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EPITHERMAL MINERALIZATION POTENTIAL OF THE VOLCANICS IN SOUTH EAST HAVRAN (BALIKESiR)

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ABSTRACT.- The Hallaçlar formation of Upper Oligocene-Lower Miocene age is the oldest unit of the area. The volcanics of this formation are affected by widespread hydrothermal alteration. The Dedetepe formation, of Lower Miocene age, unconformably overlies the Hallaçlar formation and is characterized by andesitic lavas, tuffs and aglomerates which are not affected by the hydrothermal alterations. Soma formation (Middle Miocene-Lower Pliocene in age) consists of claystones, marls, dolomites and limestones unconformably overlying the volcanics. This sequence is overlain by the Quaternary alluvium. The volcanics of Hallaçlar formation, displaying various colors as a result of the hydrothermal alteration, are divided into the units of unaltered and altered volcanics. Altered volcanics are further divided, according to the degree of alteration, into the four subunits of slightly altered volcanics, argillic, silicified and sulfidic zones. As the result of chemical analyses, it is concluded that epithermal trace element enrichments are localizied only in the Hallaçlar formation. Au, Ag, Cu, Pb, Mo, As, and Hg anomalies are determined in extensively silicified zones. It has been concluded that the silicified zones of the Hallaçlar formation seem to have a potential for precious metal mineralization.

INTRODUCTION

This investigation establishes the features of hydrothermal alterations and precious metal concentrations in an area of 60 sq km. in the SE of Havran (Bahkesir). The results and recommendations of previous studies have encouraged this study.

The previous works in the .vicinity of the study area by Tchihatcheff, 1967; Phjllipson, 1958; Kaaden, 1957, 1959 and Kovenko, 1940, produced the geologic maps of the region. More detailed geological work was carried out by Akyürek and Soysal (1978, 1982). There are a number of studies on the petrology and modes of occurence of plutonic and volcanic rocks by Aslaner, 1965; Bürküt, 1966, 1975; Izdar, 1968; Ataman, 1975; Krushensky, 1976, Krushensky et al. 1980 and Bingöl et al. 1982.

Schuiling's (1958) work on the prospection of radioactive minerals, with a negative result, indicated that there could be metallic mineralizations with the element enrichments such as Fe, Pb, Zn, W, Cu, Mn and Mo around granodiorite plutons. In geochemical prospection studies, Gonca et al. (1984) has identified Cu, Zn, Pb, Sb. Mo and As anomalies.

The earliest prospection works on mining geology in the area, are of Krushensky (1968, 1971, 1976). This author gives brief information on various ore occurences (hematite, magnetite, galena, sphalerite, calcopyrite, molibdenite, stibnite) in an area of 600 sq km. It was revealed that randomly collected andesite pebbles contained 5 gr/ton Au and 4 gr/ton Ag. The importance of hydrothermal alterations for gold and other element concentrations has been stated. Based on the results of this investigation, detailed prospection and mapping studies were recommended.

The rocks around Havran are represented by Tertiary volcanics. In the west of the study area there are three silicified (gold bearing) calcite veins which are 1 to 30 m. thick and 200 m long. These are owned by private sector. Because of the existence of Au and Ag deposits formed relation to the volcanism in Arapdağı, İzmir and Madendağ Çanakkale, (Erler and Larson, 1992), the study area was found worth for investigation. The study area was initially mapped at the scale of 1:10 000 to determine the mineral paragenesis formed by volcanic activities and their relationships to adjacent rocks and hydrothermal alterations. This map also contains hydrothermal alteration zones. The samples were collected from each volcanic unit and alteration zone for the investigation of geochemistry.

By the studies on samples collected, hydrothermal alterations have been described and alterations in the district have been correlated. The element distributions in the host rocks and alteration zones have been determined, and the behavior of elements, which could be a clue for ore minerals, has been interpreted.

THE GEOLOGY OF THE STUDY AREA

The oldest unit in the investigated area is the Hallaçlar formation. It was formed during upper Oligocene and Lower Miocene. The Hallaçlar formation contains unaltered and altered andesitic, dacitic rocks, silicified rocks and alteration clays. Dedetepe formation of Lower Miocene age. Unconformably overlies Hallaçlar formation. Dedetepe formation is unconformably overlain by Soma formation of Middle Miocene and Lower Pliocene age, all being covered by alluvium of Quaternary age. (Fig. 1).

Hallaçlar formation

Hallaçlar formation is unconformable on Bağburun formation and Kocaçal Hill limestone which are not observed in the study area. This formation is formed by andesitic, dacitic rocks, lava flows, silicified rocks, and their alteration products. The thickness of the formation is about 400 m. It outcrops typically in the vicinity of Hallaçlar village. The age of Hallaçlar formation is Upper Oligocene-Lower Miocene. (Krushensky, 1976). Hallaçlar formation is composed of lava flows of 90 % andesitic and 10 % dacitic composition. The andesites and dacites of the formation are considerably affected by hydrothermal alteration. Clay alteration and silicification occurred as a result of this process. The Hallaçlar formation is subdivided into the groups of unaltered and altered volcanics after macroscopic and microscopic studies. Altered volcanics are further subgrouped into slightly altered volcanics, sulfide zone, argillaceous zone and silicified zone.

Dedetepe formation

The volcanics, consisting of andesitic aggiomerates, lava, tuff and crystallized tuff which uncorfornrably rest on Hallaçlar formation are named as Dedetepe formation and the age of this formation is Lower Miocene (Krushensky, 1987). This formation's type section is around Dedetepe Hill. Dedetepe formation begins from soijth-west of the study field and extends towards the north-east. In the vicinity of Dedetepe Hill, from bottom to top, there are light green and gray lavas and tuffs and at the top, agglomerates similar to those of the bottom are found. These units are well stratified. The andesite blocks in the agglomerates are variable in size, differing from a few cm to 30-40 cm.

Soma formation

The units consisting of claystone, marl, dolomite and limestone in the surveyed field appearing north of the Aşağıdamlar and Köylüce villages are named Soma formation by Akyürek and Soysal (1982). The age of Soma formation is determined as Middle Miocene-Lower Pliocene by Ercan et al. (1984). The units of the Soma formation unconformably overlying Hallaçlar formation in the vicinity of Köylüce village are dirty yellow, beige and the various tones of gray. North of the Köylüce village in the massive and stratified sedimentary units, there are laminated claystones in between bedded limestone and marl. The beds are gently dipping and strike N 80 E with a thickness of 5.50 cm.

Alluvium

The Quaternary alluvium is composed of small and large pebbles and sands are found at the north west of the study field especially around Havran stream.

The tectonic units of the study area

As there is a vegetation cover in the study area and the hydrothermal solutions are substantially effective, difficulties arise in observing the tectonic structures. In the studied field, there are vertical faults positioned towards N and NE directions. There are two vertical faults located northeast to the Solar Quarter each 400 m. long and one to the west of the Çakal Hill positioned N-S direction in between altered volcanics with 300 m. long. South of the surveyed field there is one vertical fault striking NE-SW between Hallaçlar and Dedetepe forma-

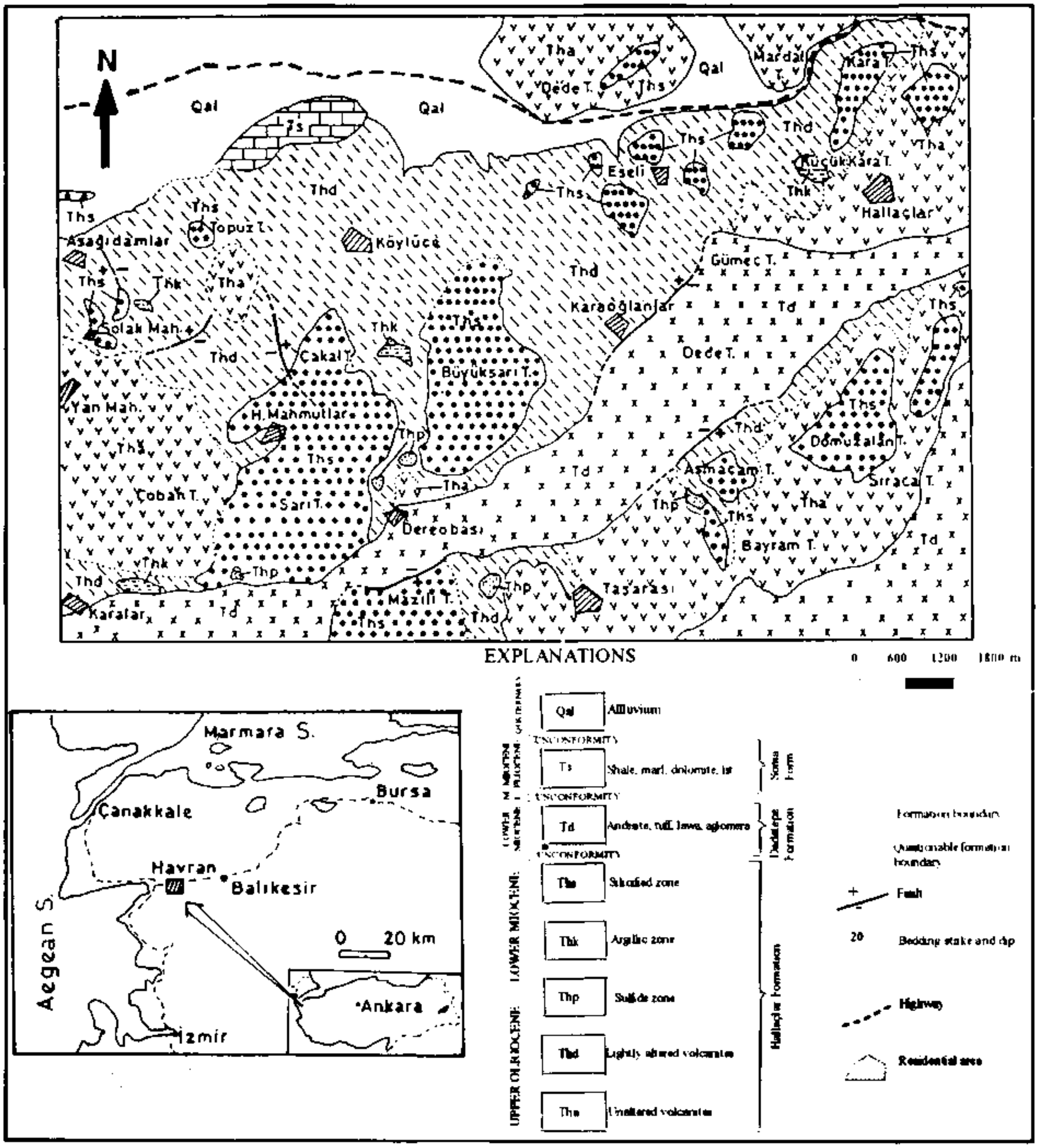

Fig. 1- Geological map and columnar section of the study area.

tion and another vertical fault north of the Karaoğlanlar formation and Asmaçam Hill. The..volcanics are jointed at various directions. This jointed structure in the rocks of the Hallaçlar formation allows easy access of hydrothermal solutions.

HYDROTHERMAL ALTERATIONS

In the research area, the hydrothermal alterations that developed due to tectonic activity, can be differentiated by contrasting colors. The hydrothermal solutions which is particularly effective in the Hallaçlar formation consisting of andesites and dacites have led to extensive silicification and clay formation in various places. For example, silicified rocks are colored in tilered and gray and beige, gray and dirty yellow colored clay formations are observed in the Küçüik- Karatepe Hill and east of the Karalar village. The field surveys are evaluated by thin section observations and consequently the Hallaçlar formation is further subdivided into the following units:

a) Unaltered volcanics

b) Altered volcanics (Slightly altered volcanics, sulfide zone, argillic zone, silicified zone.)

a)Unaltered volcanics zone:

During the field surveys, the unaltered volcanics zone, which seems to be unaffected or only insignificantly affected from hydrothermal alterations, consists of andesites and dacites which are dark gray, dirty yellow and beige. The boundaries of the unaltered volcanics which appear extensively around Çoban Hill and Hallaçlar village with other units are not very visible and in most places this boundary is gradational. During thin section studies of the unaltered volcanic rocks, the following common properties are observed. These rock specimens with a generally hyalopilitic texture; Diorite porphyr shows holocrystalline porphyritic texture. In plagioclases, albite, pericline and carlsbad twinning can be observed. In porphyry rocks plagioclases are found as phenocrysts. Among mafic minerals, there are pyroxenes, amphiboles, Biotites occasionally altering to opaque minerals. Also, though less significantly, chloritization and alteration to epidote, hematite and zeolite are also seen. In the dacitic rocks there are euhedral quartz phenocrysts.

b) Altered volcanics:

Slightly altered volcanics— These rocks which have been affected by hydrothermal solutions, widespread are in pale yellow, light green and gray and they are around Köylüce village and Eseli Quarter. These units are relatively less altered when compared to the argillic, sulphidic and silicified zones. Hydrothermal solutions seem to be effective, and completely altered the rocks in fault scarps and the effects of alteration decrease towards the gerypheric areas. The altered volcanic units and unaltered volcanics are gradational. In thin sections of slightly altered volcanic rocks, the original structures of the minerals seem to have been deformed. The origin of rocks can only be estimated from mineral remains. In these rocks which are originally andesite and dacite, alteration to hematite, limonite, silicification and chloritization is observed. The plagioclase are silicified and saussuritized and altered to clay minerals and occasionally replaced by sericite and carbonates. The mafic minerals are altered to chlorite, uralite and opaque minerals. The XRD analyses showed that these rocks contain albite, sanidine, quartz, kaolinite and illite, and hematite minerals in lower rates. (Fig. 2a).

Argillic zone.- The rocks which are substantially influenced by hydrothermal solutions are in dirty yellow, beige and grey colors. These units that can be observed most typically west of the Hallaçlar village and east of the Karalar village are completely altered to clay minerals. The argillic zones also have gradational contact with altered volcanics and silicified rocks. XRD analysis showed that in these argillic aeous rocks, montmorillonite, kaolinite, quartz, dickite, illite, albite, sanidine are major constituents and in minor amounts jarosite, feldspars and crystobalite are found. (Fig. 2b).

Sulfide zone.- These units found to the west on Mazılıtepeler, North of Dereoba, Southwest of Asmaçam Hill are grey, dirty yellow in color. In these silicified and clay alteration rocks, macroscopic disseminated pyrite crystals are observed. XRD analysis showed, in these samples which are taken from silicified rocks, quartz, crystabolite, pyrite, albite, orthoclose and illite (Fig. 2c).

Silicic zone.- Peaks of the studied area are occupied by, (Sarı Hill, Büyüksarı Hill, Domuzalanı Hill) silicified rocks. They are grey, yellowisch brown and tile-red. Brown color results from hematitization of these rocks. Completely silicified rocks (Sarı Hill, Domuzalanı Hill) are very hard, but partly silicified (Kara Hill, north of Hacımahmutlar) dacites and andesites are moderately hard. At some localities (Solak Quarter), silicification and alteration into clay minerals are found together. In the silicifed rocks, from the thin section observations, it is seen

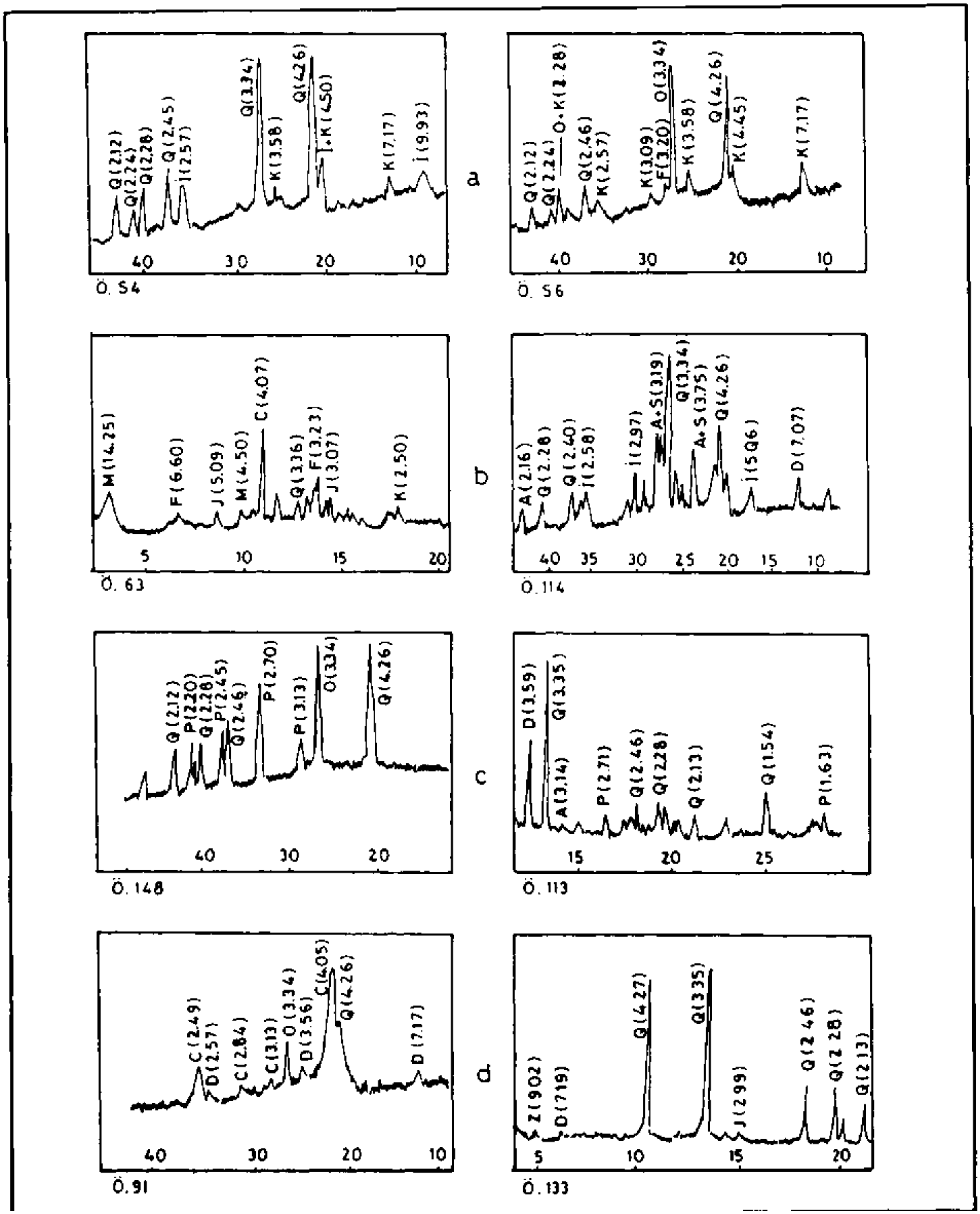

Fig. 2- XRD scans from Hallaçlar formation (6- sample no.; Q- Quartz; K- Kaolinite; I- İllite; F- Feldspar; M- Montmorillonite; J- Jarosite; A- Albite; S- Sanidine; D- Dickite; P- Pyrite; C- Cristobalite; Z- Zeolite).

a- Slightly altered volcanics; b- Argillaceous zone of altered volcanics; c- Sulphidic zone of altered volcanics; d- Silicified zone of altered volcanics.

that in the ground mass made of cryptocrystalline quartz, some quartz phenocrysts are found. In thin sections of silicified rocks, quartz phenocrysts are occassionally observed in a matrix composed of cryptocrystallame quartz. Combe, spherolitic and corona textures are found in silicified rocks.

These rocks are mostly primary but occasionally some secondary silicification is observed. In the silicified rocks, ferroxides, zeolite, clay minerals and carbonates plus opaque minerals are observed. From the XRD analysis of these silicified rocks, the main mineral is thought to be quartz and additionaly occurrences of chalcedony, dickite, zeolite, jarosite and crystobalite are found as secondary minerals.

MICROSCOPIC STUDY UNDER REFLECTED LIGHT

Polished sections of the samples, taken from various formations of the study area, are examined under reflected light. Pyrite, limonite, hematite, magnetite, rutile, anatase, chalcopynte and gold were observed. Accessory minerals are not described in detail.

Pyrite: It is found in many samples especially in the sulfide zone. Pyrite is found as euhedral or subhedral crystals and has resicular structure with concentrated shell of kidney shape. Pyrite crystals are replaced by limonite along the joint margins.

Limonite: Limonite is found along the joints or faurts in the rocks and mostly color the rock. Occasionally, they appear as the alteration product of pyrite and hematite.

Gold: They are found in silicified rocks as 5-10 micron crystals.

GEOCHEMICAL AND GEOSTATISTICAL ANALYSIS

Geochemical properties

The hydrothermal alterations seen in volcanic can lead to the occurrences of Au and Ag metals. The quality of hydrothermal alteration and the possibility of occurrences of ore minerals are determined by the composition of the volcanic rocks and the hydrothermal alteration. It is known that the solution takes Au and Ag with other elements into its constitution during circulation and at the proper environments it precipitates and deposits these elements. For this reason, especially at the localities where alteration is seen widely it is necessary to investigate the geochemical properties of the volcanic rocks whether they are plutonic or not. The tables of occurrences of Au, Ag, and their trace elements As, Hg, Sb in the unaltered volcanic rocks are given in Table 1a (Boyle, 1979) and their major oxide compositions are given in Table 1b (Jakes and White, 1972). The chemical analysis data of units obtained from the field is given in Table 2., and the

Table 1-a. Trace element content of volcanic rocks (Boyle, 1979); b. Major element content of volcanic rocks (Jakes and White, 1972).

Elements	[illegible]	Ag	Cu	Pb	Zn	As	Sb	Mo	Hg
ppm	[illegible]	[illegible]	80	6	[illegible]	7	[illegible]	[illegible]	[illegible]

Ag % Rocks	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Andesite	[illegible]	[illegible]	[illegible]	5.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Low K Andesite	[illegible]	[illegible]	[illegible]	[illegible]	0.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Andesite	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.76
High K Andesite	58.52	16.20	[illegible]	[illegible]	[illegible]	4.14	[illegible]	[illegible]	[illegible]	0.40	0.76
Dacite	66.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.40	[illegible]

Table 2- Chemical analysis of the units in the study area.

				MAJOR ELEMENTS (%)										TRACE ELEMENTS ppm (Au: ppb)								
			S.No	SiO2	Al2O3	Fe2O3	SO3	CaO	MgO	Na2O	K2O	A.Za	Top	Sb	Au	Ag	Zn	Pb	Mo	Cu	As	Hg
HALLAÇLAR FORMATION	Unaltered Volcanites		130	60.70	15.68	5.76	1.20	5.63	2.35	3.20	3.15	1.34	99.01	<4	4	<1	36	10	1	48	<5	<1
			151	64.35	14.88	4.18	1.19	5.61	0.89	3.32	3.57	1.05	99.04	<4	<2	<1	24	12	1	25	<5	<1
			S.2	60.34	14.60	5.83	0.79	6.51	2.20	2.87	3.27	2.60	99.01	4	<28	<1	50	18	2	65	5	<1
			K.5	61.42	14.99	5.63	0.34	6.34	2.40	3.00	2.50	2.41	99.05	<4	<2	<1	20	<10	4	53	<5	<1
			3	65.81	15.25	3.89	1.48	2.86	0.37	2.87	3.47	3.00	99.00	<4	7	<1	14	44	1	21	<5	<1
	Altered Volcanites	Slightly Altered Volcanites	K 2	73.91	9.03	7.52	1.78	0.35	0.18	0.00	0.00	6.25	99.02	6	2	<1	15	<10	1	32	12	2
			K 1	70.65	13.79	6.71	0.38	0.48	1.00	0.07	0.02	6.23	99.33	6	<2	<1	<10	<10	1	10	15	<1
			S.9	63.07	13.23	11.6	0.67	0.69	0.49	0.07	0.09	9.08	99.05	<4	9	<1	19	44	10	22	12	<1
			S.3	78.96	9.57	2.89	1.48	0.91	0.24	0.02	0.40	5.36	99.83	14	3	<1	8	64	8	31	130	<1
			S.6	73.42	14.78	1.28	0.17	1.35	0.49	0.10	2.83	4.63	99.05	<4	<2	<1	<10	108	1	23	10	<1
			K 3	81.20	4.84	6.41	1.21	1.03	0.24	0.04	0.12	4.07	99.26	4	2	<1	16	10	1	62	60	2
			K 4	71.75	14.14	1.46	1.21	1.10	0.79	0.10	2.87	5.61	99.03	<4	4	<1	10	32	<1	14	<5	<1
			S.11	51.83	13.48	15.4	1.05	1.38	1.19	0.04	1.15	8.89	99.41	<4	<2	1	109	16	1	69	<5	<1
		Sulf. z	65	57.84	16.63	6.79	0.11	4.03	1.36	0.48	2.44	10.8	100.5	<4	<10	<4	30	21	<1	60	55	1
			148	70.50	6.18	9.27	21.6	0.33	0.17	0.02	0.12	10.6	118.8	<4	<2	<1	83	230	3	81	120	<1
		Argillic ?	150	64.17	16.50	3.20	1.75	1.25	0.36	0.63	1.83	9.46	99.15	<4	2	<1	10	25	<1	15	60	<1
			114	64.96	16.02	2.93	1.96	1.08	0.58	0.90	3.57	7.69	99.69	<4	<2	<1	<10	44	2	9	10	<1
			S.4	66.73	18.03	1.90	1.00	2.05	0.18	0.02	1.80	8.13	99.84	<4	<2	<1	11	40	1	13	20	<1
			S.5	74.69	13.97	1.06	1.07	1.93	0.20	0.10	3.20	3.94	100.2	<4	<2	<1	<10	385	1	7	10	1
			S.10	68.00	15.74	4.20	0.41	1.25	0.54	0.04	2.95	6.13	99.07	<4	<2	<1	10	26	4	13	45	<1
		Silicified zone	S.7	91.57	0.70	3.94	0.24	0.65	0.22	0.00	0.07	1.93	99.32	44	3310	<1	23	310	8	89	25	5
			S.8	91.52	0.89	3.55	0.43	0.45	0.16	0.00	0.05	2.18	99.24	44	1850	<1	33	222	32	130	20	2
			43	86.95	4.62	0.55	1.91	0.74	0.03	0.48	0.19	5.07	100.5	<4	<10	<4	19	14	1	17	20	<1
			72	95.91	0.50	1.04	0.23	1.01	0.14	0.00	0.00	0.46	99.29	<4	<10	<4	32	7	1	12	5	<1
			25	92.74	1.31	2.72	0.11	1.01	0.01	0.02	0.03	1.94	99.89	407	24	5.3	75	22	1	2120	165	3
			125	85.53	3.09	2.33	0.51	3.12	0.78	0.04	0.17	3.95	99.52	<4	<10	<4	9	16	5	8	55	1
			131	93.55	1.53	1.02	0.74	0.96	0.14	0.07	0.17	2.15	100.4	<4	<10	<4	15	13	4	13	25	<1
			134	91.30	1.20	4.85	0.80	0.60	0.07	eser	0.07	0.35	99.34	11	<5	6.1	15	40	3	7	100	6.80
			135	94.10	1.50	2.05	0.75	0.05	0.15	eser	eser	0.30	99.00	8.00	800	3.2	13	<10	1	7	20	3.2
			40	88.17	5.06	2.17	0.28	1.18	0.02	0.00	0.07	3.02	99.95	<4	20	<4	33	43	36	20	15	1
			79	81.10	4.40	9.45	0.75	0.05	0.10	eser	0.40	2.60	99.05	<4	<5	4.6	18	50	12	7	110	2.6
			91	75.85	12.15	2.85	0.60	0.10	eser	0.10	0.40	6.55	99.70	<4	10	6.2	12	40	1	3	100	2.7
			99	74.45	12.25	6.05	0.50	0.30	0.10	0.10	0.30	5.45	99.55	<4	5	8	20	65	1	4	100	4.2
			K 6	61.53	6.36	4.36	0.91	1.58	0.38	0.04	0.14	3.70	99.30	<4	3	<1	10	32	2	21	60	<1
			128	72.41	4.64	13.5	2.06	0.88	0.21	0.13	0.17	6.31	100.4	<5	<10	<4	21	45	28	53	9	3
Dedetepe Formation			15	60.86	15.95	4.95	0.60	4.50	2.75	3.10	3.55	2.50	99.76	<4	<5	8	35	30	1	4	5	2.65
			47	61.50	15.90	4.95	0.53	4.40	2.35	3.45	3.55	1.65	99.28	<4	<5	<1	35	25	12	1.5	110	2.60
			107	63.48	13.38	4.19	0.74	8.45	1.93	2.39	3.27	3.02	100.8	<4	<10	<4	28	22.00	<1	26	<5	<1
			123	68.24	12.44	3.42	0.12	7.15	1.01	2.25	4.32	1.66	100.6	<4	<10	<4	29	16	<1	13	<5	<1
Soma Formation			1	4.1	16.50	3.20	eser	25.6	20.0	0.10	0.20	44.5	117.2	5	<5	2.5	15	<10	1	0.7	20	2.60
			132	4.70	1.20	1.00	0.15	28.5	19.6	0.10	0.30	44.1	99.6	6	<5	5.3	20	<10	1	0.7	5	1.80

results of minimum, maximum, standard deviation and mean values of these analysis are given in Table 3. In the volcanic rocks of Hallaçlar formation and altered zones oxide compositions have shown that some elements have some distinct anomalies. For example SiO_2 content in unaltered volcanics are 60%. This shows that volcanics are rich in silica. When compared to the Table 1a, Al_2O_3 content is low in the zones except the argilic. CaO and Na_2O content in altered units and MgO amount are low in all units. K_2O is of low amount in slightly altered volcanics and at faces where sulfide occurrences are found, and silicified parts of the rocks, but it is a high amount of argillic zone and unaltered volcanics (Table 2). The total iron amount has monotonous distribution among units as seen in the diagram in Figure 3. If the average iron content of volcanic rocks (7.7%) is taken into consideration, then the result of chemical analysis of the samples are below this value. The table showing the average values of samples shows us that the iron amount is high (8%) only at the sulfide zone (Table 3).

The amount of S in volcanic rocks is 0.40% (Table 16). The S contents of the units belonging to Hallaçlar formation is very high compared to the normal values. These data (Table 3) and diagram (Figure 3) show that S content increases with alteration and it is also high enough at the silicified rocks although it is comperatively lower than the other rocks. The S amount in Dedetepe formation is lower than that in the Hallaçlar formation. In Dedetepe formation, SiO_2, Al_2O_3, CaO and Na_2O values are near normal values, but K_2O is found to be relatively higher. Figure 3, shows the distribution of the major, elements in volcanics and alteration units also shows the relations between the elements. The SiO_2 curve shows that in all units silica content is over 60%, and at units where alteration is changeable, it increases especially in silicified zones where it reaches the maximum value (95.9%). In Dedetepe formation, silica content do not vary from sample to sample and it has a constant value (63%) Same thing can also be seen in the curve which is smooth and straight.

Table 3- Minimum, maximum, standard deviation and mean values of chemical analysis.

			MAJOR ELEMENTS (%)								TRACE ELEMENTS ppm (Au ppb)								
			SiO2	Al2O3	Fe2O3	[illegible]	CaO	Mg	Na2O	K2O	[illegible]	Ag	Zn	Pb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HALLAÇLAR FORMATION	Unaltered Volcanics	min	51.83	14.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	5	[illegible]		[illegible]	[illegible]		[illegible]
		max	[illegible]	15.48	15.44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	4	[illegible]		[illegible]	[illegible]
		s.s	[illegible]	[illegible]	[illegible]	[illegible]	.47	[illegible]	[illegible]	[illegible]			4		[illegible]	[illegible]			
		avg	[illegible]	15.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	4			
	Altered Volcanics [illegible]	min	51.83	4.84	1.28	0.17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	8			[illegible]	[illegible]	[illegible]	[illegible]
		max	81.30	18.48	15.40	1.78	[illegible]	[illegible]	0.10	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		s.s	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]			
		avg	70.61	[illegible]	6.66	[illegible]	[illegible]	0.58	[illegible]	[illegible]			[illegible]	[illegible]	4	[illegible]			
	[illegible]	min	57.84	6.18	6.79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		max	70.62	16.63	9.27	21.50	4.03	[illegible]	0.48	2.44	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
		s.s	9.02	7.39	1.75	15.20	2.61	0.84	[illegible]	[illegible]			[illegible]	[illegible]		[illegible]	[illegible]		
		avg	64.22	11.40	8.03	10.80	2.18	0.76	0.25	[illegible]			[illegible]	[illegible]		[illegible]	[illegible]		
	Argillic Z.	min	64.17	[illegible]	[illegible]	[illegible]	[illegible]	0.18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]
		max	74.69	[illegible]	4.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	4	[illegible]	[illegible]		[illegible]
		s.s	4.18	1.46	[illegible]	0.62	0.44	0.18	0.40	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]		
		avg	67.71	16.05	2.61	[illegible]	1.51	0.37	[illegible]	2.67				[illegible]	[illegible]	[illegible]	[illegible]		
	Silic. Z.	min	72.41	0.50	0.55	[illegible]	0.05	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	7	[illegible]	[illegible]	5	1	[illegible]
		max	95.91	12.25	13.56	2.06	[illegible]	0.28	0.48	[illegible]	[illegible]	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		s.s	7.61	3.79	3.46	0.57	0.76	0.20	0.12	0.19			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
		avg	86.45	4.03	4.10	0.72	0.85	0.17	[illegible]	0.19			24	[illegible]	[illegible]	[illegible]	[illegible]		
Dedetepe Formation		min	60.86	12.44	3.42	0.12	4.40	[illegible]	2.25	[illegible]	5	[illegible]	28	[illegible]	[illegible]	[illegible]	[illegible]	1	4
		max	68.24	16.95	4.95	0.74	8.45	2.75	[illegible]	[illegible]	5	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
		s.s	3.34	2.35	0.73	0.29	2.06	0.75	0.57	0.45			[illegible]	[illegible]		[illegible]			
		avg	[illegible]	14.91	[illegible]	0.49	6.12	[illegible]	2.79	[illegible]			[illegible]	[illegible]		[illegible]			
Soma Formation		min	4.1	1.20	1.00	eser	28.45	19.6	0.10	0.20	5	2.5	15	[illegible]	1	[illegible]	5	[illegible]	5
		max	4.7	16.50	3.20	0.15	28.60	[illegible]	0.1	0.30	5	[illegible]	20	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]
		s.s	0.42	10.82	1.55	0.11	0.11	0.28	0.00	0.07		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		avg	4.4	8.85	2.10		[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

When the Al_2O_3 and SiO_2 *curves* are compared it is seen that Al and Si elements has a reverse relation. K element in Hallaçlar formation has a higher value than average which is (2%) in volcanics. Ca and Na elements have lower values in Hallaçlar formation in the altered units. Mg is lower than the normal values in all units. The three elements are decreasing although the alteration is increasing. From the curves it is seen that Ca, Mg and Na elements are increasing from unaltered volcanics towards silicified zones. In Dedetepe formation, Ca has normal values (6.12%) where Na and mostly Mg show a decreasing trend.

Disseminated pyrite occurrences seen in Hallaçlar formation (west of Asmaçam Hill, north of Dereoba Village), can be the result of high amounts of iron and sulphur in this zone. The lowest and nearly stationary amount of iron (2.61 in average) is found in the argillic zone.

Chemical analysis data of Au, Ag, As, Hg, Ma, Pb, Zn, Cu elements of units taken from volcanics and altered zones are given in Table 2 and their diagrams are shown in Figure 3. It is seen from the diagram that the values of Cu, Zn, and Pb have ircieasing values at the zones where alteration is seen.

In slightly altered volcanics, Mo and As show a small increasing amount where it reaches the maximum (36-165 ppm) at silicified zone.

On the contrary, Au, Ag and Hg values are only seen in silicified zones (Fig. 3).

The dispersing values of gold in the various rocks are close to the amount of it to be found in volcanic rocks. (Fig. 4). Silver is commonly below the detection limit (1 ppm). As seen from the diagrams, Au (max. 3300 ppb) and Ag (max. 8 ppm) has high values at the silicified zone of Hallaçlar formation.

According to the values of unaltered volcanics, Zn (93 ppm) has a low value in the study area. Cu has high values at the silicified zones. For example, Cu normally has a value of 80 ppm in volcanic rocks but in silicified zones, it has a value of 157.1 ppm on the average. Mo is higher than the normal (1.8 ppm) in altered zones and it has a maximum value (9 ppm in average) in silicified zones. It is known that in porphyry rocks, hydrothermal solutions can lead to porphyry copper and molybdenite anomalies. These anomalies are the result of washing volcanic rocks with solutions which are enriched in Cu and Mo which are deposited in the silicified zone. Pb has an increasing trend in slightly altered volcanics. (45.3 ppm), in the argillicious zone (107 ppm in average) and in sulphide zone (125.5 ppm). Usually Sb and Hg are generally below the detection limit (Sb: 4, Hg: 1 ppm), only Hg has a high value in the silicified zone. Mo has higher values than the normal (1.8 ppm) in all samples except in those taken from the silicified zone.

Gaostatlstical evaluation

The geostatistical relation of elements can be explained by the correlation coefficient method. The accuracy of this method depends on the number of analysis. The number of analyses are limited in this research thus we can use the correlation coefficient method which will have a meaning when evaluated with the other data (Table 4). In order to clarify the effects of hydrothermal alteration on elements it will be helpful to outline the data. In the volcanics of Hallaçlar formation, as seen from Table 4 and Figure 3, there is a negative relation between Si-AI, Si-Fe, Si-Cu, Si-Ca, S-Mo, K-Mo and a positive relation between Fe-Cu, Fe-Mg, S-K, Ca-Mg, Mg-Cu elements. In the slightly altered volcanics, Si-AI, Si-Zn elements have negative AI-Mg, and Mg-Zn elements have positive relations. In the argillic zone there is a negative correlation between Fe-Ca, Ca-Mg and a positive one between Si-Pb, S-Na, Cu-As, Fe-Mo, Mo-As and Fe-Mg. In the silicified rocks, AI-Si have negative and Ca-Mg, Cu-Zn and Au-Pb elements have positive correlation. In Dedetepe volcanics Si-(AI, Na, Mg, Fe, Bp), AI-Ca, S-K, Ca-Na, Ca-Zn, Na-Cu and Zn-Cu, Mg-Pb, Na-Zn have positive correlation.

RESULTS AND DISCUSSION

Most of the elements, contained in solutions which result in the deposition of epithermal gold and other metals, are gained from plutonic rocks. (Hedenquist and Henley, 1985). The analyses obtained from the nearest rocks to the gold deposits show that the solutions carrying ore minerals have changed the chemistry of these rocks through

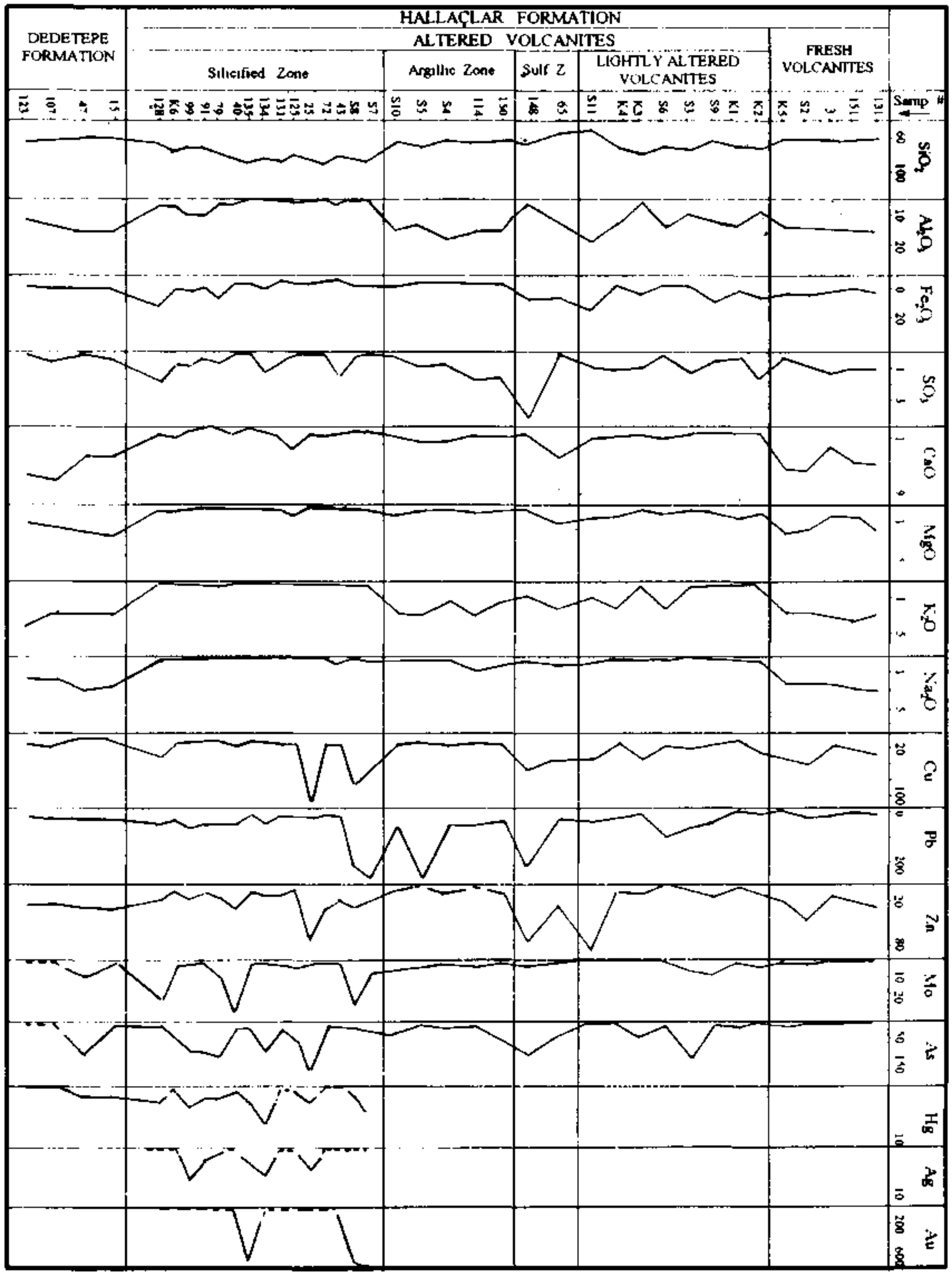

Fig. 3- Seperation diagram of the major and trace elements of Hallaçlar and Dedetepe formations.

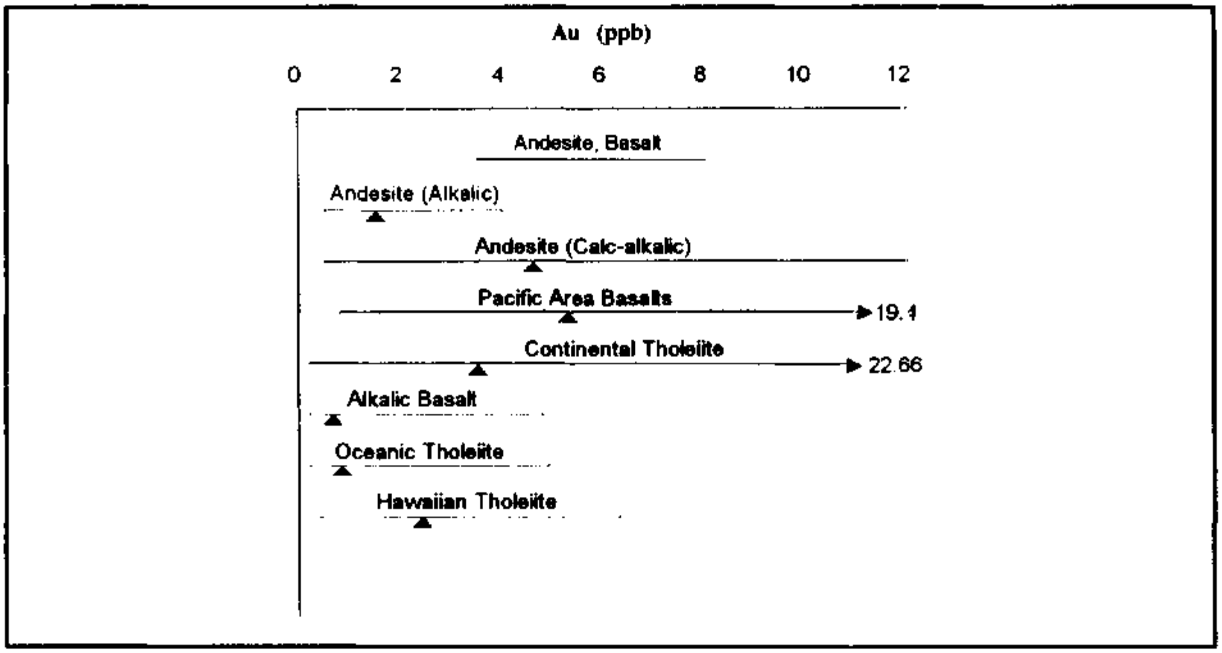

Fig. 4- Gold content of volcanic rocks (Hedenquist and Reid, 1986).

which they pass. (Krauskopf, 1967). Field surveys, microscopic and geochemical investigations showed that only the Hallaçlar formation has some alterations due to hydrothermal solutions among the other formations in the study area. Hallaçlar formation is divided into subunits, unaltered volcanics, slightly altered volcanics, argillic zone, silicified zone and sulfide zone according to the hydrothermal alteration processes that occurred in the rock. Similar subdivision is also explained by Erdoğan (1993). It is seen during the microscopic and XRD investigations that the volcanics considered unaltered, are slightly affected by hydrothermal solutions and they are enriched in silica. In these rocks, K is higher than the normal. Apart from these, Al content is lower than the volcanic rocks in all the units except the argillic zone and Mg content is low in all units. The values of Na and Ca decreases with alteration. It is expected that the elements (Ca, Mg, Na) decreases with the alteration degree (slightly altered volcanics, argillic zone, silicified zone) of the volcanic rocks affected by hydrothermal solutions (Table 2, Figure 3). On the other hand, K is high in unaltered volcanics, and normal in the argillic zone and decreases in the silierified zone. The relation of potassic montmorillonite and illite determined by X ray diffractions can explain the excess K in the argillic zone. Although Fe and Mg ions can overtake with the Al and Si elements found in clay minarals, the decrease of Fe, Mg, Ca, and Na elements in the argillic zone points out that these solutions are not rich in the considered elements. Hydrothermal alterations occurred in volcanic rocks and occurrences of ore minerals due to the same genetic period especially related with metal content of the plutonic rocks. (Hedenquist and Henley, 1985). The contents of Au, Ag metals with the trace elements Pb, Zn, Cu, As, Sb, Hg, Bi, Te in source rocks and their dispersion points out clues for ore deposition. The vertical and horizontal zoning known in epithermal systems (Hollister, 1985; Berger and Eiman, 1982) shows the importance of these mentioned elements. Hydrothermal alterations and trace element anomalies are only seen in Hallaçlar formation among the investigated volcanic rocks. Hydrothermal solutions are not effective in Dedetepe and other young formations. Observation continued in a wide area and geochemical analysis showed that hydrothermal activity has stopped before the formation of Dedetepe formation (Lower Miocene), unless alteration products should be observed in the other formations. Excluding the silicified zone of Hallaçlar formation, in the other units, Au, Ag, Cu, Mo, and Hg are lower than the normal values. On the other hand, As and Pb show anomalies in all units of this formation. In the silicified

Table 4- Correlation coefficients of element contents in the Hallaçlar and Dedetepe formations.

Hallaçlar Formation
Unaltered Volcanites

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Mo	Cu
Si											
Al	0.91	1									
Fe	0.98	0.01	1								
S	0.54	0.45	-0.68	1							
Ca	0.83	0.40	0.77	0.76	1						
Mg	[illegible]	0.01	0.98	0.73	0.32	1					
Na	0.03	0.29	0.25	0.23	0.28	0.01	1				
K	0.56	-0.04	-0.65	0.85	0.48	0.75	0.19	1			
Zn	-0.77	0.31	0.70	0.20	0.63	0.60	0.08	0.06	1		
Mo	0.29	0.35	0.51	0.94	0.52	0.57	0.32	0.91	0.37	1	
Cu	0.95	0.27	0.95	0.72	0.78	0.91	0.30	0.58	0.76	0.55	1

Hallaclar Formation
Slightly Altered Volcanites

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Pb	Mo	Cu
Si	1											
Al	0.82	1										
Fe	-0.78	0.31	1									
S	0.23	-0.49	0.05	1								
Ca	0.25	0.39	0.06	0.25	1							
Mg	-0.74	0.82	0.39	0.43	0.30	1						
Na	0.13	0.48	-0.35	0.76	0.42	0.78	1					
K	0.08	0.15	-0.49	0.31	0.70	0.27	0.75	1				
Zn	0.82	0.70	0.79	0.28	0.61	0.81	0.06	0.11	1			
Pb	0.25	0.18	-0.56	-0.63	0.15	0.31	0.41	0.45	0.48	1		
Mo	-0.03	0.05	0.06	0.07	0.16	0.28	0.01	0.28	0.41	0.1	1	
Cu	0.24	0.14	0.55	0.34	0.44	0.02	0.47	0.21	0.70	0.59	0.17	1

Hallaclar Formation
Argillic Zone

	Si	Al	Fe	S	Ca	Mg	Na	K	Pb	Mo	Cu	As
Si	1											
Al	0.74	1										
Fe	0.66	0.24	1									
S	0.47	0.09	0.06	1								
Ca	0.60	0.18	0.83	0.39	1							
Mg	0.48	0.07	0.81	0.17	0.92	1						
Na	-0.60	0.03	0.23	0.91	0.72	0.55	1					
K	0.38	0.70	0.01	0.05	-0.34	0.53	0.25	1				
Pb	0.94	0.79	-0.77	-0.15	0.53	-0.51	-0.33	0.38	1			
Mo	-0.30	0.07	0.93	0.46	-0.72	0.77	-0.02	0.27	0.48	1		
Cu	0.59	0.70	0.61	0.10	0.22	0.07	0.04	0.79	0.77	0.47		
As	0.47	0.24	0.68	0.10	-0.42	0.20	0.02	-0.56	0.50	0.85	0.85	1

Hallaçlar Formation
Silicified Zone

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Pb	Mo	Cu	As	Hg	Au
Si	1														
Al	-0.82	1													
Fe	-0.70	0.26	1												
S	0.45	0.15	0.44	1											
Ca	0.07	-0.19	0.22	0.06	1										
Mg	0.06	-0.14	0.00	-0.01	0.82	1									
Na	0.14	0.28	0.10	0.72	0.03	-0.16	1								
K	-0.76	0.75	0.37	0.24	0.22	-0.06	0.06	1							
Zn	0.33	-0.30	-0.12	0.38	0.05	0.38	0.15	0.40	1						
Pb	0.17	0.25	0.07	0.27	-0.27	0.01	-0.26	-0.20	0.04	1					
Mo	0.12	0.12	0.36	0.08	0.00	0.06	0.19	0.13	0.14	0.32	1				
Cu	0.24	-0.22	0.10	-0.30	0.05	0.22	0.11	0.27	0.89	0.09	0.14	1			
As	-0.22	0.33	0.15	0.29	0.13	0.18	0.16	0.38	0.35	0.40	0.40	0.60	1		
Hg	0.12	0.11	0.15	0.10	0.42	0.32	0.05	0.11	0.11	0.23	0.46	0.03	0.25	1	
Au	0.50	-0.50	0.01	0.29	0.20	0.33	0.51	0.38	0.08	0.97	0.20	0.19	0.51	0.47	1

Dedetepe Formation

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Pb	Cu
Si	1										
Al	-0.89	1									
Fe	-0.98	0.96	1								
S	-0.51	0.11	0.34	1							
Ca	0.62	-0.90	-0.75	0.26	1						
Mg	-0.98	0.91	0.97	0.53	0.67	1					
Na	0.82	0.96	0.91	0.07	0.90	0	1				
K	0.80	0.45	0.69	0.80	0.05	0.74	0.39	1			
Zn	-0.74	0.96	0.85	0.12	0.99	0.76	0.66	0.79	1		
Pb	-0.95	0.90	0.94	0.51	0.69	0.99	0.76	0.66	0.79	1	
Cu	0.42	0.78	0.58	0.48	0.97	0.47	0.81	0.18	0.91	0.50	1

zones of the rocks, Au, Ag, Cu, Pb, Mo, As and Hg have high values with anomalies. The behavior and dispersion of the elements in volcanics and alteration zones shows that the silicified zone of the Halaçlar formation has importance in the enrichment of valuable metals. It is known that during transportation of gold in epithermal systems, the liquids with H_2S and chlorite, having virtually neutral PH and a considerable amount of gasses in solution plays an important role (Hedenquist ,1983). The boiling, cooling and mixing of these solutions, depending on the place and time factors are the mechanisms which affects the economic importance of ore metals. The condensation near the surface or at the deeper parts of the mixture of vapor and gas produced by the boiling and evaporation of the meteoric water, reaching the source of heat can lead to different mineralization. The condensation near the surface leads to kaolinite, alunite, crystobalite, amorphous silicates, and sulphur deposition. If this mixture condenses in the deeper parts, then, montmorillonite, illite and kaolinite will appear (Hedenquist and Reid, 1986). The samples from the study area, examined by X-Ray diffraction, showed that mostly montmorillonite, illite and kaolinite occurred as clay minerals. From this data, we can conclude that the mixture of vapour and gas is condensed in fairly deep conditions. For this reason, the condensation in the deeper parts is a handicap for occurrence of ore deposit (Hedenquist and Reid, 1986), explains the precious metal deposits, or enrichments occur in small amounts.

Some metals can be deposited because of vapor condensation with ore carrying chlorite solutions rarefication. As a result, although it was not found any valuable metal enrichment in the study area, mineralogical and geochemical characteristics of hydrothermal alterations encourage further investigations. The silicified zones which reflect the remarkable increase in elements important for epithermal mineralizations implies the important circulation of the hydrothefmal solutions in this area. Although they do not directly lead to the ore mineralization. The reduction of primary porosity by widespread silicification can result in the formation of the liquid reservoir in certain parts which leads to jointing and brecciation in the later stages. In addition to the silicified zone, extremley argillicious zone are important from the point of ore mineralization in the study area. The silicified calcite veins with gold in the study area implies a detailed tectonic survey of the area should be done. Following this study, at the sites which seem to be important for precious metals (silicified and argillic zones), investigations related to determine the vertical characteristics of mineralization are to be planned in the future.

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