No. 16

REPORT
ON
THE MINERAL EXPLORATION
IN
THE ESPİYE AREA,
THE REPUBLIC OF TURKEY

PHASE I

MARCH 1996

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in reponse to the request of the Government of Republic of Turkey, conducted mineral exploration, composed analyzing existing data and geological and geophysical surveys, in Espiye, Turkey. The Japanese Government entrusted the survey work to the Japan International Cooperation Agency (JICA), and JICA in turn sought the cooperation of the Metal Mining Agency of Japan(MMAJ) to accomplish the survey work, considering the importance and technical nature of the work.

The survey work in the survey area will be carried out within a period of three years commencing from 1995. MMAJ dispatched the survey mission consisting of 7 members to Turkey from September 5th, 1995 to December 7th, 1995.

The survey work in Turkey was carried out successfully with cooperation of the Turkish Government authorities, and General Directorate of Mineral Research and Exploration. This report summarizes the results of the survey work carried out in 1995, and also forms a part of the final consolidated report which will be submitted to the Government of Republic of Turkey after completion of the survey work.

We wish to express our deep appreciation to the officials of the Government of Republic of Turkey and to the Embassy of Japan in Turkey concerned for their close cooperation extended to the survey mission.

March, 1996

Kimio Fujita
President
Japan International Cooperation Agency

Shozaburo Kiyotaki
President
Metal Mining Agency of Japan

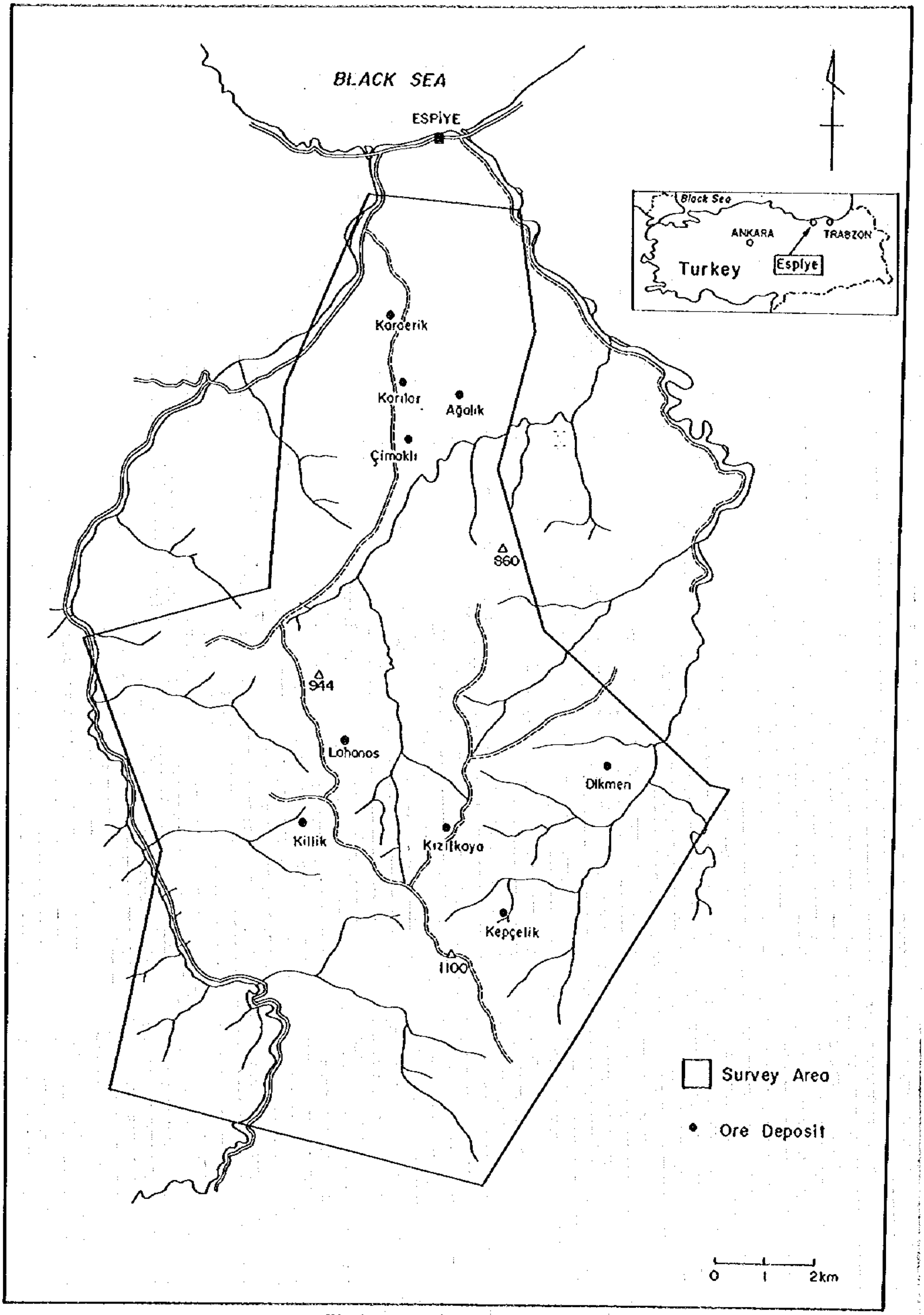

Fig. 1－1 Locality of the Survey Area

SUMMARY

This survey was carried out to discover new massive sulfide ore deposits in the Espiye area of the Republic of Turkey by investigating the geology and mineral occurrences.

In the first year of three year project commencing in 1995, surveys consists of analyzing existing data, a geological survey and a geophysical survey were conducted. In existing data analysis, geology and mineral occurrences, the characteristics of massive sulfide ore deposits, and disseminated to networked ore deposits, were studied by compiling the existing data, and then the survey routes for geological, geochemical and geophysical surveys were selected. The geological survey was performed simultaneously with the geochemical survey, and geochemically anomalous zones were detected. Gravity and IP surveys were carried out as the geophysical survey. IP surveys were performed in promising areas for new ore deposits, and IP anomalies thought to be derived from mineralization were detected.

Geology of the area is composed of the Çatak, Kızıkaya and Çağlayan formations, that are considered to have been formed in the Cretaceous. The Çatak formation mainly consisted of andesitic rocks, and The Kızıkaya and Çağlayan formations mainly consist of dacitic rocks.

In geological structure, the southern to western part was uplifted during deposition of Çatak formation, and the central to northern part was subducted during deposition of the Kızıkaya and Çağlayan formations. Dacite of the Kızıkaya formation was controlled by north-eastern to north-western fractures in the Çatak formation and extruded at subduction zones in the central part of the survey area. The center of volcanic activity shifted from south to north as time passed, and then dacite of the Çağlayan formation was extruded in the northern part under control of north-northwestern, north-eastern and east-western fractures.

On the short-wave gravity map, high gravity zones in southern part of the survey area, low gravity zones in central to northern parts, and high gravity zones aligned north-south in these low gravity zones can be recognized. Massive sulfide ore deposits such as Lahanos and Killik ore deposits develop on gradual zones from low to high gravity zones, and disseminated to networked ore deposits such as Karaerik and Kartlar ore deposits develope around marginal zones of high gravity zones.

Massive sulfide ore deposits such as Lahanos and Killik ore deposits are hosted by conformably in the uppermost members of theKızıkaya formation. Disseminated to networked ore deposits such as Karaerik and Kartlar ore deposits are contained in Çağlayan formation. Massive sulfide ore deposits are composed of pyrite, chalcopyrite and sphalerite as main components, and of galena, tetrahedrite, gold and silver minerals as accessory components. Disseminated to networked ore deposits consist of pyrite as the main ore mineral, and of chalcopyrite and sphalerite as accessary ore minerals. Scale, ore reserves and ore grade of massive sulfide ore deposits are usually much higher than those of disseminated to networked ore deposits.

Neutral to alkaline alteration by weak regional metamorphism and neutral to acidic alteration by mineralization were observed. Strongly altered zones that appear white and include kaolinite as an acidic alteration product were formed around massive sulfide ore deposits of Lahanos ore deposits. Strongly altered zones that appear white and include sericite as an neutral alteration product were formed around other massive sulfide ore deposits such as Killik and Kızıkaya ore deposits. And strongly altered zones that appear white to reddish brown and include kaolinite and hematite as neutral alteration minerals were formed around disseminated to networked ore deposits such as Karaerik and Kartlar ore deposits.

The geochemical survey revealed that Au, Ag, Cu, Pb, Zn, As, Sb, Fe and Mo behaved similaly in alteration, and amounts of these elements in this survey area were much higher than those of worldwide background values because of addition during mineralization. Geochemically anomalous zones correspond very well to The distribution of mineralized zones around known ore deposits and alteration zones. And geophysically anomalous zones, such as low resistivity zones and IP anomalous zones, detected in the Çaglayan formation also corresponde very well to geochemically anomalous zones around massive sulfide and disseminated to networked ore deposits.

After a general analysis, five areas were selected as hopeful areas for next year's program, these are, The area between Lahanos and Killik ore deposits, The area between Killik and Kepçelik ore deposits, The area between Çalkaya and Taflançık, The area between Çımakli and Karaerik ore deposits, and the Dikence area. In these areas, Kızıkaya formation containing massive sulfide ore deposits was covered by Çaglayan formation, and well mineralized and altered zones, and geochemically and geophysically anomalous zones were recognized. Next year, it is requested that drilling, detailed soil geochemical surveys, and supplementary geophysical surveys be conducted, because some of this year's surveys were not sufficiently accurate.

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PART I GENERAL REMARKS

Chapter 1 Introduction

1－1 Background and Purpose

This survey will be held for three years from 1995, and this is the first year of this survey. The survey area was established around Espiye area in the Republic of Turkey, where it is highly probable that massive polymetallic sulfide ore deposits exist. It is urgently important to explore in this area and to estimate, because real exploration work has not been carried out sufficiently. Thus the government of Turkey requested the Japanese government to survey for mineral resources in the above mentioned area, under joint technological cooperation with Japan side. The government of Japan, in response to the request of the government of Turkey, decided to conduct basic surveys such as analysis of existing documents, and geological and geophysical surveys for new ore deposits, and to transfer technology to the Turkish side as the first year's program.

1－2 Survey Area and Outlines of the Survey

The survey area is shown as Fig. 1－1 The survey this year was composed of analysis of existing documents, and geological, geophysical surveys, and analysis of acquired data in the field. Outlines of each survey item is explained as follows,

1－2－1 Analysis of Existing Documents

The documents and reports regarding geology and geophysics of the surveyed area were collected in the head office and Black－Sea branch office of General Directorate of Mineral Research and Exploration (Maden Tetkik ve Arama in Turkish)(abbreviated form; MTA). The collection and analysis of these documents were referred to in deciding the survey plan, survey routes, sampling locations and others.

1－2－2 Geological Survey

Geological and geochemical surveys were conducted simultaneously in this survey. The potential for new ore deposits was discussed, and the hopeful areas for next step of exploration were selected after the gelogical survey, detailed surveys in mineralized zones, and geochemical surveys. The area of this geophysical survey was decided after a superficial geological survey. The result of geological survey were summarized on maps at a scale of 1 to 10,000.

Rock and soil samples were collected for the geochemical survey, and their sampling intervals are small in high potential areas and rather large in low potential areas. Contents of the survey is shown as Table 1－1.

1－2－3 Geophysical Survey

Gravity and IP surveys were performed as geophysical survey. The gravity method was adopted to survey the undulation of geological units controlling massive sulfide ore deposits and to survey underground structure. IP survey lines were decided based on existing documents and the results of the geological survey, and an attempt was made to detect IP anomalies derived from mineralization.

Table 1－1 List of Survey Amount (1)

Survey Items	Amount of Survey
Collection and Analysis of Existing Documents	Duration;7 days Surveyers;2 persons
Geological Survey	Survey area;150km² Total length of survey routes;100km
Geophysical Survey (Gravity Method)	Survey area;170km² Measured points;265 points
Geophysical Survey (IP Method)	Total length of survey lines;23.3km Measured points;1,031 points

Table 1－1 List of Survey Amount (2)

Items and Analytical Elements	Amount of Samples
Geological Survey;①Thin section	20 samples
Geological Survey;②Polished section	30 samples
Geological Survey;③X-ray diffraction analysis	200 samples
Geological Survey;④Chemical analysis of rock samples Mn, Fe, Cu, Zn, As, Ag, Mo, Sb, Ba, Au, Pb, SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, CaO, Cr_2O_3, Na_2O, MgO, K_2O, P_2O_5, LOI	550 samples
Geological Survey;⑤Chemical analysis of rock samples La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, U, Th	50 samples
Geological Survey;⑥Chemical analysis of ore samples Au, Ag, Cu, Pb, Zn, As, Sb, Fe, Mn, Mo, Ba, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, U, Th	50 samples
Geological Survey;⑦Chemical analysis of soil samples Mn, Fe, Cu, Zn, As, Ag, Mo, Sb, Ba, Au, Pb	250 samples
Geophysical Survey;①Measurement of density	112 samples
Geophysical Survey;②Measurement of resistivity and chargeability	45 samples

1-3 Survey Team

Members participating in planning, negotiation, surveys, and various analysis are as follows,

(1)Planning and negotiation

Japanese Members		Turkish Members	
Junichi TOMINAGA	Metal Mining Agency of Japan	Mehmet BALCI	MTA
Kenichi TAKAHASHI	Japan International Cooperation Agency	Yavuz ULUTURK	MTA
Naoki SATO	Metal Mining Agency of Japan	Ramazan DOĞAN	MTA
Takashi OKAMOTO	Metal Mining Agency of Japan	Murat ER	MTA

MTA;General Directorate of Mineral Research and Exploration.

(2)Survey Team

Japanese Members		Turkish Members	
Jiro DATE(geologist)	DOWA	Murat ER(JYM)	MTA
Yukio KINRYU(geologist)	DOWA	Nevzat KARABALIK(JYM)	MTA
Hiroshi MIYAMOTO(geologist)	DOWA	Hüseyin YILMAZ(JYM)	MTA
Junichi ISHIKAWA(geologist)	DOWA	Kemal ÖZDĞAN(JYM)	MTA
Shigeo MORIBAYASHI(geophysist)	DOWA	Mustafa KURÇELiK(JYM)	MTA
Kuraei IWAKI(geophysist)	DOWA	Ali FAiK ALTINBAS(JYM)	MTA
Norikiyo SUGIURA(geophysist)	DOWA	Turgut ÇOLAK(JYM)	MTA
		Mustafa DEMiRHAN(Jeofz)	MTA
		Hasan UĞURLU(Jeofz)	MTA
		Kadir DEMiR(Jeofz)	MTA
		Hasan SOYLU(Jeofz)	MTA
		Ömer DUMAN(Jeofz)	MTA
		Ethem OFLU(Bolge)	MTA
		Erdem ÖZBAYRAK(Bolge)	MTA

DOWA; DOWA Engineering Comany Limited.

(3)Supervisor in Turkey

Haruhisa MOROZUMI	Metal Mining Agency of Japan

1-4 Duration of the Survey

(1)Field Survey in Turkey; September, 5th, 1995~December, 7th, 1995

(2)Data Collection in Turkey; September, 7th, 1995~September, 15th, 1995

(3)Geological Survey; September, 16th, 1995~November, 27th, 1995

(4)Geophysical Survey; October, 8th, 1995~November, 11th, 1995

(5)Data Analysis in Turkey; November, 28th, 1995~December, 4th, 1995

Chapter 2 Geography of the Survey Area

2-1 Location and Traffic

The survey area is located about 100km west from Trabzon city which runs along the Black Sea as shown in Fig. 1-1. The base camp was established in Espiye town facing the Black Sea, and the survey area is south of Espiye.

Espiye is connected with Trabzon by paved road and it takes two hours to go from Trabzon to Espiye by car. There is no paved road from the base camp to the survey area, but it takes only two hours to go from base camp to the southern end of the survey area by car.

2-2 Topography and Drainage

The survey area is in theBlack Sea coastalrange, and the Eastern Black Sea folded mountains formed in Alpine orogenesis (Inoue, 1970) are located hear the survey area. Therefore, plains occupy only a small area along the Black Sea, and altiudes vary from several tens of meters' to around 1,400m with steep undulations. The Northern part of the survey area shows hilly and mild topography except in river side areas. But the central to southern parts show mountainous and steep topography. Generally, altitudes in the survey area increase from north to south.

In the north soft pyroclastic rocks are found, and in central to southern part hard volcanic rocks are found Especially, the tops of many mountains are formad of hard intrusive rocks such as dacite.

In the center east and west, The river system is almost north-south. The river system is well developed and river water is usually abundant.

2-3 Climate and Vegetation

This is the most rainy and snowy area in Turkey, because of wet winds from the north to Black Sea Mountains. The climate of this area is called a "Black Sea type climate" (MMAJ;1970) and vegetaion is also well developed. It is very rainy and snowy from September to March, and there is an average precipitation of 1,000mm in Trabzon. The snowy season starts every year in November. Average temperatures are 24° C in August at a maximum and 6° C in February at a minimum.

This area is very rich in trees and bushes due to the high humidity, So it is rather difficult to see far in mountain ous areas. This area is well known for its production of hazelnuts and tea, and these plants are found high up mountain slopes.

Chapter 3 General Geology

3-1 Outline of Geology

According to Kormaz et al. (1992), Turkey is divided geologically into 3 regions, that is, The pontides in northern Turkey, the Anatolides in the central part, and the torides in the south. The survey area is situated in the north--eastern part of the Pontides. The basement of the Pontides area is composed of metamorphic and granitic rocks, and 6 stratigraphical units overlie these basement rocks. These 6 stratigraphical units consist of Palaeozoic, early Jurassic~early Cretaceous, late Cretaceous~early Palaeocene, middle Palaeocene~late Eocene, Miocene~Pliocene, and Pliocene~Quaternary in ascending order.

The geology of the survey area is composed of the Çatak , Kızıkaya and Çağlayan formations, and intrusive rocks which are thought to have been formed from late Cretaceous~early Palaeocene.

The Çatak formation is dark green to light green due to chloritization and epidotization, and is composed of autobrecciated andesite lava and its pyroclastic rocks. It is found in southern part of the survey area.

The Kızıkaya formation is light gray to light green, and is composed of dacite lava and its pyroclastic rocks. Chloritization and sericitization can be seen commonly, and it predominates in the central part, with a thickness of over 500m thickness.

The Çağlayan formation is whitish gray to light green in color, and is composed of strongly brecciated dacite lava, its pyroclastic rocks and muddy rocks. In this formation, montmorillonitization can be recognized commonly. Muddy rocks showing well developed bedding planes exist at the lowest level in this formation. It predominates in the northern part and at high areas of the central part.

Intrusive rocks are composed of mainly dacitic and granitic rocks, and following the field survey, the dacitic rocks were subdivided as follows, porphyrytic dacite, red dacite, navaditic dacite and biotite dacite.

3-2 Structural Geology

It is belived that the southern to western parts of this survey area were uplifted and the central to northern parts were subducted. Çatak formation, mainly composed of andesitic rocks predominates in the raised zone, and the Kızıkaya and Çağlayan formations, composed of dacite lava and its pyroclastic rocks predominate subducted zone.

The Kızıkaya formation strikes north-east in the south-west and strikes north-west in south-east wher it contacts the Çatak formation.

In both areas, the Kızıkaya formation dips north, and in the central area it is very thick. The Çağlayan formation, which overlies the Kızıkaya formation, is thinner in the central area and thicker in the northern area.

In area where the Çağlayan and upper Kızıkaya formations are distributed, north east and north western geological structures diminish in the Çatak formation, while structures that strike east north east and dip gently north, and vovanic and intrusive activity by NNW--NNE structures predominate in the Çağlayan formation .

In other words, the center of volcanic activity shifted from the south to the north with time, and the orientation of geological structures also change from north-west and north-east systems in the south to north-northwest and north-northeast systems in the northern part.

Massive sulfide ore deposits were formed in subducted zones of the Çatak formation, accompanied by acidic igneous extrusive activity at the end of the Kızıkaya formation.

Disseminated to networked ore deposits were formed during acidic volcanic activity of Çağlayan formation.

3－3 Mineralized Alteration

Many ore deposits are well known in the survey area such as the Lahanos, Kızıkaya, Killik, Kepçelik, Dikmen, Ağalik, Çımakli, Karılar and Karaerik ore deposits.

The Lahanos, Killik and Kepçelik ore deposits are the central part of the area with thick accumulations of Kızıkaya formation. They are massive sulfide type ore deposits contained in the Kızıkaya formation judging from their relation with host rocks, confining beds and textures of ore minerals. In these ore deposits, they usually overlie dacite of the Kızıkaya formation, underlie muddy rocks and pyroclastic rocks of the Çağlayan formation, and are contained conformably by the in uppermost members of Kızıkaya formation.

On the contrary, the Karılar and Karaerik ore deposits are developed around volcanic centers of the Çağlayan formation in the north and are disseminated to networked ore deposits. Sometimes parts of the networked ore upper to be small bodies of pyrite ore.

Regarding alteration, acidic alteration such as kaolinitization can be observed around the Lahanos ore deposits.

But around other massive sulfide ore deposits, such as the Killik and Kepçelik ore deposits, neutral alteration predominant. Sericitic, kaolinitic and hematitic alteration can be recognized around disseminated to networked ore deposits, such as Karılar and Karaerik ore deposits contained in the Çağlayan formation.

Chapter 4 General Discussion of Survey Results

4－1 Geological Structure, Speciality and Control of Mineralization.

It is considered that volcanic activity was very predominant in this area through Cretaceous～Eocene, because volcanic rocks develope very widely and thickly. Geology of the survey area is composed of Çatak, Kızıkaya and Çağlayan formations in ascending order, massive sulfide ore deposits are contained in Kızıkaya formation consisting of mainly dacitic rocks, and disseminated to networked ore deposits are contained in Çağlayan formation consisting of mainly dacitic rocks. Both types of ore deposits are thought to have genetical relations with dacitic volcanic activities, but mineralization in Çatak formation consisting of mainly andesitic rocks is very small in their scale.

Acidic volcanic activity of Kızıkaya formation concerning massive sulfide ore deposits is thought to be controlled geologically by structure of Çatak formation underlying. Namely, Çatak formation shows north－eastern strike dipping north－westwards in south－eastern part and shows north－western strike dipping north－eastwards in south－western part. And then subduction zone extending in east－west direction was formed on Çatak formation in central part, acidic volcanic rocks relating genetically with massive sulfide ore deposits extruded, and Kızıkaya formation filled this subduction zone.

Analytical result of gravity shows low gravity zones extending north－eastwards in central part. As this low gravity zones correspond very well to argillized zones in Kızıkaya formation, this low gravity zones must be center of subduction zones and acidic extrusive rocks of Kızıkaya formation must come out of this low gravity zones. Lahanos, Kepçelik and other main massive ore deposits are considered to have been formed in center of subduction zones with thick deposition of Kızıkaya formation.

Subduction structure in Çatak formation seems to have been formed in north-westernwards tension field and Kızıkaya formation seems to have been formed in compression field samely directed as tension, judging from geological structure and gravity distribution patterns.

At the last stage of Kızıkaya formation, massive sulfide ore deposits were formed and then deposition of muddy rocks 5~10m thick took place. Afterwards, acidic activity started again and Çağlayan formationwas formed. From thickness of the formation and distribution pattern of lavas, volcanic center was in northern part shifted was from south.

Influenced from underlying formation, Çağlayan formation shows east-northeastern strike dipping north-northwesternwards in some places, but in western part north-west~north-northwestern wards strike dipping north-east~east-northeasternwards can be seen. In northern part, reverse faults extending north-northwesternwards also can be observed. Therefore, this area should be changed to be compression field in age of Çağlayan formation. In these compression field, north-northwestern uplift structure and north-east to east-western fracture zones are thought to have developed, and acidic volcanic rocks are also thought to have extruded along these fracture zones.

Disseminated to networked ore deposits such as Kartlar and Karaerik ore deposits develope around exit of dacite lava of Çağlayan formation in northern part. Even in eastern and central parts, ore showings composed of networks can be recognized in Çağlayan formation, and these ore showings seemed to have been formed later than Kızıkaya formation.

4-2 Relation between Geochemical Anomaly and Mineralization

This area shows regional alteration, because of strong volcanic and hydrothermal activities. In Çatak formation developing in western to southern parts, neutral to alkaline alteration was formed in green color, and chlorite(Mg-rich), albite(Na), epidote(Ca, Fe and Mn) and montmorillonite(Ca, Mg and Na) were also formed. In Kızıkaya formation existing in central part, white to light green colored alteration zones were formed with neutal acidity alteration minerals such as quartz(SiO_2-rich), chlorite(Mg) and sericite(K). In Çağlayan formation in northern part, light yellow to light green colored alteration zones were formed with neutral acidity alteration minerals such as montmorillonite(Ca, Mg and Na-rich) and cristobalite(SiO_2). Besides these regional alteration, strong alteration relating with massive sulfide ore deposits was formed in Kızıkaya formation, and strong alteration relating with disseminated to networked ore deposits was formed in Çağlayan formation. Around Lahanos ore deposits that are most typical massive sulfide ore deposits here, strong white alteration zone was formed with acidic alteration minerals such as quartz(SiO_2-rich), kaolinite(Al), alunite(K), sericite(K) and pyrite(Fe). Around other massive sulfide ore deposits such as Killik, Kızıkaya and other ore deposits, strong alteration zones were formed with neutral acidity alteration minerals such as quartz, sericite and pyrite. And around disseminated to networked ore deposits such as Kartlar and Karaerik, white to reddish brown alteration zones were formed with acidic to neutral acidity alteration minerals such as quartz, kaolinite, sericite, pyrite and hematite.

According to geochemical survey using rock samples, metallic elements such as Au, Ag, Cu, Pb, Zn, As, Sb, Mo and Ba show high value in their contents around known ore deposits, and then these elements are considered to be added to host rocks during mineralization.

Contents of SiO_2 and K_2O sometimes show chemical difference of composition in each rocks, but in the other times thes two elements were added to host rocks during mineralization and alteration. Namely Çatak formation mainly composed of andesitic rocks includes small amount of these two elements, and Kızıkaya and Çağlayan formations including neutral acidity alteration minerals such as quartz and sericite show high amount of these two elements.

CaO, Na_2O, U, Th and rare earth elements show difference of original rock's composition in some cases, but these elements were depleted during mineralization in other cases. Namely Çatak formationmainly composed of andesitic rocks show high contents of Ca, and chloritized and albitized Çatak formation and Çağlayan formation rich in dacitic rocks show high contents of Na, but Na was depleted from strongly altered zones in Kızıkaya formation.

Mn, Fe, Al_2O_3 and MgO were added to or depleted from host rocks during mineralization, besides showing chemical difference of their original rocks. Andesitic rocks of Çatak formation are rich in Mn, Fe, Al_2O_3 and MgO, but parts of Kızıkaya formation rich in sericite show little amount of MgO and parts of Kızıkaya formation rich in chlorite show much amount of MgO. MnO, FeO and Al2O3 were depleted from or on forming pyrite, manganese oxidized minerals and alunite these elements were added to host rocks.

As above mentioned, these elements show addition to or depletion from host rocks during mineralization besides chemical difference of original rocks. And then principal components analysis on these data were carried out in order to understand relations between each elemental behaviours.

Consequently first principal component shows high positive correlation with Al_2O_3, TiO_2, Na_2O, CaO, MgO, P_2O_5, LOI, Cu, Pb, Zn, Mn and Fe, and high negative correlation with As, Sb, Mo, Ba, SiO_2 and K_2O. Second principal component also shows high positive correlation with Au, Ag, Cu, Pb, Zn, As, Sb, Fe and Mo, and high negative correlation with Mn, SiO_2, Al_2O_3, Na_2O, CaO and MgO. Namely 1st component explains joint behaviours among most of rock forming elements and a part of metallic elements, and 2nd component explains reverse behaviour between most of metallic elements and most of rock forming elements. Therefore, high scored areas from 2nd principal component, are considered to be mineralized area.

The high scored areas from 2nd principal component develope around known ore deposits such as Lahanos and Karılar ore deposits in central part, and Karılar and Karacrik ore deposits in northern part. Elemental assemblages in these area show a slight difference from each other, but essentially all of these high scored areas of 2nd component are considered to be mineralized zones.

Geochemical survey by soil samples was carried out in central part. In this area, massive sulfide ore deposits such as Lahanos and Killik ore deposits contained in Kızıkaya formation, and disseminated to networked ore showings contained in Çağlayan formation with pyrite, quartz and sericite are existing.

Principal components analysis were carried out as well as case of rock samples, to detect chemical behaviours between each elements. Consequently first principal component shows high positive correlation with Au, Ag, Cu, Pb, Z, As, Sb, Mn, Mo and Ba, and second principal component shows high positive correlation with Cu, Fe and Mn.

The high scored areas of 1st principal component are situated around known massive sulfide ore deposits such as Lahanos and Killik North ore deposits, and then these areas are considered to be geochemically anomalous zones relating with massive sulfide ore deposition.

On the contrary, the high scored areas from 2nd principal component develope around networked ore deposits in Çağlayan formation, and then they are considered to be gechemically anomalous zones relating networked ore deposition.

4-3 Relation between Geophysical and Geochemical Anomalies

On short wave gravity map drawn in gravity survey, high gravity zones exist in southern part, low gravity zones in central part and low gravity zones surrounded by high gravity zones in northern part.

In high gravity zones of southern part, Çatak and Kızıkaya formations develope, and generally high gravity zones correspond well to distribution of Çatak formation. But special rocks relating exclusively to high gravity anomalies can not been observed. In low gavity zones which develope in central part, Çatak to Çağlayan formations distribute, and rather clear relation between low gravity and Çağlayan formation can be seen north-eastern zone. In northern part, Çağlayan formation occupies low gravity zones, and Kızıkaya formation and intrusive rocks occupy high gravity zones.

According to above mentioned description, Çağlayan formation and intrusive rocks show rather clear relation with gravity anomalies, and Çatak and Kızıkaya formations show poor relation with gravity anomalies and in these areas gravity distribution are considered to be strongly affected by intrusive rocks and alteration.

In north-eastern and north-western zones of central part, low gravity zones seemed to be controlled by north-west to north-eastwards geological structure of Çatak formation in southern part. In these low gravity zones, low densitized rocks due to argillization and pyroclastic rocks of Kızıkaya formation might be deposited so thickly.

Massive sulfide ore deposits such as Lahanos and Killik ore deposits develope on gradual zones from low to high and around high gravity zones. And Kızıkaya formation developing from vicinities of ore deposits to low gravity zones was regionally and strongly argillized by neutral alteration.

On the contrary, in northern part high gravity zones extend north-northeasternwards as well as direction of fracture zones controlling dacite lava extrusion and intrusive activities that took place in age of Çağlayan formation. Along this high gravity zones, Karılar and Karaerik ore deposits contained in Çağlayan formation were arranged.

Survey route of geophysical survey(IP method) was established in two areas, that is, between Lahanos and Killik ore deposits, and between Çalkaya and Taflançık, based on result of geological and gravity surveys. In these two areas, Kızıkaya formation are covered by Çağlayan formation, and mineralization and alteration are observed in both formations.

In Lahanos to Killik area, strong IP anomaly zones showing over 6mV/V chargeability and weak IP anomaly zones showing 4~6mV/V chargeability were recognized widely. Origin of these IP anomalies are considered to be derived from massive sulfide ore deposition, because these IP anomalies develope in Kızıkaya formation and around boundary zones between Kızıkaya and Çağlayan formations. On the contrary, most of low resistivity zones also develope near IP anomalous zones, but some of them attain to surface. Superficial low resistivity zones seem to correspond to argillized zones in Çağlayan formation.

In Çalkaya to Taflançık areas, strong and weak IP anomalies were detected. These IP anomalies also are considered to be derived from massive sulfide ore deposition, because they develope conformably in Kızıkaya formation and around boundary zones between Kızıkaya and Çağlayan formations. On the contrary, most of low resistivity zones develope near IP anomaly zones, but some of them develope near surface like as vein. The low resistivity zones near surface seem to correspond to networked ore showings and argillized zones in Çağlayan formation.

4-4 Potentiality to Expectance of New Ore Deposits

In this survey area, two types of ore deposits are recognized. The one is massive sulfide ore deposits contained in Kızıkaya formation which are composed of pyrite, sphalerite and chalcopyrite as main ore minerals, and gold and silver minerals, galena and tetrahedrite as accessory ore minerals. The other is disseminated to networked ore deposits contained in Çağlayan formation which are composed of pyrite as main ore mineral and sphalerite as accessory ore mineral.

Around Karılar and Karaerik ore deposits in northern part, disseminated to networked ore deposits are observed and include a small mass of pyrite ore. But this small mass of pyrite ore developes in smaller scale and shows lower in ore grade than those of massive sulfide ore deposits such as Lahanos and Killik ore deposits. Therefore massive sulfide ore deposits are preferentially expected to be discovered by this survey.

Only lower part of massive sulfide ore deposits like as disseminated to networked ore deposits can be recognized where Kızıkaya formation are exposed, because uppermost members of Kızıkaya formationcontaining massive sulfide ore deposits were eroded out. For example, Kızıkaya ore deposits composed of siliceous ore and disseminated to networked ore are thought to be lower part of massive sulfide ore deposits. Therefore, areas where Kızıkaya formation are covered by Çağlayan formation and show some kinds of ore showings such as alteration are highly hopeful areas for new concealed massive sulfide ore deposits.

Geological survey revealed that Kızıkaya formation containing Lahanos and Killik ore deposits extruded under control of Çatak formation's structure. Namely dacite lava and others extruded and formed Kızıkaya formation, in subduction zones controlled by north-east and north-westwards fracture zones which was formed after deposition of Çatak formation.

Gravity survey also showed that low gavity zones extending north-east and north-westwards from vicinity of Kızıkaya formation was detected in central part, these low gravity zones were centers of subduction zones, and acidic rocks of Kızıkaya formation extruded from these centers to form thick deposition. Main massive sulfide ore deposits such as Lahanos, Killik and Kepçelik ore deposits are considered to be formed in thick deposition of Kızıkaya formation around centers of subduction.
Therefore, the areas where Kızıkaya formation deposited thickly and Çağlayan formation covered it widely are concluded to be most hopeful for new and concealed massive sulfide ore deposits, such as Lahanos～Killik～Kepçelik areas in central part, and Çalkaya～Taflançık areas in eastern part.

Even by geological survey, ore showings made from pyrite were confirmed in Bitene area between Lahanos and Killik. Alteration survey also confirmed acidic to neutral alteration zones in above mentioned areas.

After principal component analysis using geochemical data, second principal component from rock samples shows high positive correlation with Au, Ag, Cu, Pb, Zn, As, Sb, Fe and Mo, and first principal component from soil samples shows also high positive correlation with Au, Ag, Cu, Pb, Zn, As, Sb, Mn, Mo and Ba.

The high scored areas of these two principal components develope around Lahanos and Killik ore deposits, and in the above mentioned areas arranged in north–east and north–western direction. This kind of arrangement of geochemical anomalies are thought to be derived from massive sulfide ore deposition and to be controlled by north–east and north–westwards fractures related with subduction structure in underlying Çatak formation.

IP survey also revealed that low resistivity zones and IP anomalies in Kızıkaya formation were corresponding to strong alteration zones and geochemical anomalies.

Finally, areas among Lahanos~Killik~Kepçelik ore deposits and areas between Çalkaya and Taflançı kare concluded to be most hopeful for expectance of new massive sulfide ore deposits, judging from geology, geological structure, distribution of strongly altered zones, geochemical anomalies, distribution of low gravity areas and IP anomalies.

Capter 5 Conclusion and Proposal

5–1 Conclusion

The survey was composed of existing documents analysis, geological survey(including geochemical survey) and geophysical syrvey(gravity and IP methods). Conclusion from these surveys are described as follows.

1. Geology

Geology of the survey area are composed of Çatak, Kızıkaya and Çağlayan formations, and intrusive rocks in ascending order which seem to be formed in late Cretaceous to Palaeocene. Çatak formation is comprised of andesite lava and its pyroclastic rocks with small amount of muddy rocks. Kızıkaya and Çağlayan formations are mainly comprised of dacite lava and its pyroclastic rocks, and rock facies of these two formations are very resemble to each other, but muddy rocks are usually intervened between these two formations. Hematite dacite and biotite dacite intruded into the above mentioned three formations.

2. Geological Structure

Raised zones in southern to western part where Çatak formation deposited and subduction zones in central to northern part where Kızıkaya and Çağlayan formations deposited were confirmed.

Dacite of Kızıkaya formation extruded in subduction zones of central part controlled by north–east and north–western fractures in Çatak formation. As lapse of time, centers of volcanic activities were shifted from south to north, and dacite of Çağlayan formation extruded in northern part under control of north–northwest, north–east and east–western fractures.

3. Analysis of Gravity

On short wave gravity map, high gravity zones in southern part, low gravity zones in central and northern parts, and high gravity zones aligned north–southwardly in this low gravity zones were recognized. Çatak formation that developes widely in southern to western part of the survey area seems to correspond well to high gravity zones, and low gravity zones in north-eastern and north-western areas of central part were concluded to be subduction zones controlled by geological structure of Çatak formationdeveloping in southern part. Massive sulfide ore deposits such as Lahanos and killik ore deposits were considered to develope around gradual boundary zones between low and high gravity zones in central part. Kızıkaya formation existing around this low gravity zones shows regional and neutral acidity argillization.

4. Ore Deposits

In this survey area, two types of ore deposits were recognized, one is massive sulfide ore deposits and the other is disseminated to networked ore deposits. Massive sulfide ore deposits such as Lahanos and Killik ore deposits, were contained conformably in uppermost members of Kızıkaya formation Disseminated to networked ore deposits such as Karılar and Karacrik ore deposits were contained in Çağlayan formation.

Ore minerals of massive sulfide ore deposits were composed of pyrite, chalcopyrite and sphalerite as main components, and galena, tetrahedrite, gold minerals and silver minerals as accessory components. In disseminated to networked ore deposits, pyrite was a main mineral, and chalcopyrite and sphalerite were accessory minerals. Scale and ore grade of massive sulfide ore deposits seemd to be much better than those of disseminated to networked ore deposits.

5. Alteration

Neutral to acidic alterations were observed besides neutral to alkaline regional alteration.

Strongly altered zones around Lahanos ore deposits showed white and acidic alteration products such as quartz, kaolinite, alunite and pyrite. Around other massive sulfide ore deposits such as Killik and Kızıkaya ore deposits, strongly altered zones composed of neutral acidity alteration products such as quartz, sericite and pyrite were formed showing white in color.

White～reddish brown strongly altered zones composed of acidic to neutral acidity alteration products such as quartz, sericite and hematite were formed around disseminated to networked ore deposits.

6. Geochemical Survey

Analytical data from rock and soil samples were analized statistically by principal components analysis that is one of multi variables analysis. Consequently second principal component from analysis of rock samples showed high positive correlation with Au, Ag, Cu, Pb, Zn, As, Sb, Fe and Mo, and contents of these elements were higher than those of worldwide backgroud values. Then 2nd component was thought to suggest the influence of mineralization. High scored areas of 2nd component developed around massive sulfide ore deposits such as Lahanos ore deposits and around disseminated to networked ore deposits such as Karacrik ore deposits, and they corresponded very well to mineralized zones around known ore deposits and kown altered zones.

First principal component from analysis of soil samples had high positive correlation with Au, Ag, Cu, Pb, Zn, As, Sb, Mn, Mo and Ba, and second component showed high positive correlation with Cu, Fe and Mn. High scored areas of 1st component developed around massive sulfide ore deposits such as Lahanos and Killik North ore deposits, then it was concluded to suggest the influence of mineralization from massive sulfide ore deposition. High scored areas of 2nd component developed around mineralized zones in Çağlayan formation, therefore it was concluded to be anomalies derived from disseminated to networked ore deposition.

7. IP Anomaly

IP survey was performed in two areas, that is, one is area between Lahanos and Killik ore deposits and the other is area between Çalkaya and Taflançık. According to geological survey, Kızıkaya formationcontaining massive sulfide ore deposits was covered by Çağlayan formation in these two areas, and mineralization and alteration were observed in both formations.

In these two areas, strong IP anomalous zones showing over 6mV/V chargeability and weak IP anomalous zones showing 4~6mV/V chargeability were recognized widely. These IP anomalous zones developed around boundary zones between Kızıkaya and Çağlayan formations, and in Kızıkaya conformably, then they were interpreted to be influenced by massive sulfide ore deposition. On the contrary, low resistivity zones developed mainly around IP anomalous zones, but some of them were observed to have attained to surface. Then low resistivity zones reaching to surface were considered to be influenced by disseminated mineralization and argillization in Çağlayan formation.

8. New Hopeful Areas for Exploration

New hopeful areas were selected as follows, after comparison of geology, geochemistry and geophysics with those of known ore deposits.

(1)Area between Lahanos and Killik Ore Deposits

In this area, Kızıkaya formation containing massive sulfide ore deposits such as Lahanos and Killik ore deposits was covered by Çağlayan formation. In Bitene area south of Lahanos ore deposits, ore showings composed of pyrite ore were observed. In Kızıkaya formation of this area, acidic alteration zone composed of kaolinite were formed as well as case of Lahanos ore deposits, and high concentrated zones of Au, Ag, Cu, Pb, Zn, As and Sb were also observed. IP anomalous zones also developed widely, but their electrode intervals seemed not to be sufficient. In Çağlayan formation, disseminated pyrite and neutral alteration zones could be observed.

(2)Area between Killik and Kepçelik Ore Deposits

Kızıkaya formation containing massive sulfide ore deposits was covered by Çağlayan formation in this area. Neutral alteration zones composed of sericite as well as Killik ore deposits were formed in Kızıkaya formation. In Çağlayan formation too, ore showings mainly composed of disseminated pyrite and neutral alteration zones composed of sericite were formed. Geochemical anomalous zones containing high amounts of Au, Ag, Cu, Pb, Zn, As and Sb developed in Kızıkaya formation. Geochemical survey by soil samples and IP survey were not performed yet.

(3)Area between Çalkaya and Taflançık

Kızıkaya formation was covered by Çağlayan formation. Acidic to neutral alteration zones including kaolinite and sericite were formed in Kızıkaya formation.

Ore showings mainly composed of disseminated pyrite and neutral alteration zones composed of sericite were formed in some parts of Çağlayan formation. High concentrated zones of Au, Ag, Cu, Pb, Zn, As and Sb were also formed in Kızıkaya formation. IP anomalies were also detected, but their electrode intervals seemed not to be sufficient. Geochemical survey by soil samples was not carried out here.

(4)Area between Çımakli and Karaerik Ore Deposits

Kızıkaya formation was covered by Çağlayan formation. Neutral alteration zones including sericite were formed in Kızıkaya formation. Disseminated ore deposits mainly composed of pyrite such as Karılar ore deposits and neutral alteration zones including sericite were formed in Çağlayan formation. Geochemically anomalous zones with high contents of Au, Ag, Cu, Pb, Zn, As and Sb were confirmed in both Kızıkaya and Çağlayan formations. Geochemical survey by soil samples and IP survey were not performed yet.

(5)Dikence Area

Kızıkaya formation was not exposed in this area and was covered by Çağlayan formation. In Çağlayan formation, disseminated ore deposits mainly composed of pyrite and neutral alteration zones including sericite were formed. High concentrated zones of Au, Ag, Cu, Pb, Zn, As and Sb were confirmed in Çağlayan formation. Geochemical survey and IP survey were not conducted yet.

5-2 Proposal to Second Year's Program

After discussing geology, ore showings and alteration, gravity distribution, geochemical and IP anomalies resulted from this year's survey, five new hopeful areas are selected as mentioned below and the following works were proposed for next year's program.

(1)Area between Lahanos and Killik ore deposits
(2)Area between Killik and Kepçelik ore deposits
(3)Area between Çalkaya and Taflançık
(4)Area between Çımakli and Karaerik ore deposits
(5)Dikence area

(1)Area between Lahanos and Killik Ore Deposits

Drilling works are proposed in IP anomalous zones. Where electrode intervals were not sufficient in first year's IP survey and main target positions for drilling works were not decided, supplementary IP survey will be performed.

(2)Area between Killik and Kepçelik Ore Deposits

After geochemical survey by rock samples and survey for altered zones, parts of ore showings were detected. Then detailed geochemical survey by soil samples and IP survey will be necessary to delineate details of ore showings detected in first year's survey.

(3)Area between Çalkaya and Taflançık

Drilling works are proposed in the ore showings which were detected by first year's survey, that is, geochemical survey by rock samples, survey for altered zones and IP survey. Detailed geochemical survey by soil samples and geophysical survey are requested to plan another drilling works. IP survey and electro-magnetic survey should be carried out simultaneously in geophysical survey, because Çağlayan formation covers Kızıkaya formation in this area with 200～300m thickness.

(4)Area between Çımakli and Karaerik Ore Deposits

Detailed geochemical survey by soil samples and geophysical survey are proposed to clarify details of ore showings, because position of ore showings were detected roughly by first year's survey, that is, geochemical survey by rock samples and survey for altered zones. In this area too, IP and electro-magnetic surveys should be carried out simultaneously, because Kızıkaya formation containing massive sulfide ore deposits was covered by Çağlayan formation with 300m thickness.

(5)Dikence Area

Detailed geochemical survey by soil samples and geophysical survey are proposed to clarify details of ore showings, because position of ore showings were detected roughly bu first year's survey, that is, geochemical survey by rock samples and survey for altered zones. IP and electro-magnetic surveys should be performed simultaneously, because Kızıkaya formation containing massive sulfide ore deposits is covered Çağlayan formation with around 300m thickness.

Part II

Details of the Surveys

PART II DETAILS(or PARTICULAR)

Chapter 1. Analysis of Existing Documents

1－1 Survey Method

1－1－1 Purpose of Survey

The survey area was very famous of their mining potentiality for a long time. But it is difficult to find out the documents written before 1939. After 1939 MTA, ETI Bank(including KBI) and Demir Export company performed gelogical survey, geophysical survey and drilling survey vigorously in this area, and result of these surveys were summarized in their reports. It is very useful for this survey to collect and to analyze these documents. Furthermore the existing problems became clear after analysis and it was also useful for the survey.

1－1－2 Collected Documents

List of collected documents was summarized in Table 1－2. There were many documents whose authors were unidentified, but as many documents as possible were tried to be collected.

1－2 Result of Survey

1－2－1 Geology

Eastern Pontides region which consists of areas along Black Sea in Turkey lies on basement rocks composed of metamorphic rocks and granite intruded into them which distribute around 70km south from the survey area. These basement rocks were thought to be formed in Devonian to early Carboniferous.

Hamurkesen formatin exists on the basement unconformably, Madenler formation exists conformably on Hamurkesen formation and Berdiga formation also exists conformably on Madenler formation. Hamurkesen formation thought to be formed in Jurassic is composed of andesite, basalt, their pyroclastics, sandstone, mudstone and conglomerate, and its thickness is around 750m.

Madenler formation considered also to be formed in Jurassic is composed of sandstone, conglomerate, limestone and others with intercalation of basalt lava, and its thickness is around 150m.

Berdiga formation composed of tuffaceous limestone has around 200m thickness and is thought to be formed in late Jurassic to early Cretaceous. These 3 formations develope around 60km south from the survey area.

In the survey area, Çatak, Kızıkaya and Çağlayan formations(in ascending order) lie on underlying formations conformably, and they are thought to be formed in late Cretaceous to Palaeocene.

Çatak formation composed of andesite, basalt, their pyroclastics, sandstone, siltstone and limestone exists on Berdiga formation conformably, and its thickness is around 1,500m. It developes in southern part of the survey area.

Kızıkaya formation lies on Çatak formation, and is composed of dacite, rhyolite and their pyroclastics. Its thickness is around 500m and distributes in central part of the survey area. The uppermost layer of Kızıkaya formation is thought to be the horizon containing massive sulfide ore deposits that is correlated to Japanese Kuroko deposits.

Çağlayan formation lies on Kızıkaya formation conformably and is composed of mudstone, dacite lava, its pyroclastics, andesite and basalt. It developes in northern part of the survey area and its thickness is around 1, 000m.

In north-eastern area from the survey area, Kabakoy formation composed of andesite, basalt and their pyroclastics developes with 750m thickness unconformably on underlying formation. It is thought to be formed in Eocene.

Regarding intrusive plutonic rocks, granite formed in late Cretaceous, diorite and quartz diorite formed in Eocene are recognized in and around the survey area.

1-2-2 Ore Deposits

Massive sulfide ore deposits in this area are thought to be contained only in uppermost layer in Kızıkaya formation that is composed of acidic pyroclastic rock, and they underlie just the lowest layer in Çağlayan formation that is composed of mudstone and tuff. These massive sulfide ore deposits are very resemble to Japanese Kuroko deposits, except their age of formation.

Each ore deposits and ore showings in existing documents are summarized as shown in Fig. 1-2(Result Map of Analysis from Existing Documents) and Table 1-3(List of Analytical Result from Existing Documents).

(1)Lahanos mine

This mine is around 15km south from Espiye town and is also a working mine. In 1958～1960, MTA mined 2 tunnels, drilled 10 holes in tunnels and also drilled 67 holes outside. Consequently 2, 300 thousand tons(Cu 3. 59%, Zn 2. 34%) was estimated as probable ore reserves. Afterwards, Demir Export company(mining division of a Turkish plutocracy) obtained the mining right of this mine, and in 1989 they drilled 8 holes outside(total length;784m). At April of 1995, they started to produce 500t/day(Cu 3. 8%, Zn 3. 2%) as crude ore, 70t/day(Cu 22%, Zn 4%, Pb 2%) as copper concentrated ore and 10t/day(Zn 50%, Cu 5%) as zinc concentrated ore. They send copper concentrated ore to the refinery of KBI in Sumsun and sell zinc concentrated ore to a Germany company(Metalgesellshaft). Total employees in all sections such as prospecting, mining, mineral dressing and maintenance sections are around 100 persons. As capacity of mining section is over that of mineral dressing, mining personnel is shifted to mineral dressing section when stock of crude ore increases.

Ore deposits are composed of massive yellow ore that contains much pyrite and chalcopyrite, and a little sphalerite. In underlying dacite lava, argillization, silicification, brecciation, disseminated pyrite and networks of pyrite are recognized. Thickness of massive ore bodies is 15m as maximum and 5～6m in average. Several massive ore bodies are contained lenticularly in the same stratigraphical layer as the others.

(2)Kızıkaya ore deposits

The ore deposits are located at around 20km south from Espiye town, and MTA performed geological survey, geophysical survey and drilling survey between 1967and 1970. Consequently they confirmed existence of two ore bodies whose probable ore reserves were calculated as 1, 890 thousand tons(average Cu grade;1. 14%) and 1, 930 thousand tons(average Cu grade;0. 8%) respectively. But ETI Bank is still prospecting in this area. The each ore deposits are composed of massive sulfide ore body mainly containing pyrite and chalcopyrite, and of disseminated and networked ore body containing much pyrite, much chalcopyrite and poor sphalerite.

Massive ore bodies are included concordantly in dacitic pyroclastics of Kızıkaya formation, and the underlying disseminated and networks ore bodies are included in strongly silicified dacite lava.

(3)Kitlik ore deposits

They are located at around 17km south from Espiye town. MTA surveyed geologically and geophysically between 1977 and 1982, and afterwards KBI performed drilling survey. They say crude ore 5,000 tons/year(Cu 1.14%, Zn 2.5%, Pb 0.7%) was mined in 1988, but now it is closed in spite of 90 thousand tons as remained ore reserves. They consist of massive sulfide ore body, disseminated and networked ore body.

(4)Kepçelik ore deposits

They are on the western slope of Yeniyolbasi hill that is located at around 20km south from Espiye town. This zone is a famous of mining activity for a long time, therefore old tunnels and old trenches can be seen here and there. ETI Bank started exploration works such as geological syrvey, geophysical survey and drilling survey in 1960's, and afterwards MTA surveyed geologically in 1976 and 1978. The ore deposits contain pyrite, chalcopyrite, sphalerite and galena, and chemical analysis from a spot sample here showed Cu 9.4% and Zn 31.3%.

(5)Dickmen ore deposits

They are located at around 18km south from Espiye town. MTA performed exploration works such as geological survey, geophysical survey and drilling survey in 1960's and 1970's. In 1972, ETI Bank drilled 5 holes and trenched in 2 spots, and then they estimated 300 thousand tons(Cu 0.9%) as possible ore. Main mineralogical components in ore deposits are pyrite and chalcopyrite, and shape of ore deposits is massive.

(6)Karaerik ore deposits

They are very near from Cibri village that is located at around 4km south from Espiye town. In this zone, many old tunnels and much old slags which seem to have been derived from ancient mining activity can be recognized, and specially total amount of old slags was estimated as around 400 thousand tons. They say that British and Italian people excavated 300m tunnels for development before the first world war, but now they are collapsed. MTA drilled 3 holes in 1950 and they discovered poly-metallic ore deposits containing pyrite, chalcopyrite and sphalerite as main component, and barite as subordinate component. Afterwards, ETI Bank drilled in 1970, but they could not discover minable ore deposits.

(7) Kartlar ore deposits.

They are located at around 5km south from Espiye town and are at just south of Karaerik ore deposits. In this area also many old tunnels and much old slags of around 150 thousand tons are remained. MTA excavated tunnels for exploration and drilled here in 1960's, and they confirmed massive sulfide ore deposits whose ore reserves were estimated as 100 thousand tons(Cu 2%). In 1970 ETI Bank drilled again, but they could not discover minable ore deposits.

(8)Ağalik ore deposits

They are located at around 6km south from Espiye town, and are very near from both Kartlar and Karaerik ore deposits. Here also old tunnels and old slags of around 60 thousand tons are seen. MTA and ETI Bank explored in 1960's, but they could not find minable ore deposits. Anyway they think type of ore deposits here should be massive sulfide ore deposits.

(9)Çımakli ore deposits

They are located at around 6km south from Espiye town, and old tunnels and old waste dam are recognized. ETI Bank drilled several holes in 1960's and MTA performed geological survey, geophysical survey and drilling survey in 1982～1986. But they could not hit minable ore deposits. Ore deposits are mainly composed of pyrite and chalcopyrite, and kaolinitization(Al_2O_3 34%) is seen in dacite lava that is host rock of ore deposits here. They also think type of ore deposits here should be massive sulfide ore deposits.

1－2－3 Gravity Method

Existing gravity data around the survey area acquired from regional survey that was performed by MTA over whole Turkish territory for a long time were available for this survey. The survey by MTA was rough survey, because they adopted 5～10km as interval of measuring points. But it is still useful to study the regional trend of gravity. However, gravity data as well as topographical maps are treated as military secrecy, and then raw data can not be obtained and contour maps on gravity can be obtained through MTA. The obtained contour maps regarding the survey area are Bouguer anomaly maps, residual gravity maps and others which were drawn on around 1 to 500,000 scaled map in range of 60km×70km. Some parts of these obtained maps are shown as Fig. 5－8(regional Bouguer anomaly map) and Fig. 5－16(regional residual gravity map) in chapter 5(Gravity Survey), and they are utilized for understanding the gravity trend and gravity distribution pattern of the survey area.

1－2－4 IP Method

Each collected documents are explained as below mentioned, using same numbers as Table 1－2. But data of CSAMT and IP around Lahanos mine were obtained without authors and published age, then they are explained here without referred number.

NO Number;Cross sections of CSAMT and IP measured on Lahanos ore deposits.

Ore deposits lie around 30～100m below surface.

Two cross sections of CSAMT could be compared with those of IP.

CSAMT was not analized structurally.

Low resistivity zones on pseudo cross sections do not show any relation with known ore deposits.

Pantaloon shaped IP anomaly was observed.

Maximum chargeability was 30mV/V.

No. 7(1960);Resistivity survey using Schlumberger and Wenner arrangement around Killik Tepe.

Surveyed area;0.25km²

Resistivity was analized on a dimension.

After analysis, long low resistivity zone like as several Ω・m was presumed to be at around 100～200 m depth below surface.

No. 22(1987);IP survey around Killik ore deposits.

Surveyed area;1. 8km^2

On the river in western side of the area, floating ore was discovered.

High IP anomaly in dacitic pyroclastic rock around the floating ore and in north-eastern part of the area.

Maximum IP value was around 9% in intrusive rock.

IP anomaly corresponding to superficial mineralized zone showed 5% as maximum.

No. 10(1967);SP survey around Kızıkaya ore deposits.

Surveyed area;0. 9km^2

Negative SP anomaly around ore deposits. SP anomaly showed -34mV as maximum.

No. 17(1970);IP survey around Karılar area

Strong IP anomaly corresponding to superficial mineralized zone.

Surveyed area;0. 45km^2 Total measured lines;10. 2km

Maximum IP effect;9% Electrode intervals;50m n=1~4

No. 23(1989);IP survey around Çımaklı~Karılar

Surveyed area;3. 6km^2 Total measured lines;26. 8km

Clear anomaly at old workings which is around 500m north-west from Karılar ore deposits.

IP anomaly continuing from north-east to central parts in the area.

Many unsufficiently measured points.

Maximum IP effect was around 8%.

Nos. 13, 14 & 15(1970);IP survey around Kepçelik.

Kepçelik area

IP anomaly corresponding to weak mineralized zone along a small river which is 1km north-west from Çal Tepe.

Çal Tepe area

IP anomaly corresponding to mineralized zone on flank of Çal Tepe which is around 500m north-west from the top of Çal Tepe. Another anomaly in depth.

Maximum IP effect was around 8%.

Mineralized zone on north-western flank was presumed to continue to south-western flank of Çal Tepe, but they did not survey yet because of steep topography.

Mineralized zone on north-western flank was confirmed by 2 drill holes.

MTA desires to survey this area.

No. 26(1992);CSAMT survey around Karaerik

Adopted frequency;0. 25~8, 192Hz

Surveyed area;0. 3km^2 Total measured lines;1, 030. 5m

Pseudo cross sections were drawn, but resistivity was not analized structurally. Structural analysis of resistivity seems important with comparison of detailed geological map.

No. 8(1960);EM survey around Killik

Surveyed area;1. 4km^2

EM anomaly along a small river, but it seemed to be affected from topography and it did not correspond to both SP anomaly and mineralized zone.

No. 20(1982);SP survey around Killik

Surveyed area;0. 32km^2

SP anomaly around superficial mineralized zone, and it showed −260mV.

SP anomaly developed within superficial mineralized area.

No. 18(1975);IP survey around Dikmen

Surveyed area;3. 5km^2

IP anomaly distributing from Kozköy to Kurukopru, and it seems to be quite same that anomaly detected in D−line of this year's survey.

IP anomaly showed 7% as maximum value.

No. 16(1970);IP survey around Ağalik

Total measured lines;7. 0km

Clear IP anomaly corresponding to superficial mineralized zone.

Another clear IP anomaly in depth.

No. 11(1969);IP survey around Karacrik

Total measured lines;19km

Clear IP anomaly corresponding to superficial mineralized zone.

No IP anomaly in depth.

Maximum IP value was 10%.

No. 12(1970);IP survey around Kızıkaya

Survey area;2. 5km^2

Strong IP anomaly just on Kızıkaya ore deposits, and it showed several tens % as maximum.

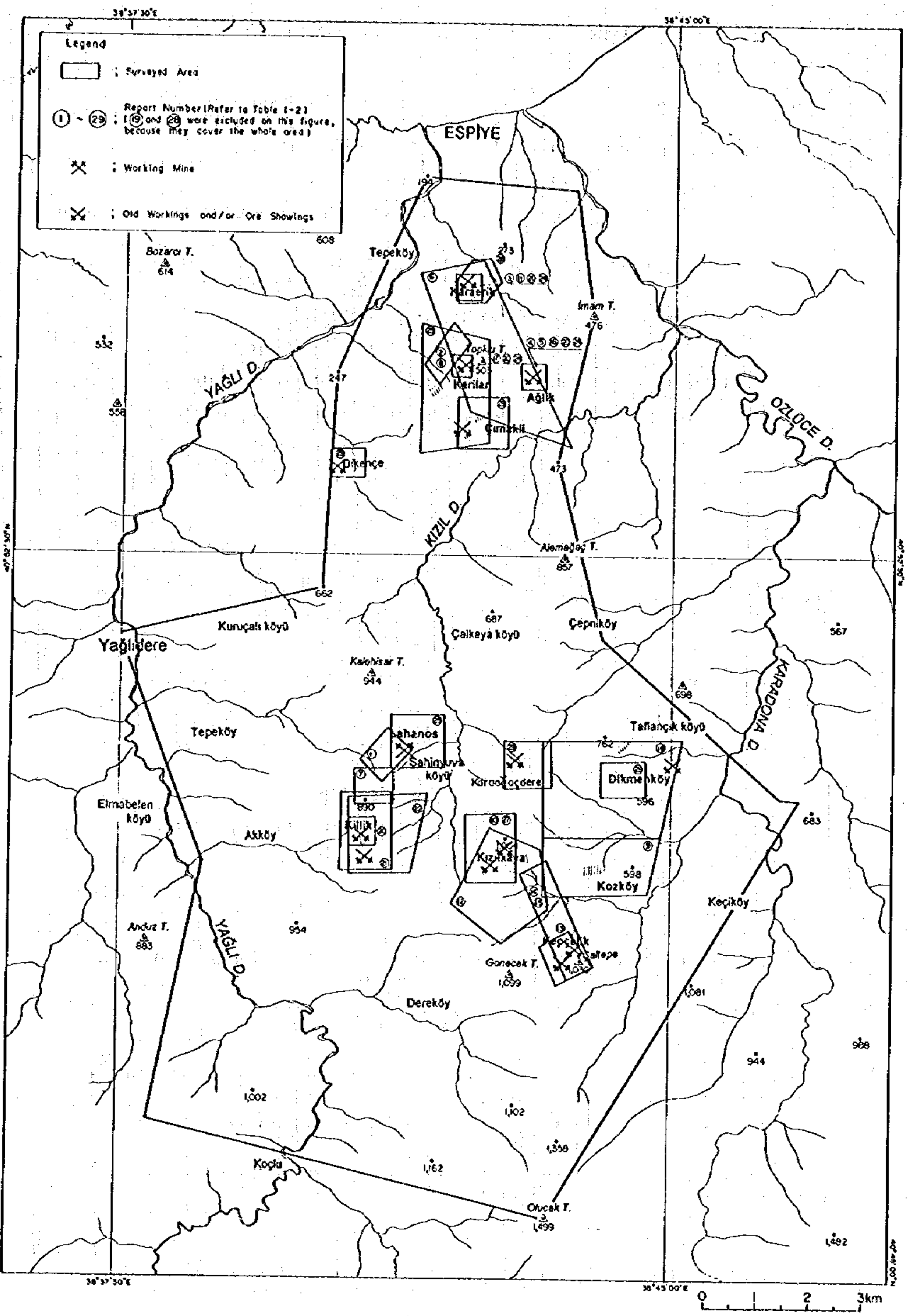

Fig. 1－2 Result Map of Analysis from Existing Documents

Table 1-2 List of Collected Existing Documents

Document Number	Author	Age	Title
01	Unidentified	1939	Electro-magnetic Data in Giresun-Espiye-Gol Area.
02	Unidentified	1939	Geophisical Data in Giresun-Espiyo-Karilar Area.
03	Eksper Muh and Breusse, J.J.	1940	Esbiye-Israil Mintakasinda Yapilan Elektrik Prospeksiyonuna Muteallik Ikinci Rapor.
04	Muh. Jeol V. Kovenko	1940	Aglikmaden(Esbiye) Ocaginin Ml Topografya Noktasi(Rakim Takriben 826m) Altinda Cevher Mevcudiyeti Imkanlarina Muteallik Not.
05	Ragib Gencer	1940	Aglik(Espiye) P.S. Etudu Hakkinda Not.
06	Unidentified	1945?	Geophysical Data in Giresun-Espiye-Agalik Area.
07	Ahmet Acar	1960	Lahanos Ile Killik Arasindaki Sahanin Rezistivite Etudu.
08	Unidentified	1960	Electro-magnetic Data in Giresun-Espiye-Karilar Area.
09	Unidentified	1961	Electro-magnetic Data in Giresun-Espiye-Kozkoy Area.
10	Unidentified	1967	Eti Bank Espiye Santiyesi Giresun Vilayeti Lahanos Maden Kizilkaya Sahasi Jeofisik Etudu Raporu.
11	Ugur Kaynak	1969	Karaerik Bakirli Pirit Zuhuru Induced Polarization Etudu Hakkinda Rapor
12	Sinasi Apaydin	1970	Giresun-Espiye-Kizilkaya Bakir Aramalari Jeofizik I.P. Etudu Raporu.
13	Ugur Kaynak	1970	Eti Bank 1970 Kepcelik I.P. Etudu Raporu.
14	Ugur Kaynak	1970	Eti Bank 1970 Kizildere I.P. Etudu Raporu.
15	Ugur Kaynak	1970	Eti Bank Giresun Espiye 1970 Kizildere I.P. Etudu Raporu.
16	Ugur Kaynak	1970	Eti Bank Maden Aramalar Subesi Agalik 1970 IP Etudu Raporu.
17	Ugur Kaynak	1970	Eti Bank Maden Aramalar Subesi Espiye Karilar Pirit Maden 1970 I.P. Etudu Raporu.
18	Unidentified	1975	Geophysical Data in Giresun-Espiye-Dikmen area.
19	Karaman, I.	1981	Geologic Research Front Report of Giresun-Espiye area.
20	Emin Kokelekli and Recai Boynukalin	1982	Israildere-Karilar-Karaerik-Killik Madeni Dogal Potansyel Calismalari.
21	Mustafa Cakir and Yusuf Cekic	1982	Giresun-Espiye Killik Yoresinin Jeoloji Raporu.
22	Seyran Sardar and Mustafa Demirhan	1987	Giresun-Espiye-Killik-Sahasi Bakir-Kursun-Cinko Aramalari Jeofizik Induklem Polaizasyon(I.P.) Etudu.
23	Mustafa Demirhan	1989	Giresun-Espiye-Cimakli-Karilar Sahasi Bakir-Kursun-Cinko Aramalari Induklenmis Polarizasyon(IP) Etudu.
24	Demir Export A.S.	1990	16.09.1988 Tarihli Anlasma Kapsaminda Giresun-Espiye Guneyi Sahalarinda 1989 Yilinda Yapilan Arama Calismalariyla Ilgili Faaliyet Raporu.
25	Demir Export A.S.	1990	Lahanos Bakir-Cinko Yataginda Yapilan Arama ve Degerlendirme Calismalari.
26	Demir Export A.S.	1992	16.09.1988 Tarihli Anlasma Kapsaminda Giresun-Espiye ve Tirebolu Sahalarinda 1991 Yilinda Yapilan Arama Calismalariyla Ilgili Faaliyet Raporu.
27	Demir Export A.S.	1993	Giresun-Espiye-Kizilkaya Cu-Zn Yataginin Jeoloji Raporu.
28	Demir Export A.S.	1994	16.09.1988 Tarihli Anlasma Kapsaminda Giresun-Espiye ve Tirebolu Sahalarinda Yapilan Arama Calismalariyla Ilgili Faaliyet Raporu.
29	Demir Export A.S.	1995	16.09.1988 Tarihli Anlasma Kapsaminda Giresun-Espiye Sahalarinda Yapilan Arama Calismalariyla Ilgili Faaliyet Raporu.

Table 1-3 List of Analytical Result from Exising Documents

Document Number	Author	Age	Area	Analytical Result
19	Karaman, I.	1981	Whole area	Explanation for the geological map drawn by MTA.
21	Mustafa Cakir and Yusuf Cekic	1982	Killik	Six drill holes(massive sulfide Cu ore with Sp), shallower than 200m.
24	Demir Export A.S.	1990	Karilar	Several short drill holes. Massive pyrite ore & disseminated ore in Karilar.
			Agalik	Several short drill holes. Massive pyrite ore & disseminated ore in Agalik.
			Karaerik	Several drill holes. Disseminated ore in Karaerik.
25	Demir Export A.S.	1990	Lahanos mine	Many short(around 100m deep) drill holes. Massive sulfide ore & disseminated ore.
26	Demir Export A.S.	1992	Karaerik	CSAMT, resistivity & many drill holes. Disseminated sulfide ore & Mn oxide deposits(veinlet).
27	Demir Export A.S.	1993	Kizilkaya	Many short(around several tens meters deep) drill holes. Massive sulfide ore & disseminated ore.
28	Demir Export A.S.	1994	Whole area	Explanation for the geological map drawn by Demir Export
29	Demir Export A.S.	1995	Cimakli	Several drill holes. Massive sulfide ore & disseminated ore in Cimakli.
			Dikence	Disseminated ore in Dikence.
			Dikmen	Several drill holes. Massive sulfide ore & disseminated ore in Dikmen.
			Karaagacdere	Disseminated ore in Karaagacdere.

Document numbers are quite same as Table 1-2.

1-3 Consideration

One of main purpose of this survey is to pursue stratigraphically the upper most layer of Kızıkaya formation that is thought to contain massive and polymetallic sulfide ore deposits. Most of collected documents say that all of ore deposits and ore showings are contained in the same horizon as the others, but this survey will reveal whether it is true or not.

All of known ore deposits, known ore showings and known geophysical anomalies were considered to be derived from ore showings on superficial exposures, and then exploration for depth, for lateral extension and for subterraneous ore deposits should be necessary from now.

According to MTA's geological map, andesitic pyroclastics developing in southern part of the survey area is considered as Çatak formation(lower than massive sulfide ore horizon). But the geological map drawn by Demir Export company says that andesitic pyroclastics can be correlated to Kabakoy formation(upper than ore horizon). This discrepancy should be solved to decide where is explored.

It was impossible to observe the existing drilling cores, but it is important to observe drill cores whose locations are clear.

Chapter 2 Geological Survey

2-1 Survey Method

In this survey project, geological and geochemical surveys were performed by geologists group. As existence of massive sulfide ore deposits are highly expected in the survey area, geological survey was carried out to reveal details of geology, mineralization and alteration.

The map scaled 1 to 10,000 was obtained by enlarging from the 1 to 25,000 scaled map and it was used as the basic map. And then route maps were drawn on the 1 to 10,000 scaled map. Survey routes were selected from the existing documents and most suitable routes were decided to be surveyed.

Massive sulfide ore deposits here were considered to be contained in special stratigraphical layer, therefore special attention was paid on distinguishing special stratigraphic units from others. Because both hanging-wall and foot-wall of massive ore deposits here were composed of dacitic compositional rocks, muddy rocks lying just on theore horizon was pursued on geological survey as key bed.

Result of geological survey was summarized on new geological map, after compiling with the existing documents and maps. Microscopical observation regarding typical rock and ore samples was also added to this report.

2-2 Result of Survey

2-2-1 Abstract of Geology

Çatak, Kızıkaya and Çaglayan formations besides intrusive rocks in ascending order compose the geology of this survey area and they seem to be formed in late Cretaceous to early Palaeocene. Names of each formations in this report are cited from the stratigraphic table by Güven et al. (1992).

2-2-2 Geologic Particular

1. Çatak formation

This formation is mainly composed of autobrecciated andesite lava(abbreviated form;Çad) and its pyroclastics(Abb. form;Çtf) with intercalation of muddy~limy rock. It developes widely along Yağlı river that flows in western and southern part of the area, and its thickness is over 1,000m. Chloritization and epidotization are recognized characteristically, and regional hydrothermal and/or low grade metamorphic alteration are also observed, but strong metamorphism can not be seen.

Andesite lava(Çad) shows dark green to light green in color, and intercalates thin beds of dacitic pyroclastics somewhere. Plagioclase with diameter of 1~2mm are seen commonly and plagioclase of 5~10 mm diameter are seen rarely by naked eye. Most of mafic minerals are replaced by chlorite. Zeolite and epidote are observed in groundmass and cavities. According to result of microscopical observation(Table 2-1), phenocrysts are composed of plagioclase and common hornblende, and groundmass are done of glass, plagiclase and iron minerals. After hydrothermal alteration, quartz, pyrite, chlorite, sericite, calcite, epidote and others became visual.

Andesitic pyroclastics(Çtf) show dark green to light green in color, and tuff to tuff breccia in rock facies. Bedding planes are very clear in tuff, and pyroclastic rocks are composed of only essential andesite breccias. Their thickness is less than 200m. Under microscope, glass and plagioclase are observed in groundmass, and quartz, clay minerals and calcite were seen because of alteration.

Muddy rocks(Çms) show grayey green to grayey brown in color, and also clear bedding planes. Their thickness is less than 50m. Limy rocks(Çms) show gray to grayey white in color, and are changed to be marble around intrusive bodies of granite after recrystallization.

These rocks just above mentioned are correlated to the upper formation than Çağlayan formation by Demir Export company's report. This report concludes these rocks are lower than Kızıkaya formationbecause the relation between these rocks and Kızıkaya formation was observed, and then these rocks are named as Çatak formation.

2. Kızıkaya formation

This formation is composed of highly autobrecciated dacite lava(Abb. form;Kdc) and its pyroclastic rocks (Abb. form;Kt1 & Kt2). This formation developes along Kizul river in central part of the area and along Yağlı river in northern part of the area. It is usually exposed on surface in central part of the area and covered by overlying Çağlayan formation in northern part of the area.

Massive sulfide ore deposits such as Lahanos ore deposits(in central part), Killik South ore deposits(in central part) and Ağalik ore deposits(in northern part) are contained in upper-most layer of this formation, and thickness of this formation attains to more than 1,000m around Lahanos ore deposits and Çalkaya area.

In this formation, chloritization, sericitization and regional hydrothermal alteration are observed commonly, but metamorphism can not be seen. Specially white argillization accompanied by mineralization is recognized besides regional hydrothermal alteration, around massive sulfide ore deposits.

Dacitic pyroclastic rocks(Abb. form;Kt1) compose lowest layer of this formation and show green to light green in color. They are composed of well bedded tuff and tuff breccia, and their breccia are essential including quartz and plagioclase commonly. Under microscope, glass, plagioclase, pyroxene and opaque minerals are seen as groundmass, and quartz, pyrite, chlorite, clay minerals and calcite seem to be formed during alteration.

Dacitic lava(Abb. form;Kdc) shows green to light green in color and sometimes intercalates thin bed of its pyroclastic rocks. Feldspar and mafic minerals in this unit are changed to be green to white clay minerals. Rock facies change in this rock unit is observed, that is, dacitic rock around Ağalik and Killik South ore deposits contains quartz more than dacitic rock around Lahanos ore deposits. Microscopical observation indicates that phenocrysts are composed of quartz and plagioclase, that groundmass are composed of glass, plagioclase, pyroxene and opaque minerals, and that alteration produced quartz, pyrite, calcite, chlorite, sericite and other clay minerals.

Dacitic pyroclastic rocks(Abb. form;Kt2) form uppermost layer in this formation and is mainly composed of green to light green tuffaceous rocks that contain massive sulfide ore deposits excluisively. Red hematite-chert bed is seen at same horizon as massive sulfide ore deposits, and then it is thought to be formed at same time as massive sulfide ore deposits.

Microscopical observation shows that phenocrysts such as quartz and feldspar are poor, that groundmass are composed of glass, quartz, plagioclase, opaque minerals such as iron minerals and others, and that alteration formed quartz, pyrite, epidote, chlorite and other clay minerals.

3. Çağlayan formation

This formation is composed of autobrecciated~massive dacite lava(Abb. form;Cdp& Cdc), dacitic pyroclastic rocks(Abb. form;Ctf), nevaditic pyroclastic rocks(Abb. form;Cnv) and muddy rocks(Abb. form;Cms). This formation distributes widely in northern part of the area and covers Kızıkaya formation in hilly zone of central part. Its thickness increases north-wards and shows 500~800m as maximum.
Its maximum thickness around Lahanos ore deposits is around 300m and around Çalkaya area it is 500~800 m. Diagenetic alteration such as montmorillonitization is recognized widely and red to reddish brown hydrothermally altered zone accompanied by networks-type mineralization is also seen around intrusive rocks.

Dacite lava of this formation(Cdp & Cdc) is sometimes resemble to that of Kızıkaya formation(Kdc). In such a case, well bedded muddy rocks of lowest layer in this formation(Cms) was used as a key bed to distinguish from underlying formation.

Dacite lava shows generally whitish gray to light green in color, and can be divided into two types, that is, one is porphyritic dacite lava(Cdp) that includes big phenocrysts such as quartz and plagioclase with 1~2mm diameter, the other is aphyric dacite lava poor in phenocrysts(Cdc). Porphyritic dacite developes mostly just under Çağlayan formation and it shows white~light green in altered parts. In strongly hematitized zone, it shows red to brown in color.

Dacitic pyroclastic rocks(Ctf) show light green to light yellow in color. This rocks also can be divided into two types, that is, one includes phenocrysts such as quartz and plagioclase with 1~2mm diameter, the other includes no phenocrysts. In altered part, they indicate white to reddish brown in color. Breccia of this rock unit is composed of essential dacite, and glass, quartz and plagioclase can be observed as groundmass, under microscope. Quartz, clay minerals and iron minerals are considered to be formed during alteration.

Nevaditic pyroclastic rocks(Cnv) show light green~light yellow~whitish gray in color, and include commonly phenocrysts of quartz and plagioclase with 3~5mm diameter. They show also low solidification and weakly bedded plane.

Muddy rocks(Cms) show white to grayey green in color, and is composed of well bedded mudstone, tuffaceous mudstone and tuff. Their thickness is less than 30m and exists at lowest level in this formation.

4. Intrusive Rocks

Granitic rock(Abb. form;Gr), andesite(Abb. form;Ad), dolerite(Abb. form;Do) and dacitic rocks indicating various facies can be recognized as intrusive rocks. Then dacitic rocks are subdivided based on result of field survey as follows;red dacite(Abb. form;Dh), porphyrytic dacite(Abb. form;Dp), nevaditic dacite(Abb. form;Nd) and biotite-dacite(Abb. form;Db).

(1)Granitic Rock(Gr)

It developes at northern end of the survey area, forming a small body with around 1km diameter. It shows whitish gray in color and is composed of equigranular quartz grains, feldspar and mafic minerals. By thermal alterration from this granitic rock, muddy rocks of Çatak formation were changed to be hornfels at contact zone with this rock and limestone of Çatak formation was changed to be marble at contact zone with this rock.

(2)Andesite(Ad)

In south of Lahanos mine, it developes forming a small body whose size in planis 1. 8km(east-west)×0. 4km(north-south). It intruded into Çağlayan formation and red dacite(Dh). It shows dark gray in color, and includes phenocrysts of plagioclase and pyroxene with 1mm diameter. It shows also columnar joints and no alteration.

Microscopical observation indicates existence of plagioclase, augite and common hornblende as phenocrysts, and those of glass, plagioclase and opaque minerals as groundmass. Quartz, chlorite and calcite are thought to be formed by alteration.

(3)Dolerite(Do)

It distributes forming small bodies in eastern, northern and south-western parts of the survey area. This rock intruded into Çağlayan formation and it is cut by nevaditic intrusive rock(Nd). The rock bodies in eastern part are inclined to extend in east-west and north-northwest direction, and those in northern and south-western parts are inclined to extend in north-northeast direction. Long diameters of the rock bodies are less than 1km and short diameters are less than 300m. It shows black to dark green in color. It shows more weathering than alteration, and consequently it shows sometimes an appearance like sandstone.

Under microscope, plagioclase, augite and olivine are observed as phenocrysts, and glass, plagioclase, pyroxene and opaque minerals are done as groundmass.

(4)Red Dacite(Dh)

This rock developes in central part of the survey area. It intruded into Çağlayan formation and was intruded by andesite(Ad). This rock which developes around Lahanos and Killik ore deposits intruded concordantly to host rocks at boundary zone between Kızıkaya and Çağlayan formations, and at boundary zone between dacite lava and its pyroclastics in Çağlayan formation.

This rock forms lava domes and small intrusive bodies. Lava domes develope in southern part of Lahanos area and in Çalkaya area, and their diameter in plan are less than 1km. Small intrusive bodies mainly show slender forms, and mainly extend towards north-east direction, but sometimes towards north-northeast or north-northwest direction.

Generally it shows reddish gray to reddish brown in color and contains rather amount of iron oxidized minerals(around 5%). It shows also massive in shape and well developed columnar joints. Quartz and feldspar can not be observed by naked eye, but sometimes feldspar crystals in size of 1mm diameter can be seen. Microscopical observation indicates that phenocrysts are composed of plagioclase, common hornblende and iron minerals, and that groundmass is composed of glass. Quartz, pyrite, hematite, chlorite and other clay minerals are considered to have been formed during alteration.

White to gray argillized zones are formed by strong alteration and such zones sometimes show reddish brown in color because of impregnated hematite.

(5)Porphyrytic Dacite

This rock distributes mainly in northern part of the survey area, forming small intrusive bodies whose sizes are less than 1km in long diameter and less than 300m in short diameter. It intruded into Çağlayan formation and nevaditic dacite(Nd). It shows grayey white to grayey brown in color, and characteristically contains quartz and feldspar with 1~2mm diameter. It is fine and hard rock, and shows well developed columnar joints. It did not accompany hydrothermal alteration.

Under microscope, phenocrysts is composed of quartz, plagioclase, biotite and iron minerals, and groundmass is composed of glass, quartz and iron minerals.
Quartz, chlorite and sericite were revealed to have been formed during alteration.

(6)Nevaditic Dacite(Nd)

This rock developes in southern and north-eastern parts of the survey area, forming big to small intrusive bodies. It intruded into Çağlayan formation and was intruded by porphyrytic dacite(Dp). In north-eastern part of the survey area(Çalkaya area), it composes a part of big intrusive body which occupies more than 5km in plan, and in central and southern parts it composes many small bodies. These small bodies are inclined to extend usually towards north-east direction, but in some cases towards north-northeast direction.

It shows grayey white to gray in color, and contains commonly big crystals of quartz and plagioclase as big as 5mm diameter. It is generally fine grained, hard and massive.

Microscopical observation revealed that phenocrysts were composed of quartz, plagioclase, biotite and iron minerals, and that groundmass were composed of glass, plagioclase and opaque minerals. Alteration is thought to have formed quartz, chlorite, sericite and epidote.

Alteration such as argillization and hematitization is recognized at contact zone between Çağlayan formation and this rock in Çalkaya area, but in other parts of the survey area strong alteration can not be observed.

Though Demir Export company(1993) says that this rock in Çalkaya area is thought to be lava of

Kızıkaya formation, this rock was concluded to be intrusive rock formed after Çağlayan formation, from the point of field observation.

(7) Biotite Dacite(Db)

This rock exists mainly in central part of the survey area as big to small bodies. These bodies show 5 km as maximum long diameter and 1km as maximum short diameter, and less than 1km as minimum long diameter and less than 200m as minimum short diameter. It intruded into Çağlayan formation, extends towards north-west or north-northeast direction, and contains xenolith of red dacite(Dh). It shows gray to grayey black in color, and feldspar and biotite in 1～2mm diameter can be seen commonly. It is fine grained and hard, and flow banding structure are also commonn.

It is generally fresh, but at boundary zones with Çağlayan formation white argillization and reddish brown hematitization are observed, and in some places it seems sandy due to weathering.

Microscopical observation tells that phenocrysts are composed of quartz, plagioclase, common hornblende and apatite, and that groundmass are composed of glass, plagioclase and opaque minerals. Quartz, pyrite, chlorite and other clay minerals are presumed to be formed during alteration.

2-2-3 Geological Structure

Generally Çatak formation shows north-east strike and dips south-westwards in south-eastern part of the survey area, and shows north-northeast strike and dips east-northeastwards in south-western and western part. Therefore, Kızıkaya formation was controlled by north-east and north-northwest structure and were deposited in structural basin opened northwards.

In western part where lowest members of Kızıkaya formation develope, they show north-northwest strike and dip east-northeastwards as well as Çatak formation. In central part where upper members of Kızıkaya formation develope, they show north-northwest or north-norteast strike and dip gently east-northeastwards or west-northwestwards. Strikely speaking, basin structure in Çatak formation was filled by volcanic effusive materials in age of Kızıkaya formation.

In central part, Çağlayan formation shows same dip and strike as Kızıkaya formation, but in northrn part it shows east-northeast strike and dips gently north-northwestwards. On overlooking from Çatak to Çağlayan formations, the more northern part they exist in, the steeper they dip. And then it is concluded that the southern part was raised relatively in these geological duration.

Intrusive rocks also were controlled by same geological structure as Çatak to Çağlayan formations. Namely in southern part where Çatak formation is predominat, intrusive rocks usually intruded north-eastwards equally as principal structure. In central to northern part where Kızıkaya and Çağlayan formations develope predominantly, they intruded north-northwestwards and north-northeastwards, besides north-eastwards and north-westwards.

In the survey area, no big faults can be found, but in southern part, faults extending north-westwards and north-eastwards are recognized. These faults are high angled and reverse faults. Furthermore dextral faults with north-east strike are seen in Çağlayan formation that exists in Çalkaya area, central part of the survey area, and reverse faults with north-northwest strike are seen in Çağlayan formation that developes in northern part.

2-3 Consideration

Geology of this area is composed of Çatak, Kızıkaya and Çağlayan formations in ascending order which were formed in Cretaceous. These formations mainly consist of volcanic rocks and pyroclastic rocks, Çatak formation developes in southern part, Kızıkaya formation does in central part and Çağlayan formationdoes in northern part of the survey area. Then it is concluded that both the center of deposition and the center of volcanic activities were shifted from south to north as lapse of time.

Bedding planes of Çatak formation in southern part have north-east and north-west strikes, lower members of Kızıkaya formation in central part show north-west~north-northeast strikes, upper members of Kızıkaya formation and whole members of Çağlayan formation in central part show north-northeast and north-northwest strikes, Çağlayan formation in northern part shows north-east strike and all of these members dip northwards. From these facts, southern part of the survey area where Çatak formation developes is concluded to have been raised relatively, northern part is presumed to have been depressed, and Kızıkaya and Çağlayan formations are thought to have deposited in such a depressed part. Lahanos massive sulfide ore deposits are considered to be situated at the ceitral of places where volcanic members of Kızıkaya formation were effused and topographical depression took place.

High angled reverse faults which extend north-westwards and north-eastwards can be seen in Çatak formation of northern part, dextral faults striked north-eastwards can be seen in Çağlayan formationof central part(Çalkaya area), and reverse faults striked north-northwestwards can be seen. In these faults, reverse faults striked north-eastwards seems to be formed under compressional field from south-east to north-east direction at the same time as uplift of Çatak formation, and on the other hand reverse faults striked north-westwards and dextral faults striked north-eastwards seem to be formed under compressional field from south-west to north-west direction.

Namely from these geological evidences, structural history on geology are considered as follows,

At the time of effusion of Çatak formation

Stress field:Tension to north-west direction

Geological structure:Depressional structure extending north-eastwards

Fracture extending north-eastwards

At the time of effusion of Kızıkaya formation

Stress field:Compression from north-west direction

Geological structure:Uplift structure extending north-eastwards

Fracture extending north-westwards

At the time of effusion of Çağlayan formation

Stress field:Compression from north-east direction

Geological structure:Uplift structure extending north-westwards

Fracture extending north-eastwards and east-westwards

At the time of formation of intrusive rocks

Stress field:Compression from north-south direction

Geological structure:Intrusion along north-northwest and north-northeast directed fracture

Intrusion along former(north-east and north-west directed) fracture

Chapter 3 Survey for Ore Showings and Mineralized Zones

3-1 Survey Method

Many massive sulfide ore deposits such as Lahanos, Killik and other ore deposits are reported to exist in this survey field. In order to discover new ore deposits same type as known ore deposits, detailed geological survey for mineralized and altered zones were performed in this survey.

At first existing documents and data regarding mineralization and alteration around known ore deposits were analized, and then survey routes were selected.

Detailed geological survey was started around known ore deposits, ore showings and on selected routes, and then was escalated to the high potentiality area for new ore deposits. Afterwards high possibility mineralized and altered areas for new massive sulfide ore deposits are extracted for next stage.

On survey, altered rocks besides typical ores were sampled to be analized chemically, and to be analized by microscopy and X-ray diffractmeter. Elements analized chemically for ore samples are 18 elements as follows, Mn, Fe, Cu, Zn, Ag, Ba, Au, Pb, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, U and Th.

Distribution of ore showings and altered zones is shown as Fig. 3-1, result of chemical analysis from ore samples is shown as Table 3-1, microscopical observation for ore samples is summarized in Table 3-2, result of X-ray analysis of altered rock samples is shown in Appendix A-1, and locations of samples is shown as Fig. 2-4.

3-2 Result of Survey

3-2-1 Mineralization

1. Known Ore Deposits

As existing ore deposits and/or ore showings in the survey area, Lahanos, Killik, Kepçelik, Kızıkaya, Dickmen, Ağalik, Çımakli, Karılar, Karaerik and other ore deposits or ore showings are well known. Lahanos mine is only one working mine and all of others were closed or have not been mined.

Lahanos to Kızıkaya ore deposits in just above mentioned list are located in central part of the survey area, Dickmen ore deposits are located in eastern part, and Ağalik to Karaerik ore deposits are located in northern part(refer to Fig. 3-1). Killik ore deposits are composed of two ore deposits, and then one is called Killik North ore deposits and the other is called Killik South ore deposits. Details of each ore deposits are explained as follows,

(1) Lahanos Ore Deposits

The ore deposits exist in central part of the survey area. At this moment, Demir Export company is mining underground. Demir Export company(1990) says that they estimated 2,300 thousand tons(average Cu 3.6% and average Zn 2.3%) as probable ore after drilling in 14 places and excavating exploration pits(total length;1,315m).

The ore deposits are massive sulfide ore deposits which are contained in uppermost member of Kızıkaya formation, that is, dacite lava(Kdc). In ore horizon tuff(Kt2) that is defined as tuffaceous rocks exclusively including massive sulfide ore deposits, hematite-chert zone are recognized in less thickness than 1m. As hangingwall of ore deposits, muddy rocks(Cms), dacite lava(Cdc) and pyroclastic rocks(Ctf) of Çağlayan formation are observed. In some places, red dacite(Dh) intruded along boundary between ore deposits and overlying rocks. Result of chemical analysis of ore samples are summarized in Table 3-1, and according to this table result of chemical analysis are shown as follows, Au 0.4~6.3g/t, Ag 7~490g/t, Cu 0.28~24.20%, Pb <0.01~3.64%, Zn 0.31~20.00%, Fe 9.61~45.80%, Mn <0.01~0.08%, Ba 0.01~21.60%, La <1~3ppm, Ce 1~13ppm, Nd <5ppm, Sm <1~7ppm, Eu <1ppm, Tb <1~2 ppm, Yb 1ppm, Lu <1ppm, U <1~10ppm, Th <1~1ppm.

Ore deposits are composed of massive to brecciated yellow ore and semi-black ore, and sometimes accompany siliceous ore and pyrite ore. Their maximum thickness in massive part is 15m and average thickness is 3~5m. Yellow ore contains rather much amount of Au, Ag and Cu, and semi-black ore shows high contents of Au, Ag and Zn. In pyrite ore, contents of these metals are low. Ba is contained more than 10% in parts of yellow and semi-black ores. According to microscopical observation(Table 3-2), yellow ore consists of pyrite, chalcopyrite, sphalerite and barite as main components, and sometimes accompanies galena, tetrahedrite, bornite and arsenopyrite. Semi-black ore consists of pyrite, sphalerite and chalcopyrite as main components, and sometimes includes galena, tetrahedrite and barite. Pyrite ore consists mainly of pyrite, and includes small amount of sphalerite, chalcopyrite, galena and tetrahedrite. As gangue minerals, quartz, sericite and carbonate minerals besides barite are recognized. In massive ore, colloform texture made from pyrite, chalcopyrite and sphalerite are observed and framboidal pyrite is also seen.

Kızıkaya formation around ore deposits shows strong and white argillized alteration, and in some places shows silicification and disseminated pyrite. Çağlayan formation(hangingwall of massive ore deposits) also shows argillization and hematitization by later hydrothermal alteration than formation of massive sulfide ore deposits.

(2)Killik North and Killik South Ore Deposits

Killik North ore deposits are located at 2km south from Lahanos mine and Killik South ore deposits are located at 3km south from Lahanos mine. Probable ore reserves of 172 thousand tons(average Cu 1.1%, Zn 2.5%, Pb 0.7%) were estimated after 27 drilling holes(total length;2,440m), and they were stopped to work in spite of remained ore reserves of 90 thousand tons.

The type of both ore deposits is massive sulfide ore deposits. In Killik North ore deposits, dacitic pyroclastic rocks of Kızıkaya formation(Kt2) underlie, and muddy rocks(Cms) and dacitic pyroclastic rocks(Ctf) of Çağlayan formation overlie ore deposits. Andesite intruded into various parts of ore bodies.

In Killik South ore deposits, dacite lava(Kdc) and its pyroclastic rocks(Kt2) underlie, and muddy rocks(Cms) and dacitic pyroclastic rocks(Ctf) overlie ore deposits. Dacite lava below ore deposits seems porphyritic because of their phenocrysts such as quartz and plagioclase with 2~3mm diameter, and it is clearly different from dacite lava below Lahanos ore deposits that is aphyric.

According to chemical analysis, elemental contents of ore samples here are shown as follows, Au 0.4~6.3g/t, Ag 7~490g/t, Cu 0.28~24.20%, Pb <0.01~3.64%, Zn 0.31~20.00%, Fe 9.61~45.80%, Mn <0.01~0.08%, Ba 0.01~21.60%, La <1~3ppm, Ce 1~13ppm, Nd <5ppm, Sm <1~7 ppm, Eu <1ppm, Tb <1~2ppm, Yb 1ppm, Lu<1ppm, U <1~10ppm, Th <1~1ppm.

Ore deposits are composed of massive to brecciated yellow ore, semi-black ore and pyrite ore, and networked siliceous ore. Yellow ore shows high contents of Au, Ag, Cu and Zn, and in siliceous ore these elements are contained poorly. Ba is contained more than 10% in parts of pyrite and yellow ores. Under microscope, chalcopyrite, pyrite and sphalerite are observed as main components, and galena, tetrahedrite and barite are observed as subsidiary components in yellow ore. Semi-black ore consists of pyrite, barite, sphalerite and chalcopyrite. Pyrite ore mainly consists of pyrite and barite, and subsidiarily consists of sphalerite, chalcopyrite and tetrahedrite. As gangue minerals, quartz, sericite and carbonate minerals besides barite are seen. Colloform texture composed of pyrite is observed very often in ore.

(3)Kepçelik Ore Deposits

The ore deposits are located in south-eastern part of the survey area. Two drill holes performed by ETI Bank caught a extension of ore deposits.

The ore deposits are massive sulfide ore deposits contained in uppermost members of Kızıkaya formation. Dacitic pyroclastic rocks(Kt2) of Kızıkaya formation underlie, and muddy rocks(Cms) and pyroclastic rocks(Ctf) of Çağlayan formation overlie ore deposits. Porphyritic dacite(Dp) and red dacite(Dh) intruded between hangingwall and ore deposits.

Result of chemical analysis from ore samples here are shown as follows, Au 0.01～3.75g/t, Ag 2～281 g/t, Cu 0.02～24.50%, Pb <0.01～10.50%, Zn 0.44～31.20 %, Fe 7.75～32.2%, Mn <0.01～0.03%, Ba 0.02～1.07%, La <1ppm, Ce <1～7ppm, Nd<5ppm, Sm <1ppm, Eu <1ppm, Tb ≦ 1ppm, Yb <1ppm, Lu <1ppm, U <1～4ppm, Th <1ppm.

Ore deposits are composed of semi-black ore, yellow ore, pyrite ore and siliceous ore. Microscopical observation shows that semi-black ore consists mainly of sphalerite, pyrite and chalcopyrite, and subsidiarily of galena, tetrahedrite and quartz. In some parts of this ore, colloform texture made by pyrite is recognized. Siliceous ore consists mainly of quartz and pyrite, and in several spots consists of sphalerite, quartz and sericite.

In yellow ore, Au, Ag, Cu, Pb and Zn are contained highly, and in siliceous ore these elements are not contained so much.

(4)Kızıkaya Ore Deposits

The ore deposits exist in central part of the survey area. They were mined in rather big scale in the past. MTA surveyed in latter half of 1960's and Demir Export company followed exploration works. Demir Export company calculated 320 thousand tons(Cu 3.5%, Zn 2.8%, Pb 0.7%, Ag 77g/t) as remained ore reserves after they drilled 37 holes(total length;1,741m).

Disseminated ore, networked ore and dacite lava(Kdc) in Kızıkaya formation underlie, and muddy rocks(Cms) and dacitic pyroclastic rocks(Ctf) overlie massive sulfide ore deposits here. Disseminated～networked ore body shows rather large distribution range such as 1km×1km in plan, and shows strong silicification, argillization and hematitization. Affect of mineralization is clearly and strongly attained to Çağlayan formation. At some spots in disseminated～networked ore body, sulfide minerals are reported to be concentrated.

Chemical analysis of ore samples show their result as follows, Au 0.09～3.71g/t, Ag 2～212g/t, Cu

<0. 01~0. 08%, Pb <0. 01~14. 7%, Zn <0. 01~4. 26%, Fe 1. 20~33. 20%, Mn <0. 01%, Ba 0. 01~33. 90%, La < ~6ppm, Ce <1~13ppm, Nd <5~5ppm, Sm <1~1ppm, Eu <1ppm, Tb ≦1 ppm, Yb <1ppm, Lu <1~2ppm, U <1~2ppm, Th <1~2ppm.

Ore deposits consist of massive black ore, pyrite ore and networked siliceous ore. Under microscope, in black ore sphalerite and galena are observed as main components, and pyrite, chalcopyrite and tetrahedrite are observed as subsidiary components. In pyrite ore, pyrite and barite are seen as main components, and sphalerite and chalcopyrite are seen as subsidiary components. As gangue minerals, barite, quartz, carbonate minerals(siderite, ankerite, rhodochrosite) and sericite are observed. In oxidized zone, secondary minerals such as limonite, hematite, bornite and covelline are recognized. Colloform texture made from pyrite is also seen commonly.

Black ore shows high contents of Au, Ag, Pb and Zn, but contents of these elements in pyrite ore and siliceous ore are not so much. In some parts of black and pyrite ores, Ba is included more than 30%.

(5)Dikmen Ore Deposits

The ore deposits are in eastern part of the survey area. Five drill holes(total length;600m) by ETI Bank revealed 300 thousand tons(Cu 0. 9%) as probable ore reserves.

The ore deposits are massive sulfide ore deposits which are included in upper-most members of Kızıkaya formation. Dacite lava(Kdc) and dacitic pyroclastic rocks(Kt2) underlie, and muddy rocks(Cms) and dacitic pyroclastic rocks(Ctf) overlie ore deposits.

Chemical analysis from ore samples here show their result as follows, Au 0. 01~0. 17g/t, Ag 1~30g/t, Cu <0. 1~1. 28%, Pb <0. 01~0. 62%, Zn <0. 01~7. 51%, Fe 2. 91~23. 10%, Mn <0. 01%, Ba 0. 01~0. 08%, La <1~5ppm, Ce 2~10ppm, Nd <5ppm, Sm <1ppm, Eu <1ppm, Tb <1ppm, Yb <1ppm, Lu <1ppm, U ≦1ppm, Th ≦1ppm.

Ore deposits consists of massive to brecciated pyrite ore and networked siliceous ore. Under microscope in pyrite ore, pyrite is seen as main component, sphalerite is seen as subsidiary component, and tetrahedrite, quartz and carbonate minerals are reported as accessory minerals.

Siliceous ore shows high contents of Zn partly, but contents of metallic elements are usually low in pyrite ore and siliceous ore. Contents of Ba are also less than 1% in these ores.

(6)Ağalik Ore Deposits

The ore deposits are located in northern part of the survey area. MTA and ETI Bank performed exploration works, and 1, 400 thousand tons(Cu 0. 6%, Zn 2. 0%, Ag 96g/t) were estimated as probable ore.

The ore deposits are massive sulfide ore deposits which are contained in uppermost members of Kızıkaya formation. Dacite lava(Kdc) of Kızıkaya formation underlie and dacitic pyroclastic rocks(Ctf) of Çağlayan formation overlie ore deposits. Dacite lava below ore deposits here contains commonly big crystals of quartz and plagioclase with 2~4mm diameter, and is porphyrytic as same as dacite lava below Kepçelik ore deposits. It is different from aphyric dacite lava below Lahanos ore deposits.

Chemical analysis of ore samples here show their result as follows, Au 0. 72~0. 78g/t, Ag 16~31g/t, Cu <0. 01~0. 05%, Pb 0. 02%, Zn 0. 08~0. 18%, Fe 44. 2~44. 5%, Mn <0. 01%, Ba 0. 10~0. 93

%, La <0.1ppm, Ce 2~3ppm, Nd <5ppm, Sm <1ppm, Eu<1ppm, Tb <1ppm, Yb <1ppm, Lu <1ppm, U <1ppm, Th <1ppm.

Ore deposits are composed of massive to brecciated pyrite ore. Microscopical observation shows that pyrite ore consists of mainly pyrite and sphalerite, and includes barite and chalcopyrite as subsidiary minerals.

In pyrite ore, contents of Au, Ag, Cu, Pb, Zn and Ba are low and those of Fe are high.

(7)Çımakli Ore Deposits

The ore deposits are located in northern part of the survey area. MTA and ETI Bank drilled 5 holes(total length;845m).

Ore deposits are massive sulfide ore deposits which are contained in uppermost members of Kızıkaya formation. Dacite lava(Kdc) of Kızıkaya formation underlie and dacitic pyroclastic rocks(Ctf) of Çağlayan formation overlie ore deposits. Dacite lava just under ore deposits contains commonly crystals of quartz and plagioclase with 2~4mm diameter, and is porphyritic as same as dacite lava below Kepçelik and Ağalik ore deposits. Red dacite(Dh) is reported to intrude between hangingwall and ore deposits.

Ore deposits are mainly composed of siliceous ore and pyrite ore. Microscopical observation shows that main mineralogical components are pyrite, chalcopyrite and sphalerite, and subsidiary components are tetrahedrite, galena and silver minerals. Quartz, barite, sericite and carbonate minerals are observed as gangue minerals. In some spots of dacite lava(Kdc), strong argillization with kaolinitization is seen.

(8)Karılar Ore Deposits

The ore deposits are in northern part of the survey area. MTA and ETI Bank drilled 3 holes(total length;325m), and afterwards they estimated 100 thousand tons(Cu 0.5~1.1%, Zn 0.7~2.5%, Pb 1.0 %, Ag 50~69g/t, Fe 46.2%) as probable ore reserves.

The ore deposits are disseminected~networked ore deposits which are contained in dacite lava(Cdc) and dacitic pyroclastic rocks(Ctf) of Çağlayan formation.

Pyrite ore that looks like massive ore is reported in a small area of networked ore body.

Chemical analysis of ore samples here show their result as follows, Au 0.07g/t, Ag 1~2g/t, Cu <0.01~0.05%, Pb <0.01%, Zn 0.02~0.03%, Fe 44.60~46.50%, Mn<0.01%, Ba ≦0.01%, La ≦1 ppm, Ce 3~6ppm, Nd <5ppm, Sm <1ppm, Eu <1ppm, Tb <1ppm, Yb <1ppm, Lu <1ppm, U <1ppm, Th <1ppm.

Ore deposits are mainly composed of disseminated to networked siliceous ore and massive pyrite ore. Under microscope, pyrite ore includes mainly pyrite and sphalerite, and subsidiarily chalcopyrite and quartz. Barite and carbonate minerals besides quartz are reported as gangue minerals.

Pyrite ore shows low contents of Au, Ag, Cu, Pb, Zn and Ba, and high contents of Fe.

(9)Karacrik Ore Deposits

The ore deposits are located in northern part of the survey area. MTA and ETI Bank drilled 7 holes(total length;1,030m), and then the existence of disseminated to networked ore bodies were confirmed.

The ore deposits are disseminated to networked ore deposits which are contained in dacite lava(Cdc) and dacitic pyroclastic rocks(Ctf) of Çağlayan formation. In some spots of disseminated ore body, pyrite ore that seems massive is reported. Porphyritic dacite(Dp) is also reported to have intruded around ore deposits. Chemical analysis from ore samples here show their result as follows, Au 0.55 g/t, Ag 2g/t, Cu 0.025%, Pb <0.01%, Zn 0.01%, Fe 46.6%, Mn <0.01%, Ba <0.01%, La <1ppm, Ce <1 ppm, Nd <5ppm, Sm <1ppm, Eu <1ppm, Tb <1ppm, Yb <1ppm, Lu <1ppm, U 1ppm, Th <1 ppm.

Ore deposits are composed of disseminated to networked siliceous ore and partly of massive pyrite ore. Under microscope, pyrite and sphalerite are observed as main components, and chalcopyrite, quartz, barite and carbonate minerals are observed as subsidiary components. Around marginal zone of intrusive rocks, small veins filled with manganese oxidized minerals are reported to exist. Around networked ore bodies, silicification, sericitization and limonitization due to alteration can be observed.

Pyrite ore shows low contents of Au, Ag, Cu, Pb, Zn and Ba, and high contents of Fe.

2. Newly Selected Mineralized Zones

Two areas are selected as newly selected mineralized zones where real exploration works were not performed there, strong alteration and mineralization can be recognized in Kızıkaya formation that is considered to contain exclusively massive sulfide ore deposits, and Çağlayan formation covers Kızıkaya formation. Details of these two areas are explained as follows,

(1)Bitene Area

This area exists in central part of the survey area and is located between Lahanos mine and Killik ore deposits. MTA has surveyed this area, but real exploration works have not been performed yet.

Mineralized and altered zone developes widely along a branch of Kızıl river, and floating ore were confirmed. Field survey for the ore showings here suggest the expectence of massive sulfide ore deposits that are contained in uppermost member of Kızıkaya formation. Dacite lava(Kdc) of Kızıkaya formation is presumed to underlie and dacitic pyroclastic rocks(Ctf) of Çağlayan formation is presumed to overlie the ore deposits. Dacite lava here presumed to underlie ore deposits is aphyric as same as footwall dacite lava in Lahanos area. Red dacite intruded between ore showings and hangingwall in some places. Andesite(Ad) also intruded into various parts of surrounding rocks and ore showings.

Result of chemical analysis from floating ore samples is shown as follows, Au <0.01~0.20g/t, Ag 1~3g/t, Cu <0.01~0.06%, Pb ≤0.01%, Zn ≤1%, Fe 5.22~31.20%, Mn <0.01%, Ba 0.04~0.58%, La 2~5ppm, Ce 5~8ppm, Nd <5ppm, Sm <1~2ppm, Eu <1ppm, Tb <1~2ppm, Yb 2ppm, Lu <1ppm, U 3~13ppm, Th 3~4ppm.

Floating ore is composed of semi-black ore showing banded structure, pyrite ore and siliceous ore. Under microscope, pyrite, sphalerite and barite were observed as main components in semi-black ore. Framboidal pyrite is also seen, and quartz and sericite are reported as gangue minerals.

Au, Ag, Cu, Pb, Zn and Ba are contained poorly in pyrite ore and siliceous ore.

(2)Çalkaya~Taflançık Koyo Area

This area is in eastern part of the survey area and real exploration works have not been performed yet. In this area, mineralized and altered zones were recognized at exposures of dacite lava(Kdc) of Kızıkaya formation and dacitic pyroclastic rocks(Ctf) of Çağlayan formation. Strongly argillized alteration, silicification and disseminated pyrite were also seen together in these rocks. But where Kızıkaya formation is thickly covered by dacite lava(Cdc) of Çağlayan formation and was intruded in its various parts by intrusive dacite(Dh), ore showings in Kızıkaya formation could not be confirmed directly from the surface.

IP survey was performed where Çağlayan formation developes widely, and IP anomalies were recognized in dacitic pyroclastic rocks(Ctf) of Çağlayan formation, in porphyritic dacite lava(Cdp) of Çağlayan formation, and at the boundary zone between Çağlayan and underlying Kızıkaya formations. Consequently subterrancous massive sulfide ore deposits thought to be expected in this area.

Chemical analysis of ore samples here show as follows, Au 2.74g/t, Ag 21g/t, Cu 0.01%, Pb 0.09%, Zn 0.08%, Fe 9.05%, Mn <0.01%, Ba 0.01%, La 4ppm, Ce 8ppm, Nd <5ppm, Sm <1ppm, Eu <1ppm, Tb <1ppm, Yb <1ppm, Lu <1ppm, U 1ppm, Th <1ppm. Analized sample shows rather high contents of Au.

3. Other Mineralized Zones

Besides above mentiond ore deposits and ore showings, small other mineralized zones can be expected in Kızıkaya and Çağlayan formations. These small other ore showings are explained as follows,

(1)Dikence Mineralized Zone

This mineralized zone is at intermediate location between Lahanos and Çımakli ore deposits. MTA drilled one hole(depth;150m) and small mineralized zone was recognized.

Mineralized zones exist in dacite lava(Cdc) and dacitic pyroclastic rocks(Ctf) of Çağlayan formation, and red dacite(Dh) and biotite-dacite(Db) intruded around mineralized zones. Ore deposits are presumed to be composed of massive and networked ore bodies in small scale. Pyrite, sphalerite and chalcopyrite are reported as ore minerals, and quartz, sericite barite are also reported as gangue minerals.

(2)Karaagaç Area

This mineralized zone is located at 1.5km north from Kızıkaya ore deposits. MTA drilled 3 holes(total length;500m) to explore the extention from known mineralized zone, but they could not catch massive sulfide ore deposits.

Mineralized zone is presumed to have genetical relation with massive sulfide ore deposits that are contained in the uppermost members of Kızıkaya formation. Dacite lava(Kdc) of Kızıkaya formationunderlie, and muddy rocks(Cms) and dacitic pyroclastic rocks(Ctf) of Çağlayan formation overlie this mineralized zone. Dolerite intrusive bodies(Do) are seen around the mineralized zone.

The mineralized zone is composed of disseminated to networked ore bodies which include pyrite, chalcopyrite and sphalerite as ore minerals, and include quartz, sericite and barite as gangue minerals.

(3)Others

Çağlayan formation and intrusive rocks develope between Lahanos and Killik ore deposits, and between Killik and Kepçelik ore deposits. In these areas, mineralized zones can be seen. Dissemination of pyrite and sphalerite can be observed commonly in altered zone showing silicification, argillization and hematitization.

In central part of the survey area where Kızıkaya formation developes widely along Kızıl river, and around Kozkyoy area in eastern part of the survey area, disseminated to networked mineralized zones composed of pyrite and sphalerite can be seen in dacite lava(Kdc) of Kızıkaya formation. Chemical analysis of ore samples here show as follows, Au 0.01～0.05g/t, Ag 1g/t, Cu <0.01%, Pb <0.01%, Zn <0.01%, Fe 20.70～36.40%, Mn <0.01%, Ba 0.02～0.04%, La <1～16ppm, Ce 2～38ppm, Nd <5～20ppm, Sm <1～2ppm, Eu <1ppm, Tb< 1～2ppm, Yb< 1ppm, Lu <1ppm, U 1ppm, Th ≤ 1ppm. Any concentration of these elements can not be observed in analized samples.

3-2-2 Alteration

Analysis of altered rock samples by X-ray diffraction method revealed the existence of minerals as follows, quartz(20.8), cristobalite(21.8), tridymite(20.7), plagioclase(27.7), albite(28.0), potassium feldspar(27.5), halloysite(9.5), montmorillonite(6.0～7.0), sericite(8.8), chlorite(12.4), kaolinite(12.3), dickite(12.3), pyrophyllite(9.5), alunite(30.0), calcite(29.5), dolomite(30.8), siderite(32.0), epidote(17.6), clinoptilolite(9.7), mordenite(9.7), laumontite(9.4), stilbite(9.6), analcime(15.8), ferrierite(10.4), pyrite(33.2), sphalerite(28.4), galena(30.0), hematite(33.7), limonite(21.3), barite(26.0), anhydrite(25.6), biotite(8.7), corundum(36.7), anatase(25.3).

Twice θ angles on chart of X-ray diffractometer using Cu Kα line are written behind each mineral names, and intensities on chart at each angles for every minerals are indicated in Appendix A-1 to estimate and compare roughly their relative quantity.

Alteration in this survey area can be divided into two types, that is, one is regional alteration and the other is mineralized alteration. Distribution patterns of alteration and details of altered zones are explained below.

1. Regional Alteration

Çatak formation mainly consists of andesite lava and its pyroclastic rocks, and generally shows green in the field. Feldspar, mafic minerals and glass of this formation in southern part were replaced during alteration to be altered minerals. As altered minerals, quartz, albite and chlorite can be observed as main altered minerals, and calcite, montmorillonite, pyrite and zeolite(stilbite and laumontite) as subsidiary minerals. Sericite also can be seen around mineralized zones.

In northern part, Çatak formation shows weaker alteration than in southern part. Namely, albitization in plagioclase does not advanced so much, and montmorillonite and montmorillonite-sericite mixed layered mineral were formed mainly, and quartz, pyrite, albite, calcite and mordenite were formed subsidiarily.

Kızıkaya formation mainly consists of dacite lava and dacitic pyroclastic rocks, and contains massive sulfide ore deposits in its uppermost members. This formation distributes in central to northern parts widely, and shows middle~strong regional alteration. It shows light green to grayey white in color. Most of original feldspar and glass were changed to be altered minerals. Main altered minerals are quartz, albite, sericite and chlorite accompanying pyrite, montmorillonite and carbonate minerals such as siderite.

Çağlayan formation that developes in northern part of the survey area is mainly composed of dacite lava and dacitic pyroclastic rocks. Lava parts of this formation usually show original colors due to very poor alteration, but pyroclastic parts show light yellow, light green and light blue in color because of weak alteration. Most of feldspar and glass existing far away from mineralized zones are remained to be unaltered. Montmorillonite is seen as main altered mineral, and montmorillonite-sericite mixed layered mineral, cristobalite and tridymite as subsidiary minerals.

Çağlayan formation that developes rather thinly in central part shows lower grade alterarion than in northern part, and usually shows light green in color, probably due to existence of Lahanos ore deposits in underlying Kızıkaya formation. Feldspar and glass were also more altered than those in northern part. Albite, montmorillonite, montmorillonite-sericite mixed layered mineral and cristobalite can be observed as altered minerals.

Marginal zones of intrusive rock bodies were highly altered by mineralized alteration in some places, but generally they have very weak affect from regional alteration. Therefore only montmorillonite can be observed very rarely as altered mineral.

2. Mineralized Alteration

In this survey area, alteration by mineralization can be recognized in various locations, besides regional alteration above mentioned. In the parts where Çatak formation developes mineralized alteration can not be observed in large scale. In mineralized area along intrusive bodies, strongly altered zone rich in sericite developes narrowly in albite-chlorite altered zone.

Kızıkaya formation includes many strongly altered zones around ore deposits, because it contains exclusively massive sulfide ore deposits. Specially in altered zones around Lahanos ore deposits and their neighboring Bitene mineralized area in central part of the survey area, and around Çalkaya~Taflançık area in eastern part, quartz, sericite, kaolinite dickite and pyrite were formed as main altered minerals, and alunite, pyrophyllite and sericite-montmorillonite mixed layered mineral were done as subsidiary altered minerals. Around Killik and Kızıkaya ore deposits in central part, around Kepçelik and Dickmen ore deposits in south-eastern part, and around Ağalik, Çımakli and other known ore deposits, quartz, sericite, pyrite and barite which are products under neutral acidity can be observed very commonly, and altered mineral formed in acidic condition such as kaolinite can not be observed.

Around disseminated to networked ore bodies contained in Çağlayan formation, strongly altered zones can be seen. In the areas between Lahanos and Killik, and between Killik and Kepçelik where Çağlayan formation developes, disseminated to networked ore bodies distribute intermittently and strongly altered zones were formed around them. In these altered zones, quartz, sericite and pyrite are observed usually, and kaolinite occasionally.

Around Çalkaya~Taflançık area in eastern part and around Karaerik and Karılar ore deposits in northern part, Çağlayan formation was altered by mineralization to produce quartz, sericite and pyrite in much quantity, and kaolinite and hematite in small amount.

In strongly altered zones around intrusive rock bodies, quartz, kaolinite and hematite were produced, but their distributing range is so small.

3-3 Consideration

1. Ore Bearing Horizon

Two types of ore deposits can be observed in this survey area, one is contained in uppermost members of Kızıkaya formation, and the other is contained in Çağlayan formation. According to existing documents and actual field survey, massive sulfide ore deposits contained in uppermost members of Kızıkaya formation are controlled stratigraphically, and then they can be concluded to be exhalative sedimentary deposits. On the otherhand, disseminated to networked ore deposits contained in Çağlayan formation are cutting through Kızıkaya and Çağlayan formations, and then they can be concluded to be formed epigenetically.

Among known ore deposits, Lahanos, Killik and Kızıkaya ore deposits in central part, Kepçelik and Dikmen ore deposits in south-eastern~eastern part, and Ağalik and Çımakli ore deposits in northern part are considered to be massive sulfide sedimentary ore deposits contained in Kızıkaya formation. On the other hand, Karılar and Karaerik ore deposits contained in Çağlayan formation are considered to be epigenetic ore deposits.

2. Morphology, Ore Mineralogy and Ore Grade

Massive sulfide type ore deposite are composed of semi-black ore, yellow ore, massive to brecciated pyrite ore and disseminated to networked ore. And around these ores, argillized zone developes widely. In disseminated to networked type ore deposits, pyrite is included in silicified and argillized zones like as networks and/or dissemination, and in some spots pyrite forms small mass.

Massive type ore deposits include pyrite, sphalerite and and chalcopyrite as main components, and galena and tetrahedrite as subsidiary components. As gangue minerals, barite, quartz and clay minerals are observed. Colloform texture is also recognized commonly in pyrite ore.

Result of chemical analysis on ore samples show that yellow ores in Lahanos and Killik ore deposits contain much Au, Ag, Cu, Pb and Zn, and pyrite ores there contain much Fe and a small amount of Au, Ag and Cu. Black to semi-black ores in Lahanos, Killik, Kızıkaya and Kepçelik ore deposits, contain mainly Au, Ag, Pb and Zn, and subsidiarily Cu. In siliceous ores and pyrite ores, these metallic elements can not be confirmed so much.

Disseminated to networked type ore deposits include pyrite as a main ore mineral, and sphalerite and chalcopyrite as subsidiary ore minerals. As gangue minerals, quartz and clay minerals are seen mainly. Nor colloform texture can be recognized in pyrite ore.

Result of chemical analysis on ore samples show no metallic concentration except Fe in disseminated to networked ore deposits of Karılar and Karaerik ore deposits. Therefore, massive sulfide type ore deposits are more valuable in mining activity than disseminated to networked type ore deposits, from the points of ore types, mineral assemblages and chemical composition of ores. Furthermore massive sulfide type ore deposits can be expected in much bigger scale than disseminated to networked type ore deposits.

3. Alteration

Characteristics of regional alteration and mineralized alteration for each stratigraphical units are summarized as follows,

Stratigraphical units	Type of Alteration	Products by Alteration
Intrusive rocks	①Regional alteration; ②Mineralized alteration; Around intrusive bodies White and red altered zones	No alteration～weak alteration ・Montmorillonite Middle～strong alteration Acidic alteration ・Quartz ・Kaolinite ・Hematite/pyrite
Çaglayan formation	①Regional alteration Light green altered zones ②Mineralized alteration White and red altered zones Disseminated to networked ore deposits	Weak alteration ・Montmorillonite ・Cristobalite Middle～strong alteration Acidic～neutral alteration ・Quartz ・Kaolinite ・Sericite ・Pyrite/hematite
Kızıkaya formation	①Regional alteration Light green altered zones ②Mineralized alteration White altered zones Massive sulfide ore deposits	Middle～strong alteration Neutral alteration ・Sericite ・Chlorite Strong alteration Neutral～acidic alteration ・Quartz ・Sericite ・Kaolinite
Çatak formation	①Regional alteration Green altered zones	Weak～middle alteration Neutral～alkaline alteration ・Chloritization ・Epidotization ・Zeolite

Regarding mineralized alteration around massive sulfide ore deposits, two types of alteration are recognized. One is alteration composed of products by acidic alteration such as kaolinite, dickite and alunite which developes around Lahanos ore deposits. The other is alteration composed of products by neutral acidity alteration such as sericite and others which developes around Killik, Kızıkaya, Kepçelik, Dikmen, Ağalik and Çımakli ore deposits.

Around Karacrik and Kartılar ore deposits that are disseminated to networked type ore deposits contained in Çağlayan formation, altered zones composed of products by neutral~acid alteration such as kaolinite, sericite and others are observed.

In some places where Çağlayan formation covers massive sulfide ore deposits and Kızıkaya formation, altered zones composed of sericite and others by neutral acidity alteration are recognized and this kind of alteration is thought to be due to post mineralization following massive sulfide type mineralization or due to intrusive activities.

4. New Mineralized Zones

This survey clarified details of new mineralized areas such as Bitene and Çalkaya~Taflançık areas, besides known ore deposits.

In Bitene area that is located between Lahanos and Killik ore deposits, acidic alteration zone including kaolinite developes as well as Lahanos mining area, and floating ore of pyrite ore and semi-black ore thought to be derived from massive sulfide type ore deposits were discovered by this survey.

In Çalkaya~Taflançık area, real exploration works have not been performed yet. But neutral~acidic and strong alteration zones including kaolinite and sericite are formed in Kızıkaya and Çağlayan formations. Judging from type of alteration, existence of ore deposits lika as Lahanos ore deposits can be expected in Kızıkaya formation here.

Çağlayan formation between Lahanos and Killik ore deposits, and between Killik and Kapcelik shows neutral alteration zones including sericite. In Çağlayan formation around known massive sulfide ore deposits, alteration by post mineralization are observed very commonly. Therefore, massive sulfide ore deposits can be expected to exist in Kızıkaya formation underlying these alteration zones.

Chapter 4 Geochemical Survey

4-1 Survey Method

After performance of geological survey, geochemical survey areas were selected to detect geochemical anomalies and geochemical survey was performed.

In this geochemical survey, rock samnples and soil samples were taken and chemically analized. Rock samples were mainly taken in northern and central parts of the survey area where Kızıkaya and Çağlayan formations develope widely and are exposured well, and where high potentiality for massive sulfide ore deposits can be expected. Soil samples were taken around Çalkaya~Lahanos~Killik area where soils develope rather thickly and known massive sulfide ore deposits exist nearby. Samples were taken densely in high potentiality area for massive sulfideore deposits and in the other area were teken coarsely. Soil samples were taken from so-called "B-layer" that is most argillized layer in soil and various elements are thought to be concentrated in. At first soil samples were dried naturally and then were treated by sieve to adjust grain size under 80-mesh. And then rock samples and soil samples were analized chemically.

Totally 560 rock samples were taken and analized elements are as follows, Au, Ag, Cu, Pb, Zn, As, Sb, Mn, Fe, Mo, Ba, SiO_2, Al_2O_3, TiO_2, Fe_2O_3, Cr_2O_3, CaO, MgO, MnO, Na_2O, K_2O, P_2O_5 and LOI(total 23 elements). For some samples in these 560samples, 10 more elements such as rare earth elements and others were analized additionally and these 10 elements are as follows, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, U and Th.

Totally 255 soil samples were analized for 11 elements as follows, Au, Ag, Cu, Pb, Zn, As, Sb, Mn, Fe, Mo and Ba.

After chemical analysis, basic statistics were calculated for each elements and principal components analysis, that is one of multi variables analysis, were performed for rock samples and soil samples. Then results of these statistical analysis are utilized for next year's plan.

Locations of samples for geochemical survey were shown on Fig. 4-1, statistically analized result(distribution map of each elements) for rock samples was shown on Fig. 4-2, statistically analized result(distribution map of each elements) for soil samples was shown on Fig. 4-3, basic statistics from chemical analysis were summarized in Table 4-1, correlation coefficients between each elements were summarized in Table 4-2, result of principal components analysis was summarized in Table 4-3, list of result of chemical analysis were shown in Appendix A-3, and histograms and cumulative frequency curves for each elements were shown in Appendix A-4.

4-2 Result of Geochemical Survey

4-2-1 Geochemical Survey by Rock Samples

According to Table 4-1(basic statistics from chemical analysis of rock samples), arithmetic and logarithmic averages of Au, Ag, Cu, Pb, Zn, As and Fe in this area are higher than those of worldwide background values(Rose et al.;1979). Averages of Sb, Mn, Mo and Ba here are almost same as those of worldwide background values, but in some points they show high values. On the contrary, averages of Ba, U, Th and rare earth elements(La, Ce and others) here are lower than those of world background values.

As shown in cumulative frequency curves (Appendix A-4), ratio of samples which showed higher values than normal background of rocks for each elements are as follows, Au(52%), Ag(91%), Cu(91%), Pb(100%), Zn(71%), As(80%), Sb(33%), Mn(43%), Fe(62%), Mo(18%), Ba(7%), La(0%), Ce(0%), U(0%) and Th(6%).

In correlation coefficients table(as shown in Table 4-2), significance test was performed on 1% of significance level and result such as R(0.01)=0.16 was obtained. Based on this value, correlation coefficients are copmpared with each other as mentioned below.

Au shows high positive correlation with Cu, Pb, As, Sb and Mo, and specially high correlation coefficients with As and Mo that are more than 0.3. On the contrary, Au shows nagative correlation with Al_2O_3, Na_2O, CaO, MgO and MnO.

Ag shows positive correlation with Cu, Pb, As and Sb, but does not show specially high correlation with any other elements.

Cu has positive correlation with Au, Ag, Pb, Zn, As, Sb, Fe, Mo, P_2O_5 and LOI, and specially high correlation with Pb, Zn, As, Sb and Fe. On the contrary, Cu shows high negative correlation coefficient with SiO_2 less than -0.3.

Pb has positive correlation with Au, Ag, Cu, Zn, As, Sb, Fe, P_2O_5 and LOI, and specially high correlation with Cu, Zn, Sb, Fe and LOI. On the contrary, Pb has high negative correlation with SiO_2.

Zn shows positive correlation with Ag, Cu, Pb, Mn, Fe, Al_2O_3, TiO_2, CaO, MgO, P_2O_5 and LOI, and specially high correlation with Cu, Pb, Mn, Fe and LOI. On the contrary, Zn shows negative correlation with with SiO_2 and K_2O, and specially high negative correlation with SiO_2.

As shows positive correlation with Ag, Cu, Pb, Zn, Sb, Mo, and Ba, and specially high correlation with Au, Cu, Pb, Sb and Mo. On the contrary, As shows high negative correlation with TiO_2, Na_2O, CaO and MgO.

Sb shows positive correlation with Au, Ag, Cu, Pb, As, Mo and Ba, and specially high correlation with Cu, Pb, As and Mo. On the contrary, Sb shows high negative correlation with Al_2O_3, K_2O, CaO and MgO.

Mn shows high positive correlation with Zn, Fe, Al_2O_3, TiO_2, Na_2O, CaO, MgO, P_2O_5 and LOI. On the contrary, Mn shows negative correlation with Au, As, Sb, Mo, Ba, SiO_2 and K_2O, and specially high negative correlation with As, Sb, Mo and SiO_2.

Fe shows high positive correlation with Cu, Pb, Zn, Mn, Al_2O_3, TiO_2, CaO, MgO, P_2O_5 and LOI, and high negative correlation with Ba, SiO_2 and Cr_2O_3.

Mo shows positive correlation with Au, Cu, As, Sb, SiO_2 and K_2O, and specially high correlation with Au, As and Sb. On the contrary, Mo shows negative correlation with Mn, Al_2O_3, TiO_2, Na_2O, CaO, MgO, P_2O_5 and LOI, and specially high correlation with Mn, Al_2O_3, Na_2O, CaO and MgO.

Ba shows positive correlation with Mo, SiO_2 and K_2O, and specially high correlation with SiO_2. On the contrary, Ba has negative correlation with Zn, Mn, Fe, CaO, P_2O_6 and LOI, and specially high correlation with Fe.

Distribution maps of each analized elements as contour maps were drawn as Fig. 4−2. On drawing Fig. 4−2, intervals of each contours were defined 4 classes to discuss addition and depletion of each elements as follows,

(1)Cases of Au, Ag, Cu, Pb, Zn, As, Sb, Mn, Fe, Mo, Ba, SiO_2, TiO_2, K_2O, MgO, Fe_2O_3, Cr_2O_3, P_2O_5, LOI, La, Ce, U and Th.

①Less than μ (logarithmic average)

②Between μ and $\mu + 0.5\sigma$ (standard deviation)

③Between $\mu + 0.5\sigma$ and $\mu + \sigma$

④More than $\mu + \sigma$

(2)Cases of Al_2O_3, TiO_2, Na_2O, CaO, MgO, Fe_2O_3, Cr_2O_3, MnO, P_2O_5 and LOI.

①More than μ (logarithmic average)

②Between μ and $\mu - 0.5\sigma$ (standard deviation)

③Between $\mu - 0.5\sigma$ and $\mu - \sigma$

④Less than $\mu - \sigma$

Characteristics of distrubution patterns of each elements are described as below, (1)Au

High Au concentrated zones exist around known ore deposits such as Lahanos, Killik, Kepçelik, Dikmen and Kartlar ore deposits, and around Lahanos~Killik and Bitene areas, but except Karaerik ore deposits. These concentrated zones are seen in Kızıkaya formation containing massive sulfide ore deposits, but they are seen too in Çağlayan formation overlying Kızıkaya formation between Dikence and Karaerik areas. They are also seen Çatak formation in southern and western parts of the survey area.

(2)Ag

High Ag concentrated zones develope around known ore deposits such as Lahanos, Killik, Kızıkaya, Dikmen, Çımakli and Karaerik ore deposits, and around Lahanos~Killik and Betene areas. But Ag does not show so large distribution and so high concentration as Au, and its high concentrated zone scattered in Çatak to Çağlayan formations, even if in locations away from known ore deposits.

(3) Cu

High Cu concentrated zones develope mainly in Kızıkaya formation around known ore deposits such as Lahanos, Killik, Kızıkaya, Kepçelik, Dikmen and Karaerik, except Ağalik ore deposits.

Away from known ore deposits, they develope in both Kızıkaya and Çağlayan formations around Çalkaya ~Taflançık in eastern part of the survey area, around Lahanos~Dikence in central part.

(4) Pb

High Pb concentrated zones develope mainly in Kızıkaya and partly in Çağlayan formations around known ore deposits such as Lahanos, Killik, Kızıkaya, Kepçelik and Dikmen ore deposits, but except Ağalik, Çımakli and Karaerik ore deposits.

Away from known ore deposits, they develope in Kızıkaya formation around Bitene area and in Çağlayan formation around Lahanos~Dikence areas.

Slightly weaker concentrations than the above mentioned can be observed in Çatak formation that developes in southern to western parts of the survey area.

(5)Zn

High Zn concentrated zones develope mainly in Kızıkaya and partly in Çağlayan formations around known ore deposits such as Lahanos, Killik, Kepçelik and Dikmen ore deposiys, but except Kızıkaya, Ağalik and Karaerik ore deposits.

Away from known ore deposits, they develope in Kızıkaya formation around Bitene area, and in Çağlayan formation around Lahanos~Dikence, Killik~Kızıkaya and Çalkaya~Taflançık areas.

Slightly weaker concentrations than the above mentioned can be observed in Çatak formation developing in southern to western margin of the survey area.

(6)As

High As concentrated zones can be seen mainly in Kızıkaya and partly in Çağlayan formations around all of the known ore deposits such as Lahanos, Killik, Kızıkaya, Kepçelik and other ore deposits.

Away from the known ore deposits, they develope in Kızıkaya formation around Bitene area, and in Çağlayan formation around Lahanos~Dikence, Killik~Kepçelik and Çalkaya~Taflançık areas.

(7)Sb

High Sb concentrated zones develope mainly in Kızıkaya and partly in Çağlayan formations around the known ore deposits such as Lahanos, Killik, Kızıkaya and Kepçelik, except Ağalik ore deposits.

Away from the ore deposits, they develope in Lahanos~Dikence, Killik~Kepçelik, Çalkaya~Taflançık and Çalkaya~Kızıkaya areas.

(8)Mn

High Mn concentration can be seen exist at andesite of Çatak formation in southern~western part and at weakly altered rocks of Çağlayan formation in northrn part. Around the known ore deposits such as Lahanos and Kızıkaya ore deposits, low Mn concentration(may be, depletion of Mn) can be observed in Kızıkaya formation and high Mn concentration(abundance of disseminated manganese oxide) can be observed in Çağlayan formation.

(9)Fe

High Fe concentrated zones can be recognized at andesite of Çatak formation in southern~western part and at weakly altered rocks of Çağlayan formation in northern part. Around the known ore deposits such as Lahanos and Kızıkaya ore deposits, both high Fe concentration(abundance of disseminated pyrite) and low concentration(may be, depletion of Fe) can be observed together.

(10)Mo

High Mo concentrated zones develope mainly in Kızıkaya and partly in Çağlayan formation around the known ore deposits such as Lahanos, Killik, Kepçelik and Kızıkaya, except Karacrik ore deposits.

(11)Ba

High Ba concentrated zones develope mainly in Kızıkaya and partly in Çağlayan formations around the known ore deposits such as Killik, Kepçelik, Kızıkaya, Dikmen and Çımakli ore deposits.

Away from the known ore deposits, they develope in Çağlayan formation around Lahanos~Dikence, Killik~Kepçelik and Çalkaya~Taflançık areas.

(12)SiO_2

High SiO_2 concentrated zones develope mainly in Kızıkaya and partly in Çağlayan formations around all of the known ore deposits such as Lahanos, Killik, Kepçelik and Kızıkaya ore deposits.

Away from the known ore deposits, they distribute in Çağlayan formation around Lahanos~Dikence, Killik~Kepçelik and Çalkaya~Taflançık areas.

(13)TiO_2

High TiO_2 concentration can be observed at andesite of Çatak formation in southern~westerern part and at weakly altered rocks of Çağlayan formation in northern part. They develope partially around Lahanos and Kartlar ore deposits, around other ore deposits TiO_2 shows low concentration.

(14)Al_2O_3

High Al_2O_3 concentrated zones can be observed at andesite of Çatak formation in southern~western part and at Çağlayan formation in central~northern part. It shows low concentration around the known ore deposits such as Lahanos and Kartlar ore deposits.

(15)Cr_2O_3

High Cr_2O_3 concentration can be observed at andesite of Çatak formation in southern part, and at Çağlayan formation in northern part. Both high and low concentration can be observed in both Kızıkaya and Çağlayan formations around the known ore deposits such as Lahanos and Kartlar ore deposits.

(16)CaO

High CaO concentration can be seen at andesite of Çatak formation in southern～western part, and at Çağlayan formation in northern part. It shows low concentration around all of the known ore deposits.

(17)MgO

High MgO concentration can be observed at andesite of Çatak formation in southern～western part, and at weakly altered rocks of Çağlayan formation. It shows low concentration in Kızıkaya and Çağlayan formations around all of the known ore deposits.

(18) Na_2O

High Na_2O concentration can be seen at andesite of Çatak formation in southern～western part, and at Çağlayan formation in central～northern part. It shows low concentration around all of the known ore deposits.

(19)K_2O

High K_2O concentrated zones develope mainly in Kızıkaya and partly in Çağlayan formations around the known ore deposits such as Lahanos, Killik, Kepçelik, Çımakli and Karılar ore deposits, except Dikmen and Karaerik ore deposits.

Away from the known ore deposits, it shows high concentration in Çağlayan formation around Lahanos～Dikence, Killik～Kepçelik and Çalkaya～Taflançık areas.

(20)P_2O_5

High P_2O_5 concentrated zones can be observed at andesite of Çatak formation in southern～western part, and at Çağlayan formation in northern part. It shows high concentration in Kızıkaya and Çağlayan formations around only Lahanos and Kepçelik ore deposits.

Away from the known ore deposits, it shows high concentration in Kızıkaya formation of Bitene area, and in Çağlayan formation of Lahanos～Dikence, Killik～Kepçelik and Çalkaya～Taflançık areas.

(21)LOI

High LOI concentration can be observed at andesite of Çağlayan formation in western part and at Çağlayan formation in northern part. It shows high concentration in both Kızıkaya and Çağlayan formations around Lahanos and Kepçelik ore deposits, and around Bitene area. But it shows no concentration around other ore deposits.

(22)La & Ce

Distribution of La and Ce were surveyed between Lahanos and Bitene. They show high concentration in weakly alterd rocks of Kızıkaya and Çağlayan formations and in intrusive rocks, and they show low concentration in strongly altered zones of Kızıkaya and Çağlayan formations.

(23)U & Th

Distribution of U and Th were surveyed between Lahanos and Bitene. They show high concentration in Kızıkaya and Çağlayan formations around Lahanos ore deposits.

4－2－2 Geochemical Survey by Soil Samples

As shown in Table 4－1(basic statistics), arithmetic and logarithmic averages of 7 elements(Au, Ag, Cu, Pb, Zn As and Fe) from soil samples here are higher than normal background values(Rose et al. ;1979). Averages of Sb, Mn, Mo and Ba here are almost same as other areas. As shown in cumulative frequency curves(Appendix A−4), ratio of samples which showed higher values than normal background of soils for each elements are as follows, Au(75%), Ag(82%), Cu(95%), Pb(100%), Zn(96%), As(89%), Sb(13%), Mn(51%), Fe(75%), Mo(41%) and Ba(34%).

In table of correlation coefficients(Table 4−2), significance test was performed on 1% of significance level and result such as R(0. 01)=0. 25 was obtained. Based on result of this significance test, correlation coefficients are discussed as mentioned below. Au has high positive correlation with Ag, Cu, Pb, As, Sb, Fe and Ba, and specially has high correlation coefficients with Pb and As that are more than 0. 4. Ag has also high positive correlation with Au, Cu, Pb, As, Sb and Ba, but it has not specially high coefficient with other elements. Cu shows high positive correlation with Au, Ag, Pb, Zn, As, Sb, Fe and Ba, and has specially high correlation with Pb, Zn, As and Fe. Pb shows high positive correlation with Ag, Cu, Zn, As, Sb, Fe, Mo and Ba, and specially high correlation with Au, Zn, As, Sb and Fe. Zn has high positive correlation with Cu, Pb, As, Sb, Mn and Fe, and specially high correlation with Cu, Pb, Mn and Fe. As also has high positive correlation with Au, Ag, Cu, Pb, Zn, Sb, Fe, Mo and Ba, and specially high correlation with Au, Cu, Pb, Sb and Ba. Sb shows very resemble tendency to As, that is, high positive correlation with Au, Ag, Cu, Pb, Zn, As, Fe, Mo and Ba, and specially high correlation with Pb and As. Mn has positive correlation with Zn and Fe, and negative correlation with Mo. Fe has positive correlation with Au, Cu, Pb, Zn, As, Sb and Mn, and specially high correlation with Cu, Pb and Zn. Mo has positive correlation with Pb, As and Sb, and negative correlation with Mn, but specially high correlation without any metals. Ba has high positive correlation with Au, Ag, Cu, Pb and As, and specially high correlation with As. Distribution maps of each analized elements as contour map were drawn in Fig. 4−3. On drawing Fig. 4−3, intervals between each contours were defined 4 classes as follows, less than μ (logarithmic average), $\mu \sim +0.5\sigma$, $\mu+0.5\sigma \sim \mu+\sigma$, and more than $\mu+\sigma$ (standard deviation). Characteristics of distribution maps of each elements are as follows,

(1)Au

Highly Au concentrated zones develope in Kızıkaya formation around Lahanos North, Lahanos South, Bitene, Dikenlidüz, and Killik North areas. But Au concentrated zones are seen in Çağlayan formationbetween Lahanos South and Killik North.

Low concentrated zones in Au are observed in Çağlayan formation and intrusive rocks distributing area around Toroman Tepe, Güzlek and Mizuran areas.

(2)Ag

High concentrated zones in Ag develope in Kızıkaya formation around Lahanos North, Lahanos South, Dikenlidüz, Killik North and Killik South areas. But Ag concentrated zones can be confirmed in Çagalayan formation in areas between Lahanos South and Killik North and, areas around Killik South.

Çağlayan formation and intrusive rocks include low Ag concentrated zones in Toroman Tepe and Mizuran areas. And Kızıkaya formation includes low Ag concentrated zones in Guzlk and Bitene areas.

(3) Cu

High Cu concentrated zones develope in both Kızıkaya and Çağlayan formations around Lahanos North, Lahanos South and KillikNorth∼Toroman Tepe areas.

Low Cu concentrated zones develope in Çağlayan formation and intrusive rocks distributing around

Güzlek and Mizuran areas.

(4) Pb

High Pb concentrated zones develope in Kızıkaya formation around Lahanos North and Killik North areas.

Low Pb concentrated zones exist in Çağlayan formation and intrusive rocks distributing around Güzlek, Mizuran and Toroman areas.

(5)Zn

High Zn concentrated zones develope in Kızıkaya formation around Lahanos North, Lahanos South, Güzlek, Bitene and Killik North areas, and in Çağlayan formation and in intrusive rocks distributing around Güzlek area.

Low Pb concentrated zones develope in Çağlayan formation and intrusive rocks distributing areas around Mizuran and Toroman Tepe areas.

(6)As

High As concentrated zones develope in Kızıkaya formation around Lahanos North, Lahanos South, Güzlek, Bitene and Killik North areas.

Low As concentrated zones can be seen in Çağlayan formation and intrusive rocks distributing around Mizuran and Toroman areas.

(7)Sb

High Sb concentrated zones are observed in both Kızıkaya and Çağlayan formations around Lahanos North～Killik North and Killik South areas.

Low Sb concentrated zones develope in Çağlayan formation and intrusive rocks distributing around Mizuran, Güzlek and Toroman Tepe areas.

(8)Mn

High Mn concentrated zones develope widely in Çağlayan formation and along boundary zone between Kızıkaya and Çağlayan formations, around Lahanos South～Güzlek～Killik North～Toroman Tepe area.

Low Mn concentrated zones develope in Kızıkaya formation around Lahanos North, Dikenlidüz and Killik South areas.

(9)Fe

High Fe concentrated zones develope widely in Çağlayan formation and along boudary zone between Çağlayan and Kızıkaya formations, around Killik North～Güzlek～Bitene～Toroman Tepe and Lahanos North areas.

Low Fe concentrated zones are seen in Kızıkaya formation around Dikenlidüz and Lahanos South areas.

(10)Mo

High Mo concentrated zones develope in both Kızıkaya and Çağlayan formations around Lahanos North, Lahanos South, Bitene, Dikenlidüz, KillikNorth and Killik South areas.

Low Mo concentrated zones develope in Çrglayan formation and intrusive rocks distributing around Toroman Tepe and Güzlek areas.

(11)Ba

High Ba concentrated zones develope in Kızıkaya formation around Lahanos North, Bitene, Dikenlidüz, Killik North and Killik South areas.

Low Ba concentrated zones develope in Çağlayan formation and intrusive rocks distributing around Toroman Tepe, Güzlek and Mizura areas.

4-3 Consideration

1. Geochemical Survey by Rock Samples

Contents of each elements are varying depend on rock facies, mineralization and alteration. According to their behaviours in the survey area, the elements were divided as follows.

①The elements considered to be added to host rocks during mineralization.

Au, Ag, Cu, Pb, Zn, As, Sb, Mo and Ba.

②The elements considered to indicate difference of rock facies(may be, added to host rocks during mineralization)

SiO_2, K_2O, P_2O_5 and LOI.

③The elements considered to indicate difference of rock facies(may be, depleted from host rocks during mineralization)

TiO_2, CaO, U, Th, La and Ce.

④The elements considered to indicate difference of rock facies(may be, added to or depleted from host rocks during mineralization)

Mn, Fe, Al_2O_3, MgO and Na_2O.

Massive sulfide ore deposits such as Lahanos, Killik, Kepçelik and others, and disseminated to networked ore deposits such as Karılar, Karaerik and others develope in the geochemical survey area using rock samples. Massive sulfide ore deposits are contained in uppermost members of Kızıkaya formation, but disseminated to networked ore deposits are contained in both Kızıkaya and Çağlayan formations because of their genetical relation with volcanic activities in the age of Çağlayan formation.

Among elements added during mineralization, Au, Cu, Pb, Zn, As, Sb and Mo are inclined to be concentrated around both massive sulfide and disseminated to networked ore deposits. Specially, As shows its concentration around all of known ore deposits in the survey area. Among elements added during alteration, SiO_2 and K_2O concentrate around known ore deposits, and their concentrating ranges are inclined to show a little wider than those of just above mentioned metallic elements. Among elements depleted during alteration, Na_2O and CaO are depleted around known ore deposits, and their depleted zones develope widely same as the additional SiO_2 and K_2O zones. The just above mentioned facts can be observed easily in Kızıkaya formation, but in Çağlayan formation too it can be observed.

SiO_2, K_2O, P_2O_5 and LOI have inclination to be contained poorly in neutral acidity rocks(Çatak formation), to be contained abundantly in acidic rocks(Kızıkaya and Çağlayan formations), and to be added to host rocks during alteration such as silicification andargillization(sericitization and montmorillonitization).

Among Mn, Fe, MgO and Na_2O, generally neutral acidity rocks(Çatak formation) show much amount of Mn, Fe and MgO, and acidic rocks(Kızıkaya and Çatak formations) include high contents of Na_2O. But Çatak formation shows rather high amounts of Na_2O besides Mg and Fe because of pyritization, chloritization and albitization by alteration. And in some parts of Kızıkaya and Çağlayan formations where manganese oxidized minerals, pyrite, chlorite and albit are formed by alteration, they show high amounts of Mn, Fe and MgO besides Na_2O.

Concentrated parts of these element show their own directions. For examples, Au concentrated parts around Lahanos, Kepçelik and Killik ore deposits are arranged in north–northwest and north–northeast directions. Concentrated parts of Cu, Pb, Zn, As and Mo are arrayed in north–west and north–east~east–northeast directions.

Result of principal components analysis for rock samples, that is one of multivariables analysis, is shown in Table 4–3. Principal components analysis were performed on 23 elements except rare–earth elements from 557 rock samples, and then contribution rate of 1st and 2nd principal components are calculated as 29 %and 16% respectively. But that of 3rd component is less than 7%. Therefore, 45% of relations between each elements can be explained by 1st and 2nd principal components.

First principal component shows high factor loading on Al_2O_3, TiO_2, Na_2O, CaO, MgO, P_2O_5, LOI, Cu, Pb, Zn, Mn and Fe, and low factor loading on As, Sb, Mo, Ba, SiO_2 and K_2O. Second component shows high factor loading on Au, Ag, Cu, Pb, Zn, As, Sb, Fe and Mo, and low factor loading Mn, SiO_2, Al_2O_3, Na_2O, CaO and MgO. Namely 1st component indicates that most of rock forming elements and a part of metallic elements increase or decrease in their amounts together. Second component indicate that most of metallic elements behave together against rock forming elements.

High scored zones of 1st component develope in Çatak formation areas of southern and western parts of the survey area, and in Çağlayan formation areas of northern part, and low scored zones develope in Kızıkaya formation areas and around known ore deposits. Then, high scored zones of 1st component correspond very well to distribution patterns of weak mineralized zones in Çatak and Çağlayan formations.

High scored zones of 2nd principal component develope around known ore deposits in central and northern parts of the survey area. Therefore, high factor loaded elements as 2nd component are considered to be added to host rocks during mineralization, in spite of a slight difference in elemental assemblages in each ore deposits.

Away from known ore deposits, high scored zones of 2nd component are recognized in Bitene area south from Lahanos mine, between Lahanos and Killik, between Çalkaya and Taflançık, between Killik and Kepçelik, and between Lahanos and Dikence. Therefore new ore deposits like as Lahanos can be expected to be discovered in these areas. In central part of the survey area high scored zones of 2nd component show north–west to north–northwest and north–east to east–northeast direction as centers of each zones arranged around Lahanos ore deposits, and in northern part they show north–west and east–northeast direction as centers of each zones arranged around Karaerik ore deposits.

Fifty rock samples taken from Lahanos~Bitene area were chemically analized for 33elements, that is, rare earth elements such as La and Ce, and U and Th, besides above mentioned rock forming elements and metallic elements. And then principal components analysis were performed on these 50 samples. Contribution ratios of 1st and 2nd components are 19% and 15% respectively, and that of 3rd component is less than 10%. Therefore, 34% of elemental behaviours between each elements can be interpreted by 1 st and 2nd components.

First principal component shows high factor loading on SiO2, Na2O, K2O, CaO, MgO, U and Th, and rare earth elements such as La and Ce, and shows low factor loading on metallic elements such as Cu, Pb and Zn. In other words, rock forming elements behave with rare earth elements together, and metallic elements such as Cu, Pb and Zn behave against them. Namely 1st component shows high scores in weakly mineralized zones and shows very low scores in strongly mineralized zones. Low scored zones of 1st component are observed in Kızıkaya formation around Lahanos ore deposits and Bitene area, then these zones are presumed to be anomaly due to mineralization.

Second principal component shows high factor loading on SiO_2, Mo and Ba, and shows low factor loading on metallic elements such as Pb, Zn and Mn, rock forming elements such as CaO and MgO, and rare earth elements. Namely 2nd component shows high scores in strongly silicified zones and mineralized zones containing much barite.

High scored zone of 2nd component extends from Lahanos ore deposits to Killik Tepe in north-eastern direction. This zone is considered to be anomaly due to silicification and barite mineralization.

2. Geochemical Survey by Soil Samples

In the geochemically surveyed area using soil samples, there are massive sulfide ore deposits such as Lahanos and Killik South ore deposits, and networked ore deposits such as Killik North ore deposits. This survey was carried out between Kurucula, Lahanos and Killik in central part.

Massive sulfide ore deposits are contained in uppermost members of Kızıkaya formation. But networked ore deposits are contained in both Kızıkaya and Çağlayan formations, because they seem to have genetical relations with volcanic activities in the time of Çağlayan formation..

In this area containing two types of ore deposits, Pb, Zn, As and Ba are concentrated in soils only on Kızıkaya formation, but Au, Ag. Cu, As and Mo are concentrated in both soils on Kızıkaya and Çağlayan formations. As mentioned just before, kinds of elements concentrated in soils on each formations are different from each other.

Each concentrated zones has each characteristics in extending directions on distribution patterns and in assemblages of elements. For examples, in Lahanos North and Lahanos South areas all elements except Mn compose the concentrated zones extending east-northeastwards. Cu, Zn and Ba concentrated zones in Killik North~Bitene area extend north-eastwards. Au, Ag, Cu, Mo, Fe and Mn concentrated zones in Lahanos~Killik North area extend north-northeastwards. Au and Ag concentrated zones in Dikenlidüz~Güzlek area extend north-northwestwards. Sb concentrated zone in Killik North~Mizuran area extends north-northeastwards.

From above mentioned characteristics of metallic concentrations, the following interpretations can be obtained. Both mineralizations derived from massive sulfide ore deposits and from networked ore deposits are considered to be overlapped in Lahanos North and South areas, relating with geological structure(fracture zones) extending east-northeastwards through the age of Kızıkaya and Çağlayan formations. Mineralization from massive sulfide ore deposits show north-eastwards extension in Kızıkaya formation of Bitene~Killik areas, and mineralization from networked ore deposits show north-northwestwards and north-northeastwards extension in Çağlayan formation of Bitene~Killik areas.

Results of principal components analysis regarding soil samples are shown in Table 4-3. According this table, contribution ratios of first and second principal components are 38% and 16% respectively, but that of third component is very low and less than 8%. Therefore, 54% of whole behaviour of these elements can be explained by first and second principal components.

First principal component shows high factor loading on Au, Ag, Cu, Pb, Zn, As, Sb, Mn, Mo and Ba, and these elements are inclined to increse and decrease their contents together. Group of Cu, Fe and Mn contribute highly to second principal component.

High scored zones of first principal component are observed in Kızıkaya formation of Lahanos North, Lahanos South, Killik North, Bitene and Dikenlidüz areas, and specially high scored zones are confirmed around known massive sulfide ore deposits such as Lahanos and Killik ore deposits. And then first principal component can be concluded to be showing geochemical anomalies due to massive sulfide ore deposition. From the result of geochemical survey by soil samples, existence of massive sulfide ore deposits in Kızıkaya formation covered by Çağlayan formation such as Lahanos ore deposits can be expected in high scored zones of first principal component which extend north-eastwards in Lahanos South~Killik North areas and extend east-northeastwards in Killik South~Bitene areas.

High scored zones of second principal components are recognized in Çağlayan formation of Mizuran, Güzlek and Toroman Tepe areas, and in Kızıkaya formation of Lahanos North, Lahanos South and Killik North areas. Specially, second principal component shows high score around networked ore deposits in Çağlayan formation of Güzlek and Toroman Tepe areas. And then second principal component can be concluded to be geochemical anomaly due to networked ore deposition in Çağlayan formation that is younger than Kızıkaya formation. Therefore, from the points of soil geochemistry, networked ore deposits younger than massive sulfide ore deposits can be expected in high scored zones of second principal component which extend north-northeastwards in Toroman~Güzlek areas.

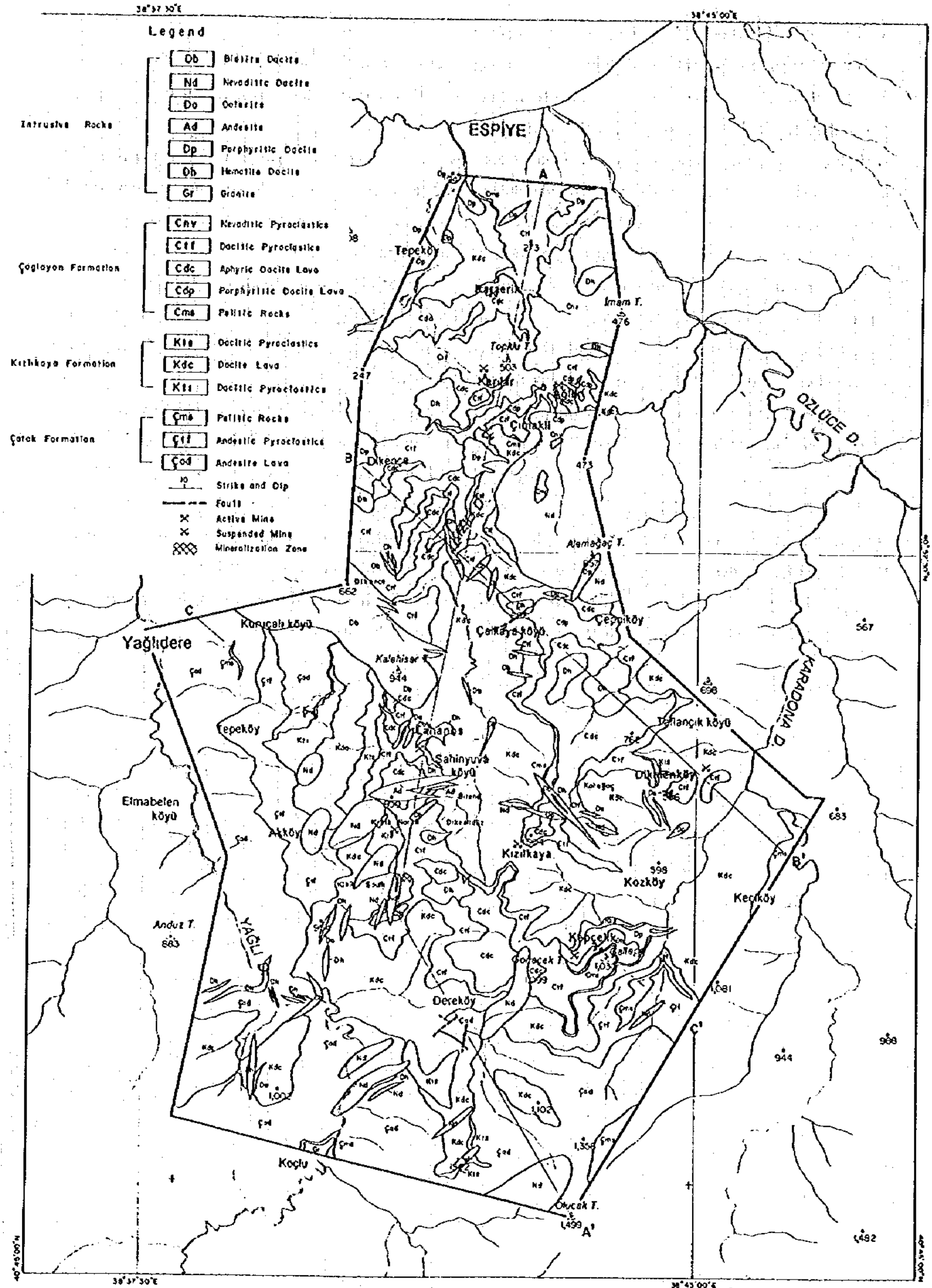

Fig. 2-1 Geological Map of the Espiye Area

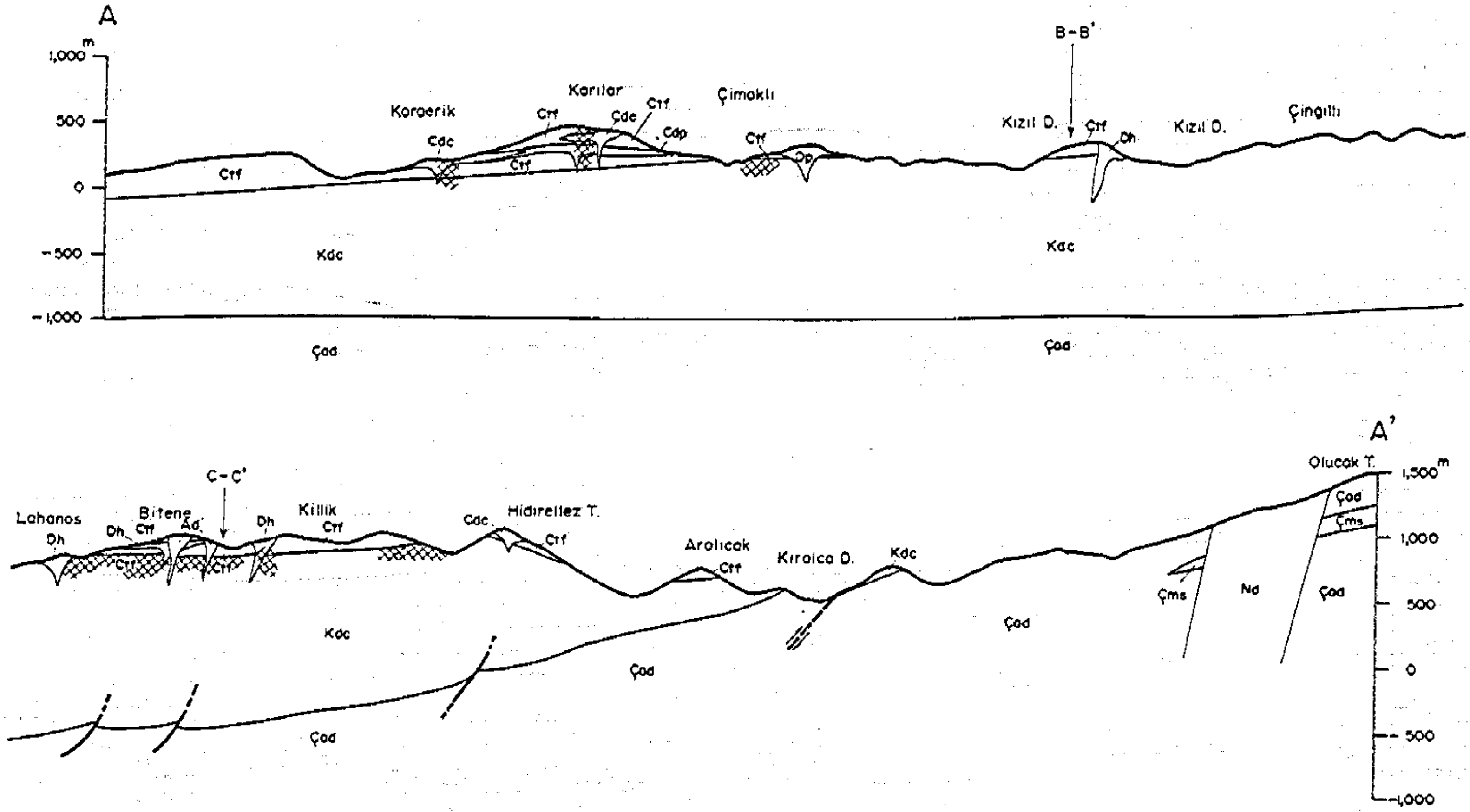

Fig. 2-2 Geological Cross Section of the Espiye Area (1)

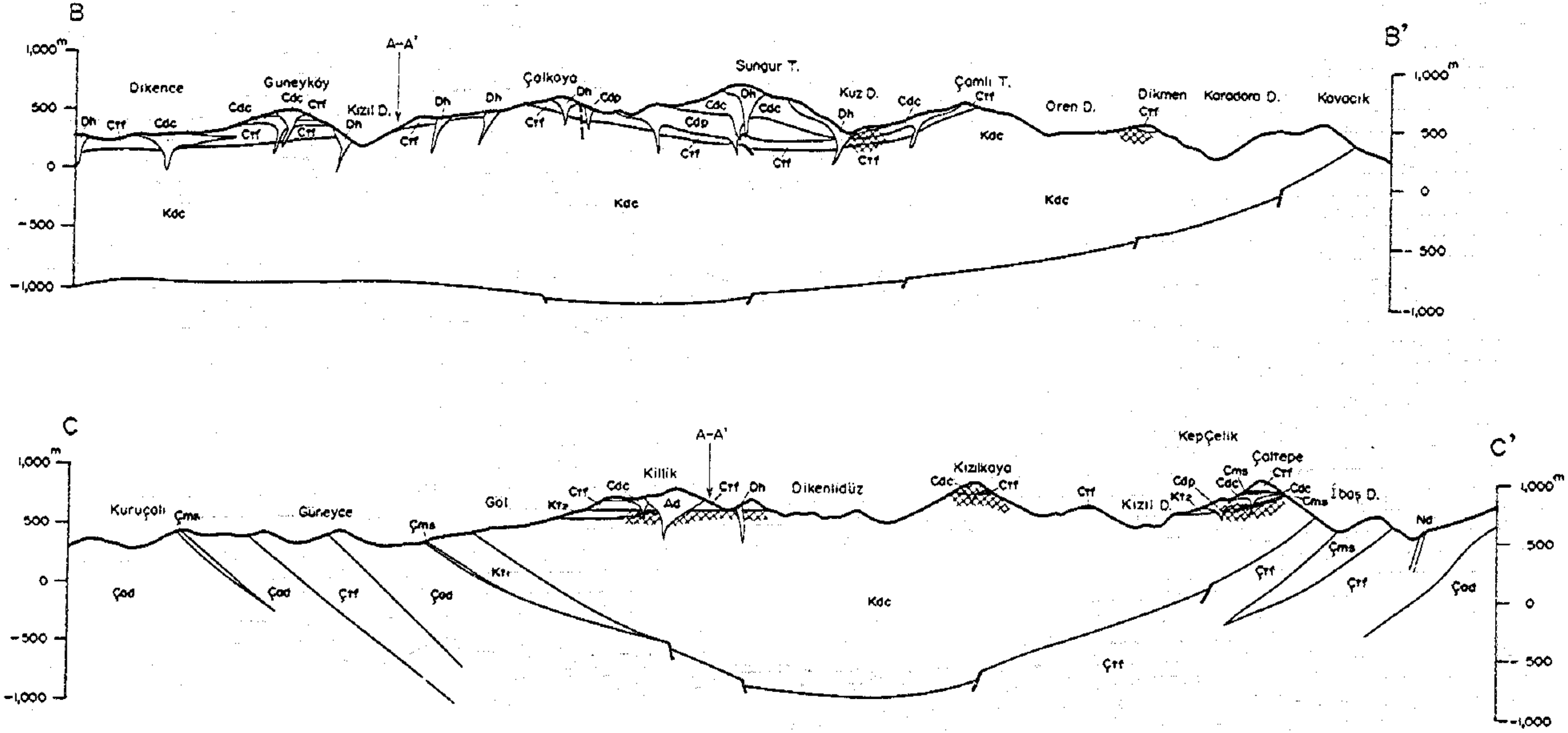

Fig. 2-2 Geological Cross Section of the Espiye Area (2)

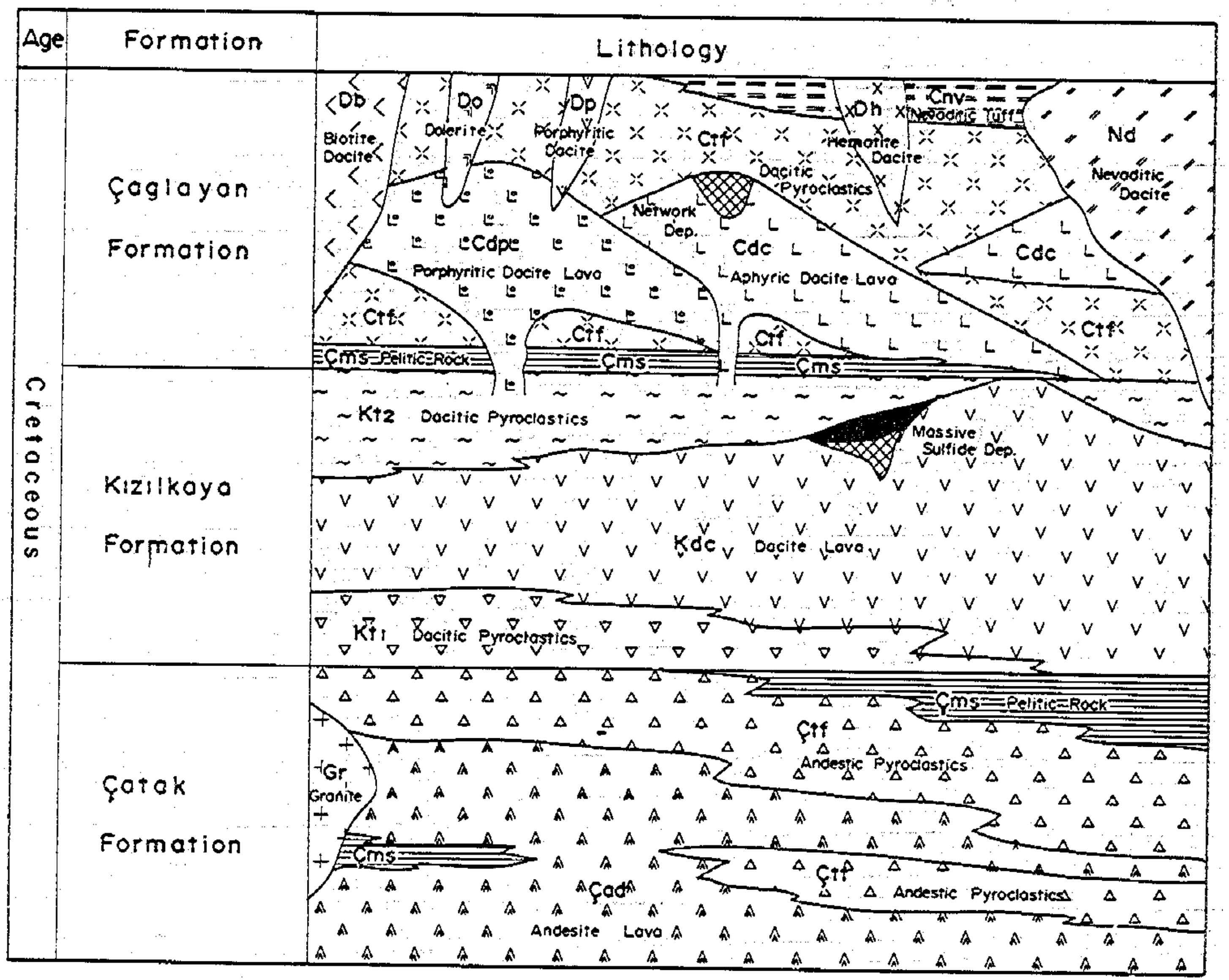

Fig. 2-3 Lithostratigraphy of the Espiye Area

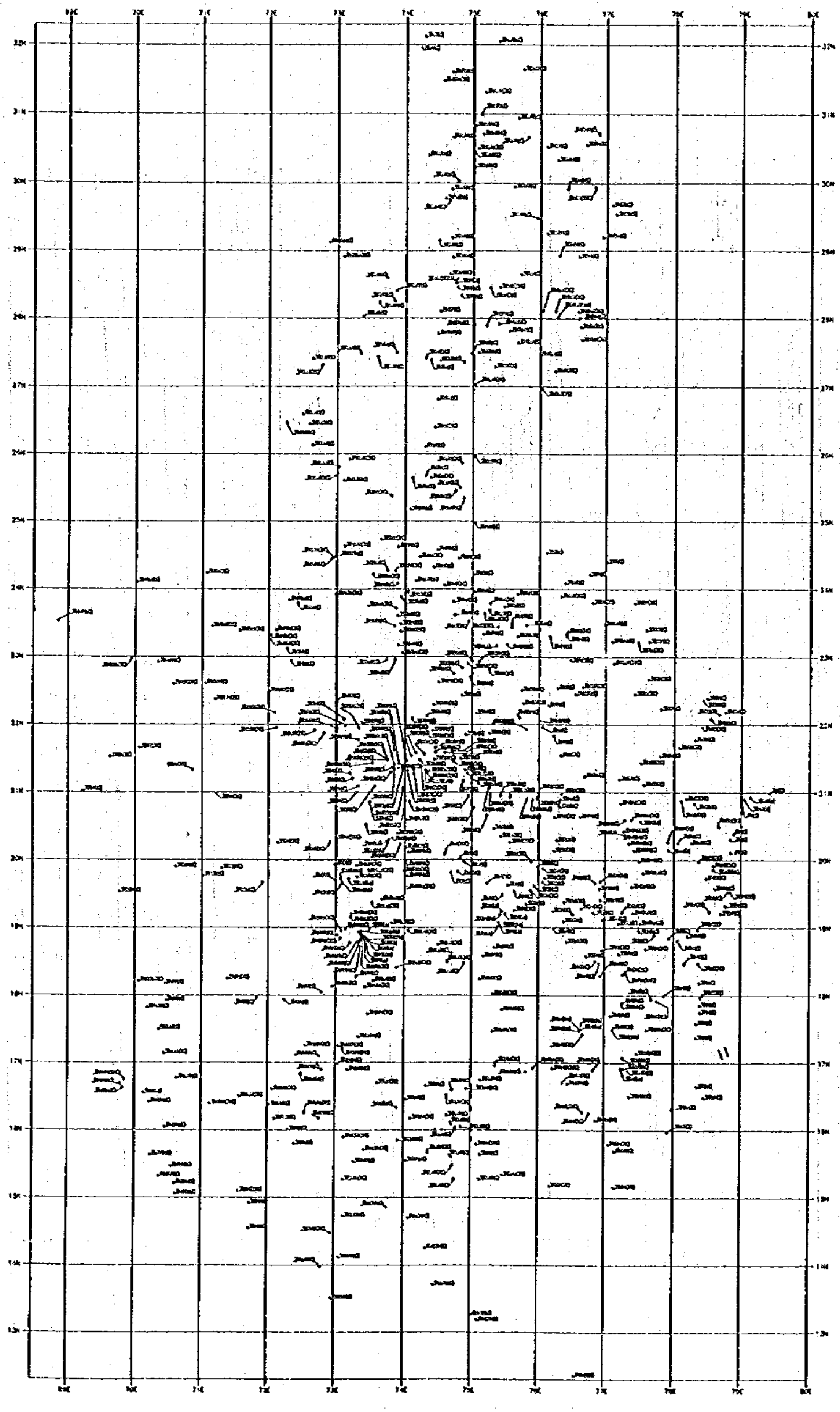

Fig. 2-4 Location of Laboratory Tests Samples

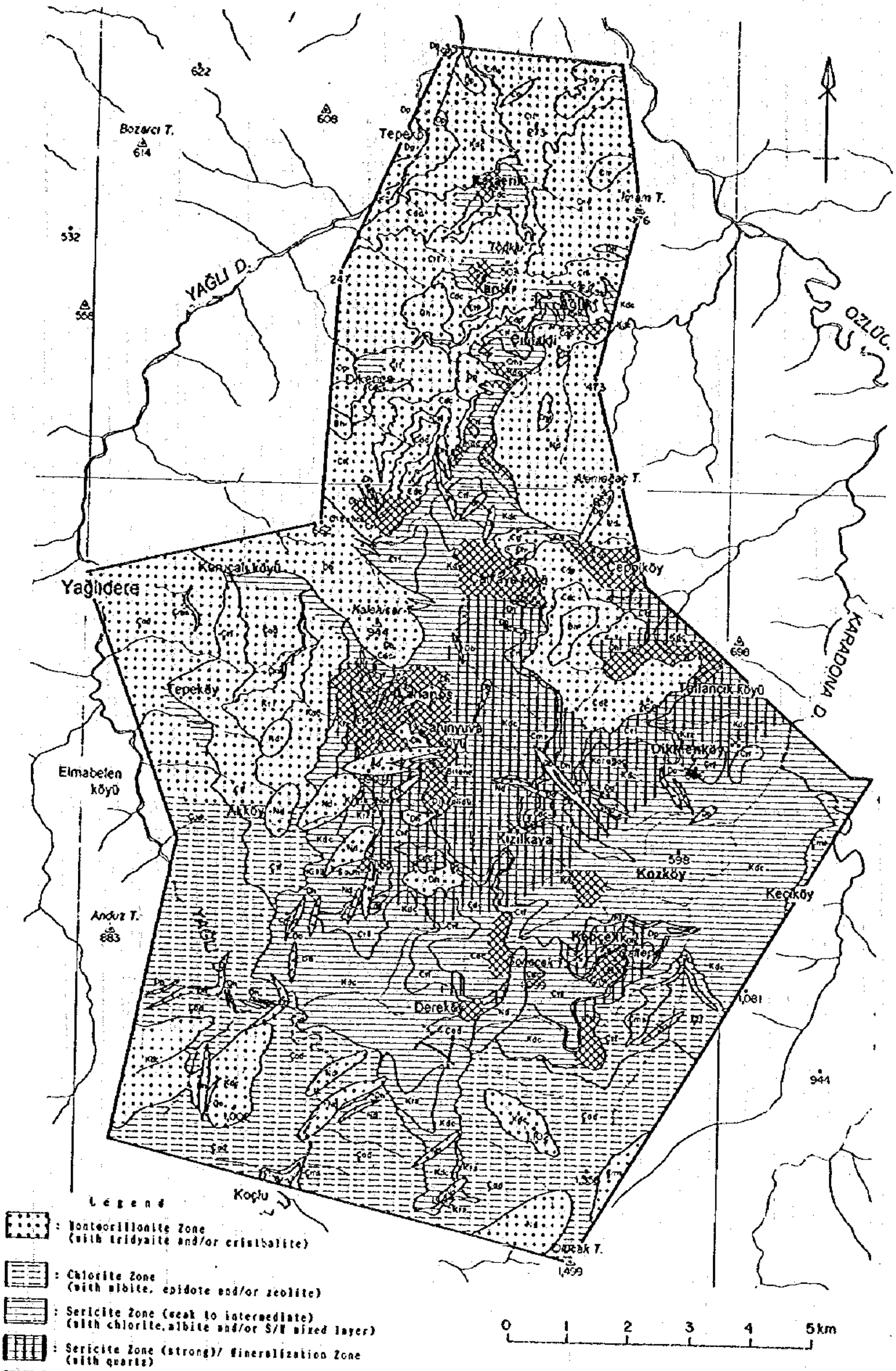

Fig. 3－1 Distribution of Mineralization and Alteration Zones

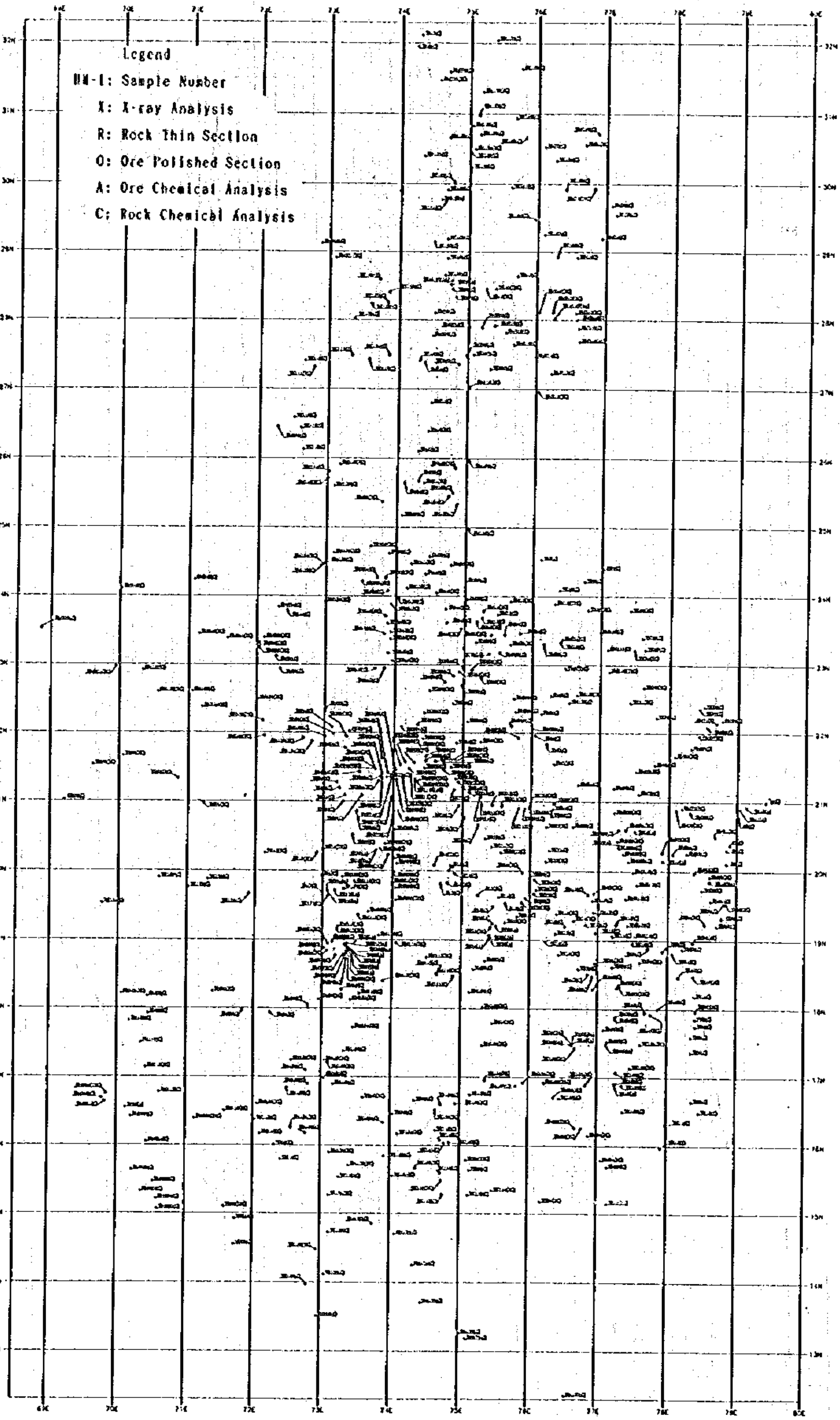

Fig. 4-1 Location of the Geochemical Samples (Rock)

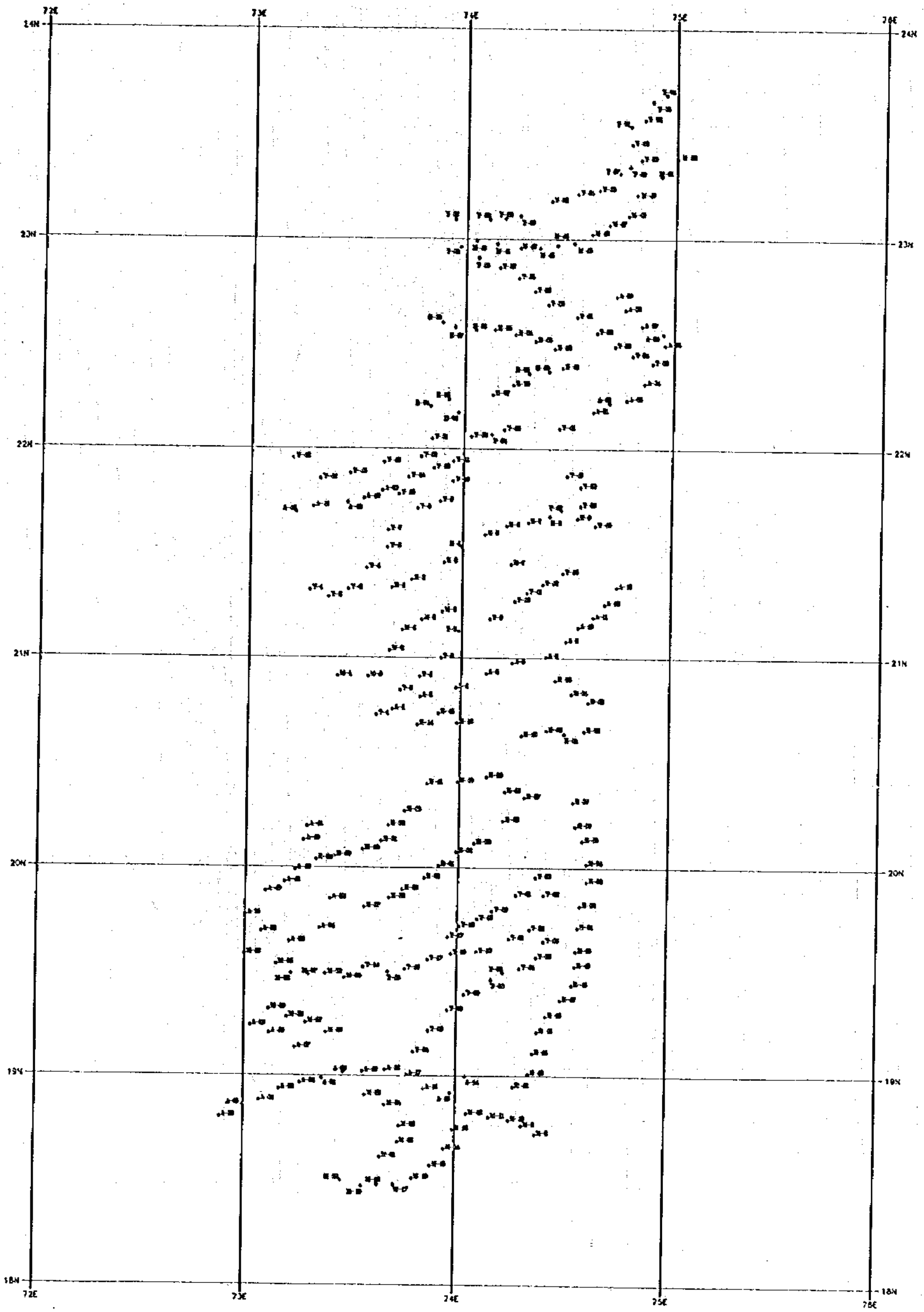

Fig. 4-1 Location of the Geochemical Samples (Soil)

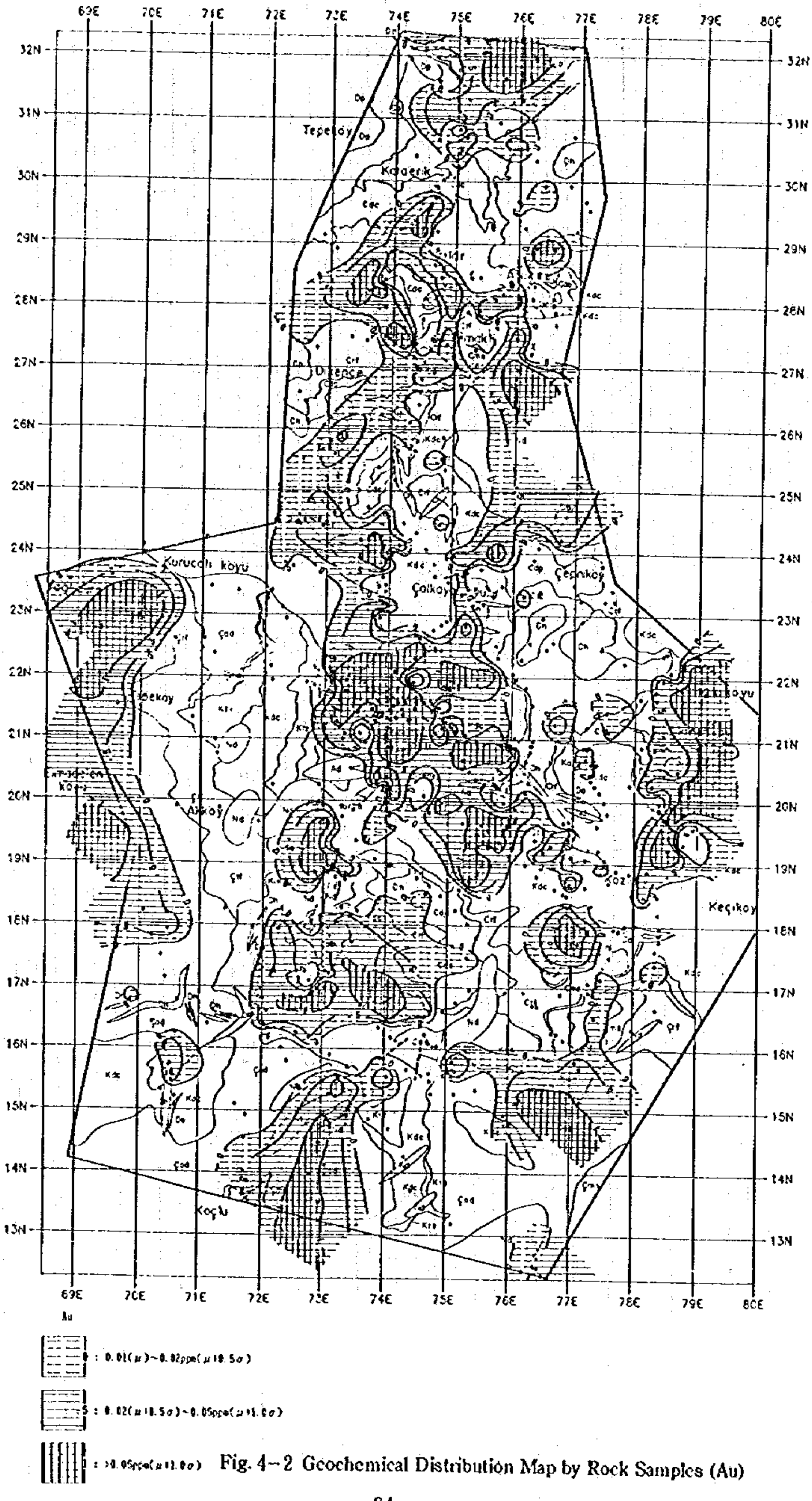

Fig. 4-2 Geochemical Distribution Map by Rock Samples (Au)