava units.

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