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Geochemistry of Ankara Volcanics and the Implications of Their K-Ar Dates on the Cenozoic Stratigraphy of Central Turkey

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Abstract: The central Ankara volcanics are composed of intermediate-acid, calc-alkaline andesites and dacites. Published K-Ar determinations give a middle-to-late Eocene age, demonstrating the post collisional setting of the volcanics after closure of the northern branch of Neotethys in the early Eocene. The regional stratigraphy requires a revision due to the inconsistency between previous field studies and age determinations.

Introduction

İzmir Ankara suture zone is considered to be lithospheric remnants of the northern branch of Neotethys which started to close along a north dipping subduction zone in the late Cretaceous. Collision took place during Palaeocene to early Eocene (Şengör and Yılmaz 1981). The central Ankara volcanics are located on this suture zone (Figure 1) and the distribution of regional Tertiary volcanic activiy, which is divided into intermediate-acid calc-alkaline and basic alkaline groups, can be observed on the Köroğlu (Galatia) complex to the North, Sincan area to the West and Elmadağ to the South (Tankut 1985; Tankut et al. 1990).

The petrography of the central Ankara volcanics was studied by Büyükönal (1971). In this paper, we will describe the geochemical characteristics of these volcanics, and discuss their geological setting and the implications of the published K-Ar ages (Ach 1982; Ach & Wilson 1986) for the regional stratigraphy.

Geological setting

The central Ankara volcanics are located around Hüseyin Gazi Tepe, Altındağ, Yenimahalle, Etlik Dağı, Bağlum and Tatlar (Figure 2). A summary of earlier studies discussed in Büyükönal (1971) presents three conflicting views regarding the age of the volcanics: (i) post-Cretaceous-pre-Neogene (Paleogene), (ii) Eocene-Late Neogene, and (iii) Neogene.

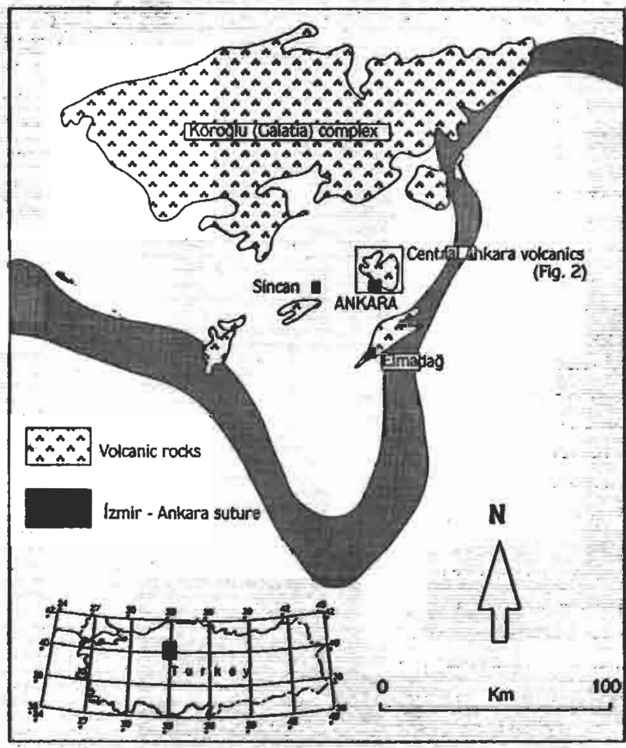

Figure 1. Regional distribution of Tertiary volcanics around Ankara (After Tankut et al. 1990; Trace of the suture zone from Görür et al. 1984).

More recent regional geological studies (Çalgın et al. 1973, Akyürek et al. 1984) of the central Ankara

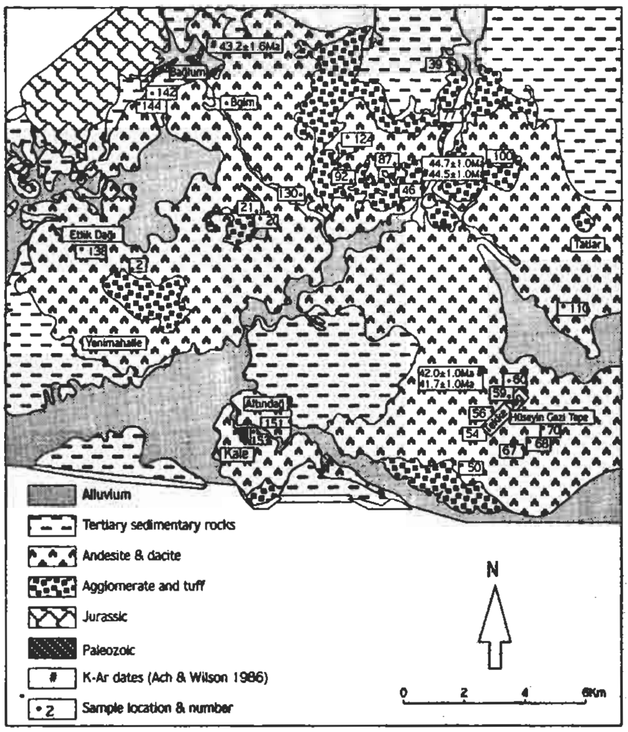

Figure 2. Sample location map (After Büyükönal 1971).

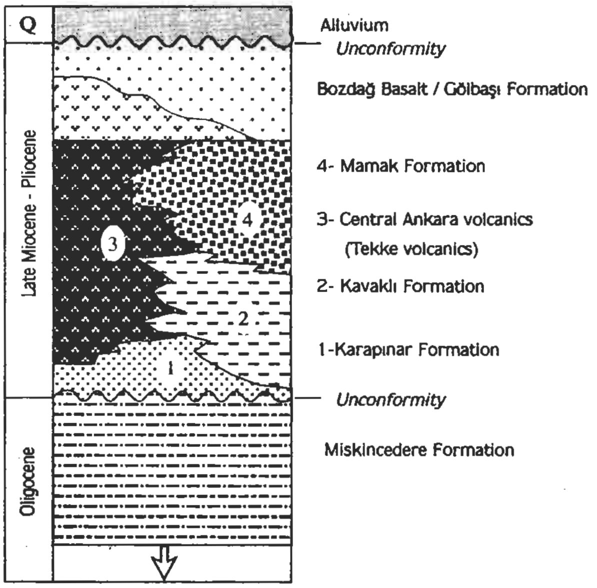

Figure 3. The relationship between central Ankara volcanics and sedimentary rocks according to Akyürek et al. (1984). Note that K-Ar dating of the volcanics (Ach 1982; Ach & Wilson 1986) provides an older age (Middle-late Eocene).

volcanics suggest an age of Neogene (Middle-Late Miocene). Akyürek et al. (1984) mapped the area in considerable detail, and their stratigraphical column suggested that the central Ankara volcanics (Tekke volcanics) are late Miocene in age and interfinger with alluvial fan deposits (Karapınar Fm.), fluvio-lacustrine deposits (Kavaklı Fm.), and agglomerates (Mamak Fm.) (Figure 3). On the other hand, a K-Ar age determination from the Bağlum sample gave 42.0 ± 1.6 Ma (Ach 1982). This date was confirmed by further analyses (Ach and Wilson 1986) that provide an age range of middle-to- late Eocene (38.8 ± 1.2 to 44.7 ± 1.0 Ma) from four samples and two minerals (biotite and hornblende) (see sample locations of Figure 2).

Petrography

The central Ankara volcanics are mainly composed of red, grey, light brown and green lavas, tuffs and agglomerates. The agglomerates interfinger with the tuff beds. Samples from the central Ankara volcanics are divided into six different groups according to their mafic mineral content under the microscope. These are: 1-biotite andesites, 2-hornblende andesites, 3-biotite augite andesites, 4-hornblende biotite andesites, 5-hornblende augite andesites, 6-hornblende biotite augite andesites (Büyükönal 1971). Their texture is essentially pilotaxitic and hyalopilitic. The phenocrysts in the rock samples are usually very large (feldspar: 1.5 to 2mm). In many samples, feldspar, hornblende, biotite, and augite phenocrysts exist in accordance with the degree of participation of the mineral composition in the sample. Augite crystals are quite rare but of considerable size. The major part of the microlites in the groundmass are feldspar and augite crystals and the minor part is made of other mafics. Almost all mafic minerals have been subjected to magmatic resorption and alteration, some have been chloritized, and some augite crystals have been uralitized (Büyükönal 1971).

The majority of feldspars containing abundant apatite and mafic inclusions show zoning and wavy extinction. The An % of plagioclase crystals were determined either by the Michel-Levy method or by the law of Albite-Karlsbad twins. The An % of plagioclase phenocrysts and plagioclase microlites ranges between $An_{25\text{-}27}$ and $An_{27\text{-}35}$, respectively. In some samples, 2V values were determined between (-76) and (-86) by using the U-stage. Albite and Karlsbad twins or their combination are more common in plagioclase than pericline twins. Apatite can be seen as an accessory mineral with zircon, magnetite and pyrite. As secondary minerals, quartz, fibrous-radial calcedony and zeolites have been found. Primary quartz is very minor and shows magmatic corrosion (Büyükönal 1971).

Geochemistry

Of a total of 26 samples, 25 were analyzed by XRF at Oxford an Keele Universities and one sample (Bglm) was analyzed at Leicester University. Sample locations are shown in Figure 2, and the results are presented in Table 1. SiO_2 values range from 52-79 wt%. These data are plotted on a total alkali vs. silica diagram (TAS, Le Bas et al. 1986) with the sub-alkaline-alkaline dividing line of Miyashiro (1978) to

Table 1. Chemical analyses of central Ankara volcanics.

	2	20	21	39	46	50	54	56	59	60	67	70	110
SiO_2	69.43	67.96	66.90	63.90	60.50	61.70	59.88	63.14	60.46	62.20	63.54	67.23	70.28
TiO_2	0.61	1.06	0.99	0.90	0.77	0.92	0.78	1.05	0.88	1.13	1.45	0.41	0.92
Al_2O_3	13.57	15.72	16.84	12.78	16.31	16.53	17.09	16.63	16.87	16.84	17.20	16.02	18.45
FeO	0.87	0.53	0.30	2.34	2.15	2.77	2.81	1.66	2.80	1.67	1.55	0.31	0.30
Fe_2O_3	2.11	2.56	2.49	2.40	2.27	2.42	2.28	2.55	2.38	2.63	2.95	1.91	0.90
MnO	0.01	0.08	0.11	0.07	0.08	0.09	0.09	0.04	0.08	0.08	0.09	0.08	0.01
MgO	2.39	1.51	0.64	0.99	3.74	1.88	3.81	1.78	2.49	2.18	0.90	1.26	0.64
CaO	2.75	3.00	3.02	4.98	4.56	4.98	4.68	4.35	5.31	5.13	4.00	2.73	0.59
Na_2O	3.00	3.55	3.29	4.13	3.07	3.82	3.20	3.77	3.77	3.18	4.03	4.28	3.42
K_2O	3.26	2.99	2.98	2.43	2.58	2.62	2.49	2.26	2.72	2.18	1.14	2.90	3.18
P_2O_5	0.18	0.19	0.14	0.23	0.33	0.27	0.30	0.24	0.29	0.29	0.27	0.09	0.08
LOI	4.0	1.02	3.02	4.00	3.18	2.60	2.27	2.40	1.81	2.13	3.50	2.69	1.18
Total	99.98	100.1	100.7	99.15	99.54	100.6	99.68	99.67	99.86	99.64	100.6	99.91	99.95
Rb	62.8	71.7	66.4	38.7	38.7	52.9	65.6	59.6	60.5	59.8	63.3	100	84.8
Ba	448.8	512.2	470.6	390.1	590.1	550.9	547.4	576	544.6	578.5	689.3	510.4	490.5
Sr	373.7	316.2	368.8	428.4	428.4	517	515.8	483.5	541.3	540.4	444.5	279.8	257.5
Zr	132.4	144.2	142.8	121.6	121.6	139.4	136.2	154.8	124	145.7	168.3	167.4	150.5
Y	15.6	14.8	18.8	14.9	14.9	19.9	22.2	20.6	21.6	22.9	27.3	14.1	233.2
Nb	15.1	21.7	23.7	17.3	17.3	16.2	17.8	19.9	18.6	20.2	20.7	14.7	22.4

	Bglm	68	77	87	92	100	124	130	138	142	144	151	153
SiO_2	66.34	62.05	61.64	58.86	67.49	63.68	66.45	63.82	66.84	52.19	60.99	67.51	67.71
TiO_2	0.89	0.89	0.99	1.30	0.74	0.62	0.60	0.87	0.65	0.85	0.72	0.93	0.92
Al_2O_3	17.16	16.68	17.00	17.31	15.44	14.93	16.07	16.34	16.32	19.57	15.46	14.96	15.49
Fe_2O_3	4.56	5.25	5.16	6.90.	4.85	4.43	4.18	5.14	4.25	8.12	5.68	4.21	3.89
MnO	0.026	0.11	0.07	0.12	0.03	0.10	0.01	0.04	0.05	0.12	0.04	0.03	0.01
MgO	1.54	2.19	1.73	1.80	0.51	1.97	0.79	1.24	0.62	6.27	3.83	1.43	0.47
CaO	4.13	4.94	6.10	5.67	3.50	3.95	3.84	4.00	4.00	5.23	5.69	2.88	2.85
Na_2O	3.63	3.56	4.04	3.54	3.38	3.69	3.92	3.55	4.01	3.18	3.55	3.58	3.85
K_2O	3.90	2.63	2.19	3.36	2.55	2.59	3.82	2.83	2.87	3.84	2.26	2.98	2.95
P_2O_5	0.21	0.29	0.29	0.38	0.22	0.19	0.19	0.24	0.20	0.31	0.24	0.16	0.16
LOI	1.82	1.58	1.41	2.15	1.07	3.05	1.02	1.67	0.95	0.99	1.80	1.32	1.28
Total	100.7	100.1	100.6	100.3	99.38	99.20	99.90	99.75	100.7	100.6	100.2	99.58	99.18
Rb	57	79	53	62	66	63	82	73	78	63	59	84	80
Sr	-	494	590	530	384	402	430	390	430	389	481	315	319
Zr	135	145	143	149	123	129	132	141	148	126	122	129	134
Y	15	18	21	20	18	15	11	18	18	20	14	18	17
Th	13	9	10	9	10	12	15	13	13	13	6	15	15
Nb	14	15	16	20	13	14	13	14	16	15	13	15	16
Ni	40	33	22	22	26	66	48	16	32	34	153	44	34
Cu	13	18	18	26	14	16	15	22	16	18	35	16	14
Cr	8	107	104	120	149	226	188	92	159	209	328	119	123
Zn	47	56	58	71	43	53	49	70	52	54	61	58	55
Pb	17	25	21	32	14	20	22	15	22	19	15	16	16
V	152	104	112	144	65	72	79	86	71	41	66	68	74
Ba	328												
La	26												
Ce	46												
Nd	13												
Mo	3												
Sn	2												
As	24												
Ga	18												
Co	23												

obtain name and character (Figure 4). The subalkaline data (except for sample 142) are also plotted on an AFM diagram with the dividing line of Irvine and Baragar (1971) to differentiate between tholeiitic and calc-alkaline suites (Figure 5). The diagrams demonstrate that the central Ankara volcanics have calc-alkaline character. The K_2O vs. SiO_2 diagram of Peccerillo and Taylor (1976) is also used for comparative purposes. Except for sample 142, all data fall into calc-alkaline and high-K calc-alkaline fields (Figure 6). The trace element patterns of the central Ankara volcanics display spikes at Th, K, Rb and troughs at Nb, Ti (Figure 7). In the Th-Hf/3-Ta discrimination di-

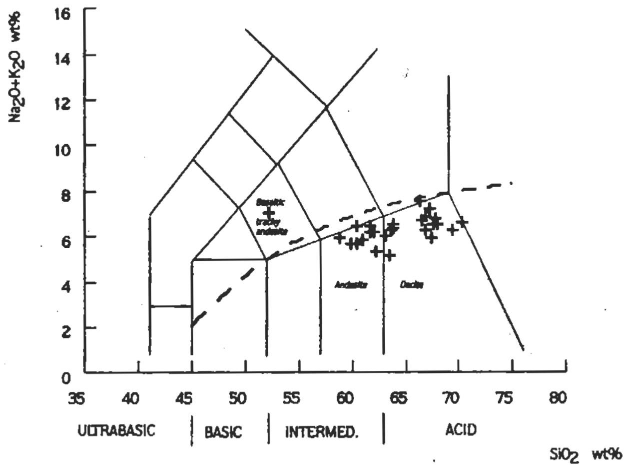

Figure 4. TAS diagram (Le Bas et al. 1986) of central Ankara volcanics with the subalkaline-alkaline dividing line of Miyashiro (1978).

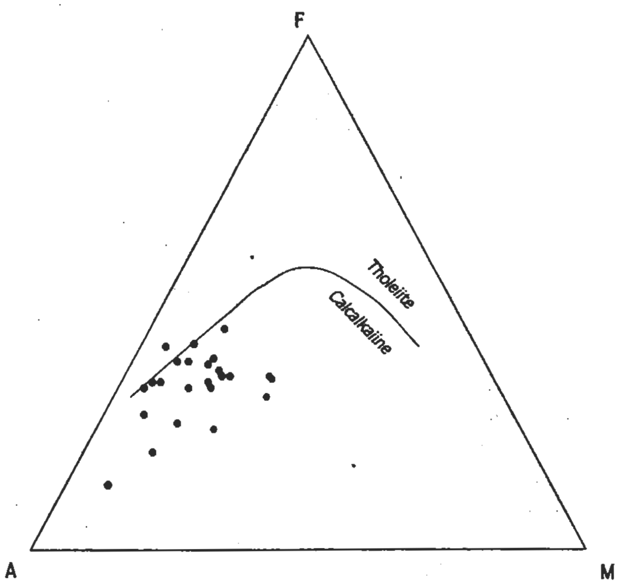

Figure 5. AFM diagram of central Ankara volcanics with the dividing line of Irvine and Baragar (1971).

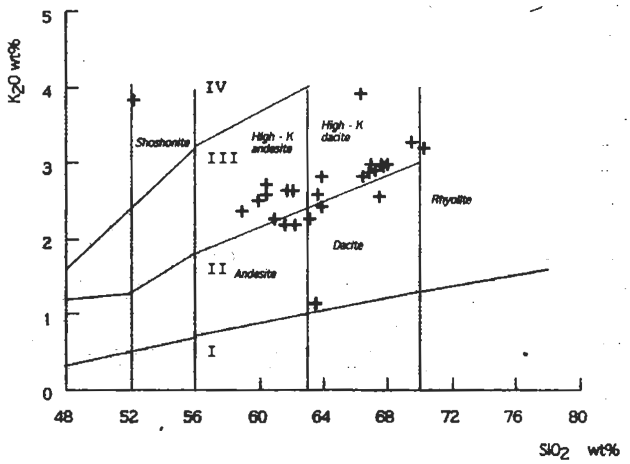

Figure 6. Central Ankara volcanics on the K_2O vs. SiO_2 diagram of Peccerillo & Taylor (1976). I-Arc Tholeiite series; II-Calcalkaline series; III-High-K calc-alkaline series; IV-Shoshonite series.

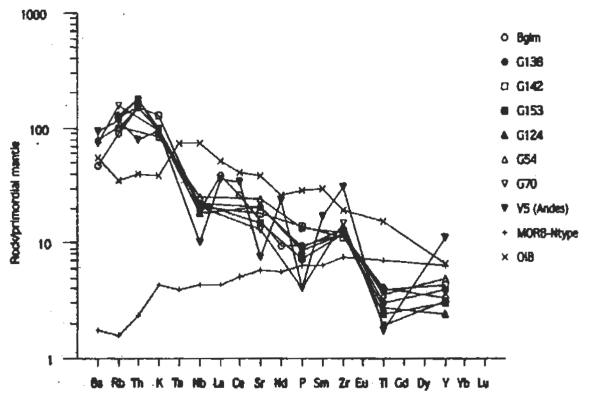

Figure 7. Spider diagram of the trace elements (Rock/primordial mantle: Normalized values from Sun & Mc Donough 1989) for central Ankara volcanics. OIB, MORB-N Type from Sun (1980) and V5 (Andes) from Hickey-Vargas (1989) is used for comparative purposes.

agram of Wood et al. (1979), 12 samples of the central Ankara volcanics are plotted near the filed of D which is representative of "magma series at destructive plate margins" (Figure 8). The MgO-FeO*-Al_2O_3 diagram of Pearce et al. (1977) can be applied only to subalkaline volcanic rocks with extended SiO_2 range 50 to 60 wt%. All selected central Ankara volcanics are plotted in the 'orogenic" area (Figure 9).

Discussion

The central Ankara volcanics are mainly andesite and dacite having calc-alkaline character. In the discrimination diagrams of Wood et al. (1979) and

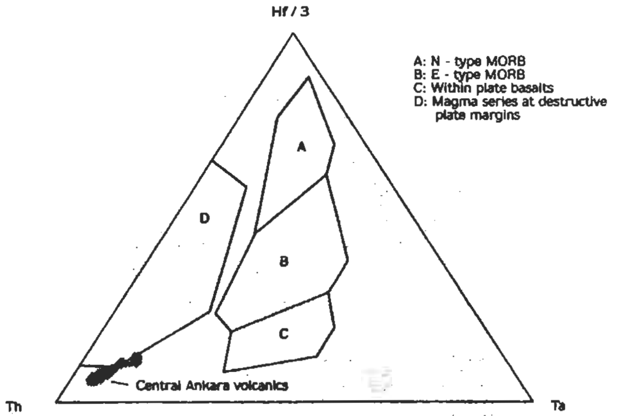

Figure 8. Central Ankara volcanics on the Th-Hf/3 - Ta discrimination diagram of Wood et al. (1979). Zr/Hf=39, Nb/Ta=16. Samples: 68, 77, 87, 92, 100, 124, 130, 138, 142, 144, 151, 153.

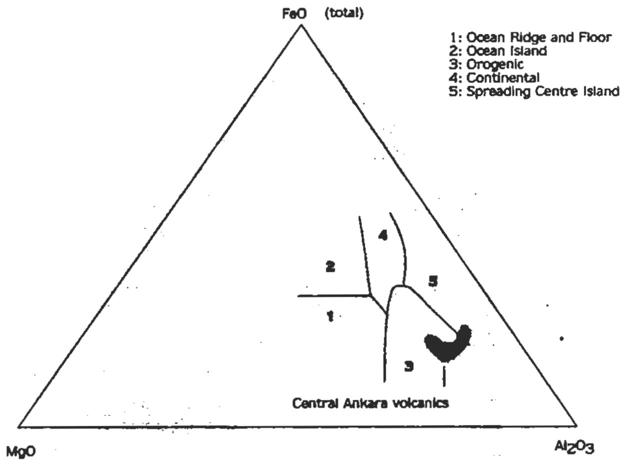

Figure 9. Central Ankara volcanics on the MgO-FeO*-Al_2O_3 diagram of Pearce et al. (1977) with the extended SiO_2 range from 50-60 wt%. Samples: 46, 54, 59, 87, 144.

Pearce et al. (1977), these volcanics fall into the fileds of "magma series at destructive plate margins" and "orogenic", respectively. Their trace element patterns demonstrate Ba, Rb, K and Th peaks and a marked Nb and Ti trough which are representative of subduction related volcanism. On the other hand, it is difficult to propose an active subduction event during the middle-late Eocene (38.8±1.2 - 44.7±1.0 Ma) in the view of the complete closure of the İzmir-Ankara ocean in the early Eocene. According to this age relationship, the central Ankara volcanics appear to be post-collisional and might reflect inheritance of a subduction-modified lithospheric mantle source.

Although the central Ankara volcanics developed immediately after the collision event, the type of regional tectonic setting will be clearer after resolving the stratigraphical problems of accompanying sedimentary rocks and the configuration of the basin type in which the volcanics occurred. According to Akyürek et al. (1984) alluvial fan and fluvio-lacustrine sediments interfinger with the central Ankara volcanics immediately east of one of the K-Ar dated locations, Hüseyin Gazi Tepe. This relationship provokes the possibility that the so-called "Miocene" Karapınar, Kavaklı and Mamak Formations of Akyürek et al. (1984) might have developed simultaneously with the central Ankara volcanics during the middle-late Eocene. In this case, all the regional stratigraphy and geological relationships need to be revised.

The above problem, which is based on both published and unpublished data, is to be solved by a detailed geological mapping.

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