THE REPUBLIC OF TURKEY
REPORT ON THE COOPERATIVE MINERAL EXPLORATION OF
GUMUŞHANE AREA
PHASE II
August 1985

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REPORT ON THE COOPERATIVE MINERAL EXPLORATION OF GUMUŞHANE AREA

PHASE 1

AUGUST 1985

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

The Government of Japan, in response to the request extended by the Government of the Republic of Turky, agreed to conduct a metallic mineral exploration survey in Gümüshane area, and commissioned its implementation to the Japan Inrernational Cooperation Agency. The agency, taking into consideration the importance of the technical nature of this survey, sought the cooperation of the Metal Mining Agency of Japan in order to accomplish the contemplated task.

The Goverment of the Republic of Turkey appointed the Mineral Research and Exploration Institute(M.T.A.) to excuse the survey as a counterpart to the Japan team. The survey is being carried out jointly by experts of both Governments.

The initial phase of the collaboration survey consists of geological and geochemical survey for metallic mineral exploration.

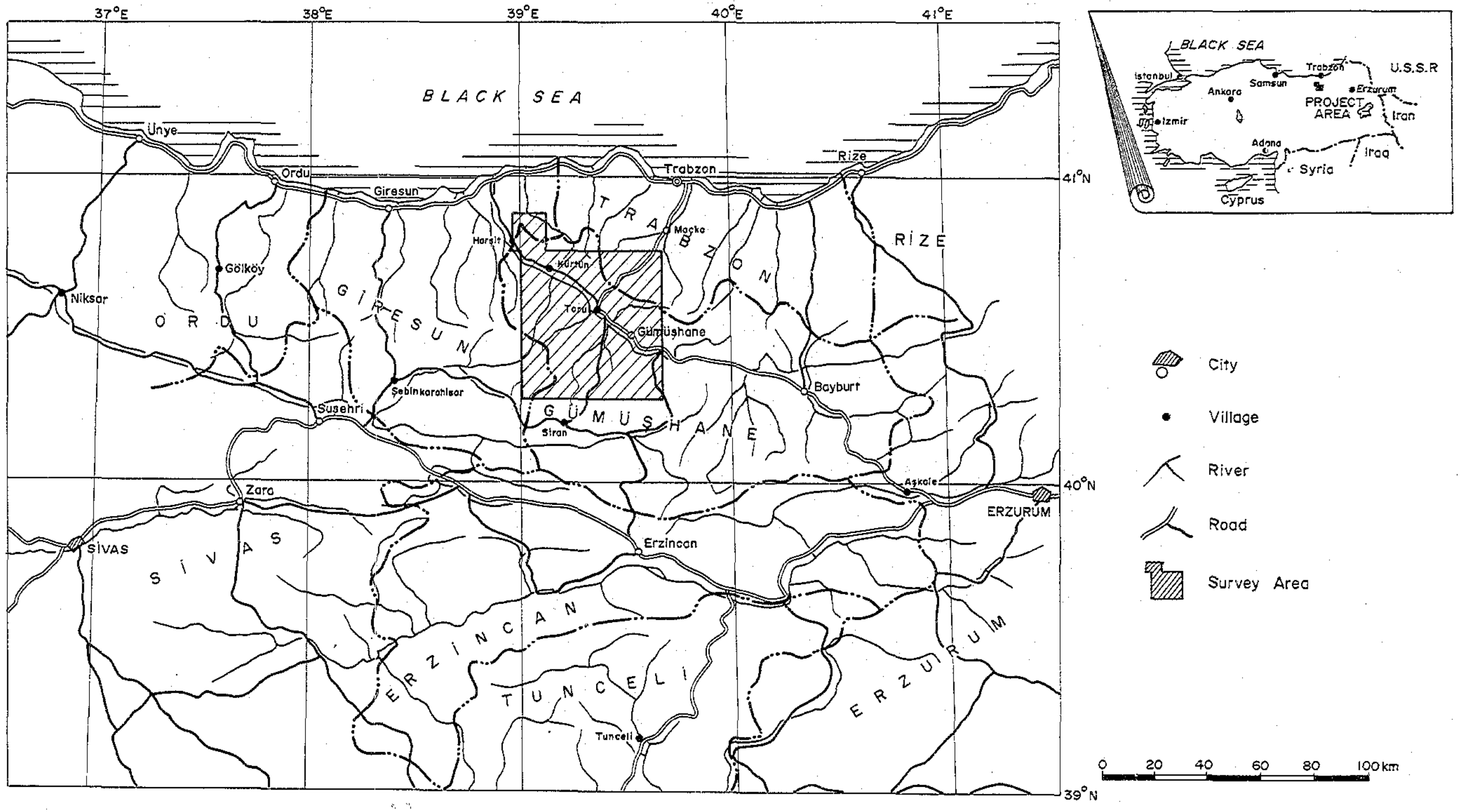
This report submitted here by summarizes results of the intial phase of the survey, and it will also form a portion of the final report that will be prepared with, regard to the result to be obtained by the survey.

We wish to take this opportunity to express our gratitude to all sides concerned in the execution of the survey.

August, 1985

Keisuke ARITA
President,
Japan International
Cooperation Agency

Masayuki NISHIIE
President,
Mental Mining Agency of Japan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Ankara
Samsun
Trabzon
Erzurum
İzmir
Adana
PROJECT AREA
U.S.S.R
Iran
Iraq
Syria
Cyprus
City
Village
River
Road
Survey Area
0
20
40
60
80
100km

Summary

The present survey was conducted with the objective of clarifying the occurrence of non-ferrous (silver, copper, lead, zinc etc.) ore deposits of the Gümüşhane area. Geological survey and geochemical prospecting were conducted over an area of 2,800 km^2. As a result, the following three areas were extracted to be promising.

Hasandere area where molybdenum-copper dissemination deposits can be expected.

Karadağ area where copper-zinc dissemination deposits can be expected.

Belen Tepe area where copper-lead-zinc skarn deposits can be expected.

The geological basement of this area comprises Kurtoğlu Metamorphic Complex consisting gneiss and biotite schist considered to be of Carboniferous-Permian age and Gümüşhane Ganite. These rocks are unconformabley overlain by Jurassic-Eocene basic-acidic volcanic and pyroclastic rocks. Limestone, mudstone, sandstone and others are intercalated representing the dormant stage of volcanism. These sedimentary units are classified by fossils into, in the stratigraphically ascending order; Lower Jurassic Kırıklı Formation, Upper Jurassic Kusakkaya Limestone Formation, Upper Cretaceous Zigana Formation and Eocene Veny Yayla Formation. Gavur Daği Volcanics which is considered to be upper-Eocene overlies the above formations.

The intrusive rocks are old granite, the Gümüşhane Granite which intruded during Paleozoic and young granodiorite, quartz porphyry and dolerite which intruded during Late Cretaceous to Eocene.

Structually, the area can be divided into northern and southern parts with E-W trending Gümüşhane Thrust as the boundary. Gümüşhane Granite and Lower Jurassic basalt are developed in the south while Upper Cretaceous andesite is widely distributed in the northern part. Young intrusive bodies are more abundant in the northern part.

The mineralization of this area is largely grouped into skarn, vein(fissure-filling) and dissemination(porphyry copper) types. Skarn type mineralization occur at the contact of andesite and limestone of the Zigana Formation with iron minerals, somes accompanied by chalcopyrite, sphalerite and galena. This type is more abundant in the northern part. Vein type deposits are of small scale but have high grade, and they occur in Kırıklı, Zigana and Venk

Yayla Formations. Dissemination mineralization is associated with young intrusives, developed in and near granodiorite bodies and forms low grade molybdenum-copper, copper-zinc, pyrite-molybdenum mineralized zones. There are veins which contain unique minerals such as the vein consisting mainly of stibnite which occur in the Zigana Formation at Avliyana. It is thin but extends off and on for more than 500 meters. Also there are barite veins which occur only in Gümüşhane Granite.

The ore minerals are, in skarn type, specularite, magnetite, chalcopyrite, sphalerite, galena;in vein(fissure-filling) type, chalcopyrite, sphalerite, galena;in dissenination type, many consist mostly of pyrite, but in some cases combinations of molmybdenite, chalcopyrite, pyrite and chalcopyrite, sphalerite occur and they are noted. In the surveyed area as a whole, the major intrusive bodies were intruded in ENE-WSW to NE-SW direction while many of the vein type mineralization occured along ENE-WSW to E-W trending fissures. E-W trending folds and faults are prevalent in the geological structure of Turkey and the area under consideration probably has a large number of E-W trending fissures.

The result of the geochemical work of the following samples were taken into consideration in dealing with the problem of geochemical anomalies and mineralization. Approximately 2,000 stream sediment samples of Zone B collected by UNDP project of 1970-1974, 942 soil samples collected from Hasandere by MTA in 1984, 406 stream sediment samples at Zone A and 504 at Zone B collected by the present work. Analysing and interprting the combined results of both geochemical and geological work, we have delineated 50 geochemical anomalous zones. And from these zones we have selected three geochemically anomalous zones which warrant further invesigation. They are Hasandere(Mo,Cu), Karadag (Ag,Cu,Pb,Zn) and Belen Tepe (Cu,Pb,Zn,Mo).

From the above results it is recommended that following surveys be conducted during the second year. Detailed geological survey and drilling at Hasandere, detailed geological survey and geophysical prospecting (IP,SIP) at Karadag, and detailed geolaogical survey and geo-physical prospecting (IP,SIP) at Belen Tepe.

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Part 1 INTRODUCTION

PART I INTRODUCTION

Chapter 1 Outline of the Survey

1-1 Introduction

Cooperative Mineral Exploration Projects in the Republic of Turkey were conducted in Trabzon Area(1974～1976) and in Tuncelli and Kopdag Areas (1977～1980), and these projects have described the occurrence of fundamental materials on the exploration of metallic mineral resources. Moreover, these surveys have contributed to the improvment of the survey technicians of the Mineral Research and Exploration Institute, participating in the projects.

The Ministry of Energy and Natural Resources of the Republic of Turkey deliveredto the Japanese Government a proposal for a new cooperative survey on metallic mineral resoures, and requested that the Japanese Government execute the survey. The Japanese Government responded to the request by dispatching a preliminary survey mission headed by Kensuke ADACHI of the Ministry of International Trade and Intdustry in February,1985. The survey mission conducted preliminary investigations as to the proposal survey areas, and consulted with Mineral Research and Exploration Institute,which is in charge of the project as the Turkish counterpart.

It was agreed by both Governments that Gümüşhane area would be surveyed. The survey was conducted with the objective of understanding the nature of metal concentration in the Gümüşhane area of the Republic of Turkey by clarifying the detailed geolgy.

1-2 Duration and Organization of the Survey

1-2-1 Survey planning and consultation

Japanese mission with the following schedule was dispatched to Turkey in order to participate in preliminary and discussions required for the planning of Joint Mineral Exploration, and to engage in planning sessions for the first phase.

(1) Duration for Field planning and Consulation

From 3 Feburary 1985 to 14 Feburary 1985

(2) Turkish memberes

Sitki SANCAR	General Director, Mineral Research and Exploration Institute Maden Tetkik ve Arama Enstitute(M.T.A.)
Orhan ÖZOÇAK	Deputy General Director,M.T.A.
Mehmet C.YILDIZ	Director of Metallic Mineral Department,M.T.A.
Ömer T.AKINCI	Deputy Director of Metallic Minerals Department, M.T.A.
Temer.Y.NEGIOĞLU	General Manager of Black Sea Branch, M.T.A.

(3)Japanese memberes

Kensuke ADATCHI	Ministry of the International Trade and Industry
Toshio SAKASEGAWA	Metal Mining Agency of Japan
Tadaaki EZAWA	Metal Mining Agency of Japan
Shigeo WADA	Japan International Cooperation Agency

1-2-2 Survey of the First Phase

The survey of first phase was carried out during the period from 17 March 1985 to 15 August 1985. The field survey and the organization of the survey team were as follows.

(1) Duration of the Field Survey

Geological and geochemical survey

From 22 March 1985 To 15 June 1985

(2) Survey Team

Superviser of planning and coordinating

Kohei ARAKAWA	Metal Mining Agency of Japan
Katsuhiro ASAI	Metal Mining Agency of Japan
Tadaaki EZAWA	Metal Mining Agency of Japan
Yoshiyuki KITA	Metal Mining Agency of Japan

Japanese survey Team:

Hisashi MIZUMOTO	Nikko Exploration and Development Co.Ltd(NED) (Leader,Chief Geologist)
Susumu TAKEDA	NED (Geologist)
Kazuyasu SUGAWARA	NED (Geologist)
Hiroshi KANBARA	NED (Geologist)

Turkish Team:

Dr.Yusuf Z.OZKAN	M.T.A.(Coordinater,Chief Geologist)
İsmail H.GÜVEN	M.T.A.(Leader,Chief Geologist)
Murat ER	M.T.A.(Geologist)
Huseyin YILMAZ	M.T.A.(Geologist)
Ali İ.ERCİN	M.T.A.(Geologist)
Kemal OZDOĞAN	M.T.A.(Geologist)

1-3 Surveyed Area

The first phase survey covers an area of 2,800km^2, which are bounded by following longitude and latitude(Fig.2).

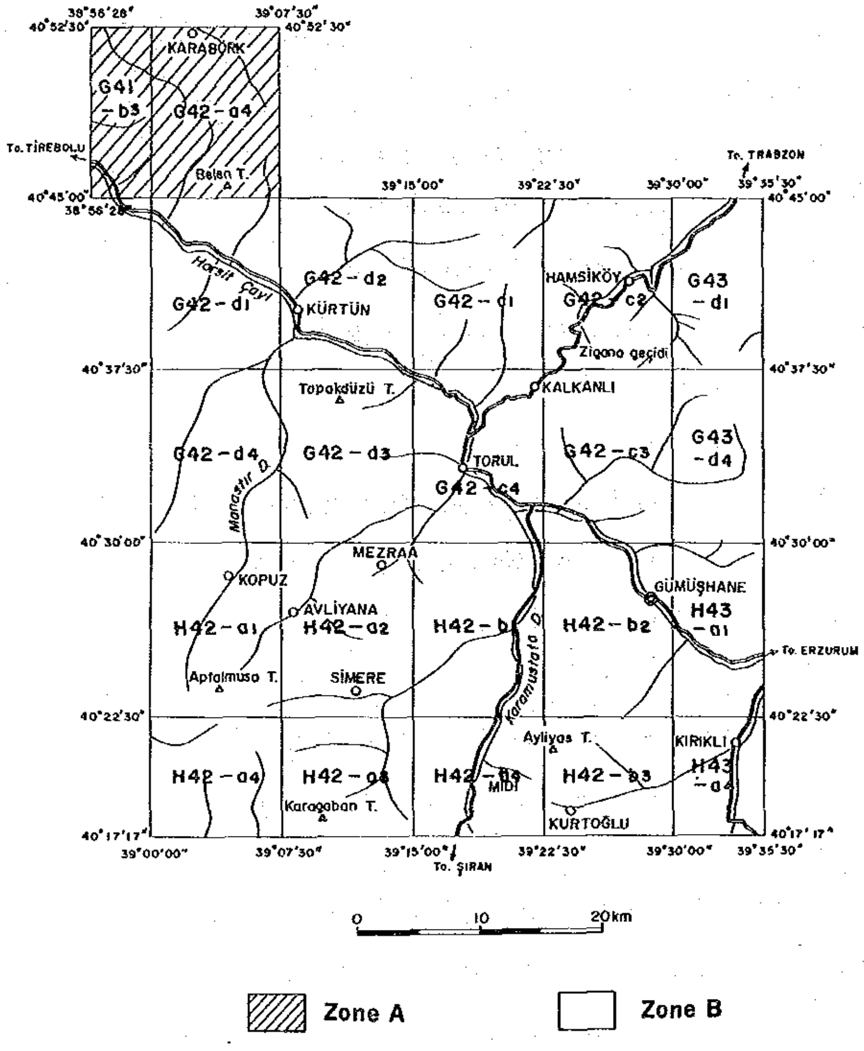


Fig.2 Location Map of the Surveyed Area

1-4 Survey Method and Amount of Work

(1) Geological Survey

The topographic maps were permitted to use only in Turkey for the very limited purposes. The reproduction of drainage map of 1:50,000 scale from the topographic map of 1:25,000 scale were carried out in M.T.A. office.

The topographic maps of 1:25,000 scale were enlarged 1:10,000 scale for field work, and results were compiled to 1:50,000 scale drainage maps. The length of the total surveyed route was 1,568 Km.

The number of collected samples totaled 30 for whole rock anlysis, 35 for microscopic observation, 10 for X-ray analysis, 2 for Rb-Sr radiometoric determination and 3 for K-Ar.

(2) Geochemical Survey

Together with geological survey, stream sediment samples were collected in the Zone and Zone B for geochemical investigation. The number of samples amounted to 406 in the Zone A and 504 in the Zone B.

Because of the existing stream sediment samples by UNDP in zone B , we forcused the four area: Hasandere, Kalkanlı, Beşkise, as well as the area distributed of Gümüşhane Granite where graizeization can be expected.

Chapter 2 Outline of the Survey Area

2-1 Geography

(1) Topography: The survey area is located aproximately 550 km east of Ankara and 60km south of Trabzon of Black Sea. The highest peak in the survey area is the Aptalmtusa Tepe (3,331m), and Karbörk village (300m) of Zone A is lowest. Small streams which cut the high plateaus caused the steep and broken grounds.

Torul (940m) in the centre of the survey area is not so steep with altititude ranging from 1,000 to 1500m.

(2) Climate: Zigana pass(2,000m) which is located along the route 65 between Trabzon and Gümüşhane, forms the dividing ridge extending E ~W direction. The coasta climate of northern dividing ridge is humid and there are many rainy days at alll seasons. Average precipitation is 700 ~ 1,000m/year. The intercontinental climate of southern dividing ridge has low humidity. During the summer season (July-August) the temperature reaches 30oC, the temperature of winter season(December-Feburuary) often goes down below zero degree.

There is almost no snow near Trabzon, but permanent snow during six months from November to May in high plateaus.

(3) Vegitation: Vegitation in the northern area of a dividing randge is extremely developed, but the general area in the southern area consists of vegetation with small trees and grass.

The high mountains are more than 2,000m, and they are above the upper limits of forest and used as a summer camping areas for villagers and also for meadows. These placees are called "Yayla".

(4) Access: The Turkish Airline has daily services between Ankara and Trabzon by DC-9 jet airliner. The transportation to other cities can be done on highways. The m main road in the survey area is the route 65 connecting Trabzon,Troul and Gümüşhane, and paved 70%. There are several unpaved roads which branch from the main road and they are mostly

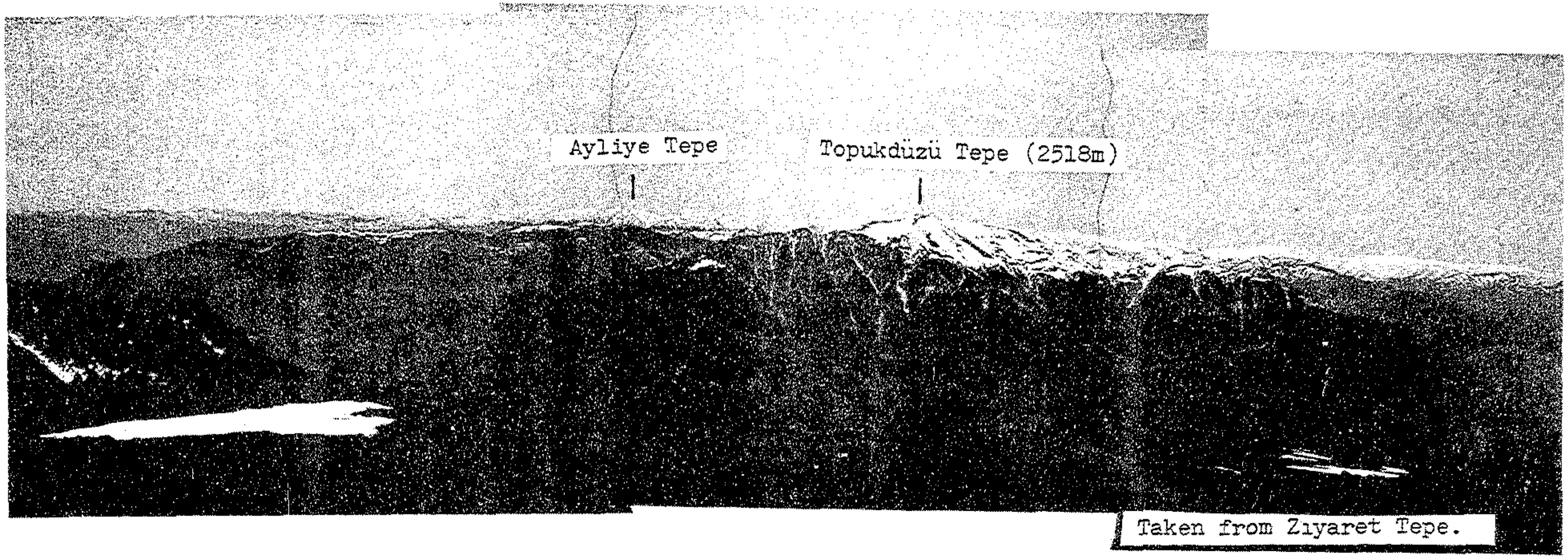


Photo.1 Pancramic Photograph of the Southern Survey Area

accessible except snowy and rainy seasons, then four-wheel driven vehicles can be used.

It takes about two and half hours by car from Trabzon to Torul.

Most of roads in the survey area are in poor conditions and vehicles can be driven less than 30 km/h.

(5) Population: Gümüşhane is the largest city in the survey area, and facilities such as bank, police, hospital, hotel are available. The population is about 12,000. Torul, on which the base camp of filed work was set up, is the second largest city of the Gümüşhane Province, and its population is more than 3,000. Besides, small villeges are scattered in the area.

(6) Industry

Agriculture: People mainly live on agriculture. Nuts and tea are the main products of Zone A near the Black Sea Coast. Animal products, milk, butter, etc. are the main income of the people living in the high land.

Forest: The products of forest make income for people. Lumber is mainly transported to Trabzon and sawmill is working during summer season at Karadag village.

Factory: Cement,juice factory and flour mill are operated on a small scale in Gümüşhane.

Mining: Midi mine which is located 15 km SW of Gümüşhane, is operated during summer season. This mine producted lumpy zinc ore of 400 tons last year.

2-2 Previous Works

There are few studies on the geology and mineral deposits of the project area. In 1962, the geological map of Trabzon area 1:500,000 in scale was compiled and published by M.T.A., based on the geological map of 1:100,000 and 25,000 compiled in 1959. Recently M.T.A. has conducted the geological survey in southwestern portion of the ptroject area.

Gümüşhane Granite widely distributed in the project area was petrographycally studied by YILMAZ(1974).

With respect to mineral occurrences in the project area, there is a report on two mines, Hazine Magara and Kırkpavlı in Eski Gümüşhane. Kovenvo(1937) reported that Hazine

Magara is a Ag replacement deposit in calcareous sediments overlaying Paleozoic Granite (Gümüşhane Granite), and that Kırkpavlı is of Ag-Au vein-type. M.T.A. has carried out a follow-up survey in Eski Gümüşhane area in these years. Any other report or study except above deposits is not available.

Mineral Exploration Project in Merzifon-İspir and Menders Massif areas was excuted jointly by the United Nations and the Government of Turkey between 1970-1974. A regional geochemical reconnaissance survey was carried out. The Gümüşhane area is a central portion in the Merzion-İspir of about 24,000 km^2. This work resulted in the recognition of 47 geochemical anomalies in the Merzifon-İspir area, of which 8 anomalies are concered with the Gümüşhane area.

2-3 General Geology and Ore Deposits of the Survey Area

Turkey is a geologically divided into four tectonic units, namely Pontids, Anatolids, Taurids and Border Folds from north to south. These belts generally extend with E-W direction. The surveyed area belongs to the Pontids, cosisiting of the Ordovician to Oligocene.

The Pontids is characterized by extensive volcanic activities, including calc-alkaline basalt-andesite-dacite series in Upper Cretaceous-Tertiary period. This violent volcanism is acccompanied with emplacement of granitic rocks. Most of ore deposits in Pontids have a genetical relation to this magmatism.

The surveyed area predominates in andesite and its equivalent pyroclastics of the Upper Cretaceous(Zigana Formation), dipping gently northward, with some subsidiaryfolds. On the contray, to north of the surveyed area, dacite series is mainly distributed according to the result of collaboration mineral exploration programme in 1974 ~1976(Trabzon area).

The great majority of the massive and stockwork sulfide deposits are located between the Black Sea Coast and the Gireson-Harşit-Caykara-Artvin line in the Eastern Pontids. These deposits are associated with dacite series of the Upper Createaceous, and has similarity to the Kuroko deposits in Japan in regard to geological environments and modes. Murgul is a represetative operating mine in this region. The Rize-Çayeli copper deposit near Samsun

(Indicated reserves: 30 million tons,3.3% Cu, 10.2% Zn, 1.1 g/t Au, 55g/t Ag) is planned to develop by Etibank and a joint venture of Phelps Dodge, Gama Industrie and Demir Export.

In the Eastern Pontids, a few porphyry copper type deposits were explored by drilling at Bakirçay and Ultus. The mineralization, mainly of copper and molybdenum, is related to Laramian quartz diorite and quartz monzonite.

Skarn-Type mineralization is found in limestone intercalating in andesite piles in this region. Main ore minerals is iron oxides, with a small amount of copper ,lead and zinc.

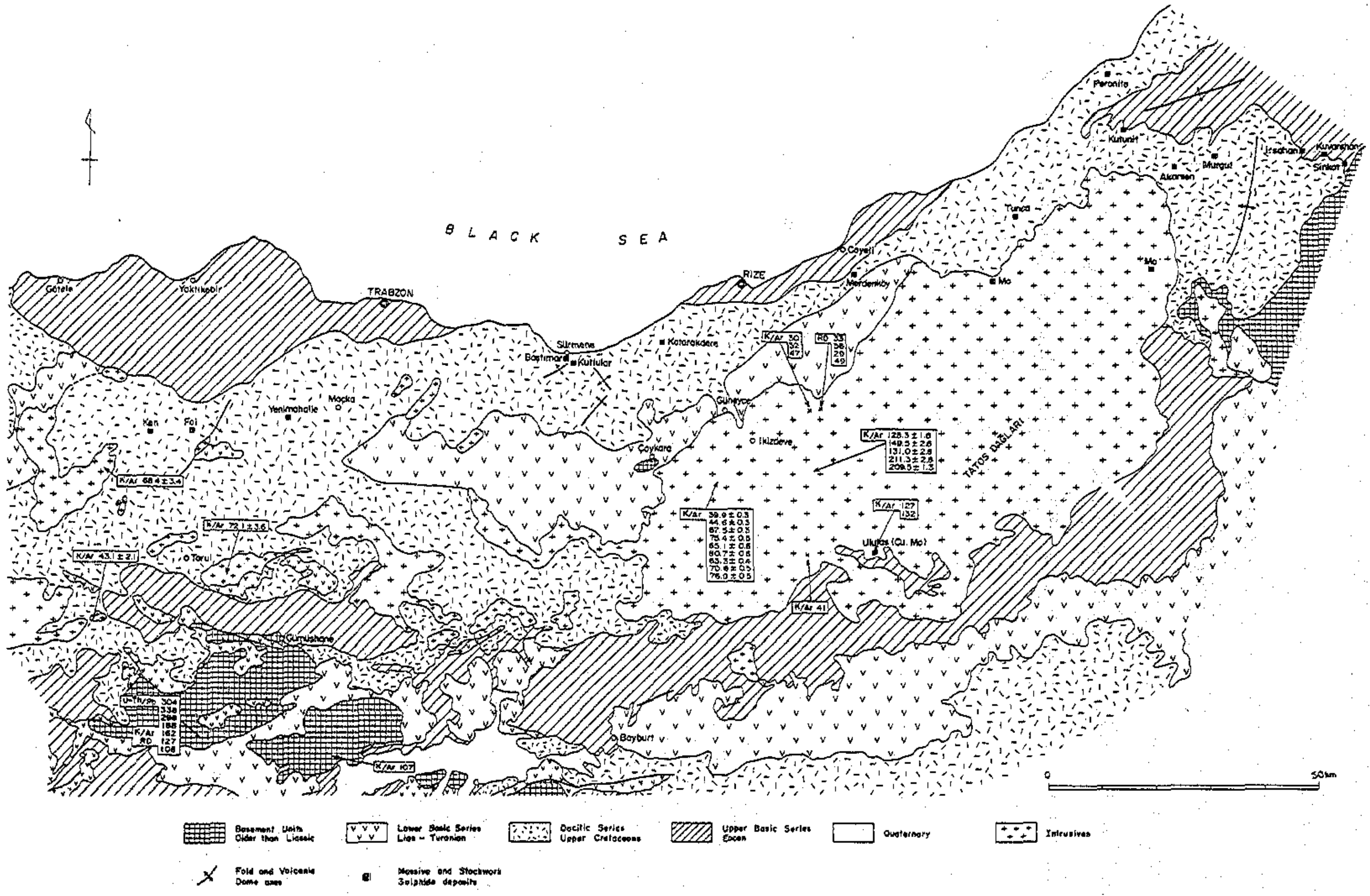


Fig. 3 Generalized Geologcal Map

Part 2 GEOLOGICAL SURVEY

Part II GEOLOGICAL SURVEY

Chapter 1 Geology

1-1 General Geology

The basement rocks of the surveyed area consists of Paleozoic Kurtoğlu Metamorphics (mainly gneiss and biotite schist) which are distributed in the southern part of Gümüşhane area and the Gümüşhane Granite which intruded into these rocks during late Paleozoic period.

These basement rocks are overlain by the Kırıklı Formation consisting of Lower Jurassic Lias basaltic rocks. The major unit of this formation is basalt lava with some spilite lava and sandstones. Red limestone is developed locally and this is correlated to the Lias Stage by fossils in the limestone which occurs to the east of the surveyed area. Basal conglonerate locally overlies the Gümüşhane Granite(near Midi mine).

Kuşakkaya Limestone Formation (massive limestone) overlies the Kırıklı Formation. Jurassic fossils were found in this massive limestone and thus this formation is correlated to the Dogger-Malm Stage.

Zigana Formation is widely distributed unconformably overlying the basement, Kırıklı Formation, and Kuşakkaya Formation. The major unit of this formation is andesitic volcanics rocks. In the southern part of the surveyed area, basaltic activity is observed below this formation, and dacitic volcanic rocks are associated towards the later phase of the Zigana Formation. Flysch type sedimentary formations are developed in the southeastern part of the area and this indicates that the andesitic volcanic activity ceased during this period. This sedimentary formation consists of rhythmical alternation of mudstone and sandstone. Massive limestone, red limestone, mudstone and others are intercalated in this formation, but these intercalations are not continuous. Fossils of Upper Cretaceous Senonian Stage are found in the limestone of the lower part of this formation.

Venk Yayla Formation overlies the Zigana Formation unconformably and it is composed of andesitic volcanic rocks and flysch type sedimentary rocks. It is distributed in the central part of the area. A large amount of nummulites considered to be ofEocene age occur in limestone which is developed in the lower part of this formation.

The uppermost formation of this area is the Gavur Dagi Volcanics which is considered to be of late Eocene age. It is distributed in the highland with elevation of more than 2,500m above sea level in the southwestern part.

The intrusive rocks of this area are mostly granodiorite and quartz porphyry. Also small veins of dacite and dolerite are observed. Large bodies of granodiorite are observed particularly in Torul, Kürtün and Kopuz areas. Also small bodies have intruded into the Gümüşhane Granite.

The WNW-ESE trending thrust (Gümüşhane Thrust) forms the geologic boundary of this area with the development of the basement rocks consisting of Kurtoglu Metamorphics and Gümüşhane Granite, Kırıklı Formation and Kuşakkaya Limestone to the south of this thrust. While to the north, the major unit is granodiorite which intruded into the Zigana Formation and Tertiary strata.

1-2 Stratigraphy

(1) Kurtoglu Metamorphic Complex

Type Locality: Vicinity of Kurtoglu Village in the southern part of the surveyed area.
Thickness: 500m.

These metamorphic rocks are distributed in a ENE-WSW trending belt with several kilometers in width. The belt extends from the Kurtoglu Village to the Tezene River, along the Kurtoglu River and also near the Tersun Range. The lithology of this unit consists of gneiss, biotite schist, muscovite schist and quartz-sericite schist. Gneiss is widely distributed from the vicinity of the Yeniköy Village along the Kurtoglu River to the west of the Kurtoglu Village. The rock is grayish white, coarse-grained with strong foliation. Megacrysts of muscovite up to 2cm are observed in some parts of this rock. Muscovite schist and quartz-sericite schist are white with frequent occurrence of megacrysts of muscovite.

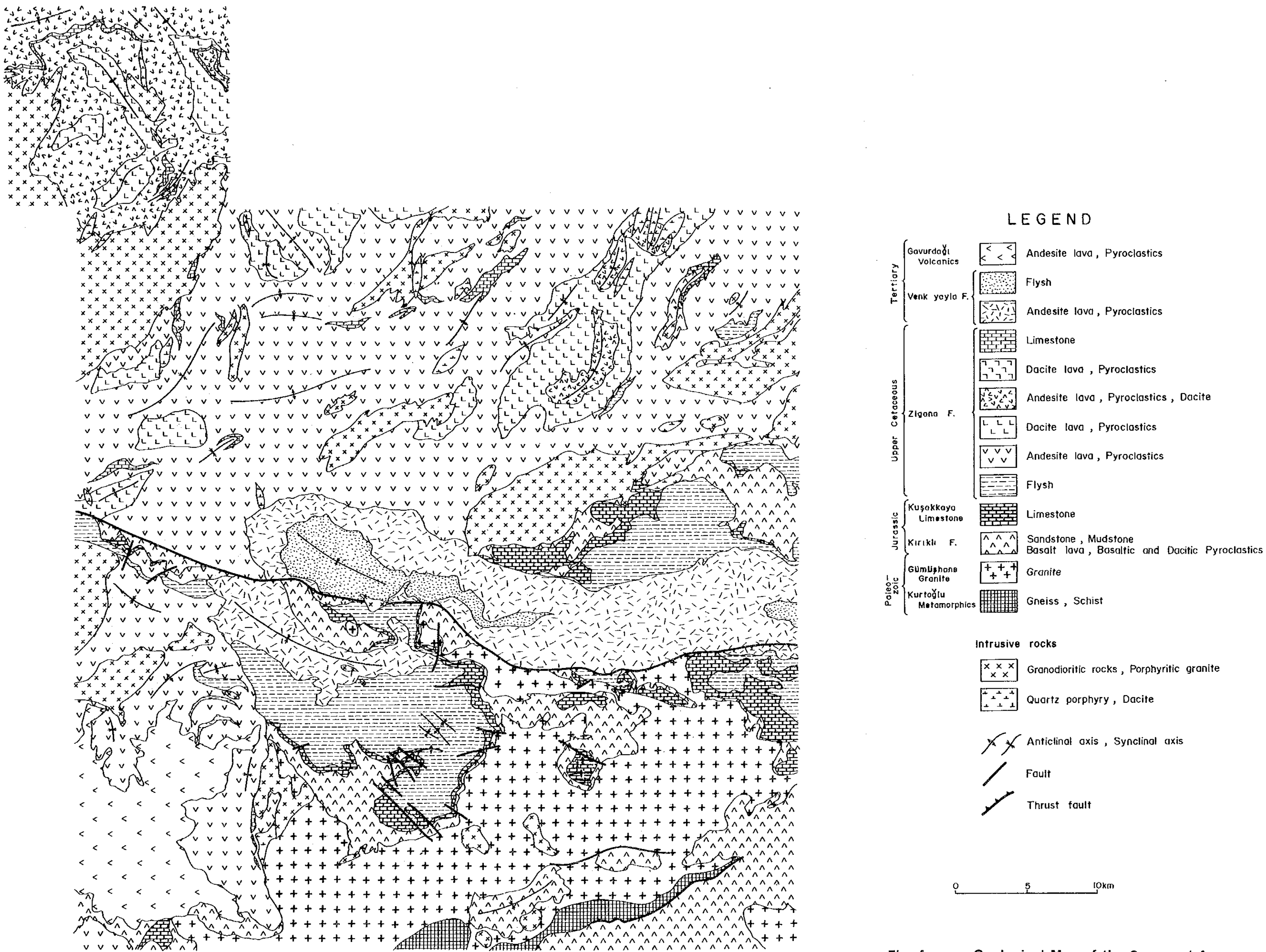


Fig. 4 Geological Map of the Surveyed Area

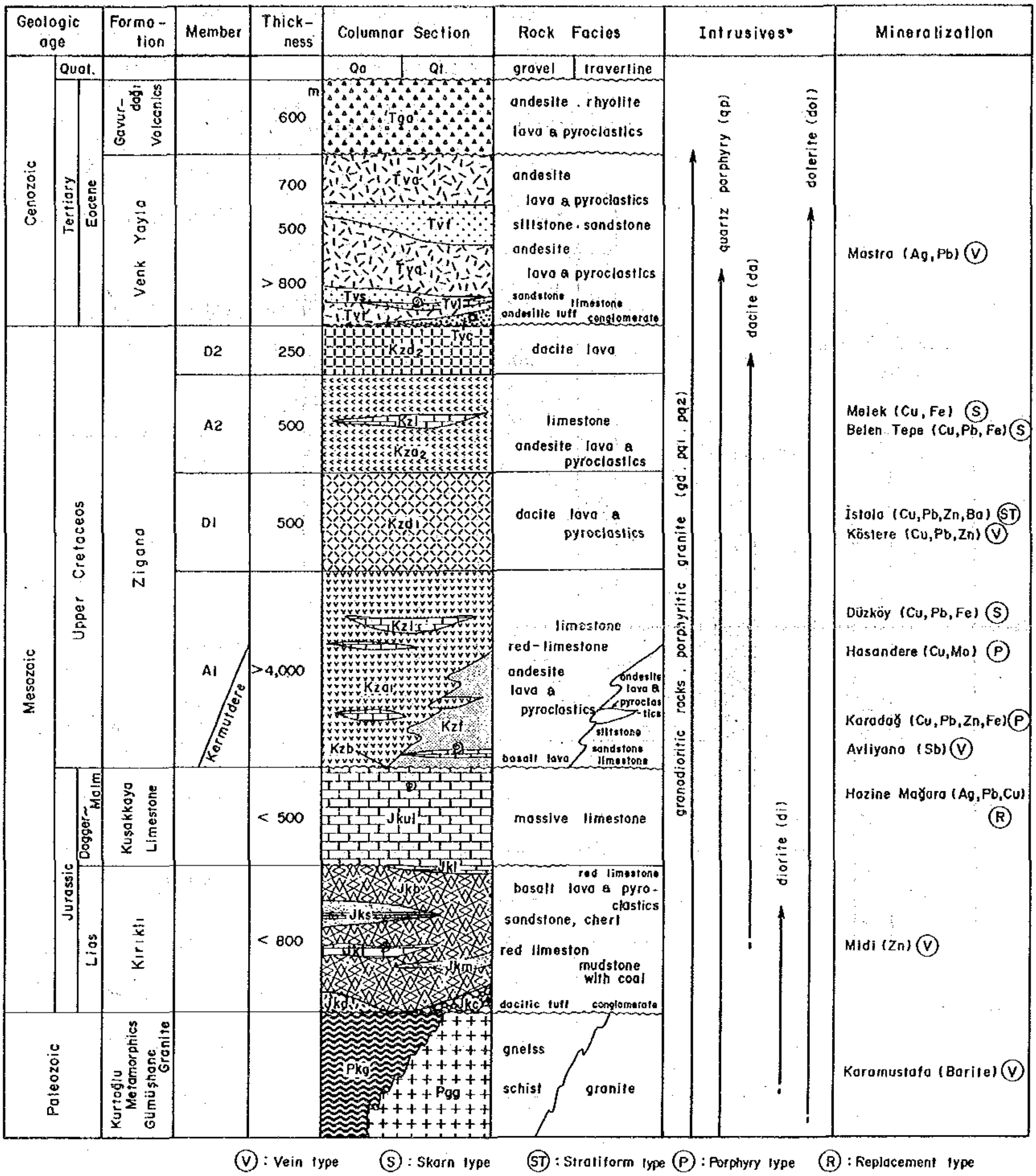


Fig. 5 Schematic Geological Column of Gümüşhane Area

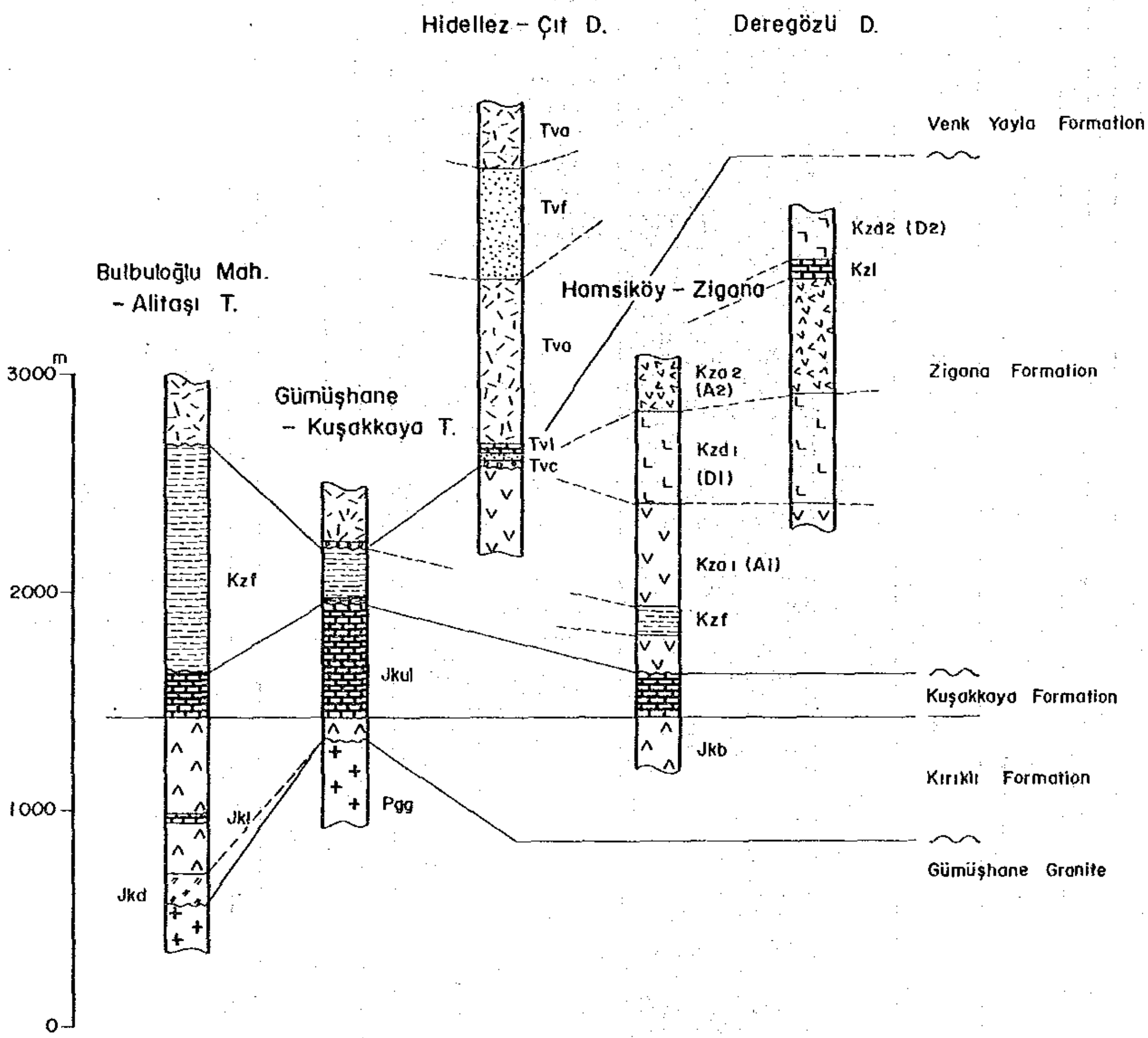


Fig. 6 Correlation Map of Individual Rock Facies

Biotite schist is dark brown, fine-grained and hard. Also there are intercalations of metamorphosed conglomerate lenses of 0.5m.

The biotite and muscovite schists show lepidoblastic texture microscopically. The major rock forming minerals are biotite, muscovite, quartz, plagioclase with small amounts of opaque minerals.

Althouth these rocks are metamorphosed and folded and thus the detailed structure is not clear, it is inferred that the general trend of the foliation and the fold axisis is E-W with a northward plunge. The thickness of this formation is not clear, but is estimated to be more than 500m by its surface distribution.

This complex is bounded by a thrust to the Kırıklı Formation in the south and is intruded by Gümüşhane Granite in the north. The thrust is observed to the south of Asagıtezene village, the strike is approximately E-W with northward dip and it extends to the Kurtoglu River in the west.

Yilmaz (1974) determined the age of this formation to be Carboniferous to Permian.

(2) Kırıklı Formation

Type Locality: Vicinity of Kırıklı Village located 14km south of Gümüşhane.
Thickness: 800m.

This formation is distributed in many parts of the surveyed area unconformably overlying the Paleozoic formations. The major occurrences other than the Kırıklı Village are Gümüşhane, half way down the Nivena River and downstream of Korum River in the south; also Hamşiköy River in the north; and north of Kopuz Village in the western part of the area.

This formation consists of basal conglomerate, dacitic tuff, basalt lava, basaltic pyroclastics, spilite lava, red limestone, sandstone, mudstone, chert and thin coal seams.

Basal conglomerate: Development is local and the unit is not continuous. It unconformably overlies the Gümüşhane Granite in the southern part of the surveyed area as well as near the Midi Village and the vicinity of Gümüşhane City in the southeast, and it similarly overlies the

Kurtoglu Metamorphics to the east of Kurtoglu Village. It is pale pink and most of the pebbles are granite with some metamorphic rocks. The pebbles are several to ten centimeters in diameter, rounded to subangular in shape and the matrix is pale green to grayish white consisting of quartz and feldspar grains.

Dacitic tuff: This is found only to the north of the Altıntaşlar Village in the southern part of the surveyed area and overlies the Gümüşhane Granite unconformably. It is pale yellow, strongly silicified and argillized, with dissemination of pyrite and oxidized copper minerals. Quartz veins are also developed.

Basalt lava, basalt pyroclastics, spilite lava: These rocks are distributed mainly to the north of Altıntaşlar Village, Mezraa Village and vicinity of Gümüşhane City in the south-southeastern part of the area and along the downstream part of the Korum stream. The basalt lava is generally dark green to reddish brown, the plagioclase is green and is chloritized and epidotized, and calcite veinlets are well developed. Subhedral phenocrysts (1-2mm) of plagioclase occur throughout the basalt and in many cases they are altered to chlorite, sericite and calcite. Also hypersthene and augite phenocrysts are observed and they are chloritized. The matrix is mostly chloritized, but there are glass filling the interstices of prismatic feldspars. The basaltic pyroclastics consist of tuff breccia, lapilli tuff, and fine tuff with similar colour as the basalt lava, namely dark green to reddish brown. Also pillow lava occurs locally in the down stream area of the Korum Stream.

Red limestone: Red limestone occurs as lenses and is not continuous. It is distributed at Şimere Village in the south, along the upstream part of the Uzun Stream in the southeast and to the southwest of the Gümüşhane City. This is marl limestone and is characteristically red. The occurrence of the following fossils are reportedfrom this limestone at Kermut Village (outside of the surveyed area) 10km east of Gümüşhane City (MTA data).

Inyolutina liassica (Jones)

Trocholina sp.

Spirillina sp.

Lenticalina sp.

These fossiles are correlated to Lias of Late Jurassic.

Sandstone, mudstone, chert, coal seams: These rocks occur near the Kırıklı Village in the southeast. They occur as alternation of sandstone and mudstone with sandstone as the major component. Bedding is developed clearly and basalt lava and basaltic pyroclastics are intercalated locally. The sandstone is dark gray to gray and the grain size ranges from coarse to fine. The mudstone is mostly sandy mudstone. The sandstone near Mt. Karagaban in the southwest is reddish gray, coarse-grained consisting mostly of quartz and plagioclase with arkosic nature. The chert occurs in sandstone-mudstone alternation in the southwestern part of Şimere Village in the south. It is red to leucocratic and is opaline in places. It also occurs in basalt lava south of Gümüşhane. Coal seams occur as intercalations in mudstone at the southwestern part of Eski Gümüşhane Village. They are black to dark blue bituminous coal. Three layers of thin lenses with thickness of 1～10cm are observed.

(3) Kuşakkaya Limestone Formation

Type Locality: Vicinity of Mt. Kuşakkaya located approximately 2km east of Gümüşha ne City.

Thickness: 500m.

This formation covers the underlying Kırıklı Formation. It overlies conformably the red limestone of the Kırıklı Formation and unconformably the pyroclastics of the same formation. The occurrence of the Kuşakkaya Formation is limited to localities where Kırıklı Formation is distributed, mainly in the southern part of the surveyed area. The limestone of this formation is grayish white to white and mostly massive, but also red limestone, dolomitic limestone, detrital limestone and others are observed.

The following fossils are reported from the vicinity of Mt. Ucbacali which is located approximately 3km northeast of the Altıntaşlar Village (MTA data).

Cunealina sp.

Ophthalmidium sp.

Miliolida

Textulariidae

These fossils are correlated to the Upper Jurassc Dogger-Malm Stage.

(4) Zigana Formation

Type locality: This formation is divided into five stratigraphic units, they are in ascending order A1, D1, A2 and D2 Members. The Kermut Dere Member is also present. A1, D1 and A2 Members occur near the Zigana Pass between Trabzon~Gümüşhane along National Highway 65. D2 Member is distributed near Mt. Kertaş and the Kermut Dere Member occurs along the Kermut River 10km east of Gümüşhane.

Thickness: 5,000m.

Kermut Dere Member: This member is distributed to the northwest and north of the Gümüşhane Granite. The lithology become mostly alternation of mudstone and sandstone near the northwestern body of the Gümüşhane Granite, while near the Avliyana Village which is at a distance from the Gümüşhane Granite, mudstone and sandstone rapidly decrease and andesite becomes predominant. Pale gray to pale grayish white and some times brownish gray to pale brown mudstone, calcareous siltstone and sandstone alternates rhythmically, gradually intercalating andesite and andesitic pyroclastics in the upper parts finally changing to the adesite (A1 Member) of the overlying unit. It is the flysch type sedimentary rock. The strike and dip vary considerably and in some parts the unit stands rather steeply, but generally it has a low angle dip (approximately 30°). There are many faults but large ones are scarce. H. Gündüz (MTA) identified Globotruncana sp. and Gloveriginidae from the calcareous siltstone of this member and thus it belongs to Upper Cretaceous Senonian Stage. In localities where this member is developed, it often overlies Kuşakkaya Limestone unconformably.

A1 Member: The major part of the Zigana Formation consists of this member. Basalt lava is developed in the lower part and the lithology gradually changes upward to andesite lava, autobrecciated lava, agglomerate, lapilli tuff and medium to fine-grained tuff. The colour is generally pale green to dark green. Basalt lava is developed along the anticlinal axes of Karadag～Avliyana and 10km north of Torul in the southern part of the surveyed area. Andesites are developed in other parts. The vicinity of Zigana to Torul is considered to be the centre of volcanic activity because lavas and pyroclastics are predominant. Mudstone, sandstone, limestone and siltstone are intercalated increasingly to the north and west. The intercalated sedimentary rocks are not continuous, but bedding plane and laminae are well developed.

Phenocrysts of plagioclase and small amount of pyroxene are observed microscopically. They are all strongly altered to chlorite and sericite and only the outline of the crystals can be seen. The matrix has hyalopilitic texture and glass has altered to chlorite and calcite which fill the interstices of prismatic plagioclase.

Microscopic study shows that the andesite is augite andesite, but the mafic minerals have altered to epidotes and chlorites by diagensis. Locally there are strongly altered zones which are white to pale gray and do not show any trace of the original andesite. There are zones of several meters to half of a meter which have argillized to white clay. These zones and propylitized zones often alternate and this is observed along the national highway from Zigana Pass to Torul.

D1 Member: The major rocks of this unit are dacite and dacitic pyroclastic rocks. There are two types of dacite. Dacite lava is grayish white to grayish green massive with clear flow structure. Autobrecciated lava is grayish white to white. The pyroclastic rocks consist of tuff breccia, lapilli tuff and fine-grained tuff. These pyroclastic rocks are altered, white to pale green and small amount of pyrite is associated. D1 is distributed in the mountains to the north of Zigana Pass, northern part of Kürtün, the moutains (over 1,500m above sealevel) in the southwest and Zone A. In the southern part of Zone A, there are lava flows with distinct flow structure and columnar joints are developed in some localities. In other areas autobrecciated lavas and pyroclastics are notable. Andesitic lava, andesitic pyroclastics and limestone are intercalated in these dacitic pyroclastic rocks and the petrological nature of the andesite of D1 is similar to that of A1. Phenocrysts of quartz and plagioclase occur in dacite and they are strongly sericitized. The matrix consists mostly of fine-grained secondary quartz, sericite, chlorite and calcite. D1 overlies A1 conformably.

A2 Member: The major rocks of this member are andesite and andesitic pyroclastics, they are similar to those of A1. This unit occurs to the north of Zigana Pass and Zone A overlying D1 conformably. It undulates and generally dips northward, thus it is distributed widely in Zone A in the north.

Andesite lava is predominant near the Zigana Pass, but the major rocks become dark green andesite agglomerate to tuff breccia at the west of Dikkaya Village in the north. The distribution of this unit is narrow near the Zigana Formation with no intercalation of sedimentary rocks, while in Zone A it occurs widely with massive limestone intercalations and is relatively continuous. In the eastern part of Zone A, there are localities where the lowermost horizon is grayish white massive limestone with A2 andesite above, but in the central to western part, the andesite directly overlies D1. In the northern Zone A, grayish white to white massive limestone is intercalated and the member is continuous for a relatively wide range with varying width. The predominance of andesite lava and grayish black to dark black andesitic fine-grained tuff is characteristic of A2.

D2 Member: This unit consists of pale green to white dacite lava and conformably overlies A2 in a relatively narrow range of 1,400～1,800m altitude of relatively high mountains in western Zone A.

(5) Venk Yayla Formation

Type locality: Vicinity of Venk Yayla Village approximately 4km west of Gümüşhane City.
Thickness: 2,000m.

This formation overlies the Paleozoic and Mesozoic formations unconformably and occurs at Çit, Kodil, along Haşara River and other localities in the central part of the surveyed area. The major components of this formation are andesite lava and andesitic pyroclastics.

This volcanism is slightly dacitic. It is characteristic of this formation that flysch type sedimesntary rocks develop during the dormant period of the andesitic volcanic activity. This formation is composed of piles of basal conglomerate, limestone, sandstone and andesitic pyroclastics, and rhythmic alternation of sandstone-siltstone occupies the volcanically inactive period. This formation is developed in the Paleogene sedimentary basin which is closed in the west, but it continues outside of the surveyed area to the east. The size of the basin is 60km east-west and over 10km north-south.

Basal conglomerate: This is developed locally and is not continuous. This formation unconformably overlies the Kırıklı Formation at the Dere Village along Avliyana River, andesite of the Zigana Formation near the Venk Yayla and Hidrellez Village and the Kermut Formation near Bapdagı west of Gümüşhane. The conglomerate is reddish brown with maximum thickness of about 10m and the matrix is tuffaceous and sandy.

Limestone: The thickness is 30-60m and is developed overlying the basal conglomerate. Dark gray thin sandstone layers are intercalated. It is gray, massive and contains a large amount of large foraminifera represented by nummulites. The diameter of the nummulites is 2mm-1cm, they occur frequently and they often protrude when the rocks are weathered. In some localities, black calcareous sandstones are predonimant . The follwing microfossils are reported from Venk Yayla Village by H. Gündüz (MTA).

Nummulites sp.
Discocyclina sp.
Aktinocyclina sp.
Operculina sp.
Sphaerogypsina sp.
Glovorotalia sp.
Globotruncana sp.

Also the following fossils have been identified from Kozevresi River (approximately 10km west of Gümüşhane) which is near the surveyed area.

Nummulites sp.

Assilina sp.

Discocyclina sp.

Other fossils observed are those of molluscs such as pelecypodes (Ostra sp.), brachiopodes and gastropodes. This formation is correlated to Eocene Lutetian Stage by the above microfossils.

Andesite, andesitic pyroclastic rocks: This andesite lava characteristically contains hornblende phenocrysts and forms this unit together with pyroclastic flow of the same lithology. Dacite and pyroxene andesite are locally intercalated. The tuff is reddish green, contains plagioclase, hornblende crystals, and locally biotite, and it is coarse-grained. The lava is gray to reddish gray, contains plagioclase and hornblende phenocrysts and is massive to brecciated. The andesite consists mainly of plagioclase, hornblende, augite with occasional association of biotite and hypersthene. The matrix shows hyaloophitic texture with glass filling, the interstices of long prismatic plagioclase and prismatic to granular pyroxene and opaque minerals. In some samples, zeolites are found in cavities. These volcanic rocks locally contain tuffaceous sansdtone. At Mt. Ögletş to Mt. Kuşhuktaşı, andesite lava intruded this sandstone, quenched by water, brecciated and the sand filled the matrix. Columnar joints are developed widely along the national highway to Siran. Reddish white hornblende-dacite with clear flow structure is intercalated at Topçatı Village.

Flysch type sedimentary rocks: This sandstone-siltstone alternation is widely developed along the Çit River and the maximum thickness of 500m is observed. The thickness decreases eastward to about 100m. The lowermost unit of this alternation is calcareous siltstone containing nummulites. Andesitic pyroclastic rocks are intercalated in the upper horizons.

(6) Gavur Daği Volcanic Rocks

Type locality: Gavur Daği Mountains.

Thickness: 600m.

These volcanic rocks form the Gavur Range located at the southwestern part of the surveyed area. Mt. Aptalmşa is the main peak of this range. These rocks unconformably overlie Paleozoic and Mesozoic formations (Gümüşhane Granite, Kırıklı Formation, Zigana Formation). They are distributed over approximately 15km north-south and 10km east-west and also outside of the surveyed area to the west. The major components are pale gray to grayish brown andesite lava rich in plagioclase phenocrysts and tuff breccia of the same lithology. The andesite generally contains minor amount of hornblende phenocrysts, but locally these are sometimes abundant and show flow structure. Generally, the lava is massive with clear joints, but in some cases the rock is autobrecciated. Reddish brown tuff breccia without clear bedding plane is intercalated.

Purplish-grayish white dacite lava occurs in the vicinity of Mt. Eşekmeydan. This lava is characterized by plagioclase phenocrysts as large as several millimeters and idiomorphic phenocrysts of hornblende and biotite. Grayish brown rhyolite with fine banded flow structure occurs as small bodies at Boğaz Dere. This rhyolite does not contain any phenocrysts.

1-3 Intrusive Rocks

(1) Pre-Jurassic Intrusive Rocks - Gümüşhane Granite

Type locality: South of Gümüşhane City

The distribution of this granite is wide and is elongated in southwestern direction from the south of Gümüşhane City. It covers an area of 37km E-W and 15km N-S.

The lithology of this intrusive body was described in detail by Yilmaz in 1974. The body is divided in this report into granodiorite, Çamliça adamellite, Gümüşhane adamellite and fine-grained porphyritic granite. The major part of the igneous body, however, consists of fine-grained porphyritic granite. As it was difficult to distinguish the lithology in the field, we identified this body as the granite which intruded into Paleozoic formations.

The rock is generally massive, grayish white, greenish gray, yellowish gray to pink. The appearance varies greatly from fine to coarse-grained. The general tendency is finer-grained toward the periphery and coarser-grained toward the inner parts of the intrusive body. In the large area to the south of Gümüşhane City, the rock is coarse-grained, generally brittle and contains large crystals of potash feldspar, quartz grains of 2-3mm and is rich in biotites. Microscopically, it is holocrystalline, has equigranular to porphyritic texture and consists of quartz, alkali feldspar, plagioclase, biotite, muscovite and amphibole. The alkali feldspar is anhedral to irregular in shape often shows perthitic texture. Plagioclase is euhedral to subhedral, often shows albite twinning and sometimes has zonal structure. Some of the mafic minerals are replaced by chlorite and epidote. It is classified microscopically as quartz monzonite. Aplitic properties are observed in this body at west of Altıntaşlar Village, east of Artabel, vicinity of Edire Village and other areas. The aplitic part is compact, massive and rich in quartz, plagioclase and feldspars.

(2) Younger Intrusive Rocks

Hypabyssal rocks: Many intrusive bodies of dacite, quartz porphyry and other rocks which are closely associated with Upper Jurrassic submarine volcanic activities are found in Upper Jurassic Zigana Formation (A1, D1, A2). Most of these bodies are elongated in NE-SW to N-S directions and rarely in NW-SE. These bodies are distributed to the north of Gümüşhane Thrust. Both weakly altered to the unaided eyes. Minor amount of pyrite is associated. Also, the youngest quartz porphyry intrudes the Venk Yayla Formation and granodiorite. Small scale dolerite intrusion is observed in Gümüşhane Granite.

Plutonic rocks: Most of the plutonic rocks of the surveyed area is granodiorite.They are named according to their geographic distribution as Kopuz Granodiorite, Kürtün Granodiorite, Torul Granodiorite and Hasandere Porphyritic Granite. These intrusive bodies are elongated in NE-SW, N-S directions. They form a batholith in the central to northern part of the surveyed area and occur as stocks near the periphery. There are granodiorite and diorite intrusions into the Gümüşhane Granite, but they are of small scale.

Kopuz Granodiorite: This granodiorite is distributed from Kopuz to Asagı Villageand consists mainly of three bodies.

The stock which occurs northeast of Kopuz Village is fine-grained biotite-amphibole granodiorite and extends 3km E-W and 2km N-S. Plagioclase, alkali feldspar, amphibole biotite and opaque minerals are found under the microscope. The plagioclase is euhedral granular and has Carlsbad, Albite twinning with strong zonal structure. The granodiorite body near Asagı Village is large and extends westward out of the surveyed area. It is pale grayish white and contains euhedral amphibole of 2-3mm.The rock is holocrystalline with equigranular texture and euhedral plagioclase. The constituent minerals are plagioclase, quartz, alkali feldspar, amphibole and opaque minerals. Some stocks are found near this body and altered zones with pyrite associations are developed in the stock and the host rocks at Beşkise.

Kürtün Granodiorite: This is a large batholith extending from Kürtün to Dogankent which lies west outside of Zone A of the surveyed area. The major rocks are amphibole granodiorite and biotite granodiorite associated partly by quartz porphyry, dacite and dolerite dykes.

The granodiorite is holocrystalline with equigranular texture and some of the plagioclase forms porphyritic megacrystals. The constituent minerals are plagioclase, quartz, alkali feldspar, amphibole and with or without biotite. Some of the mafic minerals are replaced by chlorite and epidote.

Torul Granodiorite: There are some medium to small scale granodiorite bodies in the vicinity of Torul. These are called Torul Granodiorite. These bodies are generally elongated in NE-SW direction. The granodiorite body extending from Sarisamn 7km northwest of Torul to Şive Village is pale gray to pale brownish white to pink andthe rock is amphibole ganodiorite, but the rock becomes finer-grained and dacitic tothe east.

The mass which extends from Torul to the south of Mt. Ayaser is 20kmx5km and is elongated in NE-SW～ENE-WSW. This granodiorite is characterized by biotite and quartz, plagioclase, alkali feldspar, biotite, muscovite, epidote and opaque minerals are observed microscopically. In some places alkali feldspar and plagioclase have been altered to fine grain size. This intrusive body cuts through Kurtoglu and Zigana Formations. Mt. Ayaser to the north of this intrusive body is composed of fine-grained amphibole-biotite granodiorite.

Hasandere Porphyritic Granite: This granite is distributed from the Maden Stream(main stream of Hasan Stream) to Turnagöl River. Although there are parts which show equi-granular texture, these are local and the general characteristics of this rockis porphyritic texture of quartz and plagioclase. Thus the above name is given.

This rock is grouped into two types by alteration, namely pg1 and pg2. Altered porphyritic granodiorite (pg2) constitutes a small body consisting mainly of sericite and biotite. It is argillized and silicified. Pg1, on the other hand, is unaltered porphyry granodiorite elongated in ENE-WSW direction.

1-4 Volcanic Activity

The surveyed area belongs to the Pontids Fold Belt which is characterized by intensive Upper Cretaceous and Tertiary volcanic activity. This volcanism is mostly submarine and cycles of basic to acidic activity have been repeated several times.

The volcanism started with basaltic activity in Lias shallow sea which is characterized by pillow lava. The area uplifted and limestone deposition occured after subsidence. In Upper Cretaceous time, basaltic activity started again, but the following andesitic volcanism lasted for a long time with intense activity over a large area emitting large amount of lava and pyroclastics. During the early phase of the andesitic volcanism, flysch type sediments of deep sea turbidity current is associated. As the volcanism become intense, however, these sediments disappear and volcanic rocks bigin to ocupy the area between Zigana and Torul in the central part of the surveyed area. Mudstone and limestone are intercalated at distances from the central part, but they are not continuous. As the sedimentation and volcanism shifted northward, dacitic submarine volcanism became predominant. In some localities, dacitic activity occured together with andesitic type. The area was uplifted and then subsided from Late Cretaceous to Eocene and subsequently submarine volcanism resumed. The activity during this period was mainly acidic andesite, associated with small dacite in a sedimentary basin intercalating flysch type sediments. This volcanism is of far smaller scale compared to that of Cretaceous. The only subsequent activity is andesitic Gavur Daği Volcanics which probably is of late Eocene age.

1-5 Diagenesis and Alteration

Of the geological units in the surveyed area, Kırıklı and Zigana Formations have suffered wide spread diagenesis and strong alteration. Epidotization, chloritization and carbonatization are conspicuous in Kırıklı Formation. On the other hand, in the andesites of Zigana A1, A2, some contain fresh original minerals and some have totally new mineral composition due to the formation of epidote, secondary quartz and chlorite by diagenesis.

Haviliyana and Altıntaşlar are the two localities where alteration occured in the Kırıklı Formation. Silicification and argillization accompanied by pyrite mineralization is notable. In the Zigana Formation, the zone between Torul and Zigana has been strongly altered. In some places sericitization and silicification is so strong that original rock cannot be indentified. Also some zones of contact with granodiorite are altered, particularly D1 is strongly argillized.

1-6 Geologic Structure

The geologic structure of the surveyed area is largely controled by E-W thrusts and NE-SW fold structure.

Faults: The Gümüşhane Thrust extends in NWN-SES direction through the central part of the area. To the south of this thrust, Kurtoglu Metamorphics and Gümüşhane Granite are exposed over a wide area, these are both basement rocks. The Gümüşhane Thrust forms the boundary of the two zones. On the other hand to the north of the thrust, the geology is characterized by the Upper Cretaceous Zigana Formation. Small thrusts are also found, one extends in ENE-WSW and occur near the Asağitezene Village. This thrust dips northward at about 40° and is the boundary of Kurtoglu Metamorphics and Kırıklı Formation. The Gümüşhane Thrust cuts through the Venk Yayla Formation, and as the younger granodiorite has intruded along this fault, it is inferred that it was formed sometime between late Eocene to Miocene.

Fold structure: The gologic units generally dip northward at low angles with gentle undulation in the northern half of the area. The axes of the fold trend in NE-SW, NNE-SSW and NW-SE. NE-SW is particularly conspicuous and the younger granodiorite has intruded in this direction.

In the southern half of the area, the main trend of the folds are NEN-SES, the direction of the Gümüshane Trust. Other faults are found in the southern part where Kirikli Formation and Kusakkaya Limestone Formation are developed and these are mostly NW-SW, NE-SW trending with less than 100m displacement.

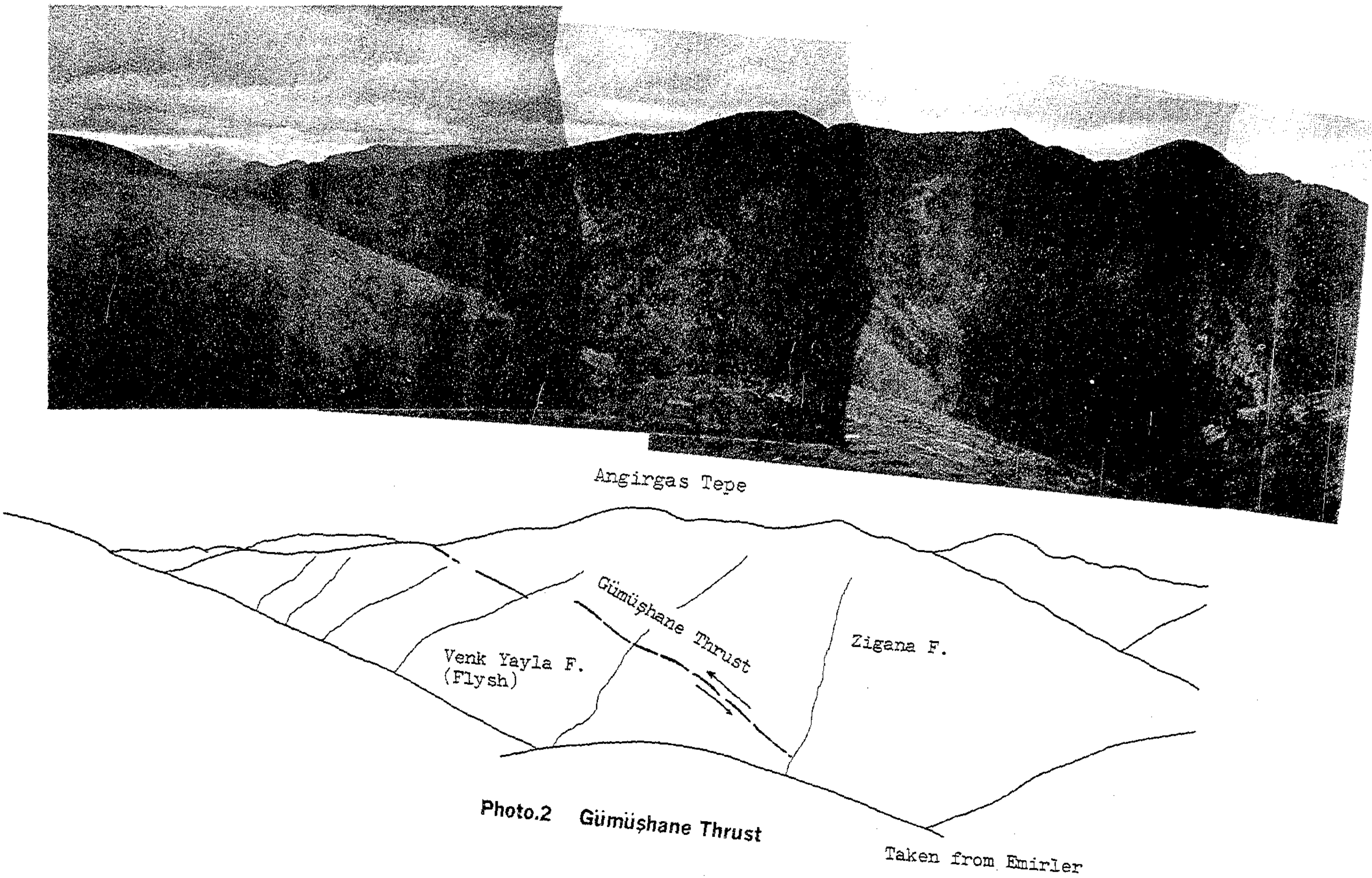


Photo.2 Gümüşhane Thrust

1-7 Age Determination

The granites of the surveyed area are largely divided into old granites which intruded befor Jurassic, namely the Gümüshane Granite and the young granodiorite whichintruded from Cretaceous to Tertiary, namely Torul, Kürtün, Kopuz, Hasandere Granodiorites. The age of the old granites was inferred to be 300 Ma and that of the young granodiorites to be 100 Ma. The former was determined by Rb-Sr method and the latter by K-Ar method.

(1) Rb-Sr method

Samples for age determination were collected at two localities. One at Gümüshane City along National Highway 65 (Sample No. H-1, 5, 7. H series), this locality lies on the northern side of the Gümüshane Granite Body. The other at Karamustafa (Sample No. A-2, 3, 5. A series), this locality lies on the southerrn side of the granite body. Efforts were made to obtain samples of fresh rocks and those of different lithology were collected from the same rock body. This granite is two mica granite and although the appearance by unaided eyes are fresh, the detailed examination under microscope showed it to be altered. For example, the margins of amphiboles and biotite are replaced by chlorite and epidote, and plagioclase is partly sericitized. Also the ratio of the constituent minerals of each sample varied considerably. The collected samples were dated by Teledyne Isotope Inc. USA. The result of the measurements are as follows.

	Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
H-1	183.5ppm	74.1ppm	7.20	0.74999± 0.00005
H-5	163.5ppm	95.2ppm	4.99	0.73721± 0.00009
H-7	143.2ppm	140.9ppm	2.95	0.71965± 0.00006
A-2	138.3ppm	97.8ppm	4.10	0.72695± 0.00009
A-3	141.6ppm	103.7ppm	3.96	0.72721± 0.00013
A-5	143.2ppm	105.0ppm	3.96	0.72630± 0.00010

Figure 7 is the computor graphic of this result.

The $^{87}Rb/^{86}Sr$ values of H series varies while those of the A series samples are relatively constant. The age of H series from isochron obtained by the least square method is 533Ma, but in this case the initial isotope ratio becomes 0.6975 and is too low for the age to be credible.

The samples of A series have different lithology, but the values are similar. These values should be significant, but the age calculated using the measurements of both A and H series becomes 535 Ma (Fig.7). In this case the initial values are again very low, 0.6968 and thus is not correct. The values of two points N-1 and H-5 are not necessarily conclusive, the calculation shows the initial value to be 0.7084 and the age 406 Ma, Early Devonian.

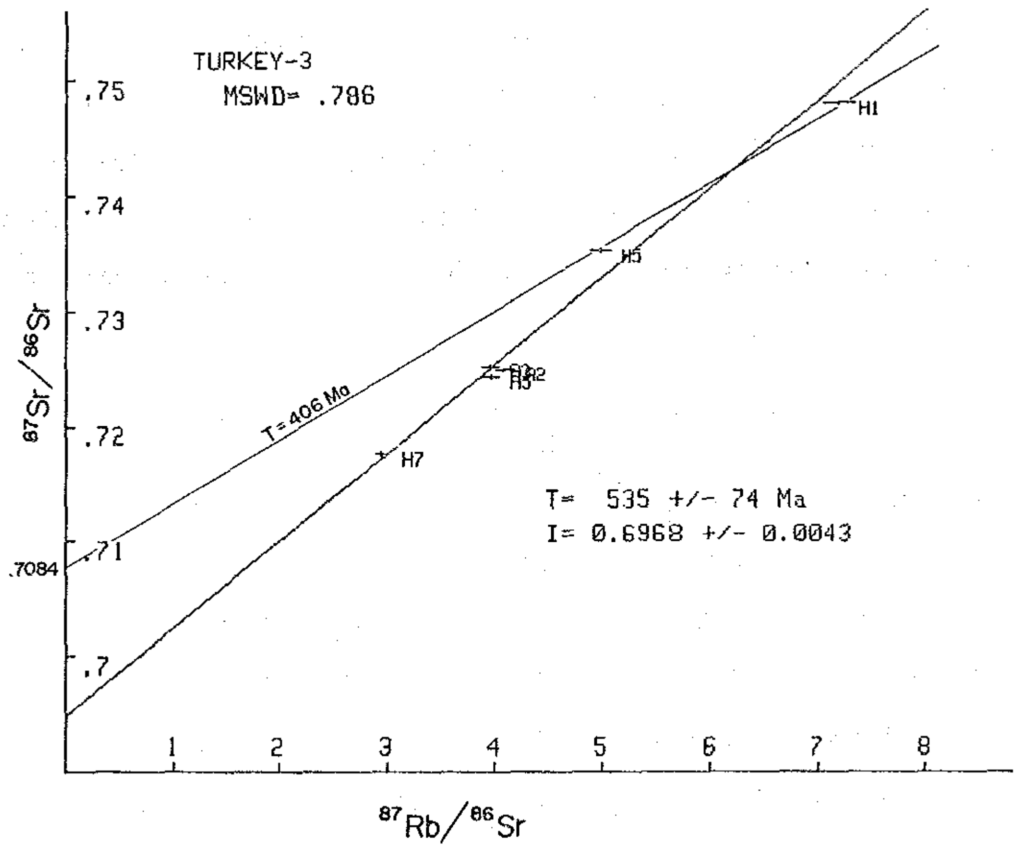


Fig. 7 Result of Rb-Sr Age Determination in Gumushane Granite

In the past, age determination by U-Th/Pb method has been attempted for this granite body and the result was 298, 338 Ma a carboniferous intrusion. The plutonic intrusive bodies of this period is considered to be those of Hercynian Orogeny and the age should be Devonian, but the determination showed younger age. The reason for this age discrepancy probably is the result of some kind of isotopic disequilibrium within the granite body which caused variations in the initial values of the isochron.

(2) K-Ar method

The samples were collected from the granodiorite mass at Torul (Sample No. M-30), Kürtün (Sample No. S-69), Kopuz (Sample No. T-1).

Sample No.	40Ar* (Sec/gm $\times 10^{-5}$)	%40Ar*	%K
M-30	0.450 ,0.474	93.0 ,94.7	2.72, 2.73
S-69	0.561 ,0.590	74.1 ,74.5	2.12, 2.13
T-1	0.881 ,0.915	88.5 ,88.2	3.13, 3.15

Ar*;Radiogenic Argon

The calculated ages are

Torul Granodiorite	72.1±3.6Ma	Upper Cretaceous
Kürtün Granodiorite	68.4±3.4Ma	Upper Cretaceous
Kopuz Granodiorite	43.1±2.2Ma	Middle Eocene

The decay constants used are

$\lambda_e = 0.581 \times 10^{-10} / y$, $\lambda_\beta = 4.962 \times 10^{-10} / y$.

The Torul and Kürtün Granodiorite were emplaced during the Upper Cretaceous. This indicates that these bodies intruded at the latest stage of the Upper Cretaceous marine volcanism. On the other hand, Kopuz Granodiorite intruded in Eocene time. Thus granodiorite intrusion occured from Mesozoic to Tertiary in the Pontids Fold belt and these bodies are widely distributed. The age of the rocks distributed at Tatos northeast of Torul has also been determined by K-Ar method with the result of 30-80 Ma, mid-Alpine orogeny. This is correlated to the Laramide phase of North America. The intrusion of the host rocks of the major porphyry copper deposits of North America is 54-72 Ma (K-Ar), similar period.

1-8 Whole Rock Analysis

A total of 30 rock samples representing the surveyed area were chemically analysed, namely 9 old granites, 10 young granodiorites and 11 Jurassic to Eocene volcanic rocks. Analysis were made for 12 elements including a minor constituent Ba. Potassium permanganate titration was used for FeO determination and X-ray fluorescence and atomic absorption were applied for other elements. The results of the analysis together with normative minerals, differentiation index (DI) and solidification index (SI) are shown in Table 1.

All analysed samples were microscopically studied. Some of the granite samples were used for radiometric age determination.

(1) Granites

The chemical composition of the old granites and young granodiorites were studied as shown in the diagrams of Figures 8-14. The results are summarized as follows.

a) The old granite occupies an area of higher of than the young granite in the norm quartz-plagioclase-orthoclase diagrm, in other words, it is quartz monzonite of the Bateman et al (1963) classification. The young granite occupies the granodiorite range.

b) Both granites have distinctive compositional range as shown in the DI-oxide diagram.

	Old Granite	Young Granodiorite
DI	82~91	60~78
SiO_2	71~75	61~69
MgO	0.3~ 1.2	1.1~ 2.6
CaO	0.5~ 1.8	2.0~ 5.4

c) Similar trend appears in the CaO-alkali ratio with the young granodiorite in the high CaO field (Fig.11).

Recently, genetic classification of granitic rocks has been proposed by Chappell and

White (1974) and Ishihara (1977). Chappell and White (1974) uses Na_2O content, $Al_2O_3/(Na_2O+K_2O+CaO)$ mol ratio, normative diopside and corundum values are used as basis for the classification. In this classification, both granites of this area belong to the I-type. Also the low $^{87}Sr/^{86}Sr$ initial value indicates I-type for the old granites.

Ishihara (1977) classified granites on the basis of the mode content of opaque minerals and the Fe_2O_3/FeO ratio. The opaque minerals have not been studied under reflected light, but from the mode content and the Fe_2O_3-FeO diagram (Fig.12), the young granodiorite is inferred to be of the magnetite series. There are some old granites with low Fe_2O_3/FeO ratio, but they are inferred to belong to the magnetite series from the initial strontium values and the amount of opaque mineral.

Generally the magnetite series granite is characterized by Mo and those of ilmenite series by Sn. The fact that these granites belong to the magnetite series support that no greisenization accompanied by Sn occurs in the area.

(2) Volcanic rocks

The volcanic rocks of the Venk Yayla Formation belong to the andesite-dacite field of the SiO_2-Na_2O-K_2O diagram (Fig.9). The andesite-dacite of the Zigana Formation lie in the rhyolite field, but this probably is the result of the increase of SiO_2 by alteration. Also the characteristics of basalt of Zigana Formation and basaltic andesite of Kırıklı Formation is the relatively high alkali (Na_2O+K_2O) content, but strong alteration is observed microscopically and thus it will not be discussed in detail here.

Also MFA diagram (Fig.10) and SiO_2-$FeO*/MgO$ diagram (Fig.13) indicate the volcanic rocks of Venk Yayla Formation to be of the calc-alkaline series.

(3) Barium

Barium, due to the similarity of the ionic radius, behaves in a similalr manner with potassium and often is a constituent of biotite and potassium feldspar. Therefore, the relation of the element with SiO_2, K_2O and DI was studied and the result is shown in figure 15.

The result is summarized as follows.

a) Granites contain larger amount of Ba than volcanic rocks excent for those of Venk Yayla.

b) The Ba content of old granites vary widely from 200-1,000ppm while that of young granites lies in a relatively narrow range.

c) In granites, no correlation between Ba and SiO_2, K_2O was observed while Ba increases rapidly with high DI values.

d) Volcanic rocks can be divided into high and low Ba groups. Those of Venk Yayla Formation have high Ba content and positive correlation between Ba and SiO_2, K_2O, DI is observed while the volcanic rocks of Zigana and Kırıklı Formation have low Ba content and the relation between Ba and SiO_2, K_2O, DI is not clear.

Table 1 Chemical Analyses and CIPW Norms for Granitic Rocks and Volcancis (1)

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sample No.	H-1	H-3	H-5	H-6	H-7	A-2	A-3	A-5	T-107	E-198	S-69	E-3	M-30	H-141	Y-2
SiO_2	71.47	74.88	70.85	71.28	71.30	71.30	72.35	70.45	73.05	61.42	74.79	68.02	61.69	61.05	68.47
TiO_2	0.29	0.24	0.37	0.34	0.31	0.33	0.31	0.29	0.29	0.61	0.24	0.38	0.62	0.54	0.38
Al_2O_3	15.08	13.36	14.59	14.47	13.94	15.17	14.42	14.88	14.65	15.97	13.17	15.30	16.76	16.83	14.93
Fe_2O_3	0.62	0.55	0.25	0.01	0.40	1.37	0.01	1.42	0.18	2.04	0.75	1.18	2.22	0.70	1.49
FeO	1.09	0.82	1.72	2.44	2.11	0.11	1.82	1.23	1.48	3.74	1.16	2.12	3.23	4.74	1.57
MnO	0.07	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.07	0.10	0.08	0.10	0.10	0.13	0.10
MgO	0.45	0.43	0.69	1.23	0.83	0.29	0.45	0.50	0.42	2.63	0.69	1.31	2.46	2.49	1.69
CaO	0.71	0.53	0.89	0.63	1.80	1.55	1.41	0.91	1.28	5.44	1.51	3.22	5.07	5.03	1.94
Na_2O	4.39	3.52	3.81	3.40	3.63	3.89	3.70	4.55	3.85	2.79	4.36	3.36	3.39	3.31	3.99
K_2O	5.12	4.08	5.41	4.11	3.82	3.81	4.00	4.87	4.10	3.71	2.47	4.46	3.72	4.26	2.96
P_2O_5	0.25	0.20	0.31	0.08	0.06	0.07	0.06	0.05	0.05	0.14	0.05	0.10	0.13	0.17	0.09
$H_2O(+)$	0.58	0.83	0.80	1.76	1.61	1.07	0.87	0.85	0.73	1.62	0.49	0.59	0.86	0.46	1.84
$H_2O(-)$	0.12	0.15	0.14	0.22	0.16	0.37	0.22	0.26	0.09	0.21	0.25	0.06	0.17	0.14	0.19
Total	100.24	99.66	99.91	100.04	100.05	99.40	99.69	100.34	100.24	100.42	100.01	100.20	100.42	99.85	99.64
Ba (ppm)	299	184	274	998	714	656	561	612	960	999	405	877	1001	897	1082
Q	24.33	37.22	24.79	30.97	29.19	30.54	30.65	22.45	30.72	15.11	35.28	22.10	13.12	9.23	26.96
C	1.62	2.67	1.59	3.47	0.70	2.00	1.58	0.59	1.67	–	0.70	–	–	–	1.85
or	30.26	24.11	31.97	24.29	22.58	22.52	23.64	28.78	24.23	21.93	14.60	26.36	21.98	25.18	17.49
ab	37.15	29.79	32.24	28.77	30.72	32.92	31.31	38.50	32.58	23.61	36.89	28.43	28.69	28.01	33.76
an	1.89	1.32	2.39	2.60	8.54	7.23	6.60	4.19	6.02	20.09	7.16	13.49	19.53	18.48	9.04
ne	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
di wo	–	–	–	–	–	–	–	–	–	2.50	–	0.76	1.99	2.24	–
di en	–	–	–	–	–	–	–	–	–	1.43	–	0.42	1.23	1.01	–
di fs	–	–	–	–	–	–	–	–	–	0.95	–	0.32	0.65	1.22	–
hy en	1.12	1.07	1.72	3.06	2.07	0.72	1.12	1.25	1.05	5.12	1.72	2.84	4.90	5.19	4.21
hy fs	1.14	0.78	2.49	4.04	3.18	–	2.95	0.76	2.22	3.41	1.26	2.16	2.61	6.26	1.21
ol fo	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ol fa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
mt	0.90	0.80	0.36	0.01	0.58	–	0.01	2.06	0.26	2.96	1.09	1.71	3.22	1.01	2.16
hm	–	–	–	–	–	1.37	–	–	–	–	–	–	–	–	–
il	0.55	0.46	0.70	0.65	0.59	0.38	0.59	0.55	0.55	1.16	0.46	0.72	1.18	1.03	0.72
ru	–	–	–	–	–	0.22	–	–	–	–	–	–	–	–	–
ap	0.58	0.46	0.72	0.19	0.14	0.16	0.14	0.12	0.12	0.32	0.12	0.23	0.30	0.39	0.21
S.I.	3.86	4.57	5.81	10.99	7.69	3.06	4.51	3.98	4.19	17.64	7.32	10.54	16.38	16.06	14.44
D.I.	91.74	91.12	89.00	84.03	82.48	85.97	85.60	89.73	87.53	60.65	86.77	76.89	63.79	62.42	78.21

Rock Name	Geological Unit	Locality
1. Biotite-hornblende quartz monzonite	Gümüşhane Granite	Gümüşhane
2. Biotite-muscovite quartz monzonite	ditto	ditto
3. Biotite-muscovite quartz monzonite	ditto	ditto
4. Muscovite quartz monzonite	ditto	Southeast of Gümüşhane
5. Biotite quartz monzonite	ditto	ditto
6. Biotite quartz monzonite	ditto	Midi
7. Biotite quartz monzonite	ditto	ditto
8. Biotite quartz monzonite	ditto	ditto
9. Biotite quartz monzonite	ditto	West of Altıntaşlar
10. Hornblende granodiorite	Younger Granitic rocks	Çami (A area)
11. Biotite granodiorite	ditto	Ikibaca
12. Hornblende quartz monzonite	ditto	Sarısaman
13. Biotite-muscovite quartz monzonite	ditto	Demircıköy
14. Hornblende-biotite granodiorite	ditto	West of Ayasar Tepe
15. Porphyritic granodiorite	ditto	Maden dere(Hasendere area)

Table 1 Chemical Analyses and CIPW Norms for Granitic Rocks and Volcancis (2)

No.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Sample No.	H-38	T-1	E-202	E-201	H-31	H-108	E-204	E-205	E-158	Y-70	M-74	E-113	A-172	A-173	E-203
SiO_2	67.53	69.43	69.31	78.88	69.09	63.10	57.58	47.88	48.35	71.30	79.26	83.52	51.38	49.87	50.28
TiO_2	0.38	0.37	0.32	0.12	0.31	0.47	0.56	1.59	0.59	0.31	0.13	0.12	0.83	0.70	1.37
Al_2O_3	15.86	15.21	14.07	13.36	15.42	16.63	16.65	19.35	17.51	12.89	11.47	8.97	17.11	15.53	16.59
Fe_2O_3	1.32	1.06	1.52	0.01	1.08	2.31	3.59	5.23	1.81	1.19	1.34	0.19	4.39	4.26	6.74
FeO	2.05	1.68	1.64	0.79	0.54	2.32	2.83	4.45	6.81	2.53	0.62	0.69	3.53	4.09	2.54
MnO	0.10	0.12	0.11	0.05	0.08	0.11	0.13	0.09	0.13	0.16	0.06	0.06	0.10	0.14	0.20
MgO	1.32	1.14	1.38	0.52	0.70	2.40	3.73	7.04	5.95	1.75	0.60	0.46	3.84	4.37	6.55
CaO	3.51	2.96	4.42	0.01	0.69	5.54	8.34	6.73	5.11	0.97	0.01	0.14	8.93	10.61	3.45
Na_2O	3.84	3.52	2.90	0.41	5.24	3.60	3.17	4.12	4.87	4.69	0.43	2.23	2.80	4.52	6.30
K_2O	3.68	3.67	3.03	3.80	5.41	2.39	1.11	2.06	1.05	1.10	3.47	1.32	0.46	0.67	0.75
P_2O_5	0.11	0.09	0.07	0.01	0.07	0.15	0.18	0.31	0.08	0.07	0.02	0.01	0.11	0.09	0.30
$H_2O(+)$	0.54	0.45	1.54	1.94	0.96	0.95	2.06	1.23	6.96	2.31	2.63	1.91	5.73	4.40	4.99
$H_2O(-)$	0.09	0.17	0.24	0.07	0.32	0.09	0.58	0.21	0.46	0.16	0.03	0.45	1.16	0.98	0.29
Total	100.33	99.87	100.55	99.97	99.91	100.06	100.51	100.29	99.68	99.43	100.30	100.07	100.37	100.23	100.35
Ba (ppm)	1093	949	802	634	1492	881	804	204	221	139	108	102	192	168	135
Q	21.24	26.29	29.95	62.04	15.67	18.11	13.91	-	-	33.75	64.32	64.07	10.36	-	-
C	-	0.28	-	8.76	-	-	-	-	-	2.39	7.23	3.64	-	-	-
or	21.74	21.69	17.91	22.81	31.97	14.12	6.56	12.17	6.21	6.50	20.59	7.80	2.72	3.96	4.43
ab	32.49	29.79	24.54	3.14	44.34	30.46	26.82	28.88	38.42	39.69	3.67	18.87	23.69	33.93	51.95
an	15.17	14.10	16.42	-	2.57	22.16	27.92	28.22	22.82	4.35	-	0.63	32.67	20.02	14.77
ne	-	-	-	-	-	-	-	3.24	1.51	-	-	-	-	2.34	0.74
di wo	0.64	-	2.11	-	0.16	1.81	5.13	1.31	0.84	-	-	-	4.52	13.34	0.16
di en	0.36	-	1.38	-	0.14	1.28	3.93	1.07	0.48	-	-	-	3.45	9.48	0.14
di fs	0.25	-	0.58	-	-	0.38	0.65	0.08	0.33	-	-	-	0.60	2.69	-
hy en	2.93	2.84	2.05	1.30	1.60	4.70	5.36	-	-	4.36	1.50	1.15	6.12	-	-
hy fs	1.99	1.82	0.86	1.45	-	1.40	0.89	-	-	3.45	0.13	1.02	1.07	-	-
ol fo	-	-	-	-	-	-	-	11.54	10.05	-	-	-	-	0.99	11.34
ol fa	-	-	-	-	-	-	-	1.01	7.68	-	-	-	-	0.31	-
mt	1.91	1.54	2.20	-	1.10	3.35	5.20	7.58	2.62	1.72	1.85	0.28	6.36	6.18	4.87
hm	-	-	-	-	0.32	-	-	-	-	-	-	-	-	-	3.38
il	0.72	0.70	0.61	0.46	0.59	0.89	1.06	3.02	1.12	0.59	0.15	0.23	1.58	1.33	2.60
ru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ap	0.25	0.21	0.16	-	0.16	0.35	0.42	0.72	0.19	0.16	-	0.02	0.25	0.21	0.70
S.I.	10.81	10.30	13.18	9.40	5.40	18.43	25.85	30.74	29.04	15.54	9.29	9.41	25.57	24.40	28.63
D.I.	75.48	77.77	72.40	87.99	91.98	62.70	47.30	44.30	46.14	79.94	88.58	90.74	36.77	40.23	57.12

Rock Name	Geological Unit	Locality
16. Hornblende granodiorite	Younger Granitic rocks	Aşàğı
17. Hornblende-biotite granodiorite	ditto	Kopuz
18. Hornblende granodiorite	ditto	Karadağ area
19. Muscovite quartz porphyry	Dyke	ditto
20. Augite-hornblende dacite	Venk Yayla Formation	Topcatı
21. Biotie-hyperthene-augite-hornblende dacite	ditto	Southeast of Hıdrellez
22. Qz bearing hyperthene-biotite-augite-hornblende andesite	ditto	Kodil
23. Basalt	Zigana Formation	Avliyana
24. Basalt	ditto	North of Evliya Tepe
25. Andesite (altered)	ditto	Çalman
26. Dacite (altered)	ditto	Soğuksu Dere (A area)
27. Dacite (altered)	ditto	Zıyaret Tepe
28. Basaltic andesite	Kırıklı Formation	Kırıklı
29. Hyperthene-augite basaltic andesite	ditto	Yeniköy
30. Basaltic andesite	ditto	Loncunos

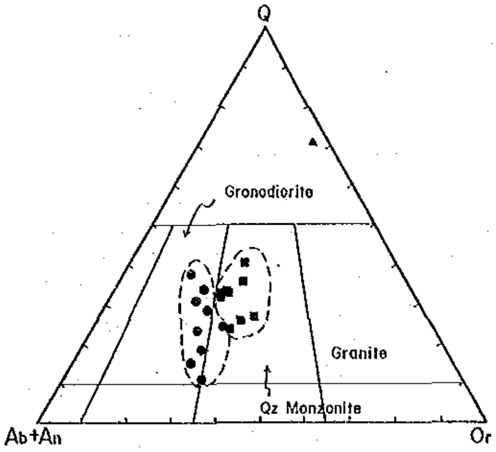


Fig. 8 * Classification of Granitic Rocks

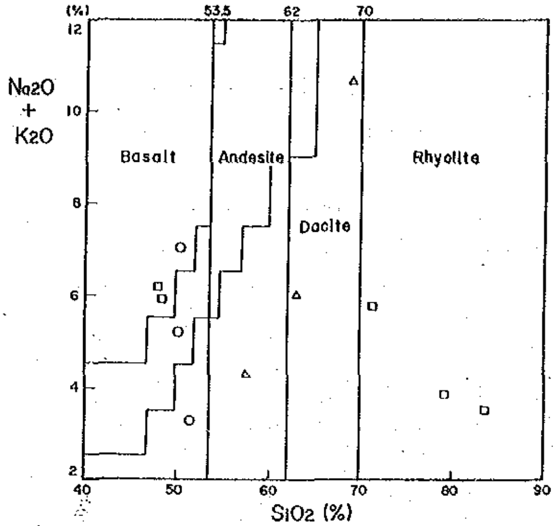


Fig. 9 * Classification of Volcanics

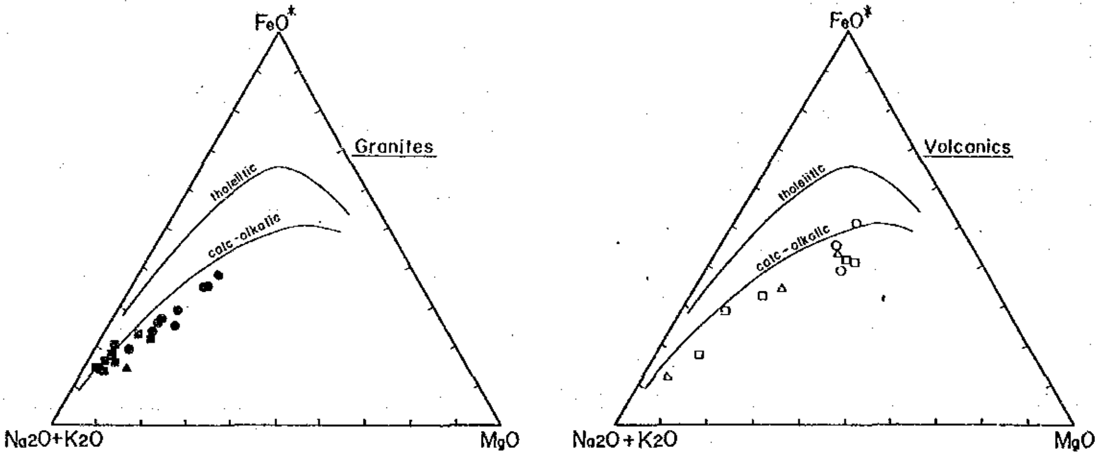


Fig.10 * MFA Diagrams.

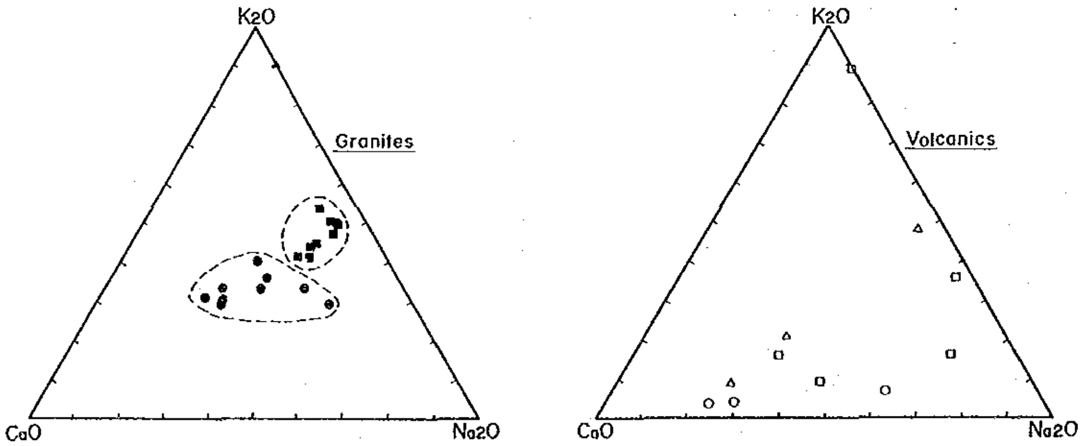
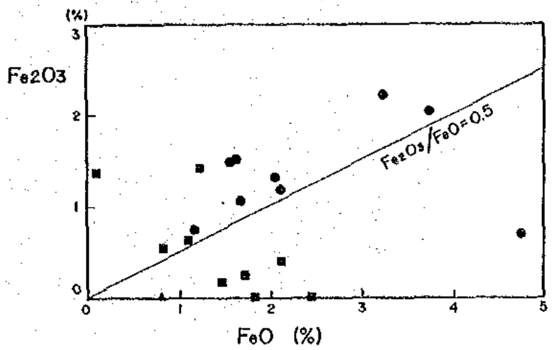


Fig.11 * $CaO - Na_2O - K_2O$ Diagrams

* Simbols in each figure are same : See in Fig. 15.



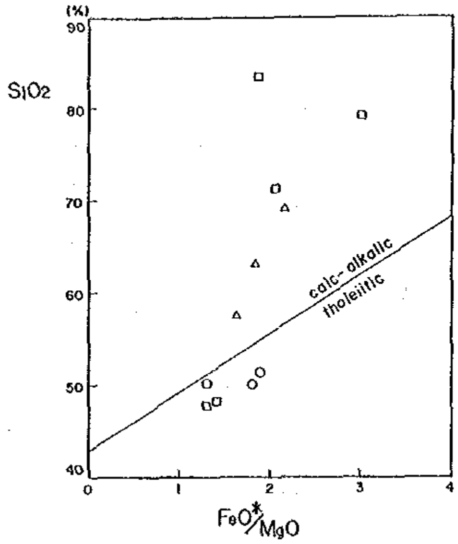


Fig.12 * Fe_2O_3 - FeO Diagram for Granitic Rocks

Fig.13 * SiO_2 - FeO * /MgO Diagram for Volcanics

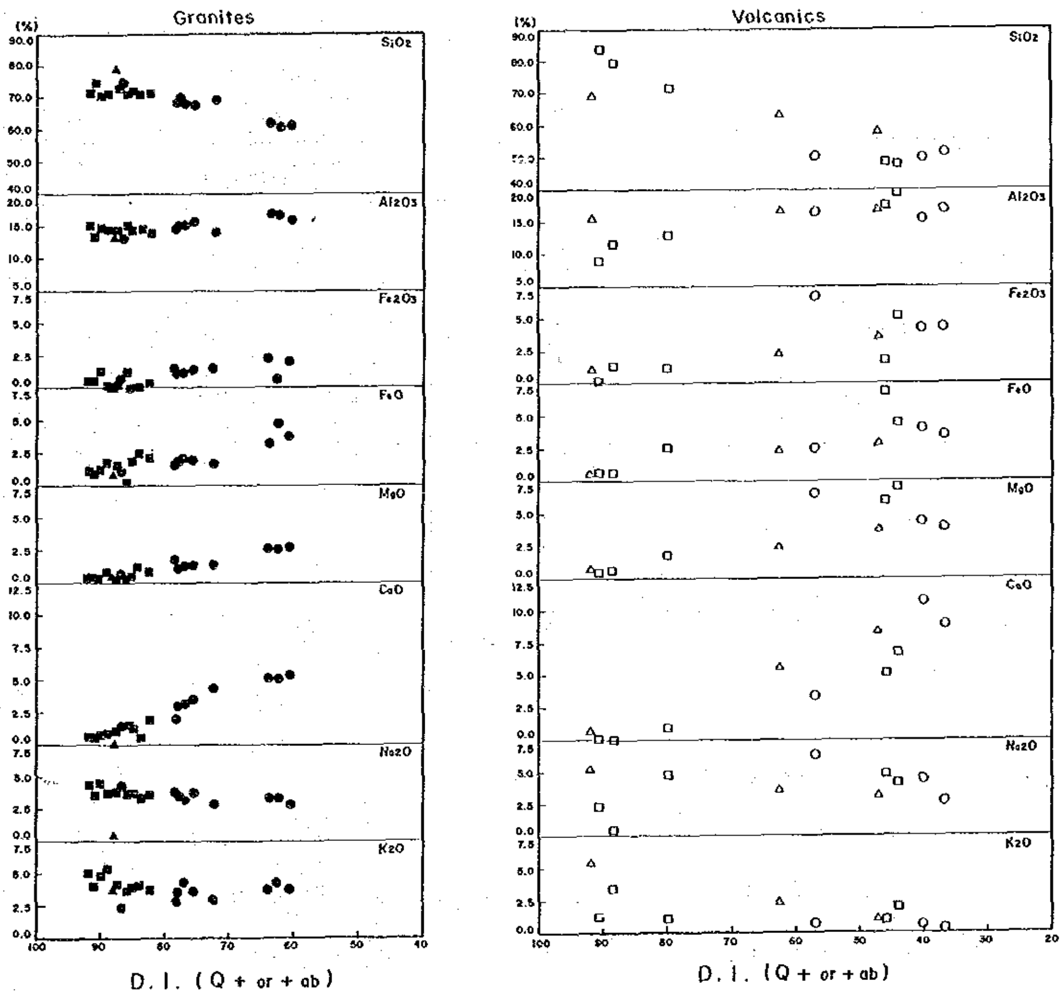
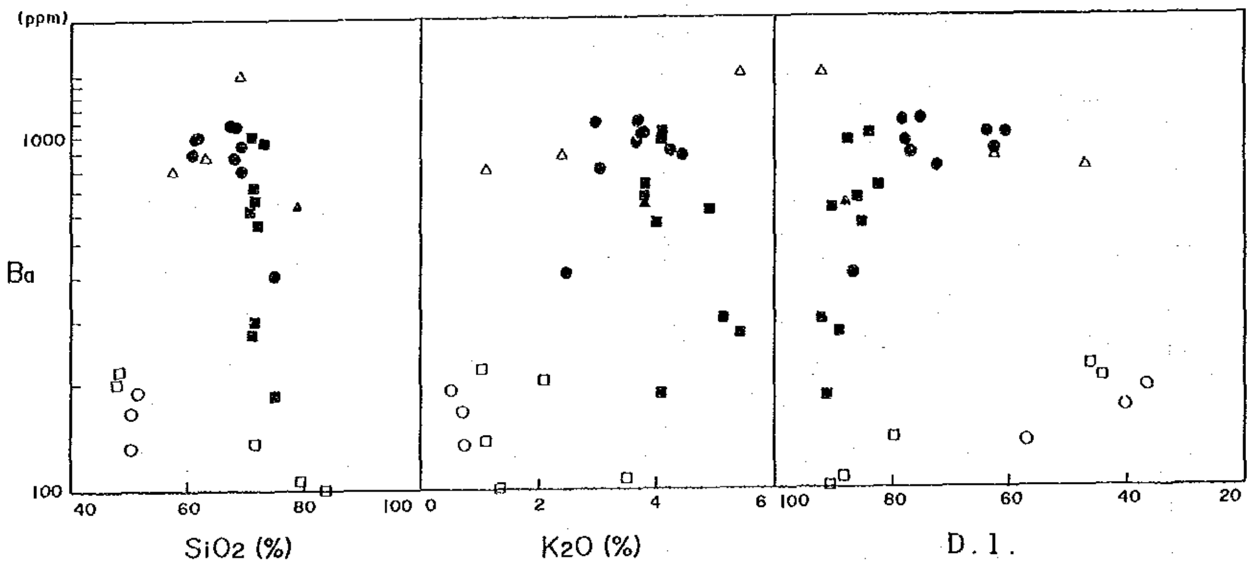


Fig.14 * Variations Diagrams (DI - Oxides)

*** Simbols in each figure are same : See in Fig. 15.**



Symbols (Same as in Fig. 8 ~ Fig.14)

■ : Gümüşhane Granite

● : Younger Granitic rocks

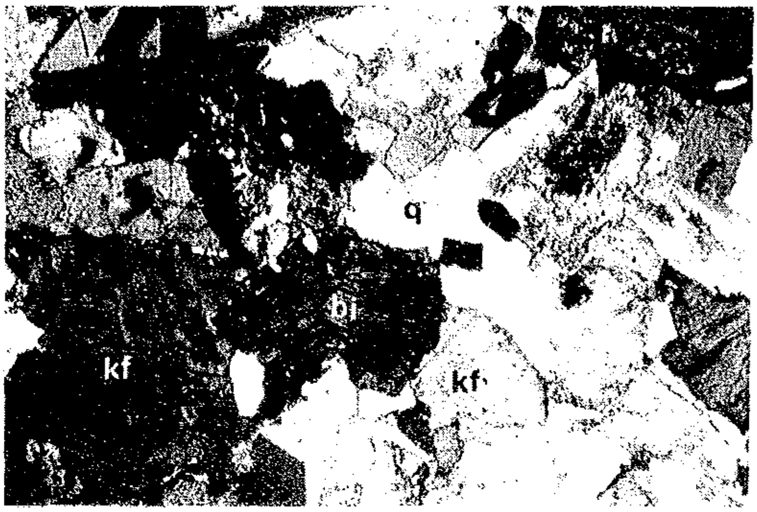
▲ : Quartz porphyry dyke

△ : Venk Yayla Formation

□ : Zigana Formation

○ : Kırıklı Formation

Fig.15 Variation of Ba contents with SiO_2, K_2O and DI



Sample No.: A-2
Locality: Midi
Rock Name: Gümüşhane Granite
(Biotite quartz monzonite)

q: quartz
kf: K-feldspar
bi: biotite
Cross nicols

0 1mm

Sample No.: E-198
Locality: Çami
Rock Name: Younger Granitic Rocks
(Hornblende grano-diorite)

q: quartz
kf: K-feldspar
ho: hornblende

Open nicol

0 1mm

Sample No.: H-31
Locality: Topcatı
Rock Name: Venk Yayla Formation
(Augite-hornblende dacite)

pl: plagioclase
ho: hornblende

Open nicol

0 1mm

Photo.3 Microscopic photograph