DISTRIBUTION OF THE MAJOR AND TRACE ELEMENTS IN THE VOLCANIC ROCKS OF YOZGAT AREA, TURKEY

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ABSTRACT. — The investigation has been carried out the petrographycal and geochemical properties of the volcanic rocks in Yozgat area. These volcanic rocks are compared with some other volcanic formations and their origins are examined. The volcanic rock units of investigated area are pre-Lutetian diabases, amygdaloidal basalt intercalated with Lutetian sediments, tuff, agglomerates and post-Lutetian andesite-basalts. These volcanic rocks of the region present an affinity to the calc-alkaline suites of the island-arcs.

INTRODUCTION

Purpose of this investigation is to determine the petrological and geochemical characteristics and to establish the conditinal origin of the rocks in Yozgat area. By using the analysis of major and trace elements of lavas in this research region, were explained about the plate tectonics attitude of this area and this result will be provided to the future studies. The age of the layers have been determined by the work on lithology and stratigraphy of the area (Büyükonal, 1979). The oldest unit of the lavas, namely diabases, which is overlain by Lutetian sandstones around the Kösekkömü region. The amygdaloidal basalt crop out around Yozgat city and generally west and south-west of the investigated area. Basalt-andesite which is the youngest unit is existed the northwest of Yozgat city (Fig. 1).

Some geological studies were made for different purposes by the researchers in Yozgat area. Between 1867 and 1950 the researchers agreed that the area was interior region of Kırşehir massif which is Paleozoic age (Chaput, 1947; Lahn, 1949 and Bailey-McCallien, 1950). Most of acidic and basic igneous rocks in the region are influenced by Hersinien and Alpine orogeny.

New studies and age determination carried out after 1950 were under the hypothesis that plutonites are Tertiary in age and these acidic and basic rocks combinational settled at the same or within a very close time interval (Ketin, 1954, 1955, 1961, 1966; Ataman, 1972, 1974). Tümer-Remzi (1975), found hematite, magnesite and wolframite ores in vicinity of Yozgat. The contact of the acidic intrusion and sedimentary units bearing-flourite have been explained.

GEOLOGY

Magmatism is dominant in the studied area. In the vicinity of Yozgat was cropped out by pre-Lutetian diabases, the submarine volcanic units, of Lutetian age, tuff, sandstones in rich fossils and consisting fine holocrystaline texture of basalt-andesite of post-Lutetian age with basic and acidic plutonites. The acidic plutonites are essentially granites, but the basic plutonites are gabbros. The age of these plutonites are the Upper Cretaceous-Eocene and they have been overlaid by the Eocene flysh. The region studied were under the effect of Alpin orogeny and exhibits a faulty structural generally, in the direction of southeast and northwest (Büyükonal, 1973).

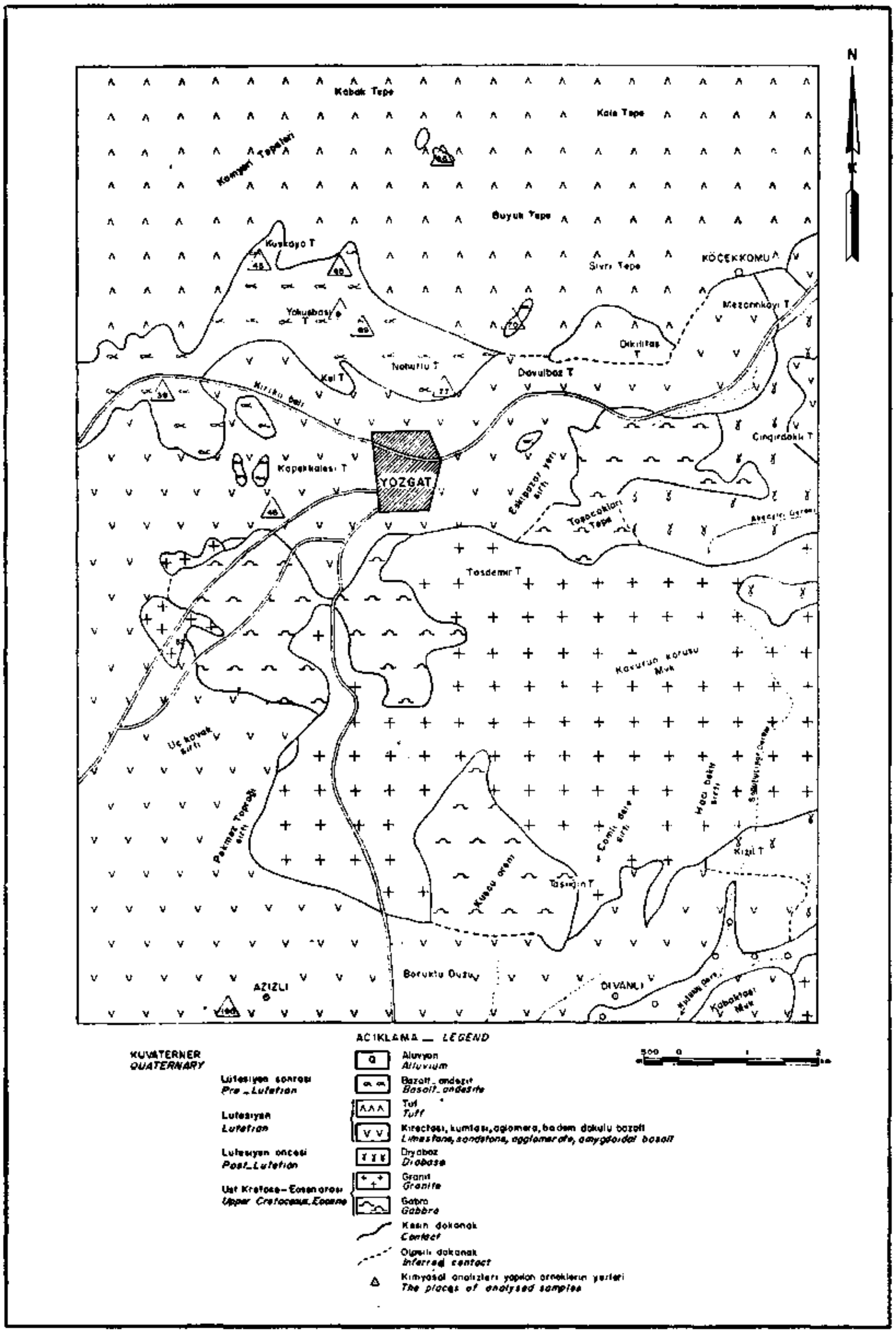

Fig. 1 - Geological map of Yozgat region.

The volcanic units as amygdaloidal basalt and diabases in Yozgat region are altered. Also, the amygdaloidal basalt are intercalated with agglomerates and Lutetian sandstones. On the other side, the basalt-andesite are very dark colour and show column structure.

PETROLOGY OF THE LAVAS OF YOZGAT

Thin-sectional lavas examination shows, diabasic, porphyric and holocrystaline textures. The chloritisation at all of the crystals in the matrix were observed and most of the feldspars in the lavas show the albitisation.

The most of lavas consist of diabase, amgydaloidal basalt and andesite-basalt units. The term andesite-basalt were used based on its mineralogical and-petrographical characteristics (Moorhouse, 1972) and (Coat, in Hess and Poldervaart, 1968). The two investigators used the terms andesite-basalt or basaltic-andesite interchangeably. The amygdules of the amygdaloidal basalts filled with chalsedony, zeolite (natrolite) and quartz. The magma samples to which lavas belong were examined and interpretation of the field completed under the light cast by the principles of plate tectonics. The major and trace elements analysis carried out at Oxford University and at the University of Vienn, by utilization of the XRF melting method, on 10 lava samples taken from the area for the purpose of solving problems of origin were utilized and the results produced were evaluated. Places where the samples were taken are shown in Figure 1 and the chemical results of the major and trace elements are shown at Table 1 and 4.

Rittmann parameters, CIPW norms and SI index were computed.

Since the classification of volcanic rocks of Yozgat were completed according to alkali (Na_2O+K_2O) and SiO_2 contents Irvine and Baragar (1971), MacDonald and Katsura (1964) and Kuno (1960), it can be observed by using the concept of segmantation most lavas are at the subalkalin region, but majority between the lines dividing MacDonald and Katsura with Kuno (Fig. 2).

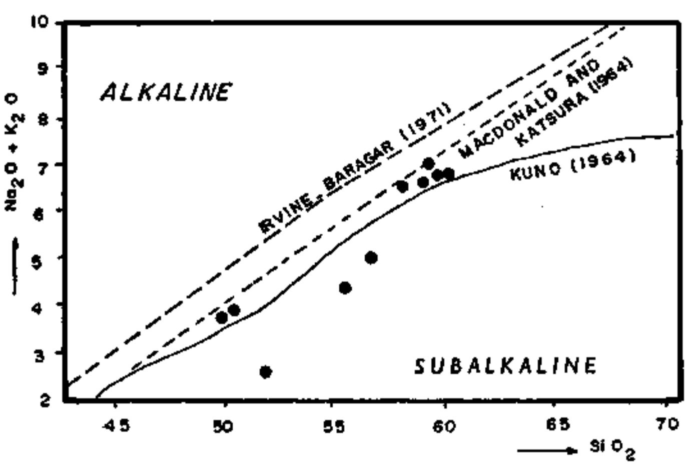

Fig. 2 - Classification of the volcanic rocks of Yozgat region according to alkaline versus silica content.

On the other hand, the samples taken from the Yozgat area were shown in the Rittmann (1953) diagram (Fig. 3) and they formed a calc-alkaline region according to these diagram arrangements which was made according to the An-SiO_2 contents.

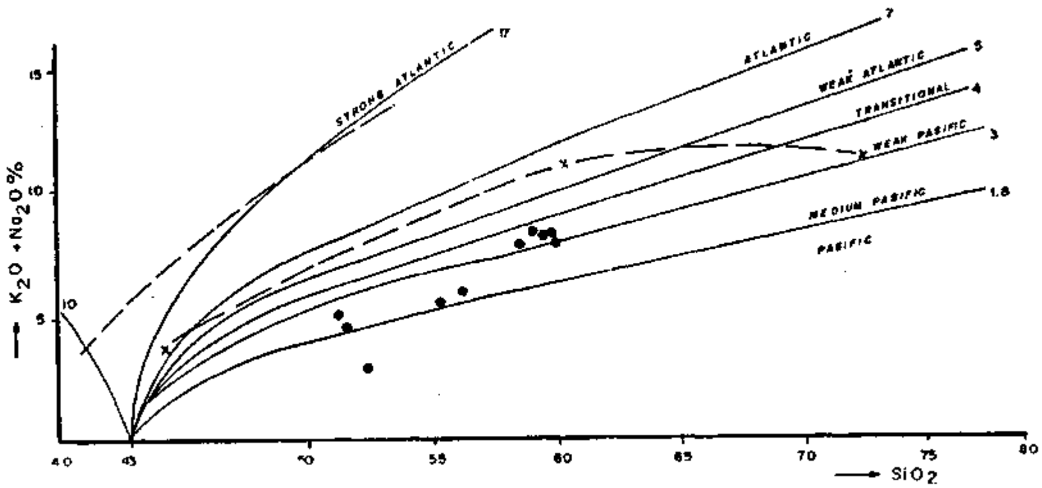

Fig. 3 - Rittmann (1962; in Wright, 1969) diagram of the volcanics of Yozgat region.

The using serial index contemplated by Rittmann (1962) and Wright (1969), to determine the origin of the volcanic rocks of the region, were computed for the lavas. It came to a conclusion that the values all the samples except one, ranges between 1.84 to 3.05. This indicates that a less the four Rittmann index is enough to classify calc-alkaline P values of the area lavas were computed by use of Rittmann parameters and are changing between 59 and 62. This is an occurance supporting the conclusion that the volcanic rocks are of calc-alkaline type (Fig. 4).

Other parameters were used to classify Rittmann (1953) volcanics and it was seet that samples on the hand could be classified under such names as pigeonite, andesite, olivine andesite-basalt, dacite and trachy andesite (Table 2). However, it must be expressed here that the quartz, olivine and pigeonite formations theorotically extracted during the norm analysis were not observed during the microscopic studies. This condition is used to explain that there could not always be a complete match in classification of volcanics solely by basing them on mineralogical compund norm analysis (Büyükonal, 1979).

The samples from the studied area were classified according to the Rittmann (1952) normative names in addition to Taylor (1973) who based his classification on K_2O contents of the SiO_2 function. The normative plagioclase and normative color index of Irvine-Baragar (1971) together with diagrams drawen by Cox and others (1979) according to the Na_2O+K_2O and SiO_2 contents appear along with the diagrams of Di Paola (1974), in Ercan and others (1983) where K_2O/Na_2O and SiO_2 functions are given. Table 3 classifies units by using of the principle of comparing them with each other. In addition to this classifications by Taylor, Irvine-Baragar, Di Paola, Cox and et al. are given by the following diagrams in Figure 5, 6, 7, 8, 9.

The samples of the region are evaluated-in diagrams of Rittmann (1952), Taylor (1973), Cox, et al. (1979), Irvine and Baragar (1971) and Di Paola (1974 in Ercan et al., 1983). However the character of calc-alkaline, have been taken in different names when evaluated in these diagrams mentioned above (Table 3). Having K_2O/Na_2O> 1 also indicate that these are the calc-alkaline origin.

Table 1 - Chemical analysis and CIPW norms of volcanic rocks of Yozgat region

Samples no.	*BCR*-39	*BCR*-48	*BCR*-45	*BCR*-43	*BCR*-70	*BCR*-77	*BCR*-90	*BCR*-66	*BCR*-89	*BCR*-190	W-380
SiO_2	59.90	51.50	56.35	59.71	55.30	59.70	60.30	59.00	51.50	52.90	52.38
TiO_2	0.67	1.24	0.69	0.35	0.69	0.67	0.72	0.66	1.24	0.71	1.14
Al_2O_3	16.80	15.60	17.06	17.87	15.07	16.80	17.18	16.80	14.60	13.24	15.50
Fe_2O_3	1.25	3.76	2.19	1.29	3.96	1.81	1.25	1.16	1.80	2.33	3.25
FeO	4.20	4.32	3.78	3.44	4.08	3.70	4.20	3.92	6.08	5.46	6.41
MnO	0.14	0.14	0.13	0.08	0.15	0.14	0.15	0.13	0.14	0.13	0.20
MgO	1.56	9.76	4.03	3.25	0.56	1.56	1.42	1.82	9.76	11.60	4.64
CaO	5.24	6.22	6.66	5.03	11.11	5.24	5.18	4.96	6.22	7.48	5.31
Na_2O	5.20	3.04	3.95	5.16	3.04	5.20	5.14	5.37	3.04	1.97	5.30
K_2O	1.60	1.34	1.27	1.92	1.72	1.60	1.82	1.30	1.34	0.66	0.05
H_2O +	—	—				—	—				
H_2O —	—	—	2.00	2.18	2.13	—	—	2.18	1.68	1.93	2.73
P_2O_3	2.99	2.50	1.27	0.17	0.25	2.99	3.01	2.02	2.50	1.99	0.10
CO_2	—	—	1.14	—	2.43	—	—	0.75	—	—	.2.96
Total	99.55	99.42	100.52	100.45	100.49	99.61	100.37	100.07	99.90	100.40	99.97
					CIPW norms						
Or	9.46	7.92	7.51	8.69	10.17	9.46	10.76	7.68	7:92	3.90	0.30
Ab	44.00	25.72	33.42	43.15	25.72	44.00	43.49	45.43	25.72	16.67	44.84
An	6.46	14.53	17.54	20.66	22.40	6.46	6.03	11.41	14.53	24.11	18.36
Qz	15.76	6.48	13.00	9.59	15.60	16.39	16.09	12.69	4.27	7.95	1.48
Hy	9.72	27.35	14.27	9.58	—	8.34	9.31	9.92	32.20	36.06	16.21
Di	—	—	—	1.52	9.33	—	—	—	—	—	5.98
Ap-(OH)	7.05	5.90	—	0.40	0.59	7.05	7.10	4.77	5.90	4.69	0.24
Il	1.27	2.35	1.31	1.10	1.31	1.27	1.37	1.25	2.35	1.35	2.16
C	4.15	3.83	2.76	—	—	4.15	4.55	2.38	2.83	0.45	—
Mt	1.81	5.45	3.17	1.51	5.74	2.62	2.26	1.68	2.61	3.38	4.71

Table 2 - Rittmann parameters of the volcanic rocks of Yozgat region (Rittmann, 1953)

Sample no.	SiO_2	*Al*	*Alk*	*An*	*CaO*	*Fm*	*k*	*Ca*	*P values*
BCR 39	59.90	15.12	9.40	0.2357	5.24	9.144	0.1702	1.772	56
BCR 48	51.50	14.04	5.90	0.4082	6.22	28.186	0.2270	1.336	57
BCR 45	56.35	15.35	7.20	0.3617	6.66	14.551	0.1765	1.765	60
BCR 43	59.71	16.08	9.66	0.2494	5.03	11.662	0.1987	1.177	57
BCR 70	55.33	13.56	6.28	0.3669	11.11	9.773	0.2738	6.741	59
BCR 77	59.70	15.12	9.40	0.2357	5.24	12.134	0.1702	1.818	56
BCR 90	60.30	15.46	9.53	0.2364	5.18	8.875	0.1908	1.627	57
BCR 66	59.00	15.12	9.36	0.2984	4.98	9.255	0.1591	0.786	55
BCR 89	51.50	13.14	5.90	0.3803	6.22	28.162	0.2271	1.876	56
BCR 190	52.90	11.92	3.62	0.5344	7.48	31.719	0.1825	2.4994	65

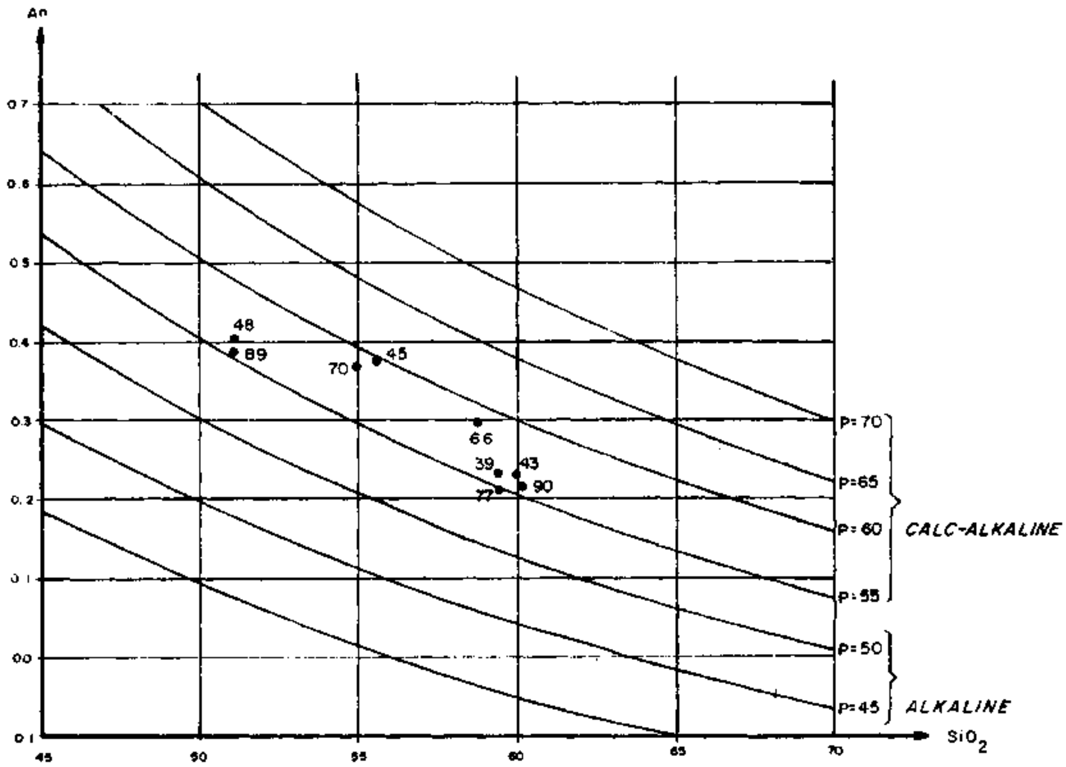

Fig. 4 - The places of the volcanic rocks of Yozgat region according to P values in the diagram of an versus SiO_2 of Rittmann (1953).

Table 3 - Classification of the volcanic rocks in Yozgat region according to another investigators.

Sample no. 888	*Rittmann (1952)*	*Taylor (1973)*	*Irvine-Baragar (1971)*	*Di Paola (1974)*	*Cox, and et al. (1979)*
BCR 39	Dacite	Andesite	Andesite	Andesite	Trachy-andesite
BCR 48	Olivine andezine basalt	Al. rich basalt	Basalt	High Al. basalt	Basalt
BCR 45	Pigeonite, andesite	Andesite	Andesite	Andesite	Basaltic-andesite
BCR 43	Pigeonite, andesite	Andesite	Andesite	Andesite	Trachy-andesite
BCR 70	Trachy-andesite	Poor Si. andesite	Andesite	Poor Si. andesite	Basaltic-andesite
BCR 77	Pigeonite, andesite	Andesite	Dacite	Andesite	Trachy-andesite
BCR 90	Dacite	Andesite	Dacite	Andesite	Trachy-andesite
BCR 66	Dacite	Andesite	Dacite	Andesite	Trachy-andesite
BCR 89	Olivine, andezine basalt	Al. rich basalt	Basalt	High Al. basalt	Basalt
BCR 190	Pigeonite, basalt	Al. rich basalt	Basalt	High Al. basalt	Basaltic-andesite

Table 4 - The trace elements (Zr, Y, Sr, Rb), Ti (ppm) and K % values and the ratios of K/Rb,Rb/Sr, the volcanic rocks of Yozgat region

Sample no.	*Zr ppm*	*Y ppm*	*Sr ppm*	*Rb ppm*	*Ti ppm*	*% K*	*K/Rb*	*Rb/Sr*
BCR 39	193.96	15.75	321.90	47.48	4020	0.66	139	0.147
BCR 48	107.49	17.98	380,38	25.41	7440	0.56	220	0.067
BCR 45	142.45	16.29	308.44	98.80	4140	0.53	54	0.320
BCR 43	134.86	15.54	312.15	46.93	2100	0.80	170	0.150
BCR 70	58.86	17.89	328.59	25.18	4140	0.71	282	0.077
BCR 77	145.55	16.49	327.23	59.98	4020	0.66	110	0.183
BCR 90	146.70	16.80	327.53	51.15	4320	0.76	149	0.156
BCR 66	142.45	16.29	308.44	98.80	3960	0.54	55	0.320
BCR 89	109.49	17.98	380.38	25.41	7440	0.56	220	0.067
BCR 190	61.44	13.81	436.72	46.74	4260	0.27	58	0.107

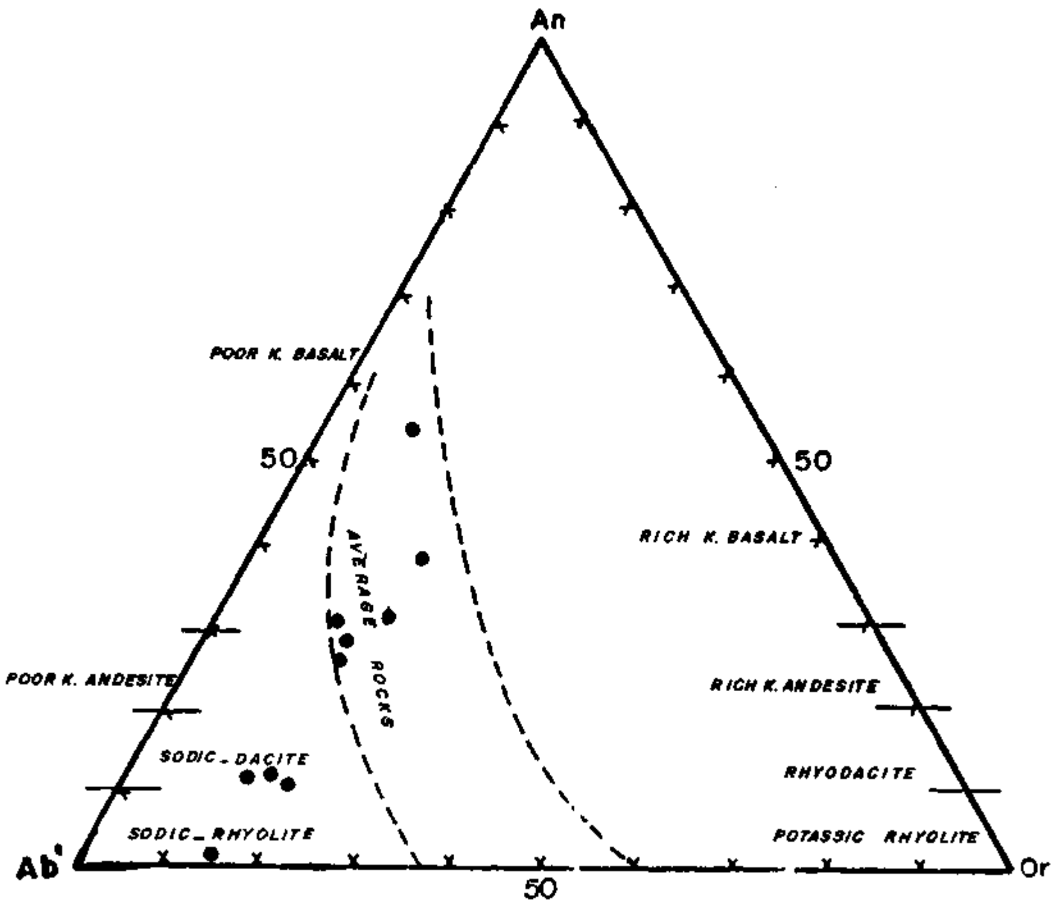

Fig. 5 - Classification of the volcanic rocks of Yozgat region in Irvine-Baragar (1971) diagram.

The SI index of the samples were used in the classification of the volcanic rocks (Hutchison, 1974). According to these, the lavas of the region have been named as basalt, andesite, basaltic-andesite and dacitic-andesite (Büyükönal, 1979).

Furthermore, according to the diagram of An+Ab'+Or of Irvine and Baragar (1971), the volcanics of the area could be classified as transitional and generally sodic in character (Fig. 5). However, while some of the rocks show sodic dacite character, others take place in the section of andesites poor in K in this diagram.

Trace element contents such as Y, Zr, Rb and Sr of some of the lavas of Yozgat and its close vicinity are given at Table 4 together with Ti, K, K/Rb and Rb/Sr ratios.

The Y distribution of the lavas of this area range between 16 and 18 ppm. Calc-alkaline rocks' Zr values are relatively higher than tholeiites (Jakes-White, 1972). According to the Zr values, the samples of this area can again be classified as calc-alkaline type.

The Rb distribution of volcanic rocks of Yozgat, broadly varies between 0.32 ppm and 98.80 ppm. The highest values may be interpreted as tendency progressing towards the shoshonites (Jakes-White, 1972).

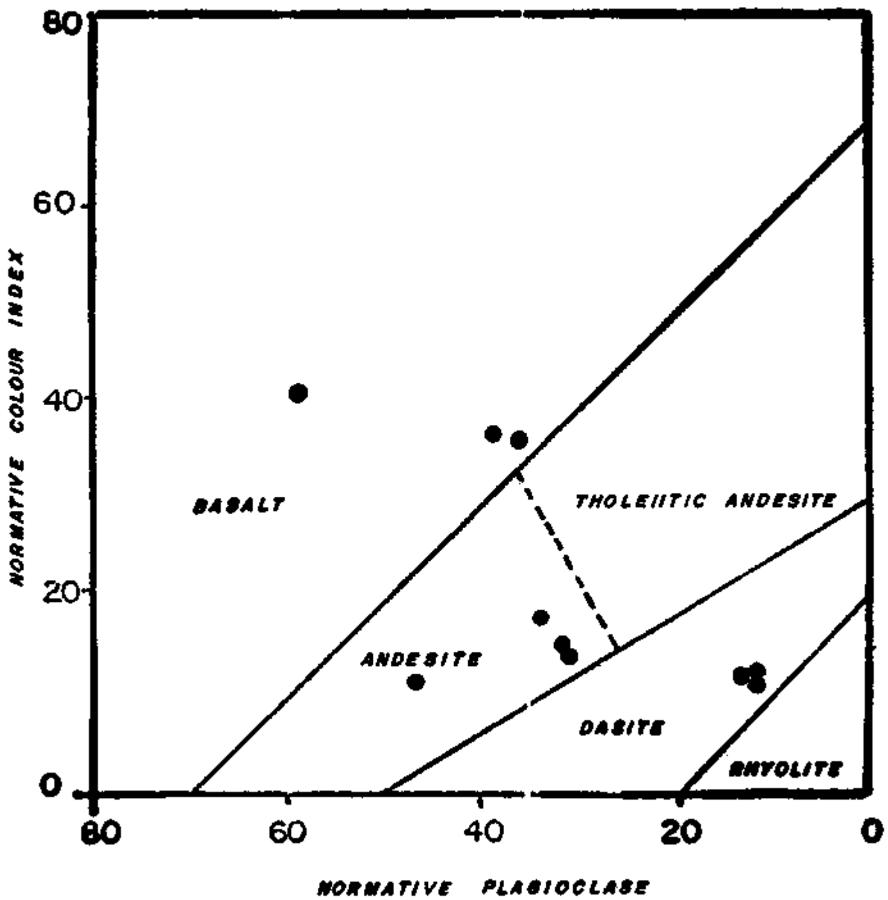

Fig. 6 - Classification of the volcanic rocks according to normative plagioclase versus normative colour index in Yozgat region (Irvine-Baragar, 1971).

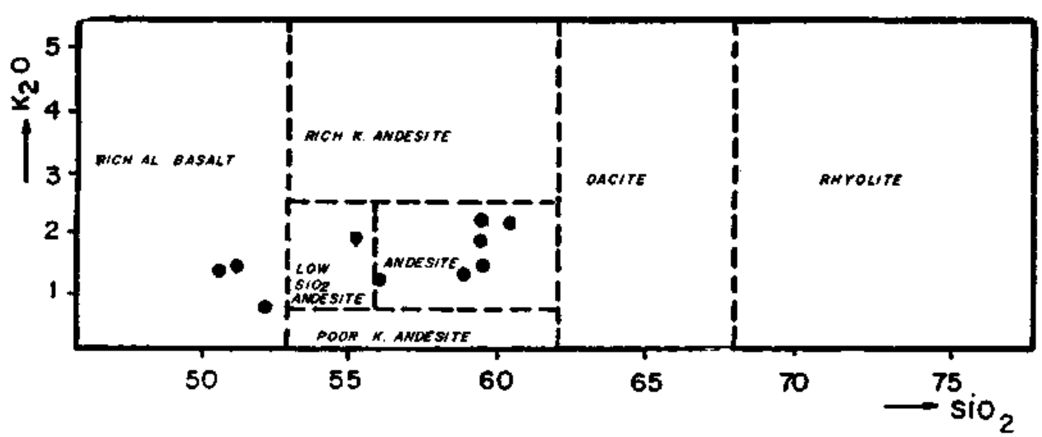

Fig. 7 - Classification of the volcanics of Yozgat region according to K_2O/SiO_2 ratios (Taylor, 1969; from McCurry-Wright, 1977).

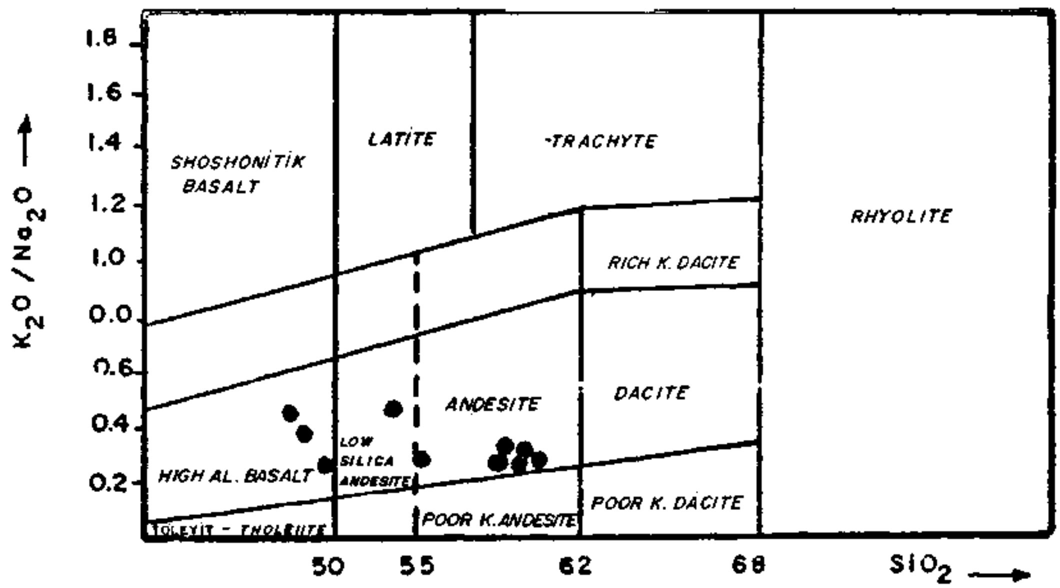

Fig. 8 - Classification of the lavas of Yozgat region according to ratios of K_2O/Na_2O and SiO_2 content (Di Paola, 1974; in Ercan, Günay, Baş, 1983).

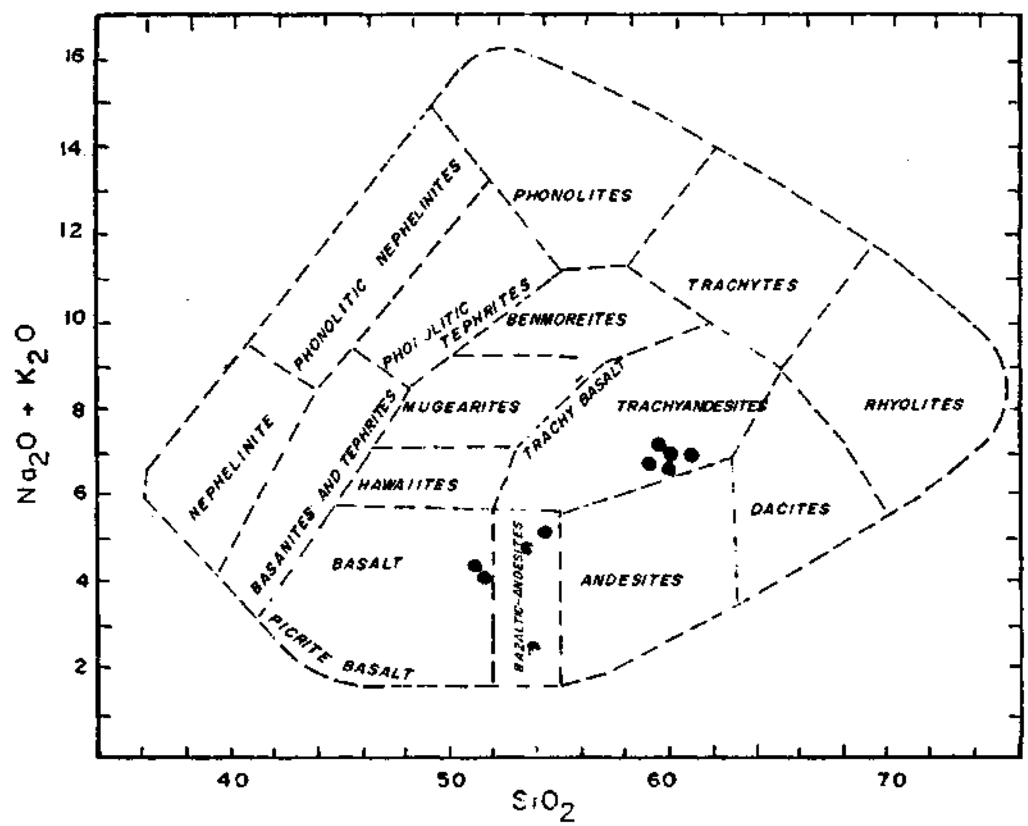

Fig. 9 - Nomenclature of the volcanic rocks of Yozgat region according to Cox et al. (1979).

However, the Sr values are rather stable. Except two samples Sr contents range between 300 and 380 ppm. The concentration of Sr plays an important role for identification of the island arc tholeiites. The geochemical characteristics of the samples of Yozgat region conform to the calc-alkaline suites of the island-arcs. The mobility of the Rb contents of samples caused to raise a family broad range in K/Rb ratios. A decreasing in the K/Rb ratios of the volcanics of the island-arc towards the contient in favor of shoshonites, had been asserted by Jakes and White (1972). Besides these, the lavas of the investigated area display a calc-alkaline trend in the diagram of Pearce (1973), McCurry and Wright (1977) employed Zr versus Sr (Fig. 10).

Pearce and Cann (1973), Bickle and Pearce (1974) in their diagrams showed Ti+Zr+Y (Fig. 11), Ti+Zr+Sr (Fig. 12) and Zr-+Ti (Fig. 13) relationships and places of the volcanic rocks of Yozgat region generally with the island-arc calc-alkaline partly of tholeiitic calc-alkaline.

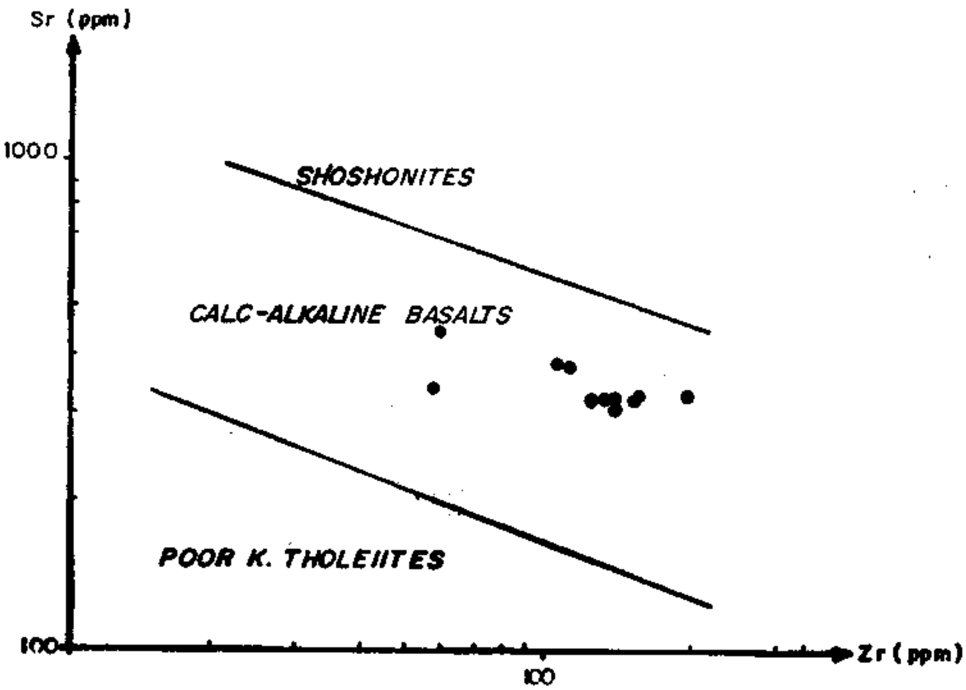

Fig. 10 - Sr/Zr diagram of the lavas in Yozgat region.

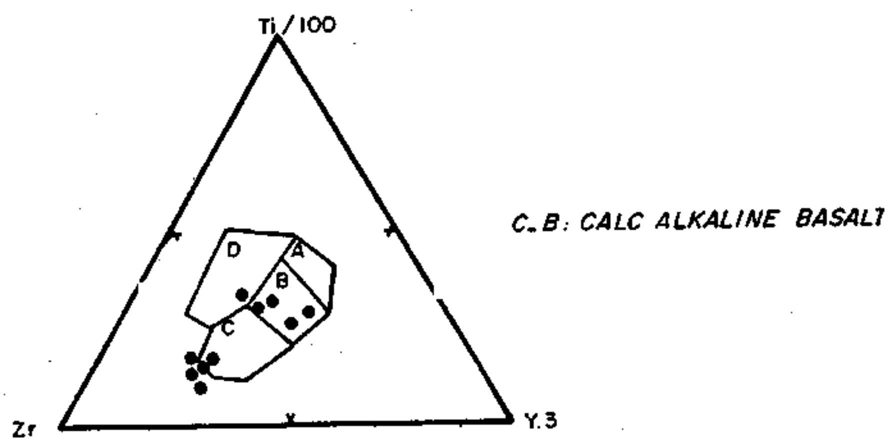

Fig. 11 - Triangle diagram of Ti+Zr+Y of volcanics in Yozgat region.

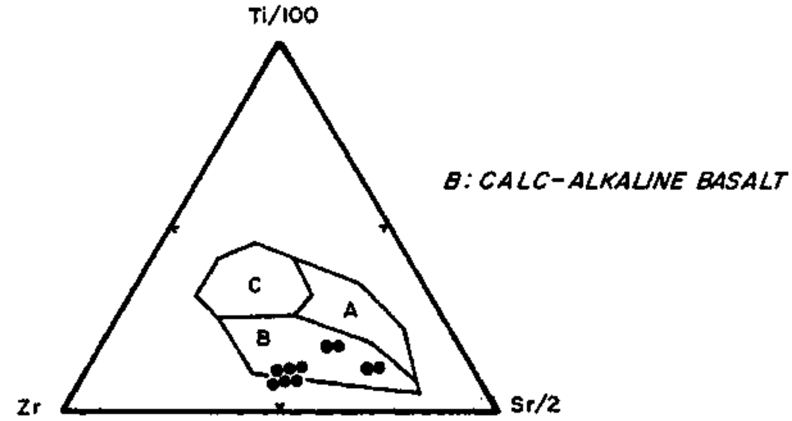

Fig. 12 - Triangle diagram of Ti+Zr+Sr of the lavas in Yozgat region.

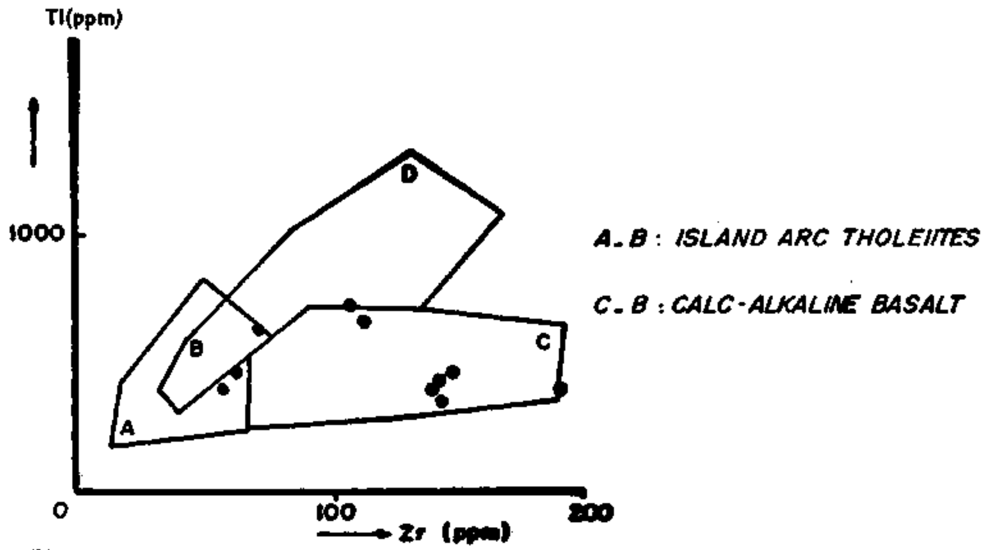

Fig. 13 - Diagram of the Ti versus Zr of the Yozgat region's volcanics.

CONCLUSION

Following interpretations are given for further discussion of the results of studies on the volcanic rocks of Yozgat area composed partly of the Kırşehir massif which is located in the Central Anatolia. The Zr in calc-alkaline rocks is higher than tholeiites and reported to be around of 100 ppm (Jakes-White, 1972). Zr value of volcanic rocks of Yozgat is generally higher than 100 ppm which may show, a calc-alkaline trend.

In general, trace elements such as Rb and Sr exhibit very broad distributions in concentration and increase towards the continental margin commencing from oceanic side, and also increase towards the youngest unite (Jakes-White, 1972). The Rb distribution is observed between 0.32 and 98.80 in the lavas of the area. The highest Rb value is interpreted as a transition towards the shoshonite. The Sr varies between 300 and 380 ppm in the rocks which is consistent to the calc-alkaline suites of the islandarcs. The changings in the concentration of the Rb control the K/Rb ratios. It was reported by Jakes and White (1972) that the K/Rb ratio indicates the highest value in the island-arc, tholeiites and decrease towards the shoshonites which are formed in the interior parts of the continent. Therefore, volcanic rocks of Yozgat, extends in character between tholeiites and shoshonites and generally exhibit a calc-alkaline trend. In the diagrams of Pearce, 1973 and McCurry-Wright, 1977 based on the relation of Zr and Sr, the lavas of Yozgat are taken place in the calc-alkaline section. This statement is also consistent to the view of Bickle and Pearce (1975).

In conclusion, it can be asserted that the lavas of the area were generally, in calc-alkaline character, but very few of them display a tholeiitic calc-alkaline trend.

In future studies, making increase the number of samples and examining of the trace and REE would help to clarify the geotectonical settlement problem of the region.

ACKNOWLEDGEMENTS

I would like to express my thanks to Prof. Dr. A.E. Vincet and to Prof. Dr. H. Wieseneder for providing facilities in the Geochemical Laboratories of Oxford and Vienna Universities, Dr. J.W.E. Whittekar, Dr. J.D. Bell and Dr. K.G.Cox for their contributions.

Besides these the financial support of the UNESCO and the Government of Austria arc greatly acknowledged.

Manuscript received January 29, 1985

REFERENCES

Ataman, G., 1972, Ankara'nın güneydoğusundaki granitik-granodiyoritik kütlelerden Cefalık dağın radyometrik yaşı hakkında ön çalışma: Hacettepe Fen Müh. Bilim. Bull., 2, 1, 44-49.

———, 1974, Revue geochronologique des Massif Plutoniques et Metamorphiques de l'Anatolie: Hacettepe Bull. Natural Sci. Engin., 3, 75-87.

Bailey, E.B. and McCallien, W.J., 1950, Ankara Melanjı ve Anadolu Şaryajı: MTA Bull., 40, 12-17.

Bickle, M.J. and Pearce, J. A., 1975, Oceanic mafic rocks in the Eastern Alps: Contrib. Mineral. Petrol. 49, 1977-189.

Büyükonal, G., 1973, Kırşehir Masifinin Yozgat ve yakın çevresinde magmatik kayaçlarda petrokimyasal-petrografik bir araştırma: A.Ü.F.F.Jeoloji Müh. Böl. (unpublished).

———, 1979, Yozgat yöresi plütonit ve volkanitlerinin petrolojisi: A.Ü.F.F. Jeoloji Müh. Böl. (unpublished).

Chaput, E., 1947, Türkiye'de jeolojik ve jeomorfolojik teknik seyahatları (Türkçe tercümesi): İst. Üniv. Publ., 324, Ed. Fak. Coğ. Enst. Publ., 11, İstanbul.

Coat, R.R., 1968, Basaltic andesites: pp. 639-736. In H.H. Hess and A. Poldervaart, ed. Basalts, volume 2. Interscience publishers a divison of John Wiley and Sons, London, New York, 862 pp.

Cox, K.G.; Bell, J.D. and Pankhurst, R.J., 1979, The interpretation of igneous rocks: George Allen and Unwin Ltd. London, 450 pp.

Di Paolo, G.M., 1974, Volcanology and petrology of Nisyrosisland (Dodecanese, Greece): Bulletin Volcanologique, 38/4, 944-987.

Ercan, T.; Günay, E. and Baş, H., 1983, Denizli volkanitlerinin petrolojisi ve plaka açısından bölgesel yorumu: TJK Bull., 26, 153-160.

Hutchison, C.S., 1974, Laboratory handbook of petrographic techniques: John Wiley and Sons, Inc., New York, 525 pp.

Irvine, T.N. and Baragar, W.P.A., 1971, A guide to the chemical classification of the common volcanic rocks: Canadian Jour, of Earth Scien., 8, 523-548.

Jakes, P., 1972, Major and trace element abundances in volcanic rocks of orogenic areas: Geological Society of America Bull., 83, 29-40.

Ketin, İ., 1954, Yozgat bölgesinin jeolojik lövesi hakkında memuar (Yozgat bölgesinin 1:100 000 lik 59/1, 2, 3 paftalar: Jeolojik lövesi ait memuar): MTA Rep., 2141 (unpublished), Ankara.

———, 1955, Yozgat bölgesinin jeolojisi ve Orta Anadolu Masifinin tektonik durumu: TJK Bull., 6/1, 40.

———, 1961, Türkiye'de magmatik faaliyetler: TJK Bull., 2, 16-33.

———, 1966, Tectonic unit of Anatolia (Asia Minor): Bull. Min. Res. Explo. Inst. Turkey (foreign edition), 66, 23-44.

Kuno, H., 1960, High alumina basalt: Journal of petrology 1, 121-145.

Lahn, E., 1949. Orta Anadolu'nun jeolojisi hakkında: TJK Bull., 2, 1, 90.

MacDonald, G.A. and Katsura, J., 1964, Chemical composition of Hawaiian lavas: Journal of Petrology, 5, 82-133.

McCurry, P. and Wright, J.B., 1977, Geochemistry of calcalkaline volcanic in north-western Nigeria and a possible Pan-Africa suture zone: Earth and Planetary Sci. Letters, 37, 90-96.

Moorhouse, W.W., 1959, The study of rocks in thin section: Harper and Brother, New York, 514 pp.

Pearce, J.A., 1973, Some relationships between the geochemistry and tectonic setting of volcanic rocks: Dh. Thesis. Univ., of East Anglia.

———and Cann, J.R., 1973, Tectonic setting of basic volcanic rocks determined using trace element analyses: Earth and Planet. Sci. Lett., 19.

Rittmann, A., 1952, Nomenclature of volcanic rocks: Bull., Vole., 11, 12, 75-102.

———, 1953, Magmatic character and tectonic position of the Indonesien volcanoes: Bull., Volcan., 11, 45-58.

———, 1962, Volcanoes and their activity: John Wiley and Sons, New York, London, 305 pp.

Taylor, S.R., 1969, Trace element chemistry of andesites and associated calcalkaline rocks, in: Proc. Andesite Conf. A.R. McBirney, ed., Dep. Geol. Miner. Res. Oregen. 65, 43-63.

Turner, T. and Remzi, H., 1975, Yozgat-Akdağmadeni ve civarının genel grafit prospeksiyonu ile Hatapalan 1 dere zuhurunun detay ön etüdü raporu: MTA Rep., 5382 (unpublished), Ankara.

Wright, J.B., 1969, A simple alkalinity ratio and its application to questions of non-orogenic granite genesis: Geol. Mag, 106/4, 370-384.