REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE SOUTH BATINAH COAST AREA
SULTANATE OF OMAN

(PHASE I)

MARCH 1998

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Sultanate of Oman, the Japanese Government decided to conduct a Mineral Exploration Project in South Batinah Coast Area and entrusted the project to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

JICA and MMAJ sent to Oman a survey team headed by Mr. Yoshiaki Shibata from August 17, 1997 to January 9, 1998.

The team exchanged views with the officials concerned of the Government of Oman and conducted a field survey in the South Batinah Coast area. After the team returned to Japan, further studies were made and present report has been prepared. This report includes the survey results of geological, geophysical and drilling surveys in Phase I.

We hope that this report will serve for the development of the mineral resources and contribute to the promotion of friendly relations between Japan and Oman.

We wish to express our deep appreciation to the officials concerned of the Government of Oman for their close cooperation extended to the team.

March, 1998

Kimio Fujita
President
Japan International Cooperation Agency

Hiroaki Hiyama
President
Metal Mining Agency of Japan

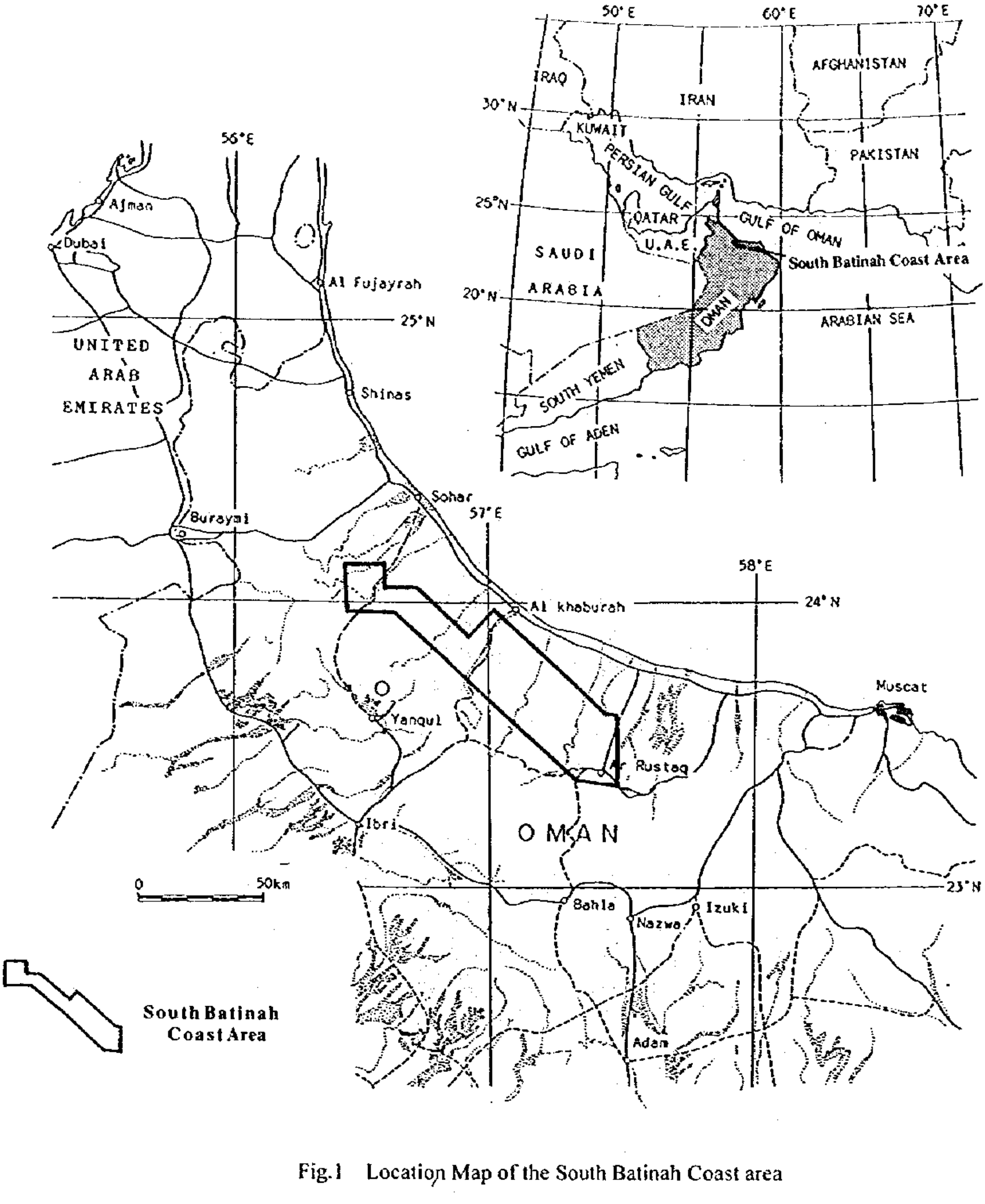

Fig.1 Location Map of the South Batinah Coast area

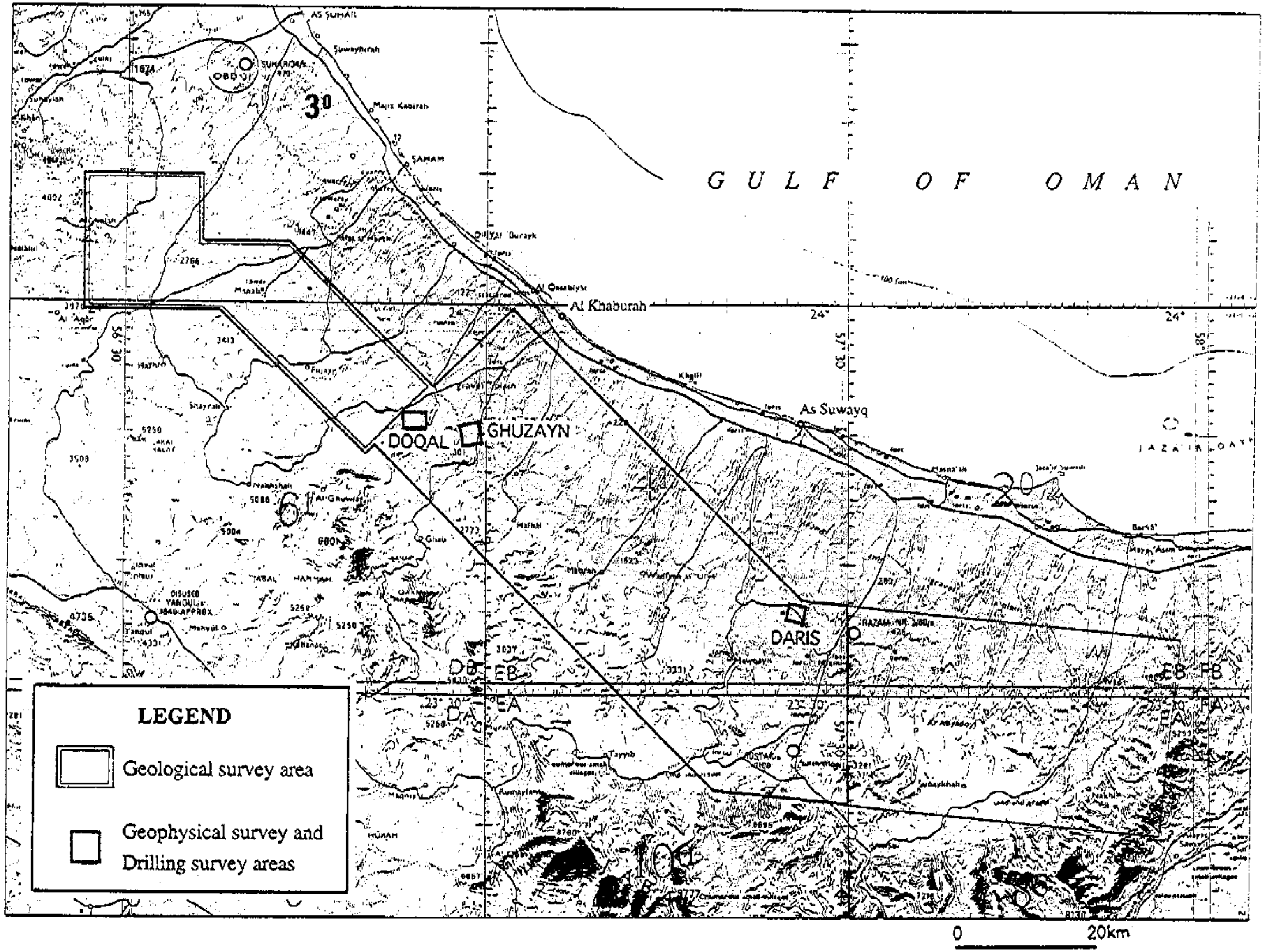

Fig.2 Location map of the survey areas

ABSTRACT

The Government of Sultanate of Oman and the Government of Japan agreed to conduct a mineral exploration project in the South Batinah Coast area. The Scope of Work for this project was signed by both governments on 17th July,1997. The objective of this project is to explore and assess the mineral potential of the survey area. This report includes the survey results of the first year (Phase I).

In the area under study, several exploration works have been already carried out mostly near the known mineral occurrences, however, other areas have been only partially explored because of wide coverage of Quaternary deposits.

The Cooperative Mineral Exploration Project conducted previously in the Central Batinah Coast was successful to discover massive sulphide ore bodies in two locations in Ghuzayn area, showing that the Batinah Coast area presents high potential for bearing massive deposits.

During the phase I of the present project and based on the recommendations of the previous project, geophysical surveys by using the TDIP and TEM methods as well as drilling survey were carried out in the areas of Ghuzayn, Doqal and Daris located in the south-eastern part of the project area. In order to expand the information of the area for further investigation, a detailed geological survey was conducted around known mineral showings in the north-western part of the project area.

The TDIP and TEM geophysical methods successfully detected a remarkable anomaly in Wadi Hawasina. To confirm the nature of this anomaly, all of the four boreholes drilled on this zone intersected a massive sulphide ore body (Ghuzayn ore body No. 3). The borehole MJOB-G30 revealed a very long ore core of 91.4m in length and an average high Cu grade of 2.68%. In the remaining three boreholes, the ore length in their cores were: 72m in G31, 39.65m in G32 and 16.45 in G33.

Further investigation was also conducted in Ghuzayn ore body No. 2. From the seven drilled boreholes, five of them intersected massive sulphide. According to these studies, it is inferred that the ore body No. 2 has an approximate extension of 400m along the north-south direction and about 200m along the east-west direction. Estimated ore reserves resulted in 5 million tons with an average Cu grade of 1.2%.

As a results of the geological survey conducted around fourteen mineral showings in the north-western part of the project area, the area between Hara Kilab and Mahab gave indication of being a promising area for massive sulphide deposits. Ancient mines as well as intense alteration due to silicification and epidotization are seen in this area.

Interesting mineralization features were also found in two locations to the west and south of the TDIP geophysical survey in Ghuzayn area.

Based on the results obtained during the phase I of this project, the following works are recommended for the Phase II of this project:

1. Geophysical and drilling surveys around Ghuzayn area in order to find sulphide mineralization
2. Geological, geophysical and drilling surveys around Mahab area to evaluate the existing mineralization of this area.

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PART I GENERAL

PART II SURVEY RESULTS

PART I GENERAL

CHAPTER 1 INTRODUCTION

1-1 Background and Objectives

This survey was carried out as a cooperative mineral exploration program in the South Batinah Coast area of Oman based on the Scope of Works agreed on 17th July, 1997 between the Government of Japan and the Government of the Sultanate of Oman.

The survey aimed at discovering new mineral deposits in the South Batinah Coast area by clarifying the geological setting and characteristics of mineral deposits.

Several exploration works were carried out in this area in and around the known mineralization zones with surface indications. However, these works were limited only to the vicinity of mineralization zones and in view of the whole area, very limited portions were merely explored. This is caused by the fact that the area is covered by Quaternary sediments in very wide range. Therefore, it is important subject for exploration in this area to know how to investigate systematically the underlying part of the sediments.

The previous Cooperative Mineral exploration project carried out in the Central Batinah Coast area from 1995 to 19976, revealed that the project area has a high potential for bearing massive sulphide deposits. During that period, two ore bodies were discovered and several interesting geophysical anomalies were detected in the areas of Ghuzayn, Doqal and Daris.

1-2 Coverage and Outline of Works

The South Batinah Coast area, the objective area of this survey, is located in the west of Muscat, the capital of the country, and lies between the Oman Mountains and the Gulf of Oman.

The survey area is shown in Figs. 1 and 2.

The massive sulphides distributed in Oman are of the Cyprus-type copper deposits. These deposits occur within the volcanic rocks conformed by basaltic pillow lava and associated to a stratigraphic control. The selection of potential areas for this kind of deposits can be achieved by first selecting the most suitable zones by tracing the pillow lava sequence by means of geological and airborne magnetic methods. The airborne magnetic method is useful to delineate demagnetized zones associated to mineralization.

The zones selected by the above methodology can be further investigated by appropriate ground geophysical methods in order to delineate in more detail areas with high potentiality. The results of the geophysical methods can be finally confirmed by a suitable exploratory drilling program. Fig. I-1-1 illustrates a flow diagram of the methodology utilized for the exploration of massive sulphide deposits in

Batinah Coast.

The surveys carried out during this phase included geophysical, drilling and geological surveys. Geophysical survey as well as drilling survey were conducted not only around the massive sulphide ore bodies discovered during the previous and present projects (ore bodies No. 1, 2 and 3) but also on the geophysical anomalies detected in the areas of Ghuzayn, Doqal and Daris.

Survey amounts carried out during this phase (1997) are indicated in Tables I-1-1 and I-1-2.

1-3 Members of the Project

The members of the project were as follows:

(1) Project planning and negotiation

Japanese Counterpart

Tadashi Ito	Metal Mining Agency of Japan
Kenji Seiyama	Ministry of Foreign Affairs
Hiroshi Shibasaki	Metal Mining Agency of Japan

Omani Counterpart

Mohammed bin Hussain Kassim	Ministry of Commerce and Industry
Hilal Mohamed Sultan Al-Azri	Ministry of Commerce and Industry
Salim Omer Abdullah Ibrahim	Ministry of Commerce and Industry
Salim Ali Al Rashidi	Ministry of Commerce and Industry

(2) Inspection of field work

Ken Yoshioka	Metal Mining Agency of Japan

(3) Field work

Japanese Counterpart

Yoshiaki Shibata	Team leader	Mitsubishi Materials Natural Resources Development Corp.
Masanori Furuno	Drilling survey	Mitsubishi Materials Natural Resources Development Corp.
Toshimasa Tajima	Geophysical Survey	Mitsubishi Materials Natural Resources Development Corp.
David Escobar	Geophysical Survey	Mitsubishi Materials Natural Resources Development Corp.
Takeharu Takahashi	Geophysical Survey	Mitsubishi Materials Natural Resources Development Corp.

Omani Counterpart

Salim Omer Abdullah Ibrahim	Director	Ministry of Commerce and Industry
Durair Ismail A'Shaikh	Geologist	Ministry of Commerce and Industry

1-4 Survey Period

The negotiation and field works were conducted in Oman during the following period:

Project planning and negotiation:	June 13, 1997 to June 22, 1997
Inspection of field work	November 13, 1997 to December 5, 1997
Drilling survey:	August 17, 1997 to January 9, 1998
Geophysical survey:	September 16, 1997 to January 2, 1998
Geological survey	October 21, 1997 to November 21, 1997

Table I-1-1 Content and amount of work of Phase I

CONTENT AND AREA		AMOUNT OF WORK	
1. Geophysical Survey		Total line length	Number of measurements
1) IP method	Ghuzayn area	23 km	780 points
	Doqal area	21 km	830 points
2) TEM method	Ghuzayn area	15.6 km	Total 581 points
	Doqal area	8.4 km	
	Daris area	4.2 km	
2. Drilling Survey		Total length	Grand total length
	Ghuzayn area	4,040.10 m	4,941.25 m
	Doqal area	550.65 m	
	Daris area	350.50 m	
3. Geological Survey		Survey area	Survey route
		20 km^2	15.5 km

Table I-1-2 Laboratory work in Phase I

LABORATORY WORK	AMOUNT
1. Geophysical Survey	
1) Resistivity and polarizability measurement	32 samples
2. Drilling Survey	
1) Thin section	30 samples
2) Polished Section	11 samples
3) X-ray diffraction analysis	21 samples
4) Chemical analysis	
ore assay (6 elements: Fe,Cu,Zn,Ag,Au,Pb)	427 samples
3. Geological Survey	
1) Thin section	6 samples
2) Polished Section	7 samples
3) X-ray diffraction analysis	19 samples
4) Chemical analysis	
ore assay (6 elements: Fe,Cu,Zn,Ag,Au,Pb)	60 samples

Flow for massive sulphide deposits exploration in Batinah Coast

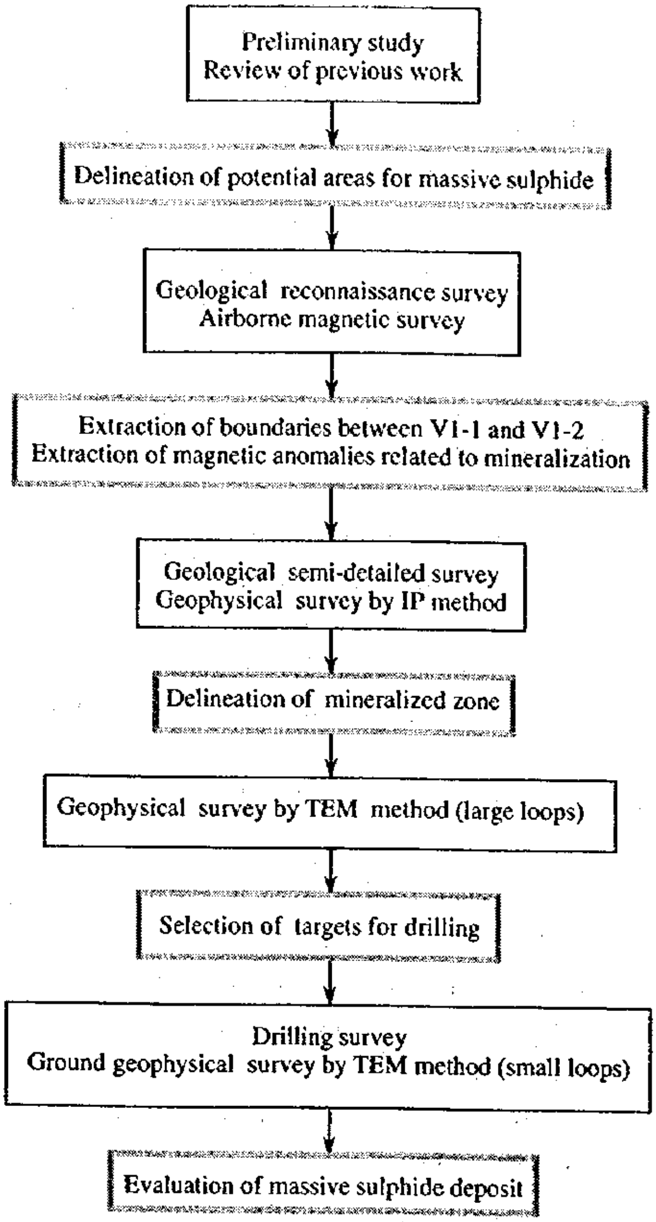


Fig. I -1-1 Flow for massive sulphide deposits exploration in Batinah Coast

CHAPTER 2 GEOGRAPHY OF THE SURVEY AREA

2-1 Location and Access

The Sultanate of Oman is situated in the southeast corner of the Arabian Peninsula with an area of about 300,000km^2. The population is approximately 2 millions and the capital city is Muscat (Fig. 1).

The survey area is located to the west of the capital city of Muscat and has an extension of about 2,900km^2 running parallel to the Oman Mountains and the Gulf of Oman. The center of the investigation area has approximately a latitude of 23° 50'N and a longitude of 57° 00'E. It takes about 2 hours by vehicle for 170 km driving along coast line from Muscat to Al Khaburah, near the central part of the survey area.

2-2 Topography and Drainage System

The survey area consists of a hilly land between an altitude of about 100m and 1,000m, forming the foot of the Oman Mountains and a coastal plain along the Gulf of Oman (Batinah Coast Plain).

Dry rivers, so-called wadis, run almost S-N in the Batinah Coast Plain from hilly land in the south to the Golf of Oman. Major wadis are in order from east to west: Wadi Hawqayn, Wadi Mabrah, Wadi Halhal, Wadi al Hawasinah, Wadi Shafan, Wadi Sarami, Wadi Sakhin and Wadi Hilti.

2-3 Climate and Vegetation

Climate of the Batinah Coast Plain is semi-dry type, though it presents high temperature and some humidity because it is separated from the desert region by the Oman Mountains. As the humidity coming from the sea is stopped by the Oman Mountains, usually rain falls in the mountain region in winter season. The infiltrated water from the rain is supplied to coastal plain, so that many kinds of vegetables are cultivated there in addition to the representative agricultural products of Oman such as lime, mango, tobacco, etc. However, excepting cultivated land, vegetation is very scarce and the vegetation of acacia, etc. is observed only in and around the wadis.

The temperature in summer season (April to October) averages 40° C and sometimes goes up to 50° C. Humidity is 40% during daytime but goes up to nearly 100% during night time. The average temperature in winter season (November to March) is approximately 25° C.

CHAPTER 3 GEOLOGY AND ECONOMIC GEOLOGY OF THE SOUTH BATINAH COAST AREA

3-1 General Geology

Geology of the project area according to 1: 250,000 geological map published by Ministry of Petroleum and Minerals, as shown in Fig.I-3-1, consists of Hawasinah Nappe and Samail Nappe assumed to have thrust over the Autochthonous to Parautochthonous units, Post-Nappe units and Quaternary sediments, which are distributed in this order from south to north.

Hawasinah Nappe is composed of the Late Permian to Jurassic Hamrat Duru Formation distributed in the north and central of the area, and of the Triassic Umar Formation cropping out in a limited way in the central part of the area. The Hamrat Duru Formation consists of quartz sandstone, shale, chert, limestone, basalt, andesite and keratophyre, and the Umar Formation consists of chert, limestone and breccia.

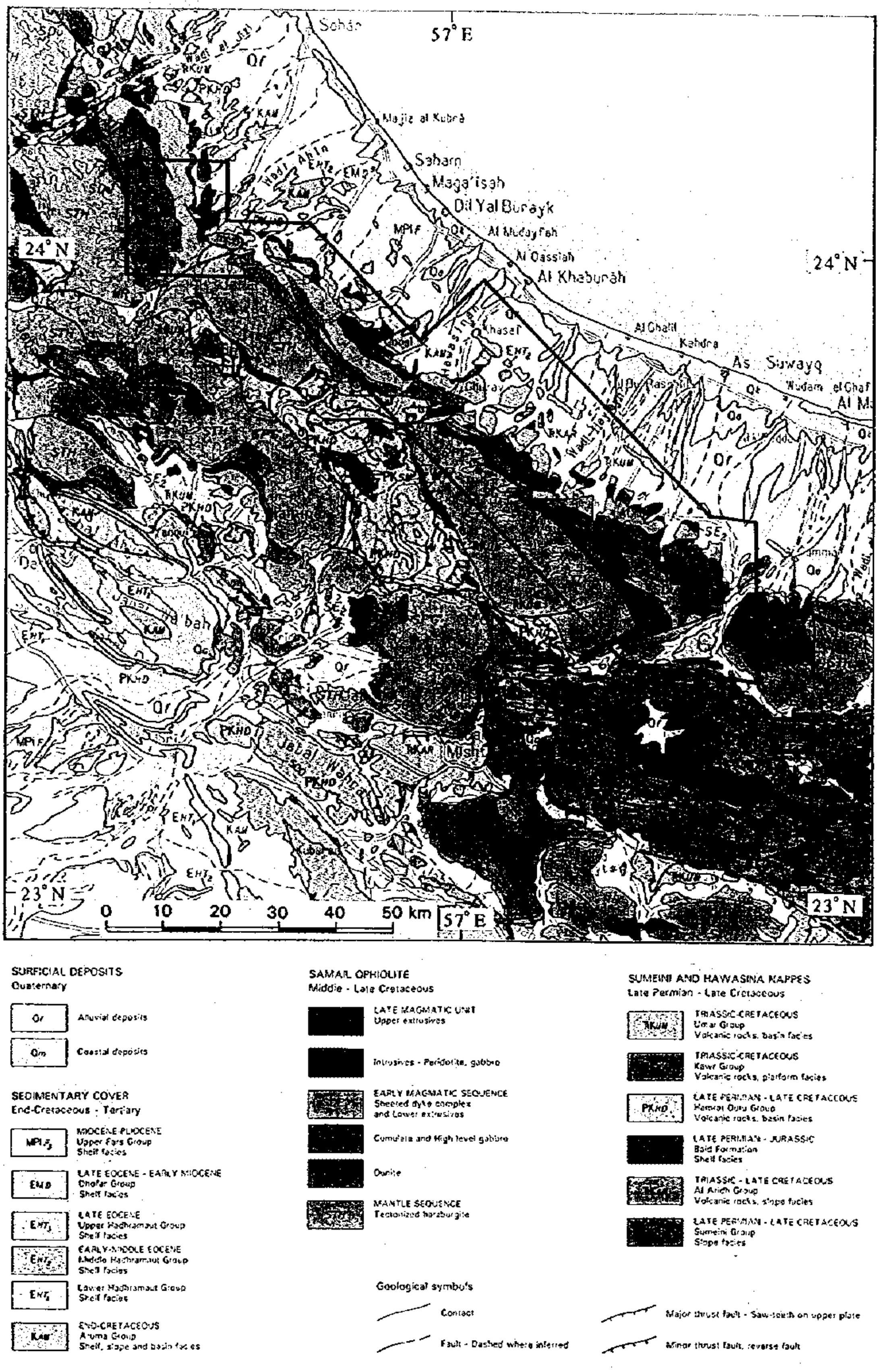
Samail Nappe is mostly composed of Ophiolite(Samail Ophiolite) and extensively distributed in the area. Succession of the Samail Ophiolite, is described as follows:

(Bottom) (1) Tectonites
(2) Cumulate sequence
(3) High-level gabbro
(4) Sheeted-dyke complex
(Top) (5) Samail volcanic rocks;

Post-Nappe units consist of the Upper Cretaceous Aruma Formation and Tertiary Hadhramut Formation, and are cropping out along a line almost parallel to the coastal line. The Aruma Formation is composed of polymict conglomerate and marl and the Hadhramut Formation is composed of limestone, carbonate rocks and marl.

Quaternary sediments are comprised of fan deposits, terrace deposits and stream sediments, and are well exposed in the northern side of the area.

Principal geologic structure of the area is the piled-up structure formed in the time when the Samail Nappe was detached from the ocean floor and obducted over the Arabian platform during the Late Cretaceous Alpine orogenic cycle. Many thrust faults are found in the area and constitute boundaries of structural and tectonic units of the Samail nappe, such as Tectonite-Cumulate Sequence-Sheeted dyke Complex -Volcanic rocks.



Ministry of Petroleum and Minerals (1993)

Fig. I -3-1 Geologic map of the South Batinah Coast area

3-2 Mineralization and Mining Activities

3-2-1 Mineralization

Occurrences of copper deposits, being the main target of the project are schematically shown in Fig.I-3-2. The massive sulphide deposits in the Oman Mountains are situated in the lower part of the Samail Volcanic Rocks and are classified into the Cyprus-type copper deposits. In general, the Cyprus-type copper deposits are understood to be formed on sea-floor and accompanied with basic volcanics rocks.

Major Cyprus-type copper deposits in Oman Mountain consist of Lasail, Aarja and Bayda deposits in the Sohar area, Rakah and Hayl as Sahil deposits in the Rakah area. The Lasail deposit is of large scale, and its general features are as follows:

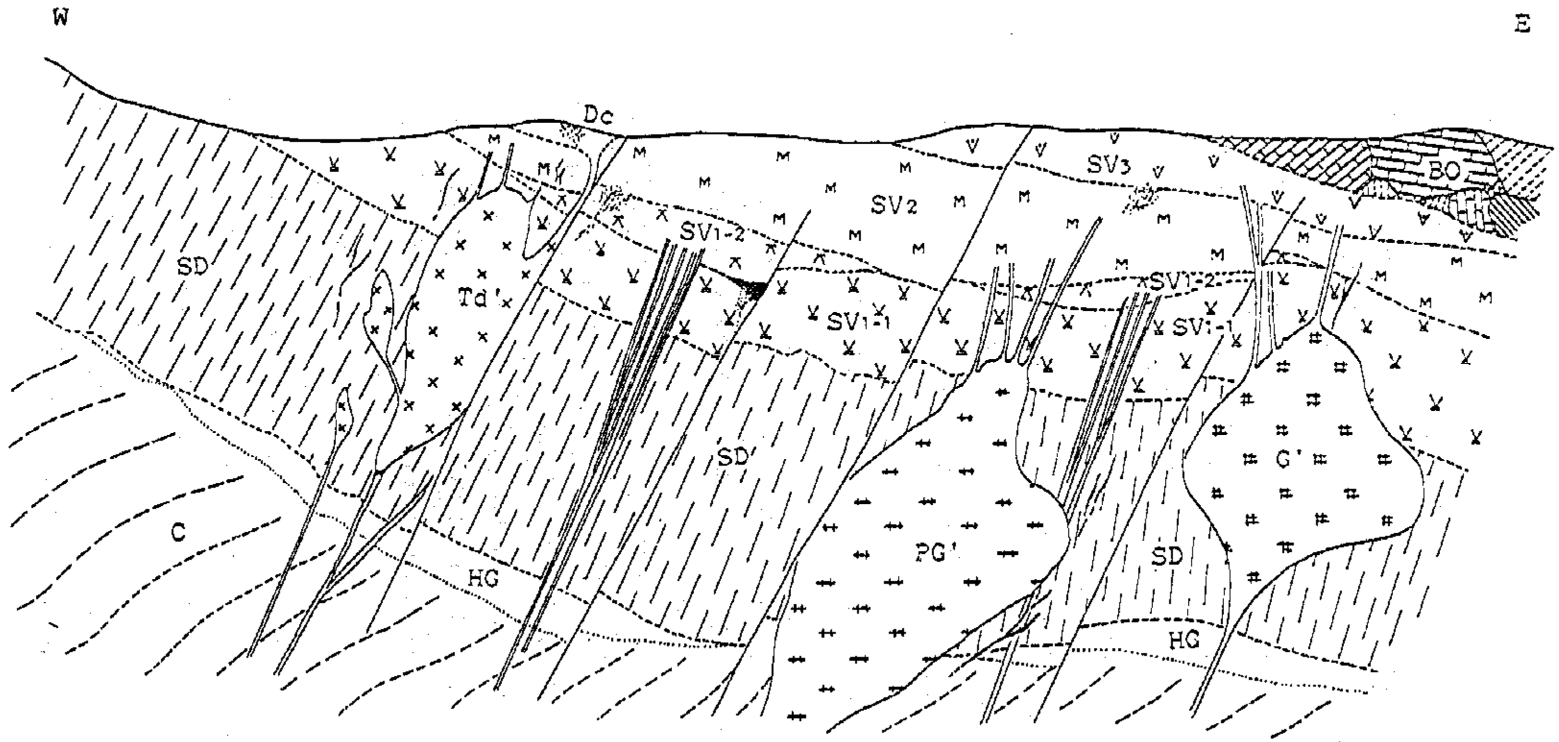
(1) The Lasail deposit occurs along the contact between the Lower extrusive 1 and 2, near a major fault (Lasail Fault) and extends in a NNW-SSE direction, parallel to the fault.
(2) The massive ore zone shows an elongated saucer shape, with a maximum thickness of about 50m at its proximal part, with maximum lengths of 600m and 300m along N-S and E-W directions, respectively.
(3) The deposit is dominated by an abundance of pyrite and chalcopyrite with minor sphalerite, magnetite, hematite, quartz and gypsum.
(4) These minerals mentioned above, represent a distinct zonal arrangement, where chalcopyrite and pyrite are dominant in the proximal zone , while sphalerite, magnetite and hematite are predominant in the distal zone.

3-2-2 Brief history of mining

The Oman Mountains region in the northern part of Oman is known as a major producer of copper during the era of Mesopotamia. It has been said that the exploitation and smelting of copper in the ancient times continued up to around 940 A.D. of the early era of Islam. The copper deposits operated in that period are presumed to be the same as the current exploitation level of the Lasail mine and Rakah deposit and a great volume of slag and ancient smelter sites can be observed in this area even at the present days.

The modern exploration activity, mainly aimed to copper deposits in the Oman Mountains, commenced by Prospection Ltd. of Canada in the decade of 1960. Presently known deposits of Lasail, Bayda, Aarja in Sohar area and Hayl as Sahil and Rakah deposits in Rakah area were explored at that period up to diamond drillings, confirming the existence of those deposits.

In the decade of 1970, the Government of Oman purchased the title of property owned by Prospection Ltd. and started the mine development in Sohar area. Consequently in 1983, the operations



C : Cumulate sequence
HG: High-level gabbro
SD: Sheeted-dyke complex
SV1-1 : Lower extrusives 1
SV1-2 : Lower extrusives 2

SV2 : Middle volcanic rocks
Dc : Dacite
SV3 : Upper volcanic rocks
BO : Batinah olistostrome
G' : Gabbro

PG' : Peridotite and gabbro complex
Td' : Trondhjemite
(symbol) : Massive type mineralization
(symbol) : Vein type mineralization
(symbol) : Stockwork/dissemination type mineralization

Fig. I -3-2 Schematic geologic model in Batinah Coast of Lasail and Bayda mines and Sohar copper smelter were commenced by OMCO(Oman Mining Company) which was established and fully owned by the Government of Oman. The capacity of this smelter has a copper metal production of 24,000 tons per year.

For the purpose of keeping a stable supply of raw material to the Sohar smelter, the Government of Oman awarded in 1984, through international tender, to Bishimetal Exploration Co., Ltd. a contract for a copper exploration program in an area of 8,000 km sq. surrounding the Sohar smelter. Investigations were carried out for a period of 4 years up to 1987 and some ore reserves were newly obtained in and around the known deposits, and at the same time, many mineralized zones were confirmed.

On the other hand, BGRM of France was awarded in 1983, a project of geological mapping in the northern Oman Mountains region by the Government of Oman and carried out such works until 1985.

During the course of their mapping program, a zone of large scaled gossan was discovered together with the confirmation of several mineralized zones near the village of Hayl as Safil, located at the foothills of the Oman Mountains.

The Government of Oman awarded in 1985 to BRGM a contract until 1986 for the exploration of 13 major copper mineralized zones discovered in the course of mapping. As a result, the existence of a massive sulphide deposit was confirmed in the gossan zone near the village of Hayl as Safil. The objective areas of the present cooperative mineral exploration program, such as Ghuzayn, Buwayrick, Daris West, Daris 3A5, Daris, Mahab6, Mahmum and Bir Mohsen were included in the above mentioned 13 mineralization zones.

In 1988, the Government of Oman requested to the Government of Japan to investigate the possibility of developing the Hayl as Safil and the Rakah deposits. In response to such request, the Government of Japan carried out a Cooperative Mineral Exploration Program and a Regional Development Plan through Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ) in order to study the possibility of mining development in this area.

On the other hand, in 1988 OMCO commenced the mine development of Aarja deposit in Sohar area by supplying raw material to the Sohar smelter due to the exhaustion of ore reserves at Lasail and Bayda mines. However, the Aaja deposit was mined out in 1993 and as such, the smelter operates by the purchased ore from abroad. The total production and grade of closed mines are as follows:

Lasail Mine	9,183,677 tonnes	1.42% Cu
Aaja Mine	2,561,887 tonnes	0.97% Cu
Bayda Mine	790,891 tonnes	1.60% Cu
Lasail West Mine	434,478 tonnes	1.02% Cu

From the above mentioned background, the Government of Oman and OMCO are aggressively continuing exploration activities for the development of the domestic mines. Especially, in Hayl as Safil deposit, intensive exploration works has been carried out and three satellite ore bodies which are Al

Jadeed, Al Asgher and Al Bishara have been confirmed in the periphery of the main deposits. The ore reserves and grade obtained by these exploration are about 11 millions tonnes with 1.44% Cu and 0.73g/t Au including Hayl as Safil deposit, its satellite ore bodies and Rakah deposits.

In 1994, Rakah gold mine started the operation utilizing gold rich gossan near surface and has been produced about 500kg gold annually.

Furthermore, to reconsider the results of the exploration works already carried out, the Government of Oman conducted an airborne magnetic survey in the northeastern side of the Oman Mountains from 1990 to 1992, and as a result, magnetic anomalous zones related to mineralization were delineated.

On this basis and since 1995, the present cooperative project commenced by conducting mainly investigations of geophysical and drilling surveys.

CHAPTER 4 SURVEY RESULTS

4-1 Geophysical Survey

The geoelectrical structure reflected by massive sulphide deposits is characterized by high chargeability and low resistivity. In this regards, the geophysical methods TDIP and TEM are quite effective for prospecting sulphide deposits.

The TDIP method is generally carried out along lines. This method has the advantage of measuring at the same time the two parameters of chargeability and resistivity, and as such, it is an effective method to delineate horizontally anomalous zones due to mineralization by covering a wide area by the survey lines spread on the area. On the other hand, the TEM method is sensitivity to the electrical response from the underground structure below the observed station, and therefore this method may assist in better defining more conductive zones such as massive sulfide deposits.

For these reasons, we used the TDIP survey as a reconnaissance method, and TEM as a detailed method.

4-1-1 TDIP survey

The TDIP survey method was conducted in selected areas in order to delineate sulphide mineralized zones in the areas of Ghuzayn and Doqal.

In Ghuzayn, TDIP measurements were taken in two zones located to the west and to the east of the previous survey locations (Fig. I-4-1).

In relation to the results of the western part, a high chargeability zone was detected in the central part of the area, within which the high metal factor zone associated to low resistivity was selected as the most promising zone.

Regarding the results of the eastern part, a relatively high chargeability zone was detected, however, the detected metal factor values were not high enough to be considered promising.

In Doqal area high chargeability zones were detected in the north-west as well as in the south-west margin of the area. In spite of the above results, no significant low resistivity values were detected in both zones.

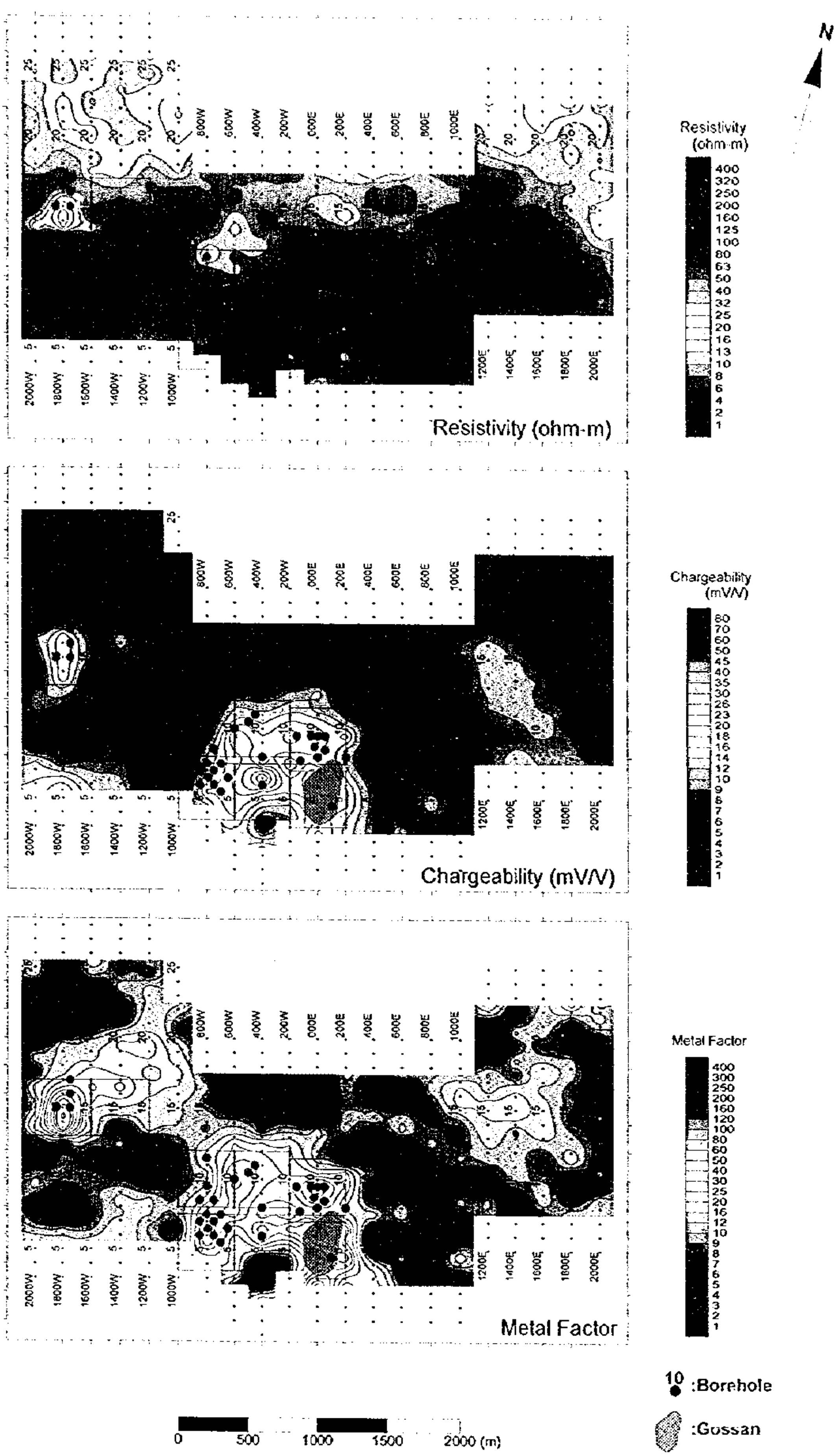


Fig. I -4-1 IP plane map in Ghuzayn area

4-1-2 TEM survey

The TEM survey was conducted in order to clarify the resistivity structure and delineate drilling locations based on the metal factor anomalies detected by the TDIP survey in Ghuzayn, Daris and Doqal areas.

By means of the detailed TEM survey by using small loops configurations, it was inferred that the scale of the ore body No.1 is small. The high TEM responses observed during the TEM large loops surveys carried out in this zone, did not indicate any anomalies.

On the other hand, the TEM data acquired in the western part of Ghuzayn area highlighted the existence of massive sulphide ore (ore body No. 3). Its extension is inferred to be 200m wide along the east-west direction and 400m long along the north-south direction. According to the present results, this ore body is thicker at the south side where a fault is inferred and becomes thinner as it gradually dips northwards.

No significant anomaly was detected in both, Doqal and Daris areas.

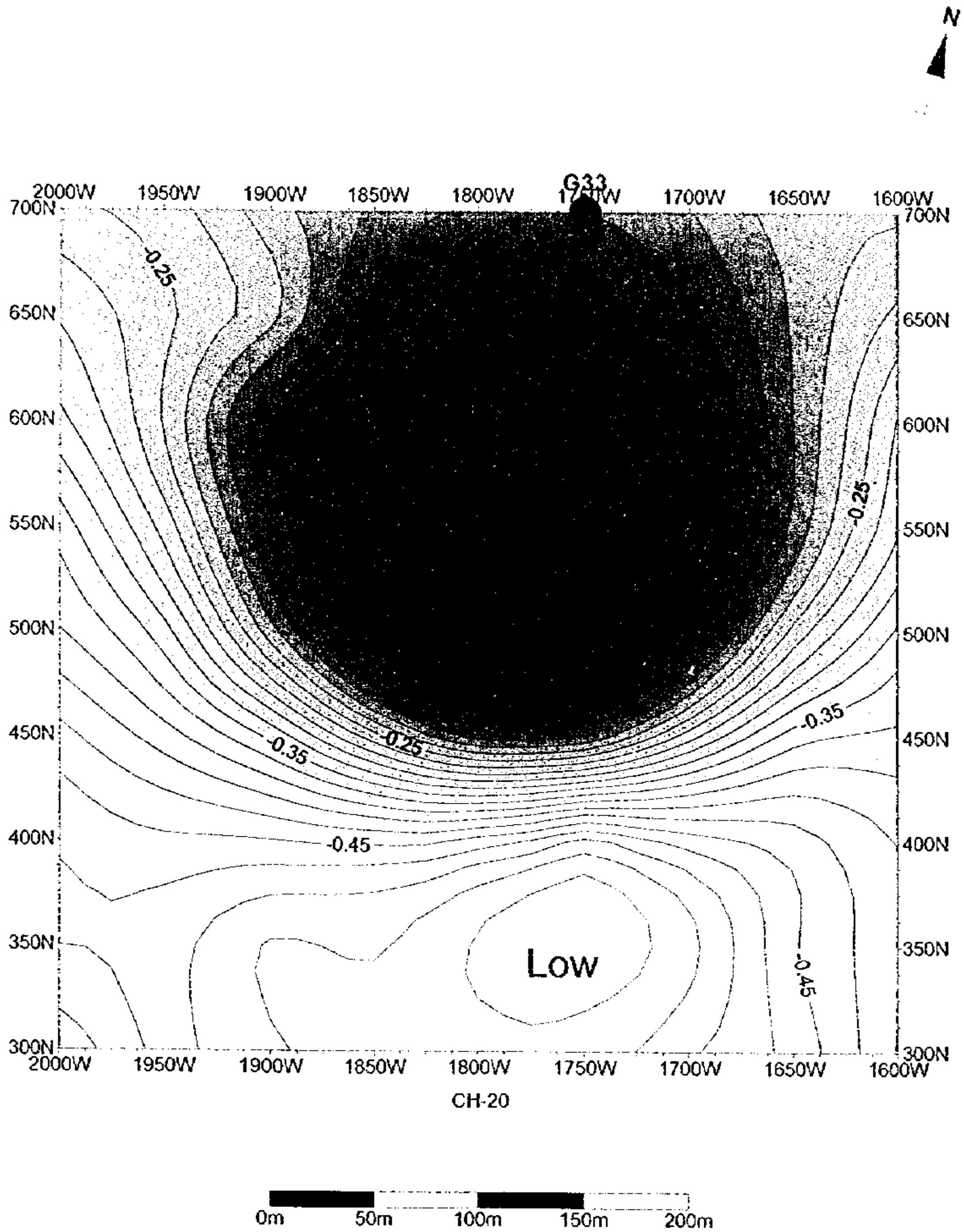


Fig. I-4-2 TEM response map in western part of Ghuzayn area

4-2 Drilling Survey

On the basis of the surveys conducted not only in 1996 but also during this phase (1997), drilling survey was carried out in the areas of Ghuzayn, Daris and Doqal, where19 boreholes were drilled with a total length of 4,941.25m.

As indicated in Fig. I-4-3, drilling survey was conducted in three parts in Ghuzayn area, i.e., in the central, eastern and western parts. The table I-4-1 shows the drilling results in Ghuzayn.

In the central part, the ore body No.2, discovered in the Phase II of the previous Cooperative Mineral Exploration project, was investigated in more detailed in order to clarify its extension and assay distribution. With this objective in mind, five boreholes drilled during this phase, intersected massive sulphide and two others confirmed a 1 to 2 m metalliferous sediments predominant in magnetite and which can be considered as marginal faces of the massive sulphide ore body. As a result of these investigations, it is inferred that the ore body No.2 has an extension of 400m along the north-south direction, 200m wide along the east-west direction, an average of about 20m in vertical thickness between the depths of about 90m and 280m, and dipping north-west by 20° to 40° . Geological reserves and its average assay can be roughly calculated in 5 millions tons and 1.2%, respectively.

In the eastern part, drilling survey was conducted to investigate in more detail the ore body No. 1 discovered in Phase II of the previous project mentioned above. As a results of this survey, the borehole No.G25 intersected massive sulphide ore considered to be part of the ore body No.1, with a core length of 7.45m and average copper grade of 3.51%. Regarding the investigations in the other locations, no massive sulphide body were encountered. However, Borehole G26 intersected a massive magnetic body with a very low copper grade.

In the western part, the drilling survey was scheduled to investigate the anomaly detected by the geophysical survey conducted during this phase. All of the four boreholes intersected a massive sulphide ore body (ore body No. 3). The borehole G30 indicated a maximum ore core length of 91.4m and the highest average assay of 2.68%Cu detected so far in the area. The other boreholes, indicated the following core length and average assay of ore, respectively: Borehole G31: 32m and 1.66%; Borehole G32: 39.65m and 1.13%; Borehole G33: 16.45m and 0.83%.

Depth of the ore body is inferred to range from 110m to 247m. Stockwork was also confirmed below the massive sulphide ore in borehole G1 and above it in G33.

The drilling survey carried out in Daris and Doqal area did not confirm any massive sulphide, but intersected only dissemination and veinlets of pyrite and chalcopyrite.

Table I-4-1 Summary of drilling results in Ghuzayn area

Ore Body Name	Bore Hole NO.	Type of Ore	Depth (m)		Thickness (m)	Average Grade	
			from	to		Cu%	Zn(%)
GHUZAYN No.1 Body	MJOB-G25	massive sulphide	**115.60**	**123.05**	**7.45**	**3.51**	**0.03**
		stockwork	123.05	148.95	25.90	0.19	0.04
GHUZAYN No.2 Body	MJOB-G18	massive sulphide	**251.80**	**267.00**	**15.20**	**0.96**	**0.08**
	MJOB-G19	massive sulphide	**194.10**	**227.50**	**33.40**	**1.15**	**0.05**
	MJOB-G20	massive sulphide	**273.90**	**279.30**	**5.40**	**0.69**	**0.02**
	MJOB-G21	massive sulphide	**126.10**	**138.75**	**12.65**	**0.50**	**0.01**
	MJOB-G22	stockwork(upper)	90.50	96.55	6.05	0.33	0.01
		massive sulphide	**96.55**	**110.20**	**13.65**	**2.70**	**0.03**
		stockwork(lower)	110.20	144.85	34.65	1.33	0.14
		stockwork(high grade)	117.85	127.85	10.00	3.56	0.10
	MJOB-G29	stockwork	132.75	142.85	10.10	1.16	0.05
GHUZAYN No.3 Body	MJOB-G30	massive sulphide	**110.40**	**201.80**	**91.40**	**2.68**	**0.01**
		massive sulphide (high grade part)	114.40	126.40	12.00	7.71	0.01
	MJOB-G31	massive sulphide	**109.30**	**181.30**	**72.00**	**1.66**	**0.04**
		stockwork	181.30	213.25	31.95	0.27	0.01
	MJOB-G32	massive sulphide	**169.35**	**209.00**	**39.65**	**1.13**	**0.05**
	MJOB-G33	stockwork	223.20	230.95	7.75	0.70	0.04
		massive sulphide	**230.95**	**247.40**	**16.45**	**0.83**	**0.06**

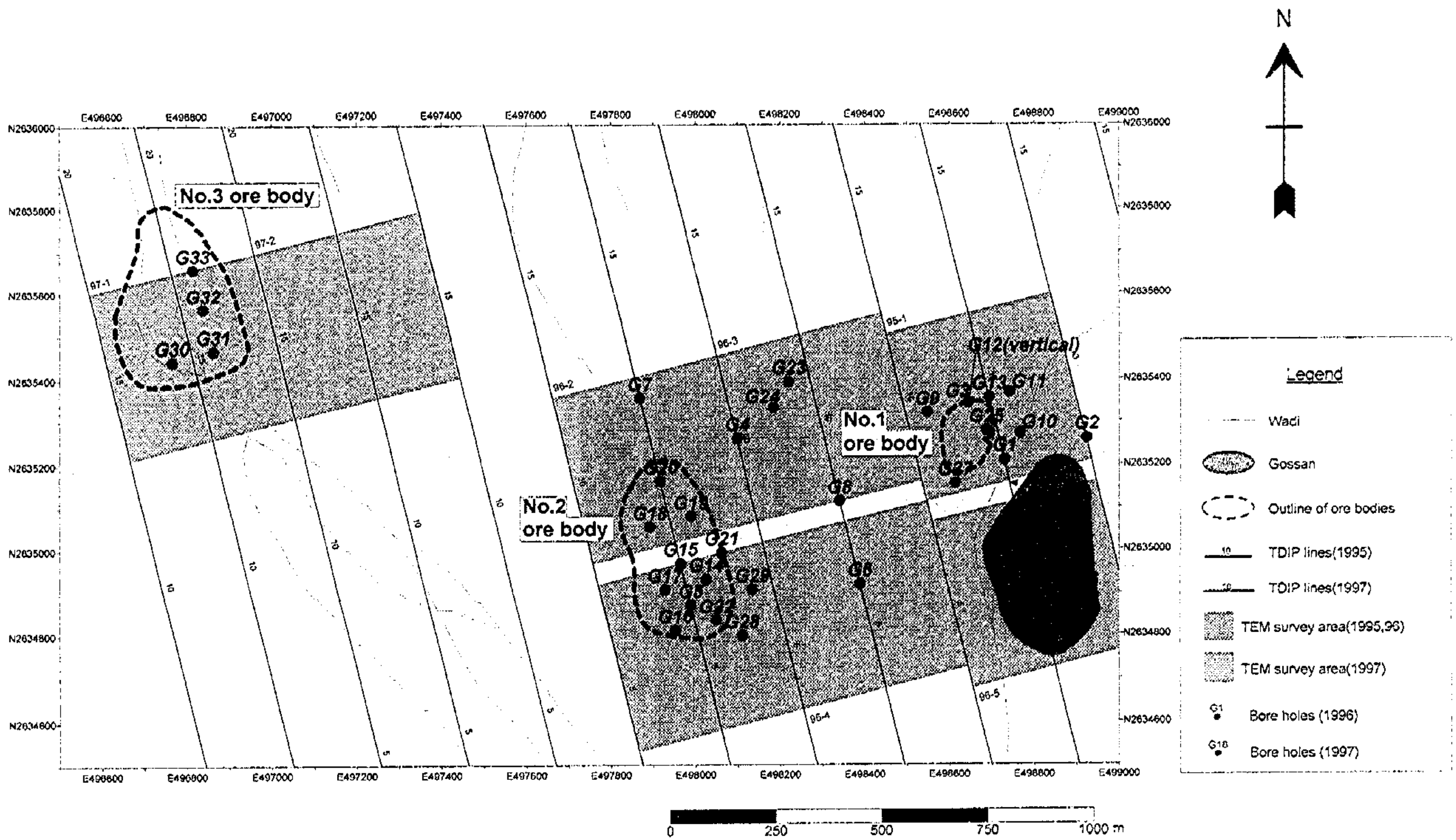


Fig. I -4-3 Location map of Ore bodies and boreholes in Ghuzayn area

4-3 Geological Survey

The methodology used during the geological survey took into consideration some exploration hypothesis based on the geology and mineralization in and around the massive sulphide deposit in Ghuzayn area..

(1) The massive sulphide deposit shows a stratigraphic control and occurs in the contact between V1-1 and V1-2.

(2) The alteration associated with mineralization consists of silicification, chloritization (Mg-rich chlorite) and epidotization. Silicification and epidotization are remarkable even in the margin of the massive sulphide ore body.

(3) The generation of massive sulphide deposit is closely related with faults.

(4) There exists the possibility that metalliferous sediment grade laterally into massive sulphide in the case that the sediment contains many magnetic layers with clear stratification and copper mineralization.

On the basis of the above hypothesis, the geological survey was conducted in 14 mineral showing locations in the north-western part of the project area. The survey resulted in the selection of seven potential areas for massive sulphide deposits: Hara Kilab, Mahab 3, Mahab 4, Mahab 5&6, Mahmum, Maqail and Maqail south. Among them, the two areas of Hara Kilab and Mahab 3 are seen as promising because of the presence of gossan with copper mineralization and a small massive sulphide ore body have been previously confirmed by other project.

Furthermore, interesting features of alteration and copper mineralization, that may lead to the discovery of a massive sulphide ore body, have been observed to the north and west of the TDIP surveyed area in Ghuzayn.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5-1 Conclusions

The survey results can be summarized as follows:

(1) A prominent IP anomaly was extracted in the western part of Ghuzayn area. This anomaly is associated to the massive sulphide detected in this part.

(2) To investigate further the above mentioned IP anomaly, a TEM survey was carried out. The TEM data taken within the large loop, supplied general information about the extension of the massive sulphide ore body . The small loops data reflected a more detailed extension as well as a probably depth and dip of the ore body.

(3) The borehole MJOB-G25 drilled for the investigation of ore body No. 1, intersected massive sulphide with a core length of 7.45m and an average assay of 3.51% Cu.

(4) Seven boreholes were drilling within the area of ore body No. 2. Massive sulphide was intersected in five of them, revealing that the ore body No. 2 has an extension of 400m along the north-south direction and 200m along east-west. Geological ore reserves are estimated in 5 million tons with an average assay of 3.51% Cu.

(5) All of the 4 boreholes drilled to investigate the IP and TEM anomalies detected in the western part of Ghuzayn area, intersected massive sulphide (ore body No. 3). The ore intersected in the borehole MJOB-G30 indicated a core length of 91.40m and an average assay of 2.68% Cu. The boreholes G31, G32 and G33 indicated core lengths of 72m, 39.65m and 16.45m, respectively.

(6) From the core analysis, it is concluded that the alteration associated with mineralization consists of silicification, chloritization (Mg-rich chlorite) and epidotization. Important indications not only for the surface geological survey, but also for the drilling survey, are the remarkable features of silicification and epidotization detected even in the margins of the ore body.

(7) As a result of the geological survey conducted around 14 mineral showings in the north-western part of the project area, the area between Hara Kilab and Mahab was selected as a promising area for massive sulphide deposits.

(8) Interesting features of alteration and copper mineralization, that may lead to the discovery of a massive sulphide ore body, have been observed to the north and west of the TDIP surveyed area in Ghuzayn.

5-2 Recommendations

The discovery of 3 ore bodies in Ghuzayn area, leads to the opinion that not only Ghuzayn area but also the Batinah Coast area presents a high potential for massive sulphide deposits. Therefore, on the basis of the Phase I results, geophysical and drilling surveys are recommended in the following areas:

(1) Ghuzayn Area

1. Drilling survey to obtain more details of ore body No. 3, along with TEM survey to delineate the northern extension of the body.
2. TDIP survey to the west and south extension of the previously TDIP surveyed area to evaluate the potentiality for massive sulphide.
3. TEM and drilling surveys based on possible IP anomalies extracted from the above mentioned zone.

(2) Doqal Area

1. TDIP survey in the south-western extension of the previously surveyed area to evaluate the potential of mineralization of this area.
2. TEM and drilling surveys based on possible IP anomalies extracted by the TDIP survey..

(3) Hara Kilab - Mahab area

1. TDIP survey in and around Hara Kilab and Mahab mineral showings considered to be promising in order to evaluate the potentiality for massive sulphide.
2. TEM and drilling surveys to evaluate possible IP anomalies extracted by the TDIP survey.

PART II SURVEY RESULTS

CHAPTER 1 GEOLOGICAL SURVEY

1.1 Objectives of the Survey

The geological survey was conducted in order to evaluate the potential of mineralization in and around known mineral showings in the northwestern part of the project area.

1.2 Survey Areas and Method

The location of the 14 mineral showings where the geological survey was conducted is illustrated in Fig. II-1-2. They are as follows:

Mahab area	(1) Hara Kilab
	(2) Mahab 5 & 6
	(3) Mahab 3
	(4) Mahab 4
	(5) Mahmum
	(6) Mahab 2
Sarami area	(7) Sarami
	(8) Sarami East
Doqal area	(9) Listwaenite
	(10) Doqal West
Salahi area	(11) Salahi V & VI
	(12) Salahi I
Maqail	(13) Maqail
	(14) Maqail South

The geological route maps were made at a scale of 1:2,500 by using topographic maps (1:100,000) and aerial photographs (1:20,000). After the study of the existing data, the survey routes were selected in the areas where Sheeted-dyke complex and Samail Volcanic rocks are found distributed. Landsat image, aerial photographs and existing data were also utilized during the analysis of the survey data. The results of the survey were compiled in a map at the scale of 1:2,500.

1.3 Results

1.3.1 Outline of geology

The general stratigraphy of the area is shown in Fig. II-1-1. The geology of the project area is mainly composed of Samail Ophiolite, Supra-ophiolite Sediments, Tertiary and Quaternary sediments. The Samail Ophiolite in the surveyed area consists of cumulate gabbro (CG), sheeted-dyke complex (SD), Samail volcanic rocks (SV) and intrusive rocks (I')

(1) Cumulate gabbro (CG)

High level gabbro appears at the top of the cumulate sequence, separating it from the sheeted-dyke complex. It is an equigranular hornblende gabbro with variable grain size.

(2) Sheeted-dyke complex (SD)

In outcrops, the sheeted-dyke complex appears as a set of sub-parallel dykes of 0.5 to 3m thick and in general with 5 to 10cm wide chilled margins, whose composition ranges from microgabbroic to doleritic. The sheeted-dyke complex appears gradually at the bottom of the Lower volcanic rocks.

(3) Samail volcanic rocks (SV)

The Samail volcanic rocks were emplaced during three episodes represented by Lower volcanic rocks (SV1), Middle volcanic rocks (SV2) and Upper volcanic rocks (SV3).

(a) Lower volcanic rocks (SV1)

The Lower volcanic rocks consist of Lower extrusives 1 (V1-1), Lower extrusives 2 (V1-2) and metalliferous sediments (U1).

The Lower extrusives 1 (V1-1) consists of differential basaltic to andesitic lavas, and composed mainly of a reddish brown colored big pillow lava of 1m to 2m size in diameter. The Lower extrusives 1 also consists of reddish brown to grey colored massive lava including sheet flow unit, hyaloclastite and pillow breccia. The pillow lava is aphanitic and accompanied with thick interpillow of 5cm to 40cm in thickness. The massive lava shows grey to brownish grey color with a thickness of several 10cm to several meters. Columnar joints are developed in the thick massive lava.

The Lower extrusives 2 (V1-2) consists of primitive basalt to lava and composed mainly of pillow lava accompanied with massive lava. The pillow lava shows light grey to purplish grey in color with pillow sizes mainly of 10cm to 1m in size and maximum of 1.5m. It is characteristically accompanied with small sized pillow lavas of 10cm to 30cm in many places. Additionally, this pillow lava is porphyritic and shows a variole-like texture. In contrary to Lower extrusive 1, it is accompanied with thin interpillow of 1cm to 5cm in thickness. The upper part of the Lower extrusives 2 includes pillow lavas with radial joints.

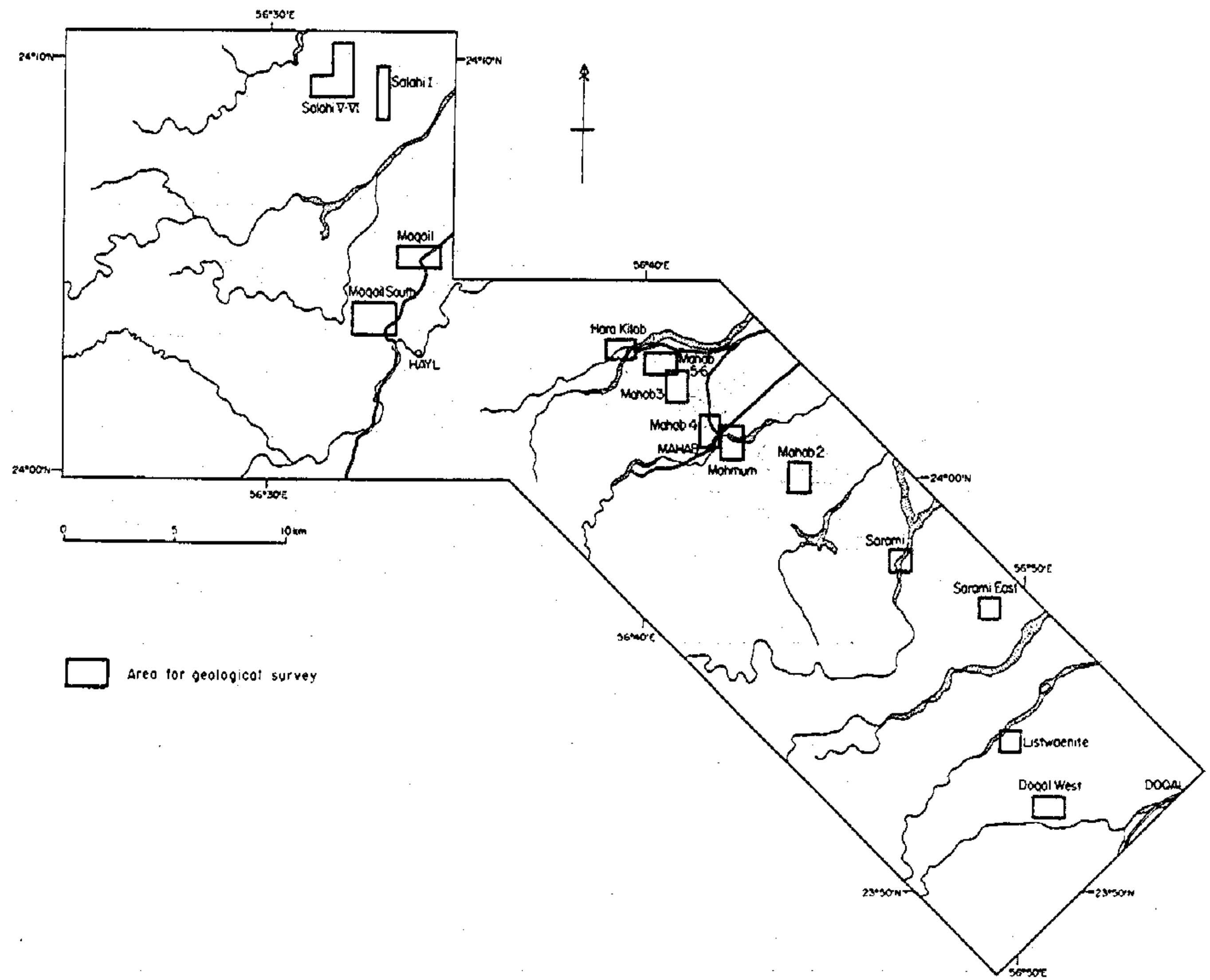


Fig. Ⅱ-1-1 Location map of mineral showings in northern part of the survey area

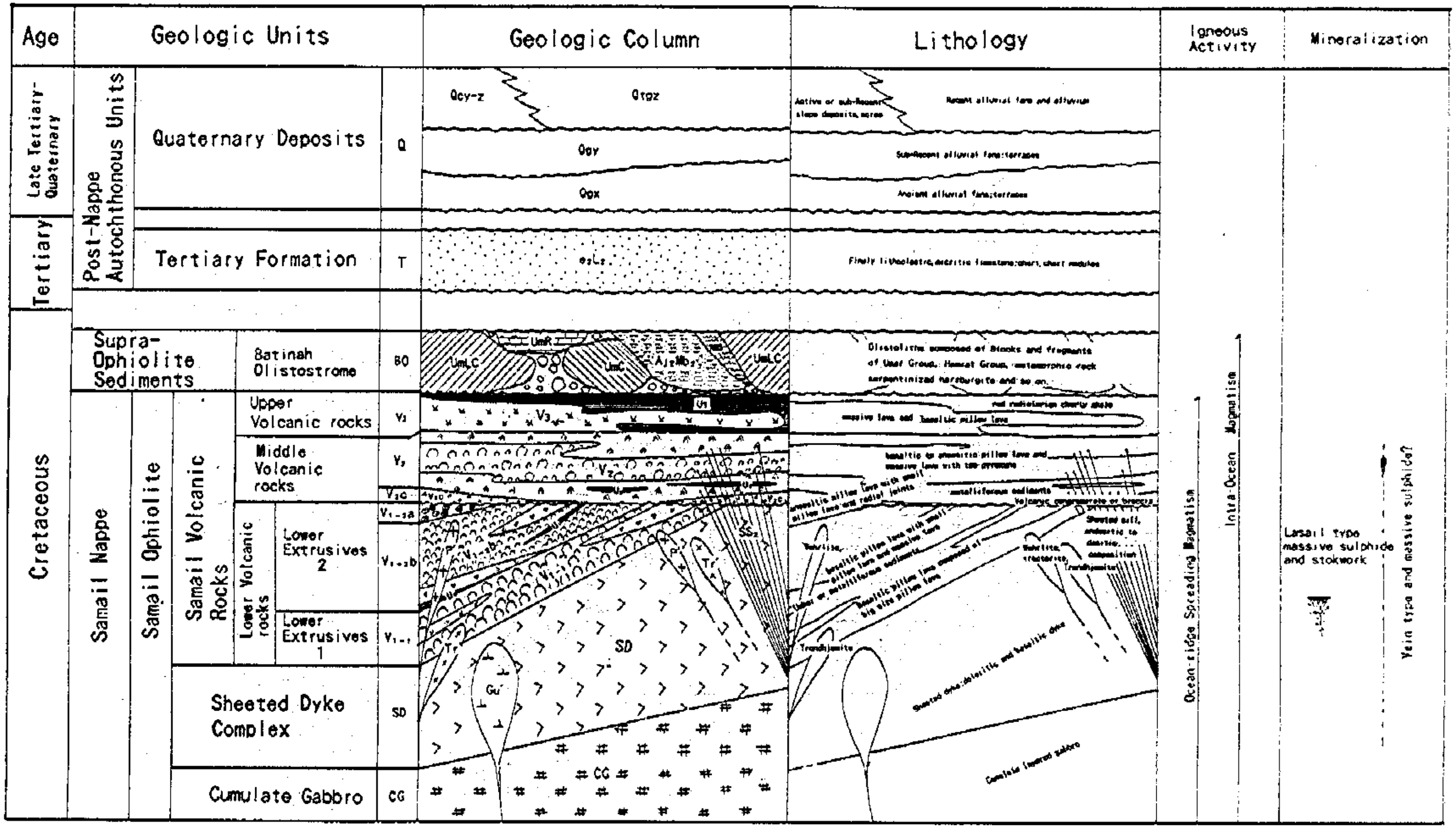


Fig. II-1-2 Stratigraphic columnar section of survey area

The metalliferous sediments (U1) is the so-called umber which includes many radiolarias and is predominant in iron. This unit shows dark brown color.

(b) Middle volcanic rocks (SV2)

The Middle volcanic rocks (V2) consist of volcanic conglomerates and breccia (V2c), sheeted sills (SS2), Middle extrusives (V2) and metalliferous sediments (U2).

The volcanic conglomerates and breccia (V2c) consist of angular to rounded matrices of sand to gravels and of fragments and blocks of sheeted dykes and Lower volcanic rocks.

The sheeted sills (SS2) consist of dykes, sheets and sills of grey-colored andesite to dacite.

The middle extrusives (V2) consist mainly of pillow lavas and massive lavas of andesite containing clinopyroxene and orthopyroxene. Most of the lavas are massive. The weathered surface shows various colors of grey, brownish grey, green, bluish grey and orange color. In general the massive lava shows a doleritic texture. The pillow lavas show purple, green and greenish grey colors. Most of the pillow lavas present irregular pillow shape and with a diameter of about 0.5 to 1.0m.

The metalliferous sediments (U2) are the so-called umber and contains many radiolarias but less amount of iron than U1. This unit shows brownish black color.

(c) Upper volcanic rocks (SV3)

The Upper volcanic rocks consist mainly of Upper extrusives(V3) and Upper metalliferous sediments (U3). V3 is composed of doleritic massive lava (sheet flow) and pillow lava.

Massive lava of V3 shows a light greenish grey color and forms a columnar joint in many places. The sheet flow of this massive lava reaches 170m in maximum thickness as one unit.

Pillow lava of V3 can be seen in the lowermost, middle and uppermost of SV3, showing in general a dark greenish color. The size of pillows range mostly between 0.6m to 1.2m in diameter.

U3 is interbedded in the uppermost and middle parts of SV3. It is mainly composed of reddish brown sediments predominant in iron materials and accompanied with pinkish shale and jasper.

(4) Intrusive rocks (I')

The intrusive rocks include peridotite (P'), gabbro (Gu'), Trondhjemite (Tr') and late dolerite dykes. The peridotite (P') consists of wehrlite, troctolite, plagioclase-bearing dunite and olivine-bearing pyroxenite. The gabbro (Gu') is associated with diorite and quartz diorite. The Trondhjemite (Tr') also includes quartz diorite in parts. The late dolerite dykes are accompanied with fine-grained gabbro.

(5) Supra-ophiolite Sediments (Batinah Olistostrome)

The sediments (BO) consists of the olistoliths of Tethys Sea sedimentary rocks formed at the same time when Tethys Sea was formed. The olistoliths came as result of the obduction process at the same time when Tethys Sea closed. The olistoliths are composed of sedimentary and igneous rocks of Triassic to Cretaceous age

(6) Post-nappe autochthonous units

These units consist of Tertiary and Quaternary sediments. The Tertiary sediments consist of yellow marl with large foraminifera (e2M1), upper nodular limestone (e2L2) and sedimentary breccia (Br) of late Paleocene to early Eocene. The Quaternary deposits consist of ancient alluvial fans (Qgx), sub-Recent alluvial fans (Qgy), active or sub-Recent slope deposits (Qcy-z), Khagra of depression with Recent or sub-Recent clay and silt (Qky-z), eolian sand of Recent or sub-Recent dunes (Qdy-z), coating of sub-Recent dunes (Qsy-z) and Recent alluvial fans and alluvium (Qtgz).

1.3.2 Geological structure

Main structure in the south Batinah coast area is the pile-up structure formed when allochthonous Samail ophiolite and supra-ophiolite sediments have been thrust over the Arabian shield at the late Cretaceous age. The Tertiary and Quaternary sediments of the post-nappe autochthonous units unconformably overlie the allochthonous units in the south Batinah coast area. Many thrust faults are developed in the area which formed contacts of piled-up blocks originated before Tertiary and sliced the autochthonous and allochthonous blocks. High-angle faults developed in the area cut each of the above blocks and displaced the geological boundaries. These fault were formed before Tertiary.

1-3-3 Geology and mineralization of mineral showings

(1) Hara Kilab mineral showing

Hara Kilab mineral showing is located about 25km southwest of Saham city. As shown in Fig.II-1-3, the geology of this showing consists mainly of SD, V1-1, V1-2, U1, Batinah Olistostrome and Quaternary sediments V1-1 is 50m to 100m in thickness and gradually change into SD. V1-2 is poorly exposed and considered to be relatively thin in thickness. The upper part of V1-1 is covered by limestone bed of Batinah Olistostrome in the northern part.

U1 crops out at the boundary between V1-1 and V1-2 in the southeastern parts. U1 in the sample point of HK-7, consists of hematite and jasper with slight copper mineralization.

Argillaceous gossan outcrops in this showing and distributed over an area of 100m x 150m. Drilling survey in 1976 by Prospection Ltd. found a small massive sulphide body under the gossan as shown in Fig.II-1-3. Ancient mining activity can be observed here and this is the reason of abundant slag found scattered around the gossan. This gossan is situated near the intersection of two faults; N80° E system and N60° W system. Along the N80° W faults, metagabbro and mylonitic trondhjemite are exposed. The N60° W fault forms the boundary between V1-2 and V1-1 or SD.

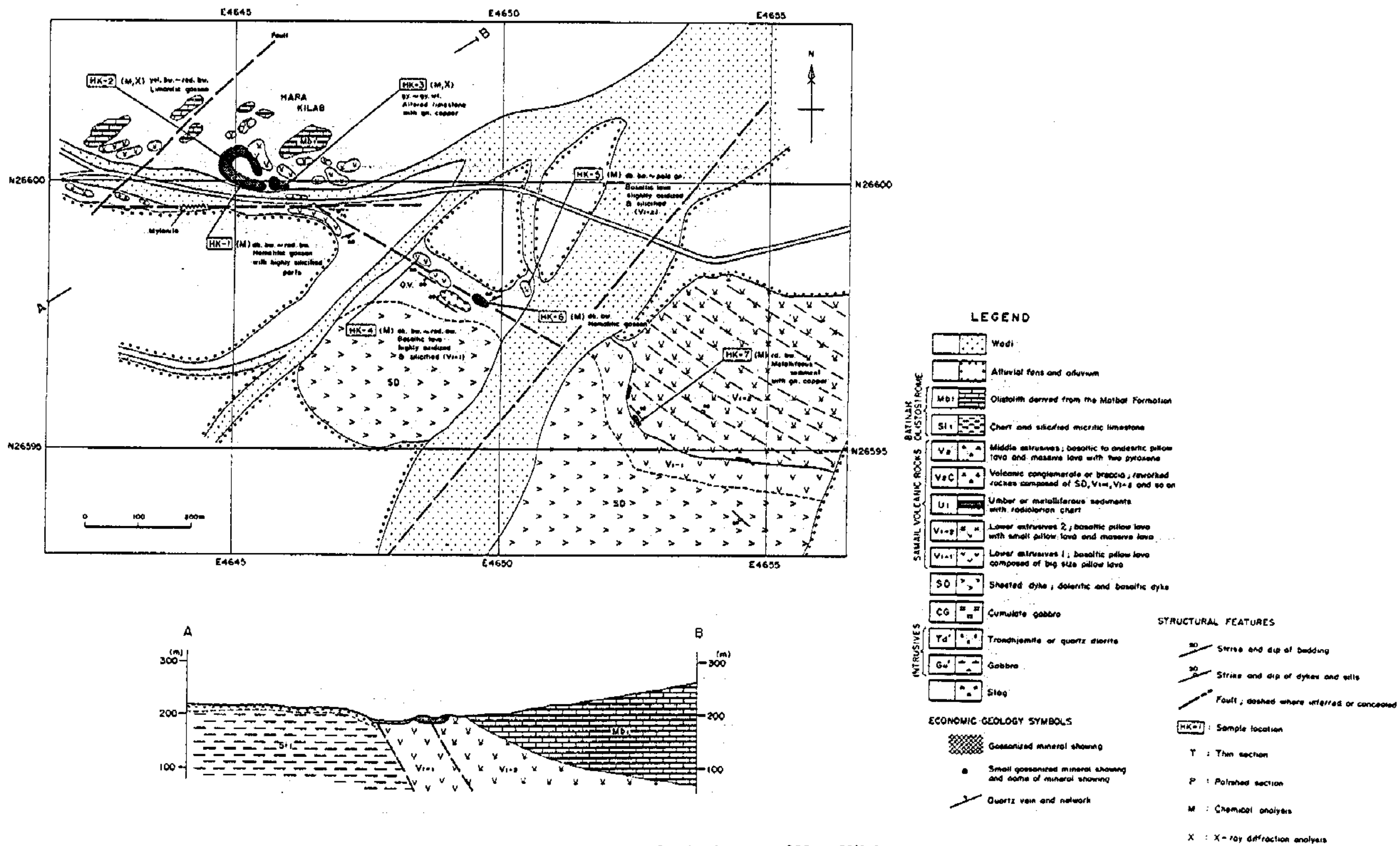


Fig. II-1-3 Geologic map of Hara Kilab area

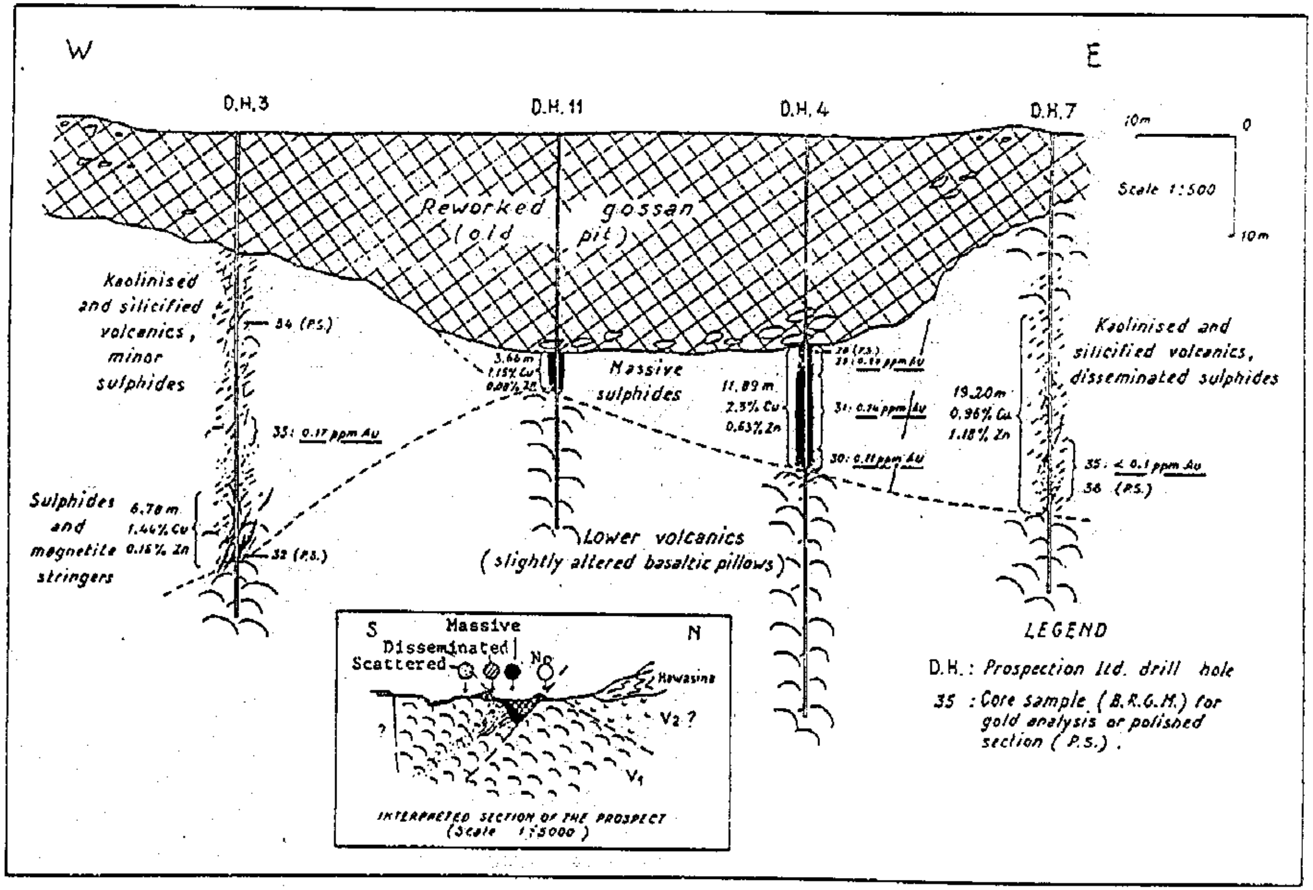


Fig. II-1-4 Cross section of borehole site in Hara Kilab area

(2) Mahab 5 and 6 mineral showings

These mineral showings are located to the southeast of Hara Kilab showing. The geology of this showing consists mainly of SD, V1-1, V1-2, U1, fan deposits and alluvium.

In Mahab 6 showing, silicification and epidotization were found in places along the faults of E-W ~N40° W running the contact of V1-1 or SD and V1-2. The strikes of faults and fractures are classified into 4 systems: E-W, NW-SE, N-S and NE-SW. Among these faults, the NE-SW faults are accompanied by very strong alteration processes of silicification and epidotization.

In Mahab 5 showing, V1-1 contacts with V1-2 by a fault. A brecciation is observed along the fault running from the sample location of MB-4 toMB-9 on the geological map. Epidotization in V1-1 was found in places.

(3) Mahab 3 mineral showing

Mahab 3 showing is located to the southeast of Mahab 5 showing. The geology of this showing consists mainly of SD, V1-1, V1-2, U1, fan deposits and alluvium. Trondhjemite is seen cropping out along the boundary between V1-1and V1-2.

Gossan with abundant copper oxide can be seen around the boundary V1-1 and V1-2. Slags of ancient mining activity can be found more abundantly than those remained in Hara Kilab showing. A large body of trondhjemite is exposed on the north of gossan. The drillings carried out by Prospection Ltd. in 1976 intersected this trondhjemite at 30m to 40m below the gossan and also confirmed massive sulphide composed mainly of pyrite.

Trondhjemite is thought to be formed after the mineralization of massive sulphide, which intruded into the boundary between V1-1and V1-2 in many places. Massive sulphide is expected to be present but probably separated into pieces by the intrusion of trondhjemite.

(4) Mahab 4 mineral showing

Mahab 4 showing is located about 1.5km north of Mahab village and to the southeast of Mahab 3 showing. The geology of this showing consists mainly of CG, SD, V1-1, V1-2, U1, fan deposits and alluvium.

Thin and continuous metalliferous sediments (U1) are exposed in sample locations of MB-16 to MB-19 as indicated on the geological map. However, slight copper mineralization is seen on the surface and metalliferous sediments found rather siliceous. The boundary between V1-1and V1-2 is well exposed in this showing, where limonitized gossan was found with copper oxide along the place of fault contact.

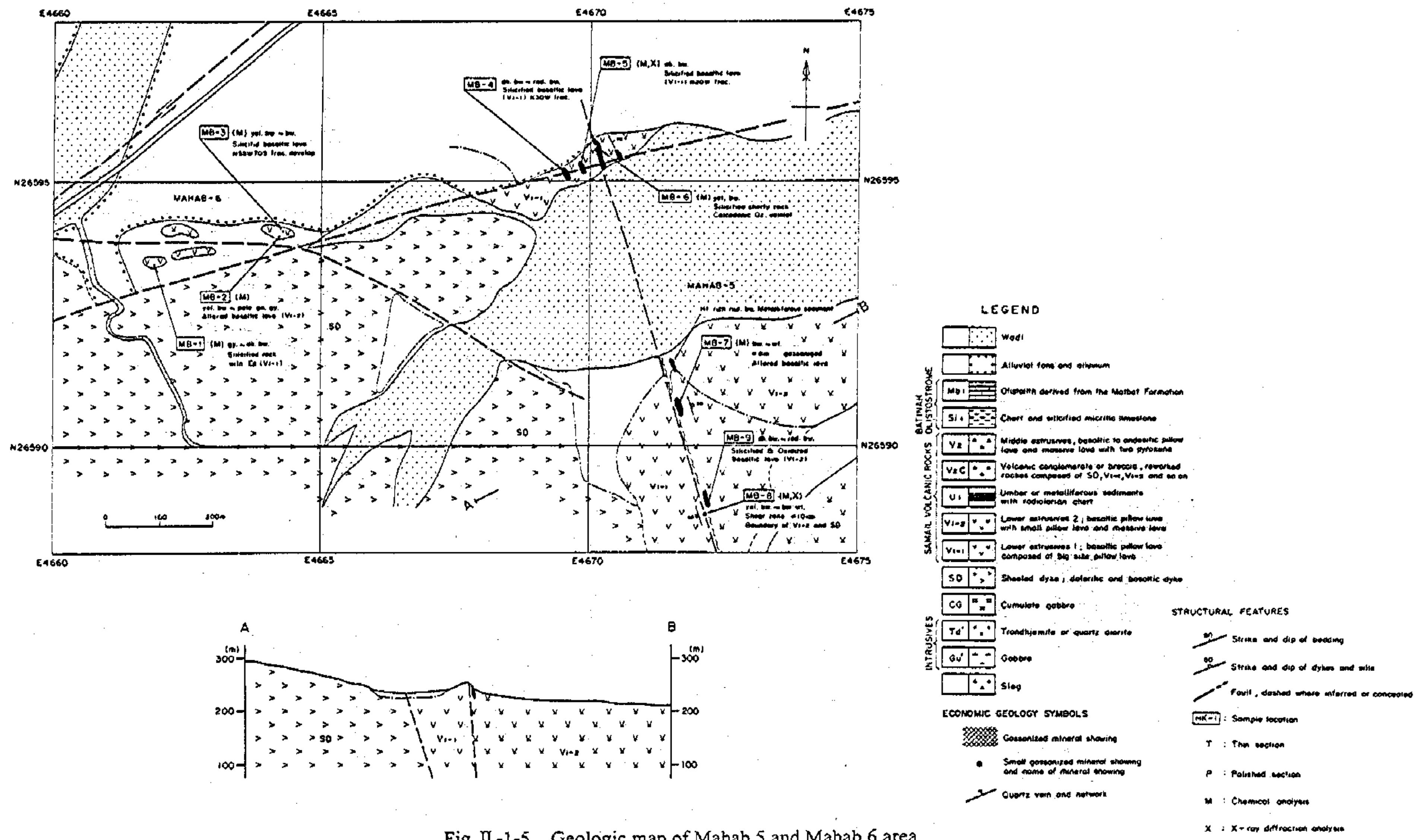


Fig. II-1-5 Geologic map of Mahab 5 and Mahab 6 area

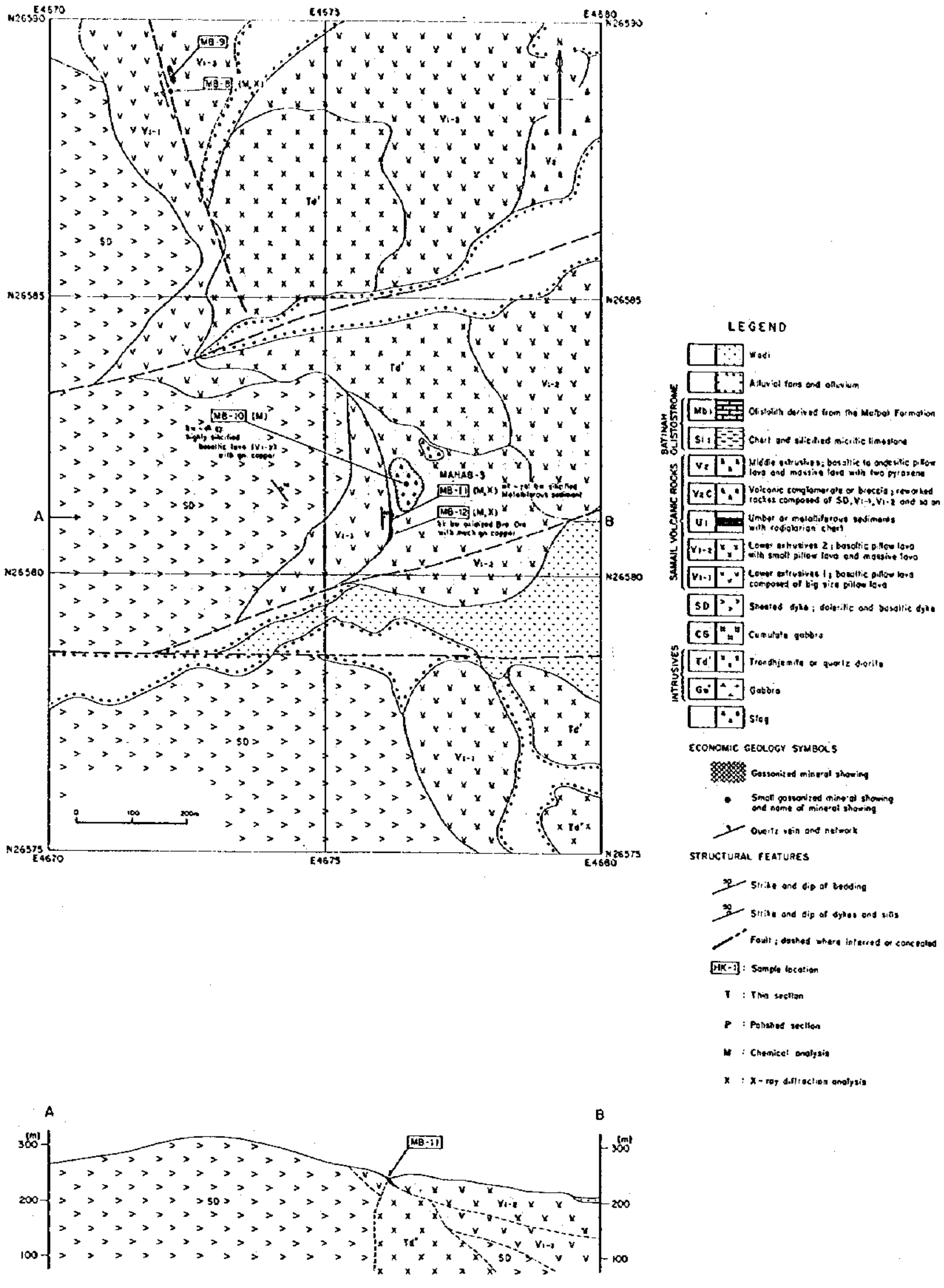


Fig. II-1-6 Geologic map of Mahab 3 area

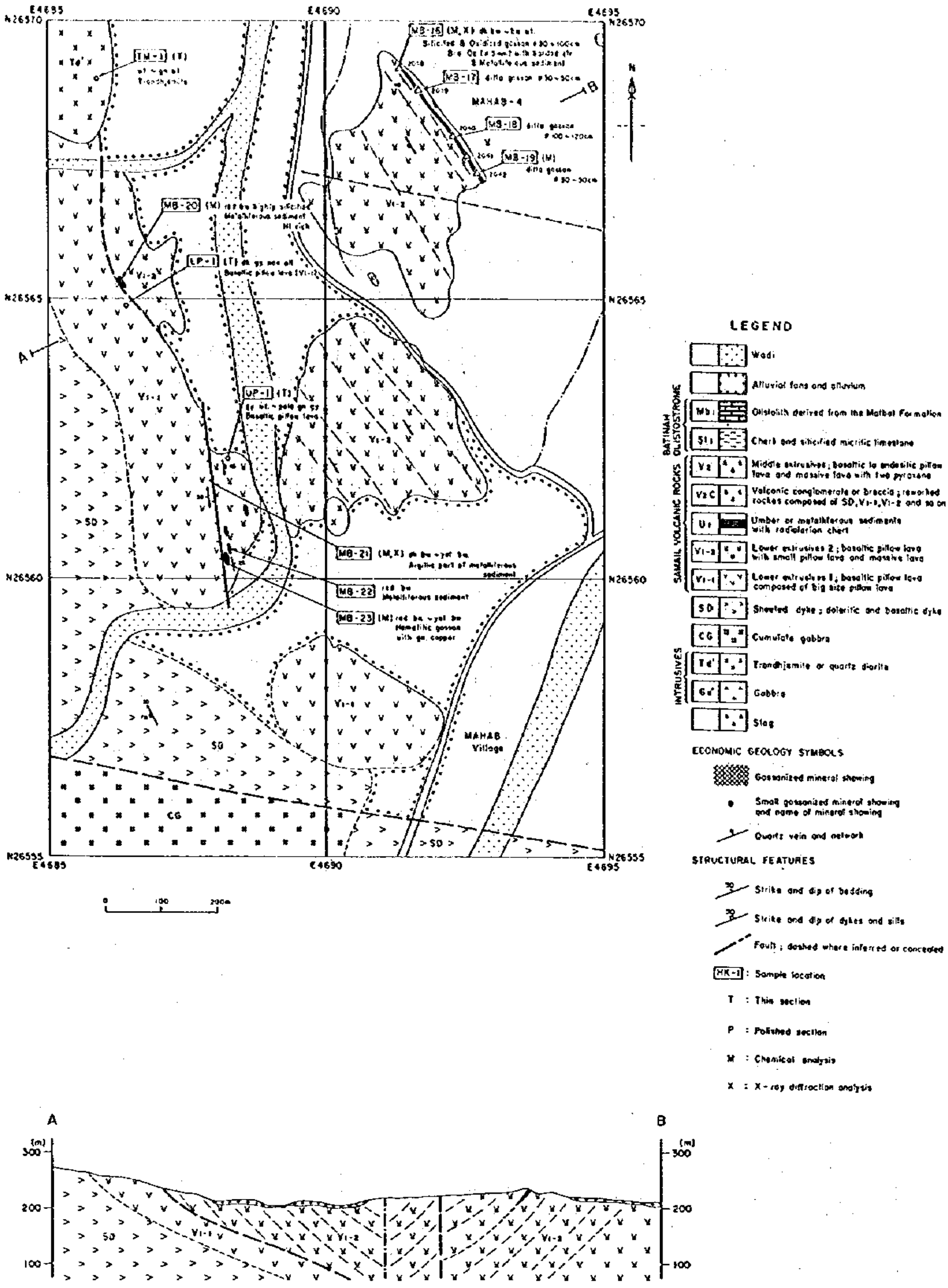


Fig. II -1-7 Geologic map of Mahab 4 area

(5) Mahmum mineral showing

Mahmum showing is located to the 1km east of Mahab village. The geology of this showing consists of SD,V1-2, V2, fan deposits and alluvium.

V1-2 is intensely brecciated along the E-W fault system. Many quartz-gypsum-epidote-hematite veinlets were found in interpillows of pillow lava and along NW-SE (E-W) trending fractures. These veinlets are oxidized in places where gossan or argillized zone are being formed.

(6) Mahab 2 mineral showing

Mahab 2 showing is located about 3.5km southeast of Mahab village. The geology of this showing consists mainly of SD, V1-1, V1-2, U1, fan deposits and alluvium. Gabbro is also found along the NW-SE trending fault. Strikes measured on dykes, sills and U1 are almost parallel to the above NW-SE trending fault.

Relatively large gossan can be seen around the intersection between the above mentioned fault and the NE-SW trending inferred fault. Abundant copper oxide was found in gossan. Prospection Ltd. conducted a drilling survey in 1976 and confirmed a silicified and epidotized zone of several meters in width with sulphide dissemination under the gossan.

(7) Sarami mineral showing

This showing is located 20km to the southeast of Saham city and southeast of Mahab 2 showing. The geology of this showing consists of V1-1, V1-2, U1, fan deposits and alluvium. Gabbro is also found along the boundary between V1-1and V1-2.

Fine grained basalt massive lava crops out and is accompanied with slight epidotization. In the sample location of SM-3, copper oxide can be seen on the gossanized basalt of V1-2.

(8) Sarami East mineral showing

This showing is located to the southeast of Sarami showing.

The geology of this showing consists of SD, V2 and U2 of Samail Ophiolite. SD directly contacts with V2 by a fault of N70° W trending. The intersection part of the faults N70° W and N10° ~20° W presents an intrusion of large scaled porphyry dyke of 20m to 30m wide with an intensely silicified brecciated zone of 10m wide. V2 is interbedded with several layers of cherty shale gossanized and partly silicified.

Dissemination of copper oxide is observed around the boundary between silicified cherty shale and basalt lava (SE-4, SE-6).

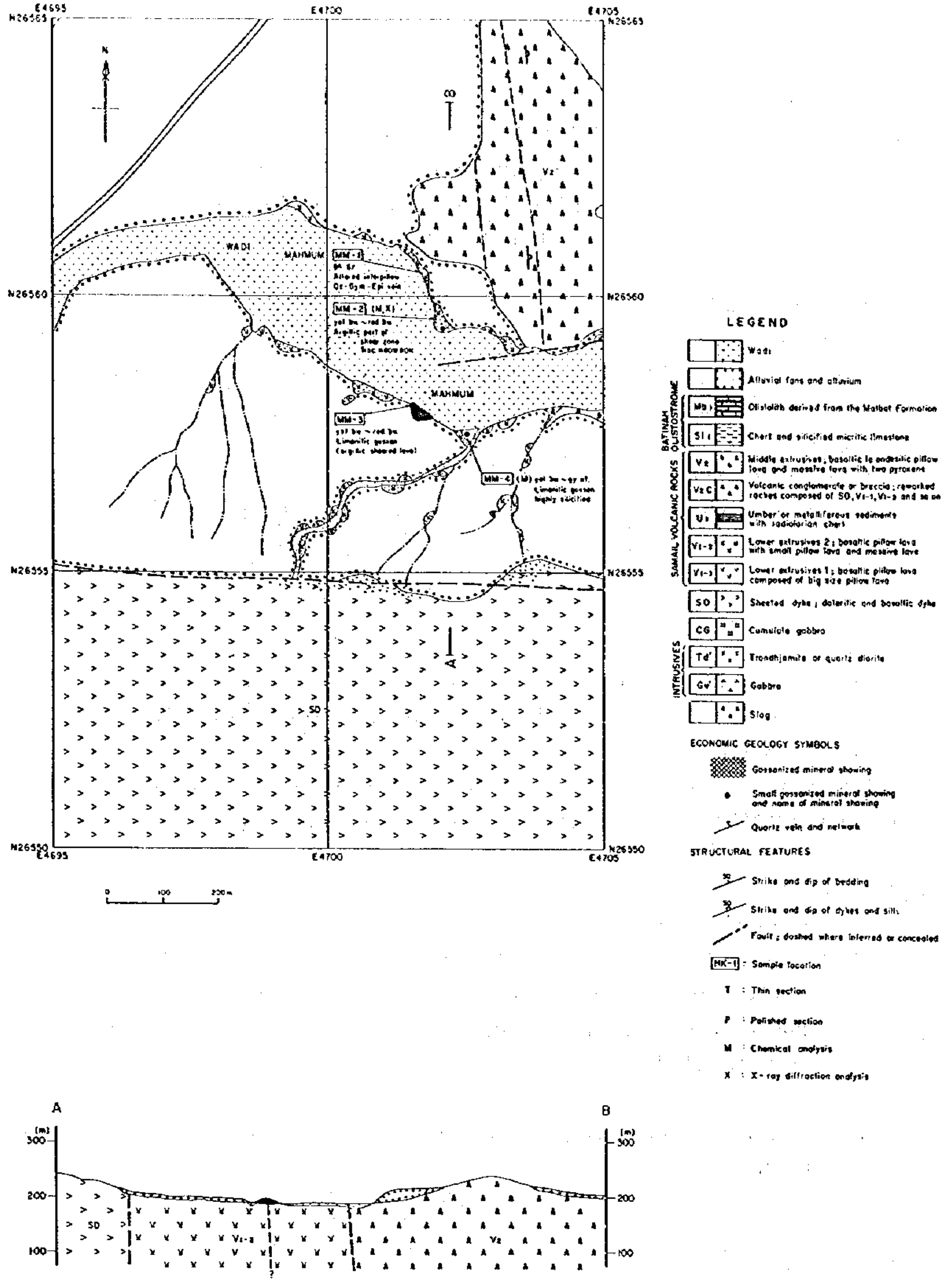


Fig. II-1-8 Geologic map of Mahmum area

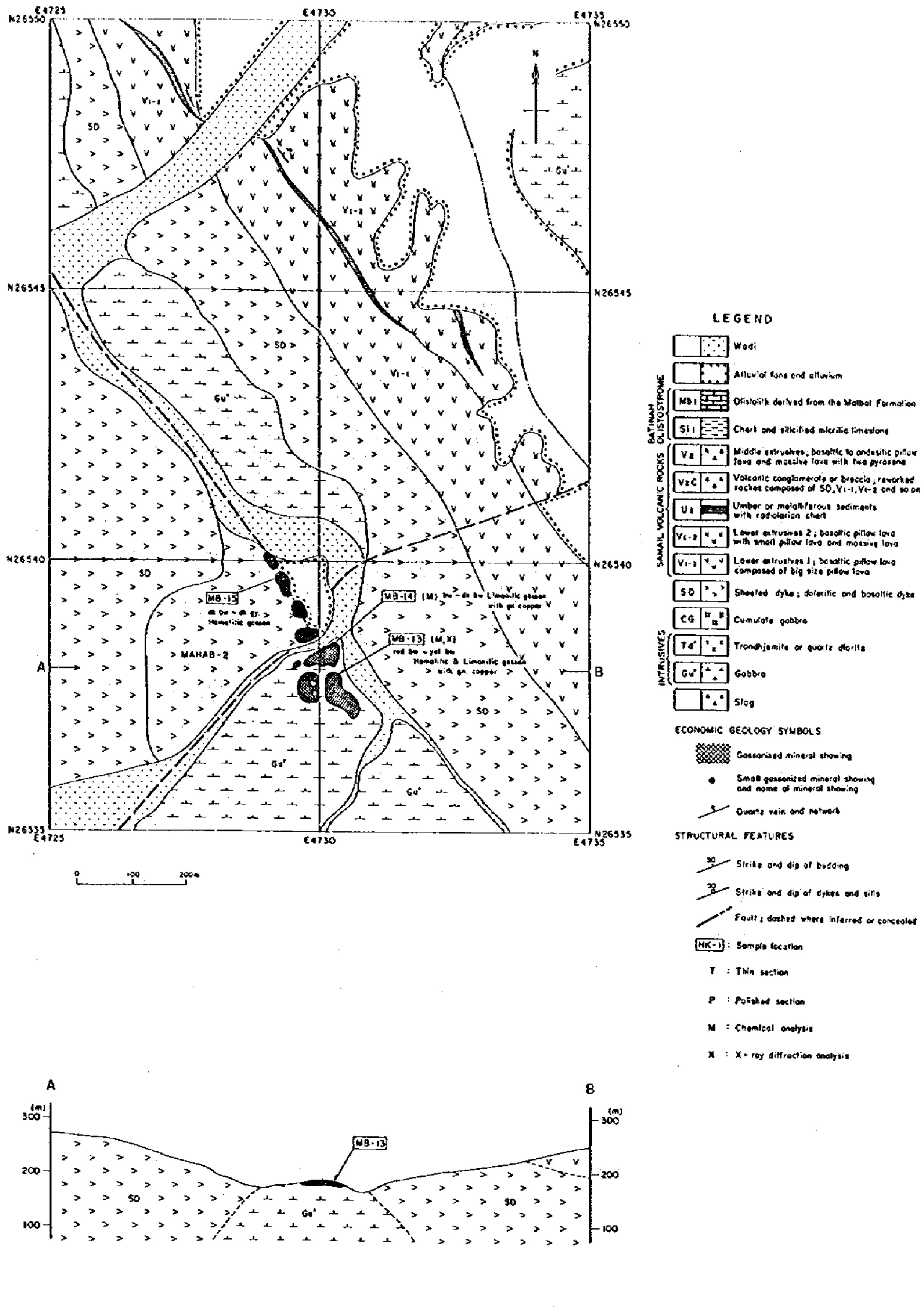


Fig. II-1-9 Geologic map of Mahab 2 area

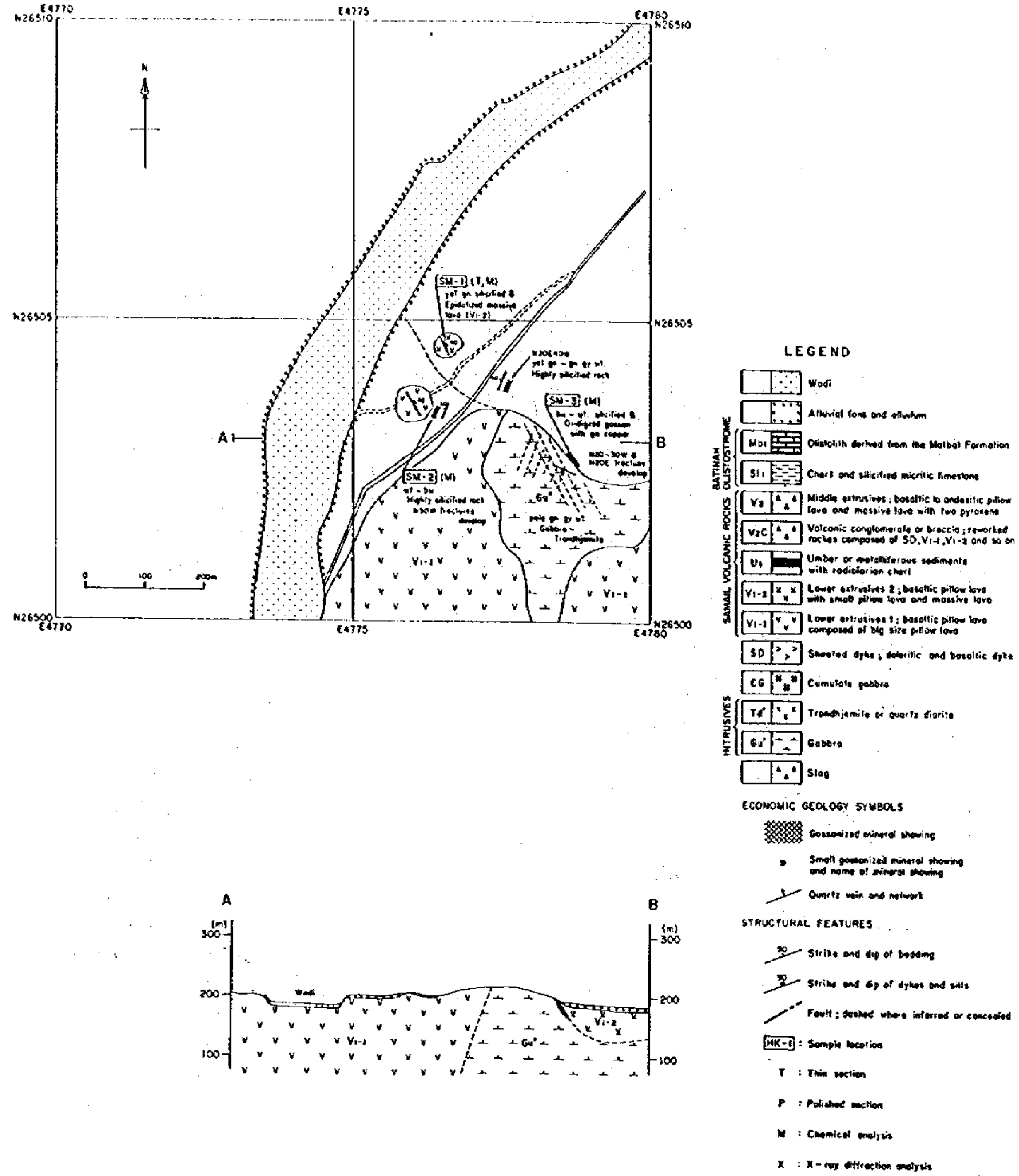


Fig. II-1-10 Geologic map of Sarami area

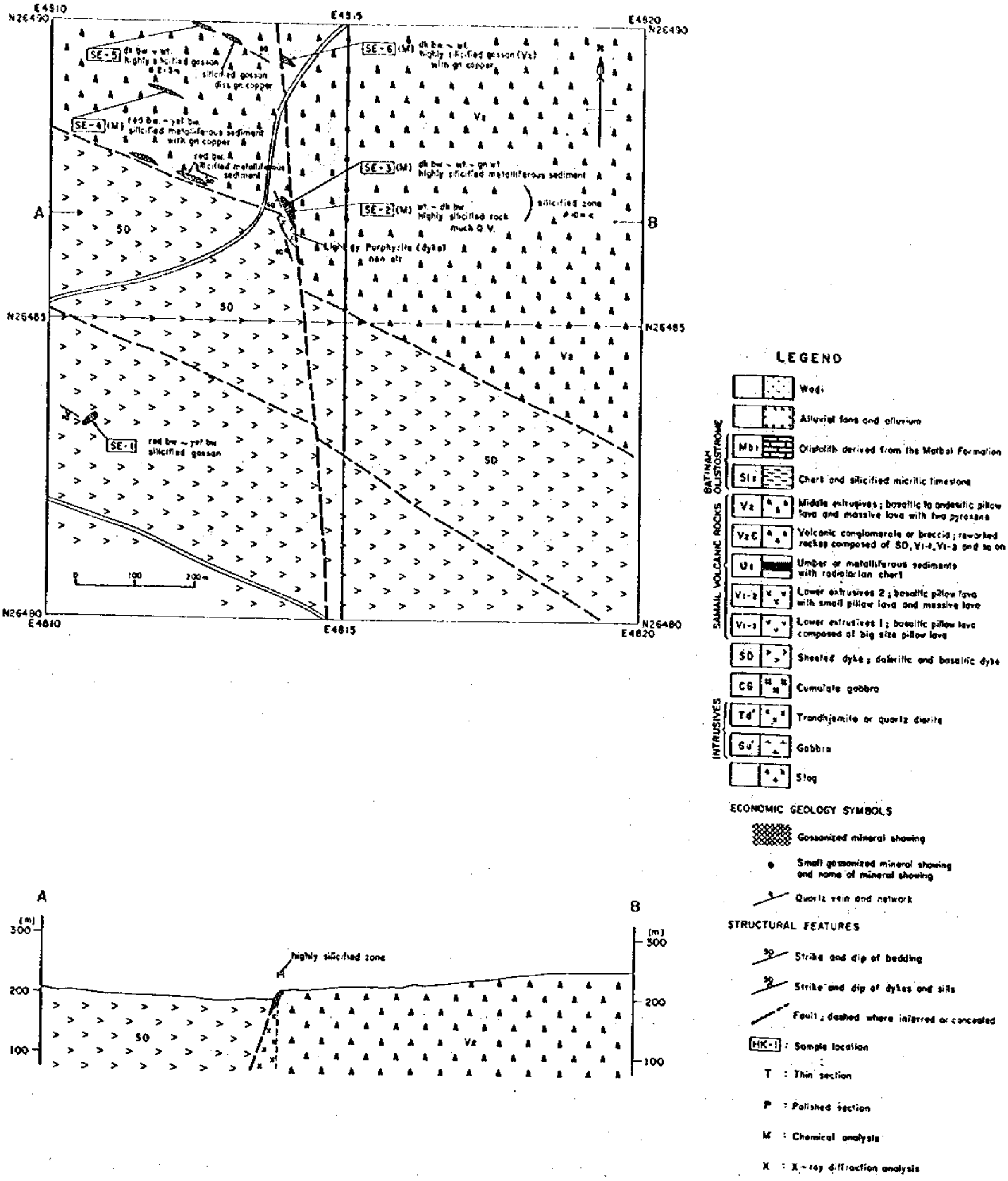


Fig. II-1-11 Geologic map of Sarami East area

(9) Listwaenite mineral showing

This showing is located about 9km northwest of Doqal village and the southeast of Sarami East showing.

The geology consists of V2 of Samail Ophiolite, fan deposits and alluvium. A large scaled gossan of the size of 120m x 30~40m is exposed at the intersection of the inferred faults formed by the E-W and NW-SE systems. At the northern side of the gossan, a remarkable silicification and a intrusion of carbonatizad felsic rocks and altered peridotite can be observed along NW-SE fracture. Propylitic alteration consisting of chlorite, epidote and quartz is remarkable under the gossan.

(10) Doqal West mineral showing

This showing is located to the 7km west of Doqal village. The geology of this showing consist mainly of V1-1, V2,V2c, U2, fan deposits and alluvium.

Large scaled gossan extending northwesterly of 50m x 15m in size is outcropping in this showing. Since this gossan is surrounded with V2 and very siliceous, it considered to be derived from U2.

Gossan is associated with intensely silicified parts, quartz network and the part containing abundant manganese oxide.

(11) Salahi V&VI mineral showing

This showing is located about 30km southwest of Sohar city. The geology consists mainly of V1-1, V1-2,U1,U2, fan deposits and alluvium. Peridotite intrusion is found in V1-2.

In this showing, V1-1 and V1-2 show a gentle dipping, while pillow lava is not developed in V1-2. Hematite predominates in the most of U1.

U1, at the sample location of SH-1, is rich in magnetite and accompanied with copper oxide. At SH-7, silicified and epidotized V1-2 can be found along the fault of WNW-ESE direction and accompanied with a slight dissemination of copper oxide.

(12) Salahi I mineral showing

This showing is located to the southeast of Salahi V&VI showing.

The geology consists mainly of V2, U2, V3, cherty shale fan deposits and alluvium. U2 is well bedded and strikes in the N-S to NNE direction with a dip around 40° to 60° east. U2 looks more like a cherty shale rather than a metalliferous sediment.

Gold mineralization was previously reported in the gossanized U2. The gossanized U2 is accompanied with limonite-clay minerals veinlets and silicification along many fractures of N70° W direction. In the vicinity of gossan, a extensive fault running from the Salahi V showing was inferred with a strike of N70° W and a south dip of 80° . Altered charty shale with a banded structure consisting of

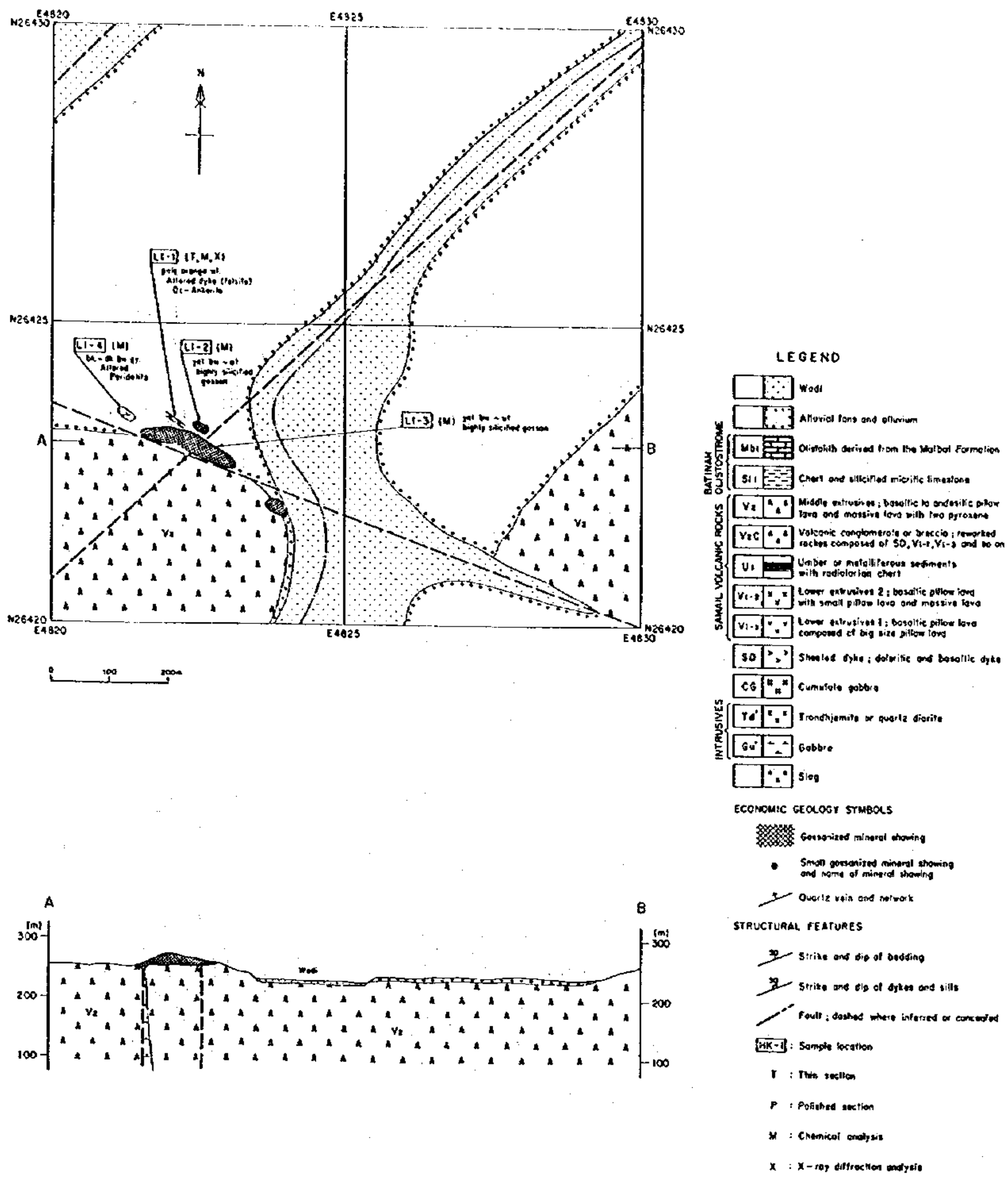


Fig. II-1-12 Geologic map of Listwaenite area

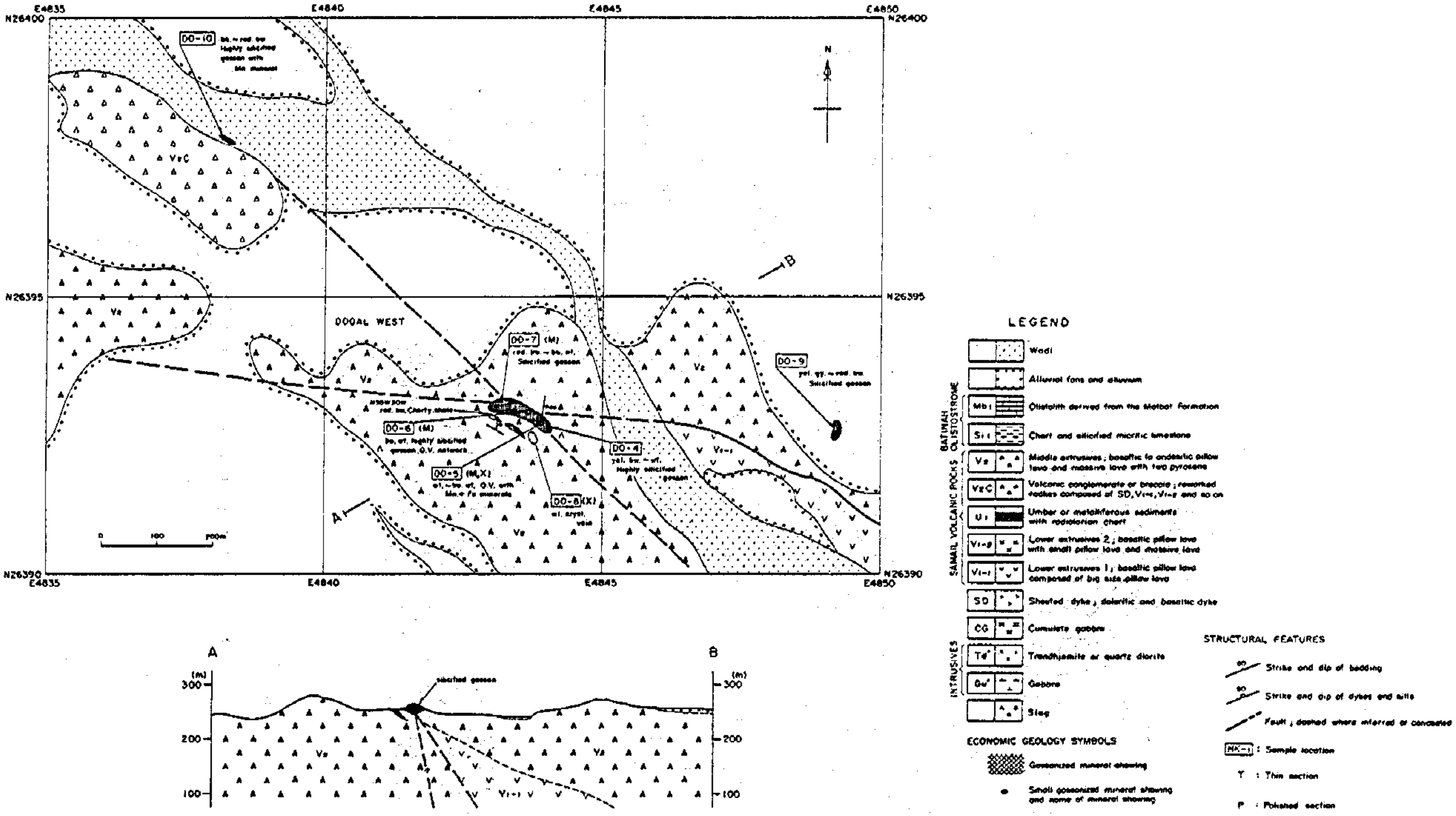


Fig. II-1-13 Geologic map of Doqal West area

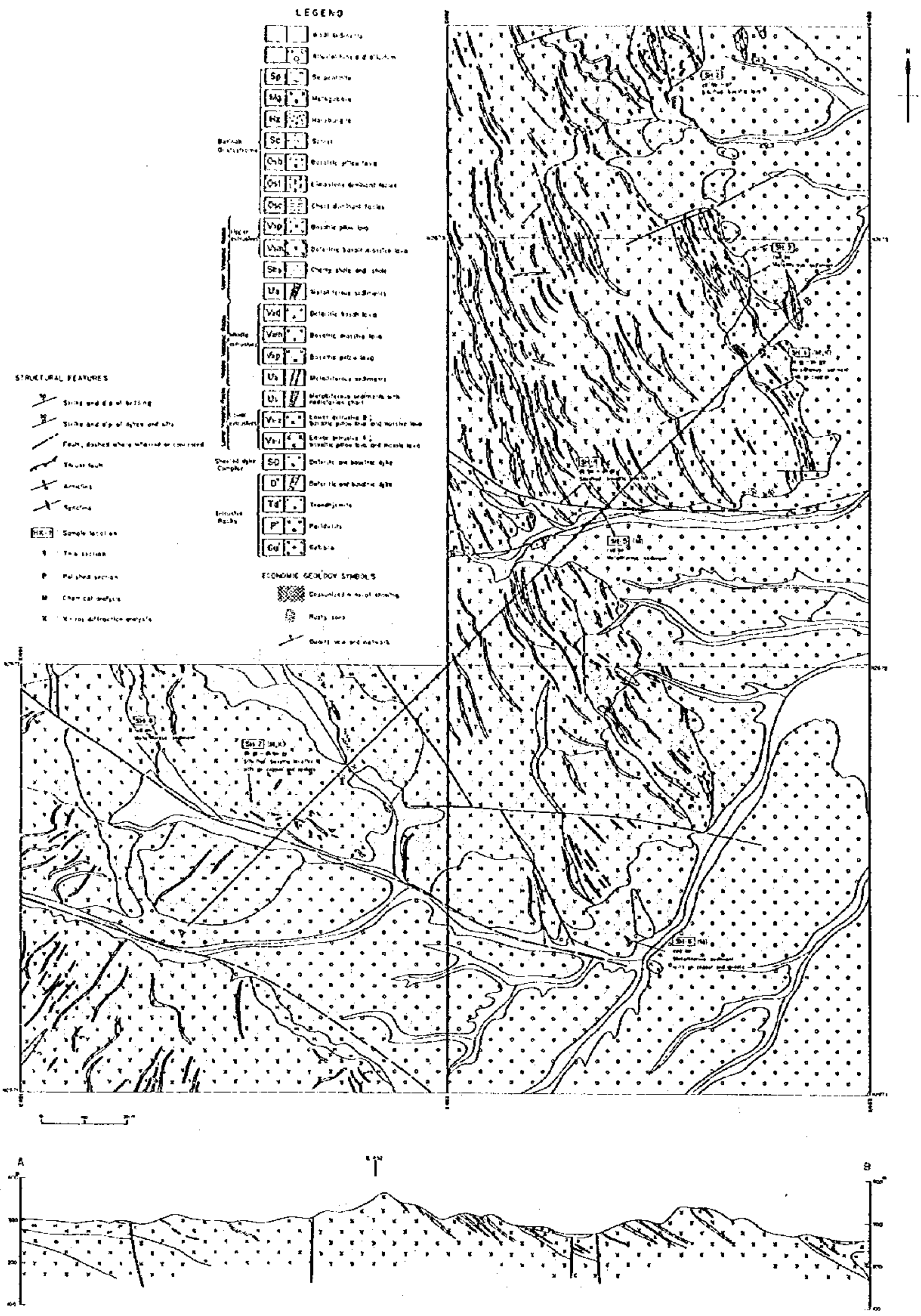


Fig. II -1-14 Geologic map of Salahi V and Salahi VI area

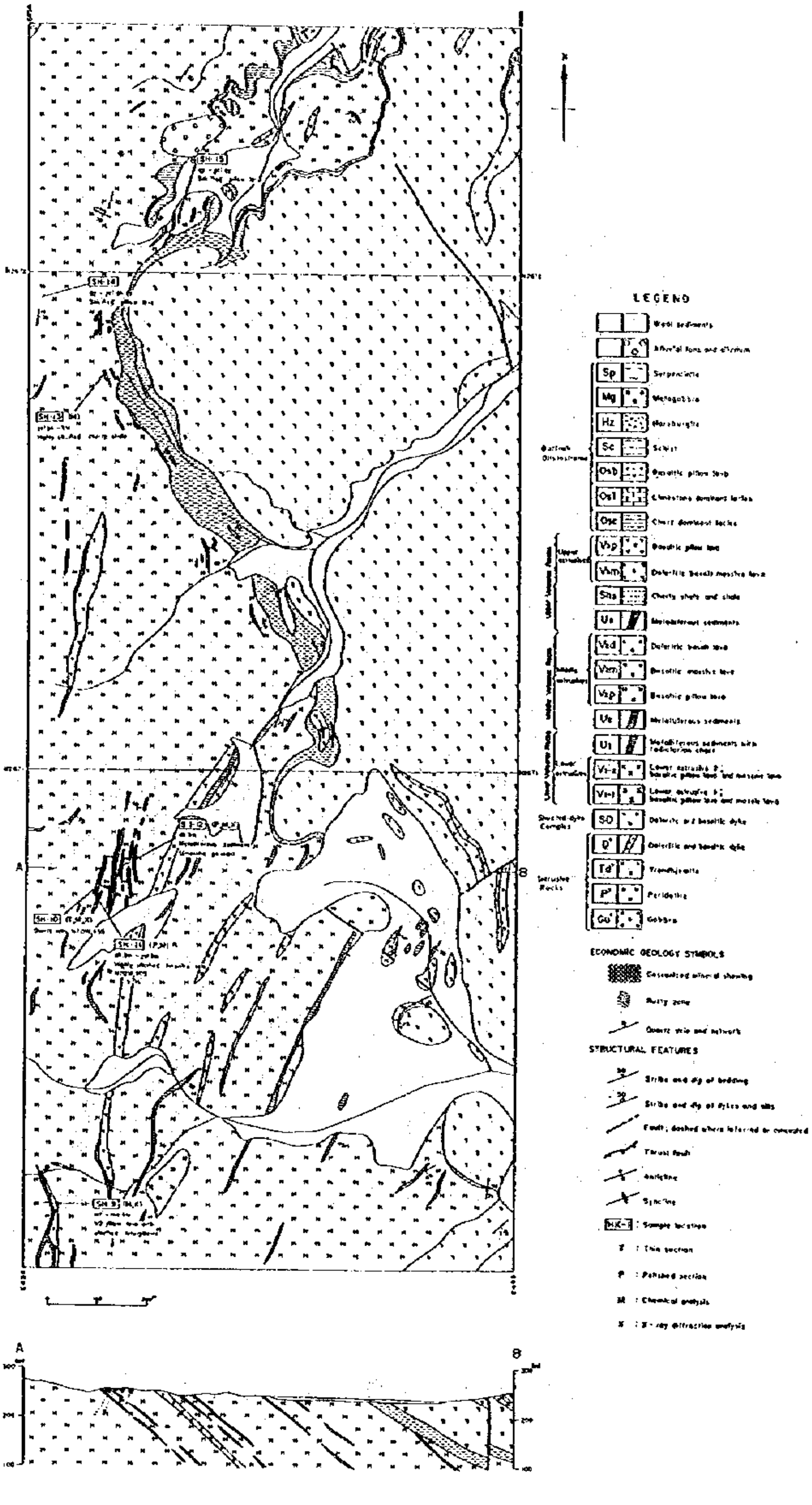


Fig. II-1-15 Geologic map of Salahi I area quartz, epidote and hematite can be found at the sample location of SH-13.

(13) Maqail mineral showing

This showing is located to the south of Salahi I showing. The geology of the showing is constituted mainly of V1-1, V1-2, U1, V2, U2, Batinah Olistostrome, fan deposits and alluvium.

U1 are distributed in many places and showing intermediate characteristics between U1 of Ghuzayn area and U2 of Salahi I showing. An intense silicification and local dissemination of copper oxide can be observed along the fault of NE-SW direction, such as at the sample location of MQ-1 to 4. Floats of massive pyrite can be also found in the sample location of MQ-6.

(14) Maqail South mineral showing

This showing is located on the southwest of Maqail showing.

The geology consists mainly of V1-1, V1-2, U1, V2, bedded chart of Batinah Olistostrome, fan deposits and alluvium. In V1-1 and V1-2 of this showing, massive lava is seen more predominant than pillow lava. Many dolerite dykes are seen.

Copper oxide are observed in silicified zone and gossan in many places. Most of copper mineralization, however, can be found along a NW-SE system fault and therefore, considered to be a secondary mineralization. Since the thick bed of U1 exposed in the sample location of MQ-10 is rich in magnetite and accompanied with sulphide minerals and copper oxide, the bed possibly graded laterally into a massive sulphide ore. In general, U1 of this showing seems more siliceous and with less content of iron minerals than U1 of Ghuzayn area.

1-4 Further Considerations

1-4-1 Relation between Lower Volcanic Rocks and Middle Volcanic Rocks

V1-1 is primarily rich in Fe component with a chemical composition characteristic of differentiated basaltic lavas. On the other hand V1-2 is poor in Fe component, showing a low Mg/Fe ratio. Fe rich metalliferous sediments exist also in V1-2 and at the boundary between V1-1 and V1-2. Therefore, it is possible that oxygen fugacity was different from each other in both active environments or periods of V1-1 and V1-2.

It seems that the active period of V1-2 is the early stage of middle volcanic rocks rather than the final stage of lower volcanic rocks because the boundaries between V1-1 and V1-2 are not generally clear but gradually change in the survey area. It is observed that small faults develop everywhere at the contacts between SD and V2. Generally, Trondhjemite or Gabbro have intruded into the boundaries between V1-1 and V1-2.

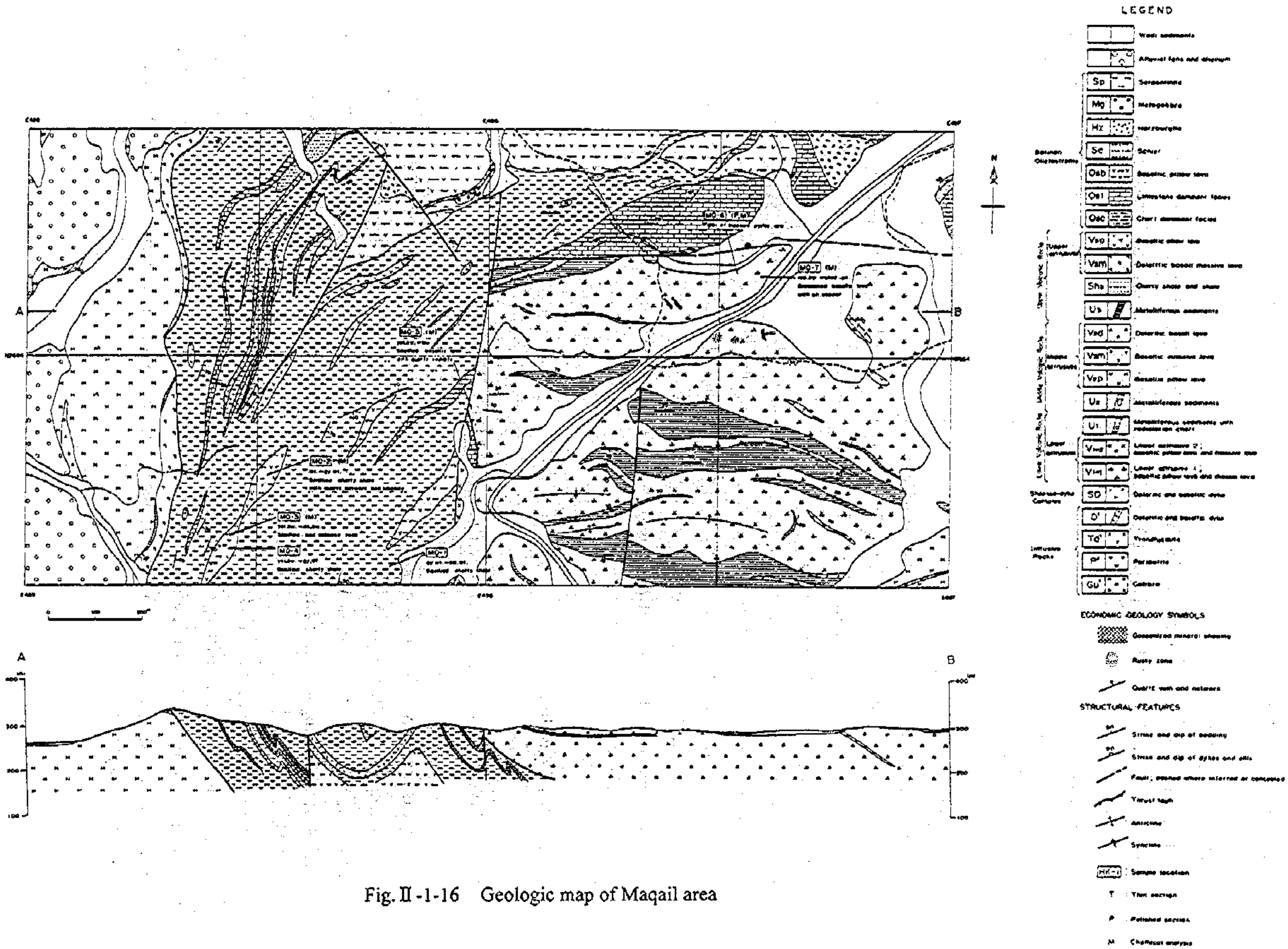


Fig. II-1-16 Geologic map of Maqail area

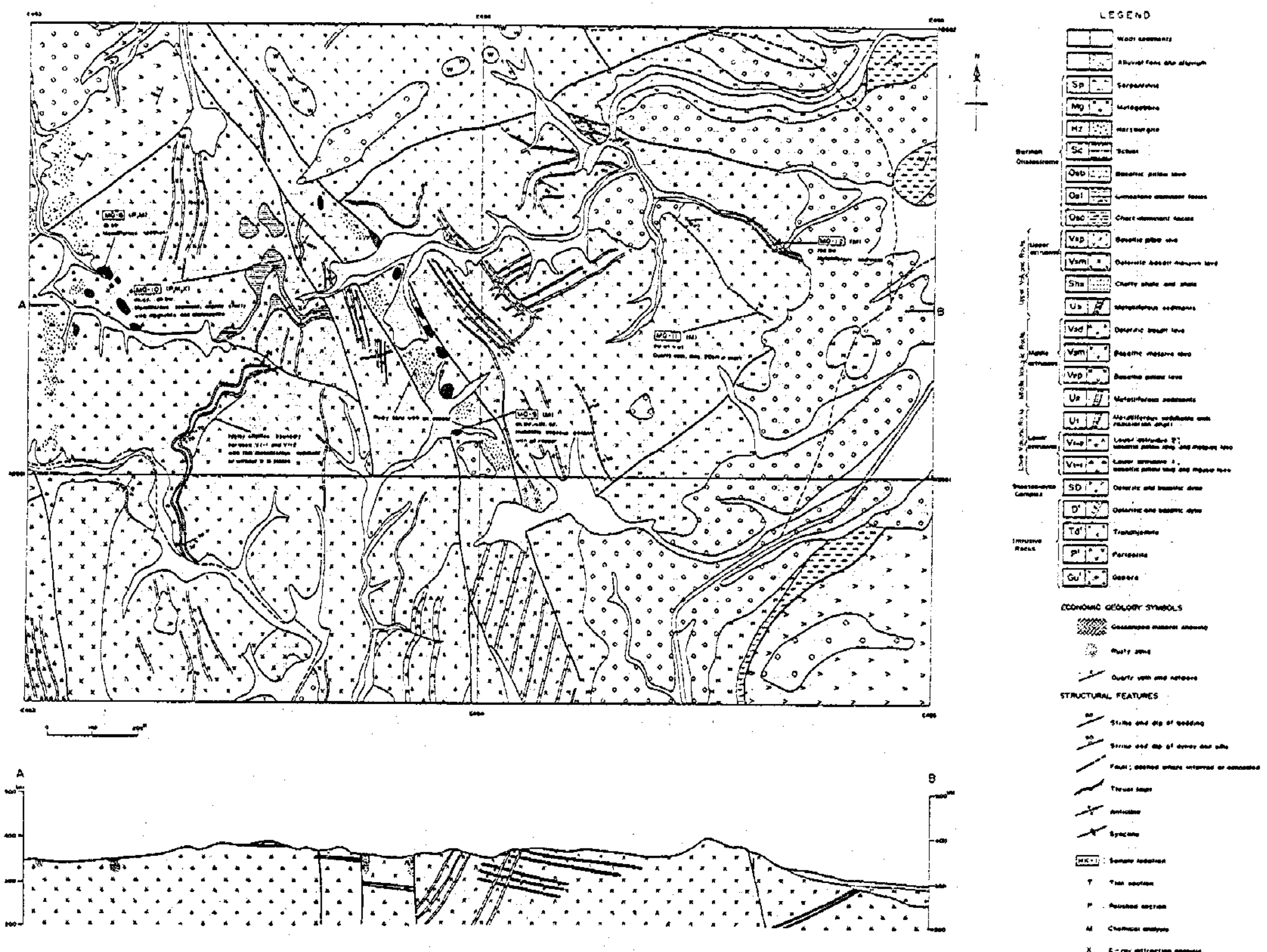


Fig. II-1-17 Geologic map of Maqail South area

It is supposed that the basic rockfacies gradually change from V1-2 to V2 and the unconformity of V1-2 and V2 are recognized only in the area where middle to acidic rockfacies are exposed.

The difference of V1-2 and V2 can be explained by the different magmatic process from the same original magma; in other words, by the different content of SiO_2

The intrusive rock facies of Trondhjemite and Gabbro are probably related with the middle volcanic rocks in the genesis.

The magma differentiation in the middle volcanic rocks is larger than that of the lower volcanic rocks, because the middle volcanic rocks show a wide variation from basic to acidic in the chemical composition (rock facies). It seems that water content is important and in this regards, the mechanism of additional water played an important role in the mixing of original magma and sea water or altered host rock with much amount of water. Therefore, to understand the above process it is important to consider the difference of oxygen fugacity and the mechanism of ore genesis.

In addition, the outcrops of V1-1 rich in epidote are mostly hard and with a sharp shape. It is recognized the trend that the metalliferous sediments develop well (the thickness of metalliferous sediments increase) on the V1-1 with abundant epidote. The metalliferous sediments which exist in the boundaries between V1-1 and V1-2 are rich in Fe content and divided into two types; one is mainly composed of pyrite or magnetite, and another is rich in hematite. The former type presents the possibility of changing gradually and laterally to massive sulphide. The metalliferous sediments(U2) in V2 generally consist of banded chert or cherty shale, and present higher SiO_2 and lower Fe contents than U1.

1-4-2 Exploration Indicators of Massive Sulphide Deposits

Based on the geology and the ore mineralization that occurred in and its vicinity of the massive sulphide deposits confirmed in the Ghuzayn Area, some exploration indicators have been found useful for future exploration works. These indicators can be briefly mentioned as follow:

(1) Massive sulphide deposits show stratigraphic control and occur in the contact between V1-1 and V1-2.

(2) The alteration associated with mineralization consists of silicification, chloritization (Mg-rich chlorite) and epidotization. Silicification and epidotization are remarkable even in the margin of the massive sulphide ore body.

(3) The generation of massive sulphide deposit is closely related to faults.

(4) There exists the possibility that metalliferous sediment grades laterally into massive sulphide in the case that the sediment contains many magnetic layers with clear stratification and copper mineralization.

1-4-3 Evaluation of each Mineral Showings

Based on the above-mentioned exploration indicators, the following seven areas (Mineral Showings) may have relatively high potential for the existence of massive sulfide deposit: Hara Kilab, Mahab 5 and 6, Mahab 3, Mahab 4, Mahmum, Maqail and Maqail South Areas. Among them, Hara Kilab and Mahab 3 Areas present the highest potential. .

Mahab 2 Area has low potential for the economical primary massive sulfide deposit, because the gossans with copper mineralization and its vicinity are mainly composed of SD and Gabbro.

The alteration of Sarami Area may have been affected by the intrusives of Gabbro or Trondhjemite along the faults rather than massive sulfide mineralization.

Sarami East Area has low potential for the primary massive deposit, because V1-1 and V1-2 are not exposed in the area.

Though Listwaenite and Doqal West Areas have big gossans, low potential for the primary massive deposit is also expected because the geology of these areas are mainly composed of V2.

Salahi V and VI Areas do not have high potential for massive sulfide deposit, because the alteration is weak around the boundaries of V1-1 and V1-2, pillow lava poorly exists and metalliferous sediment is mainly composed of hematite.

The ore forming horizon (the boundary of V1-1 and V1-2) do not exist in Salahi I Area; even so cherty shales within V2 were gossanized and associated with gold mineralization. It was recognized that the limonite and other clays alteration develops along the fractures of N70° W direction within gossanized cherty shales which are distributed in an area previously prospected by Bishimetal Exploration Co., Ltd.. The big fault having N70W, 80S exists close to the above-mentioned gossans. It is possible that some parts of the cherty shale were affected by ore mineralization when they existed in the state of non-solid or sub-solid, because they had the banded structures consisting of quartz, epidote and hematite as seen in the location point of the sample SH-13.

Based on the mentioned above, it is estimated that the gold mineralization may have been caused at the end of V2 active period, by ore solution which ascended along the faults and fractures having NW-SE trend, and ore solution which also moved laterally within and just under the cherty shales.

Table Ⅱ-1-1 Description of thin sections of surface samples

Ser. No.	Sample No.	Cordinates N (km)	Cordinates E(km)	Location	Rock Name	Texture	Primary Minerals Qz	Pl	Cp	Op	Ol	Ap	Sp	OM	Secondary Minerals Qz	Ab	Am	Ch	Ep	Ac	Pu	Pr	Cc	Sr	Sm	OM	PM
1	SM-1	2650.46	477.65	Sarami	Basalt($V_{1\text{-}2}$)	Intersertal	●	○	●			·			○	○		○	◎			○				○	
2	SH-10	2670.04	454.11	Salahi	Quartz vein										◎			●	·					·		○	
3	LI-1	2642.34	482.22	Listwaenite	Felsite(dyke)	Cryptocrystalline									·								◎			·	
4	TM-1	2656.90	468.59	Mahab-4	Trondhjemite	Hypidiomorphic granular	◎	◎				○			●	○	●	○	○				●			○	●
5	LP-1	2656.49	468.65	Mahab-4	Basalt($V_{1\text{-}1}$)	Intersertal		◎	·						●	○		○							○	○	
6	UP-1	2656.26	468.83	Mahab-4	Basalt($V_{1\text{-}2}$)	Intergranular	●	○	○	●		·	·		○	○		◎	●			○	●			·	

◎: abundant, ○: common, ●: rare, ·: very rare

Qz: Quartz, Pl: Plagioclase, Cp: Clinopyroxene, Op:Orthopyroxene, Ol: Olivine, Ap: Apatite, Sp: Spinel,

Ab: Albite, Am: Amphibole, Ch: Chlorite, Ep: Epidote, Ac: Actinolite, Pu: Pumpellyite, Pr: Prehnite, Cc: Calcit

Sr:Sericite, Sm: Smectite, OM: Opaque minerals, PM: Pseudomorph of Phenocryst, Lm: Limonite

Table Ⅱ-1-2 Description of polished section of surface samples

Ser. No.	Sample No.	Coordinate N(km)	Coordinate E(km)	Sample Description	Identified Minerals Cp	Py	Mc	Mt	Ht	Ml	Cr	Go
1	SH-7	2671.68	451.55	Silicified basalt lava with green copper						●	●	○
2	SH-11	2670.76	454.13	Limonite vein (5cm in width)								○
3	SH-12	2670.81	454.19	Gossanized metalliferous sediments								○
4	MQ-6	2664.17	456.53	Massive pyrite ore		◎	●					
5	MQ-8	2661.44	453.06	Metalliferous sediments				○	◎			
6	MQ-10	2661.44	453.49	Metalliferous sediments with green copper		●		●	○			
7	SE-2	2648.68	481.40	Silicified rock with quartz veinlets		●						●

◎ abundant　　Cp: Chalcopyrite　　Ht: Hematite
○ common　　Py: Pyrite　　Ml: Malachite
● rare　　Mc: Marcasite　　Cr: Chrysocola
　　Mt: Magnetite　　Go: Goethite

Table II-1-3 Results of X-ray diffraction analyses of surface samples

Ser. No.	Sample No.	Coordinate N(km)	Coordinate E(km)	Lithology(Formation)	Identified Minerals Qz	Pl	Ch	Cc	Cr	Ep	Gp	Py	Mt	Ml	Go
1	HK-2	2,660.04	464.48	Limonitic gossan	○						∘				∘
2	HK-3	2,659.99	464.59	Limonitic gossan with gypsum vein	●			○			◎	∘			∘
3	MB-5	2,659.52	466.98	Silicified basaltic lava(V1-1)	○	○	∘								
4	MB-8	2,658.87	467.22	Sheared rock along fault(SD,V1-1)	●	●									
5	MB-11	2,658.10	467.62	Silicified metalliferous sediments	●	○									
6	MB-12	2,658.07	467.62	Gossanized brecciated ore	◎									∘	∘
7	MB-13	2,653.80	473.03	Siliceous gossan	∘						○	∘			
8	MB-16	2,656.91	469.13	Silicified metalliferous sediments	◎	∘									
9	MB-21	2,656.16	468.80	Argillitic part of metalliferous sediments	○	∘	∘								∘
10	MM-2	2,655.95	470.20	Argillitic part of sheared zone	○	∘	∘								∘
11	SH-1	2,672.65	452.77	Metalliferous sediments	●	○	●		∘						
12	SH-7	2,671.68	451.55	Silicified basaltic lava	◎	◎	●								
13	SH-9	2,670.12	454.03	Interpillow of basaltic pillow lava(V2)		∘		○		○					∘
14	SH-10	2,670.04	454.11	Quartz vein	◎		∘								
15	SH-12	2,670.81	454.19	Gossanized metalliferous sediments	◎			●							
16	MQ-10	2,661.44	453.49	Magnetite rich metalliferous sediments	○		∘						○		
17	LI-1	2,642.34	482.22	Silicified felsic rock	◎			○							
18	DO-5	2,639.27	484.39	Quartz vein in siliceous gossan	◎										
19	DO-8	2,639.24	484.38	Calcite vein				◎							

◎ abundant
○ common
● rare
∘ very rare

Qz: Quartz
Pl: Plagioclase
Ch: Chlorite
Cc: Calcite
Cr: Cristobalite
Ep: Epidote
Gp: Gypsum
Py: Pyrite
Mt: Magnetite
Ml: Malachite
Go: Goethite

CHAPTER 2 TDIP SURVEY

2-1 Background and Objectives

Discover new ore deposits by clarifying the distribution of mineralized zones in the South Batinah Coast area.

During the geophysical surveys carried out in 1995 and 1996 in the Central Batinah Coast area, not only two massive sulphide ore bodies were discovered in Ghuzayn area, but also indications of massive sulphide were detected in Doqal area.

According to the results of the 1996 field survey, it was recommended to extend the TDIP survey in Ghuzayn area as well as in Doqal area in order to estimate the existence and extension of massive sulphide deposits.

2-2 Survey Locations and Specifications

As mentioned above, the two areas of Ghuzayn and Doqal were selected for further geophysical exploration work. In Ghuzayn area, the exploration work was extended in two parts, i.e., to the west and to the east of the main gossan area previously explored. A summary of the TDIP geophysical survey method performed in both areas is indicated in the following table:

Table II-2-1 Survey amounts of TDIP

AREA	LENGTH(Km)	No. of LINES	No. of POINTS
Ghuzayn	23.0	5 Lines×2.5Km 5 Lines×2.0Km 1 Line×0.5Km	830
Doqal	21.0	8 Lines×2.0km 2 Lines×2.5Km	780
Total	44.0	21 Lines	1610

2-3 TDIP Survey Method

2-3-1 Procedure

The measurements were carried out by means of a time-domain method and adopting a dipole-dipole electrode configuration with a separation factor from 1 to 4. IP data were taken along lines every 100m by keeping a potential dipole of 100m. In field IP surveys, a current is injected into the earth through current electrodes and a resulting voltage is measured across potential electrodes. Fig. II-2-1 shows the array utilized as well as the location of the plotting points.

For TDIP surveys, the current is turned on for a certain length of time (on-time) then turned off (off-time). The transmitted waveform is then repeated with current flow in opposite direction. The pair of positive and negative on-off waveforms constitutes a cycle, which in this survey lasted 8 seconds, as indicated in Fig. II-2-2. According to Fig. II-2-3, the polarization of the target creates a transient decay voltage and its corresponding charging response is observed in the received waveform.

In order to obtain a desired signal-to-noise ratio, the measurements were, in general, repeated 3 times with a stacking of more than about 10 times.

2-3-2 Instrumentation

The instrumentation used for the conventional time-domain IP survey are described in the following table:

Table II-2-2 Specifications of TDIP survey instruments

Receiver	Phoenix Multiporpuse Receiver V5
Number of Channels	8
Dynamic Range	(+/-)5V
Gain	From 1 to 2,148
Resolution of A/D conversion	16 bits
Notch Filter	50/60 Hz, 21st order harmonics
Transmitter	Phoenix IPT1
Maximum Output power	2 kW
Output Current	10 A maximum
Frequency	0.15 Hz, 50% duty cycle
Generator	Robin
Maximum Output Power	3 kW
Output Voltage	200 V
Output Frequency	50 Hz
Potential Electrode	Non Polarizable Pb/PbC12 Pot

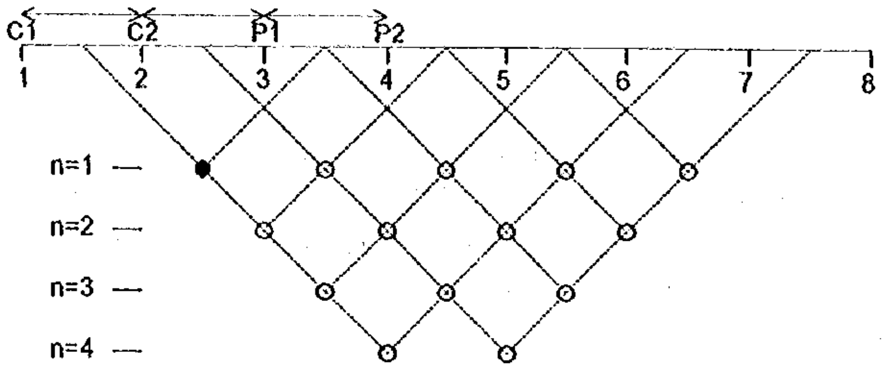


Fig. II−2−1 Dipole−dipole array and plotting procedure

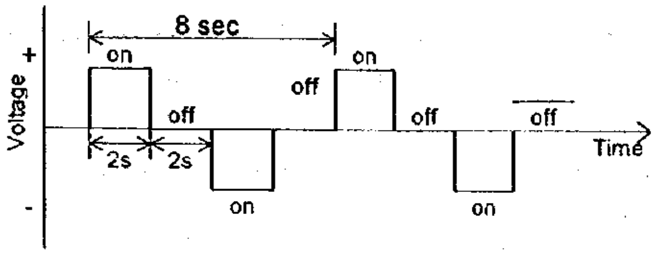


Fig. II−2−2 Waveform produced by the transmitter

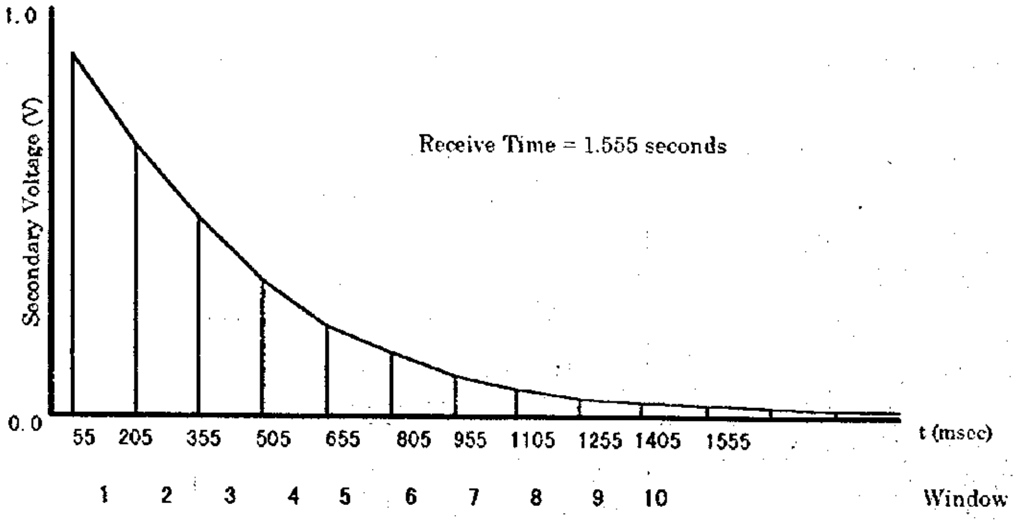


Fig. II−2−3 Sampling interval of the TDIP receiver

2-4 Analysis Method

2-4-1 Data Processing

The TDIP data processing involves the determination of 3 parameters, i.e., apparent resistivity, chargeability as well as metal factor. The first 2 parameters are calculated directly by the receiver unit during data acquisition. The third one is calculated as a simple relation between the first 2 parameters. These 3 parameters are calculated as follow:

a) Apparent resistivity (ρ)

$$\rho = K\frac{V_P}{I}$$

Where, $K = \pi an(n+1)(n+2)$ and ***Vp*** is the received voltage in volts, ***a*** is the A-spacing in meters, ***n*** is the N-spacing and ***I*** is the transmitted current in Amperes

b) Chargeability (*M*)

$$M = \frac{1}{V_P}\int_{t_1}^{t_2} V_t dt$$

Where, ***Vp*** is the primary voltage in volts and ***Vs*** is the secondary voltage in volts
Here, the secondary voltage is calculated from 55msec. to 1555msec.

c) Metal factor (*MF*)

$$MF = \frac{M}{\rho} \times 100$$

Where,

M: Chargeability (mV/V)
ρ : Apparent resistivity (Ω m)

2-4-2 Topographic Corrections

Since the apparent resistivity is calculated also in function of the location of the current and potential electrodes on a half-infinite plane, it is affected by topography depending on the location of the electrodes. For the case of a dipole-dipole configuration, the apparent resistivity appears to be high beneath a hill and low beneath a valley. On the other hand, the chargeability values are less affected by topography.

For the present survey, topography corrections were carried out in Ghuzayn in the lines from 1200E~2000E of Ghuzayn as well as from 1200W~2000W of Ghuzayn area and in the lines 800N~1000S of Doqal area. To make these corrections it was utilized a finite element method which assumes a two dimensional half space topography .

2-4-3 Two-dimensional Analysis

For the IP data analysis and according to the standard model, the apparent resistivity distribution and the chargeability distribution are used in combination to make a quantitative analysis of the pseudo-sections and plan maps. The resultant underground model is inferred by making use of the theoretical results given by the model. This is called in general a model simulation.

In the present survey, according to the limitations of the results of the forward modeling and to match the field results, it was used a 2-D inversion model which combines the FEM forward calculations with a non-linear square method. The inconveniences presented by the 1D analysis to make a layer analysis of the underground structure, are best solved by the approximation made by the 2-D model.

In order to make the model calculations, the underground structure is divided into many small blocks, each of them having initially assigned their own chargeability and resistivity value. The blocks are designed so that small blocks are placed close to the surface and they increase in size as the blocks are located at deeper levels.

2-5 Survey Results

2-5-1 Electrical Measurements of Rock Samples

Representative core samples from the survey area were analyzed in order to investigate whether the contrast in resistivity between the target mineralization and the volcanic rocks is enough to discriminate between these units in terms of electrical properties.

In general resistivity and IP measurements in rocks may not reflect in a direct way the intrinsic resistivity or chargeability because of different degree of alteration and water content over the survey area,

Table II-2-3 Resistivity and chargeability of rock samples

Sample No.	Borehole and Depth	Resistivity (Ω.m)	Chargeability (mV/V)	Rock Name and Formation	Alteration and Mineralization
1	D5-131.1m	320	22..7	Ba, Pw(V1-2)	Cp diss(very slight)
2	D5-212.0m	254	31.3	Ba, Pw(V1-2)	Py diss(very slight)
3	Q2-90.5m	1114	56.7	Ba, Pw(V1-2)	Py diss(sl), Py vein, Sili(sl)
4	Q2-123.8m	2391	50.1	Ba, Ma(V1-2)	Py diss, Py vein
5	G18-277.0m	371	7.1	Ba, Ma(V1-1)	Sili (sl)
6	G19-95.0m	2800	8.1	Ba (V1-2)	Sili(in)
7	G20-38.2m	17	1.0	Ba, Pw(V1-2)	Chl
8	G20-90.3m	258	2.6	Ba, Pw(V1-2)	
9	G20-277.9m	32	63.0	Magnetite layer	Magnetite with py
10	G21-150.6m	340	9.4	Ba, Ma(V1-1)	Sili
11	G22-82.0m	133	87.0	Ba, Pw(V1-2)	Py-Cp-Epi-Qz vein, Sili(sl)
12	G22-114.8m	181	95.8	Sili Rock(V1-1)	Py net
13	G22-121.4m	1.4	355.0	Sili Rock(V1-1)	Cp-Py-Qz net, Py diss(in)
14	G23-44.5m	99	2.9	Ba, Pw(V1-2)	
15	G23-221.5m	45	10.5	Ba, Pw(V1-2)	Py diss(sl)
16	G24-37.5m	52	1.4	Ba, Pw(V1-2)	
17	G24-191.0m	87	44.2	Ba, Pw(V1-2)	Py-Qz net
18	G24-349.6m	83	2.1	Ba, Ma(V1-1)	
19	G25-162.2m	218	29.7	Sili Rock(V1-1)	Sili(in), Argi, Py diss(in)
20	G26-85.15m	118	103.0	Mg, Py	Massive Magnetite with Py, Cp
21	G26-110.25m	88	110.0	Ba, Pw(V1-1)	Py diss(in), Sili(in), Argi(sl
22	G27-120.2m	465	12.0	Ba, Pw(V1-1)	Py diss
23	G27-132.6m	570	4.0	Ba, Pw(V1-1)	
24	G27-186.3m	273	2.8	Ba, Ma(V1-1)	
25	G28-73.6m	92	9.9	Mg layer(V1-2)	
26	G29-125.3m	966	19.6	Ba, Pw(V1-1)	Cp-Py diss
27	G29-162.5m	487	23.0	Ba, Ma(V1-1)	Py diss(sl), Sili(sl)
28	G30-89.4m	180	27.6	Ba, Pw(V1-2)	Py diss(sl), Py vein, Sili
29	G30-245.8m	59	74.6	Ba, Pw(V1-1)	Py diss(in), Sili(in)
30	G31-139.1m	1.6	453.0	MS	Massive Sulphide
31	G31-169.9m	1.7	308.0	MS	Massive Sulphide
32	G31-187.8m	132	9.0	Ba, Pw(V1-1)	Py,Cp diss(in), Py net, Sili(in

Remarks:

DA : DARIS
Q : DOQAL
G : GHUZAYN

V1-1 : Lower Extrusives 1
V1-2 : Lower Extrusives 2

Ba : Basalt
Pw : Pillow lava
Ma : Massive lava
Ba : Basalt
Mg : Magnetite

MS : Massive Sulphide
Cp : Caloopyrite
Epi : Epidote
Qz : Quartz
Py : Pyrite
Argi : Argillization
diss : Dissemination
(sl) : Slight
(in) : Intense
Sili : Silicified
Vein : Veinlets
Net : Network

Chl:Chlorite

however, clear ideas can be obtained related to the relative variations between rocks units and mineralization.

(1) Measurement Method

Measurement of the electrical properties of rock samples, such as resistivity and IP chargeability were carried out on some core samples selected from the survey area. 32 pieces of the rocks collected from boreholes located within the survey area were formed into a cylindrical shape and thereafter, soaked into water for a reasonable amount of days. Apparent resistivity as well as chargeability values were measured according to the IP time domain procedures in the laboratory.

(2) Results

Results of the electrical properties of rocks measured in the laboratory are indicated in Table II-2-3. The resistivity values measured in the laboratory ranged from 1.4 to 2,800 Ωm. The rock samples Nos. 13, 30 and 31 taken from the massive sulphide deposit, presented extremely low resistivity values around 1.5 Ωm. This result provided sufficient resistivity contrast with surrounding volcanic units to be confident about the results obtained during the survey. Not special difference in resistivity was found between the rocks of the upper and lower volcanics(V1-1). Silicified rocks resulted in resistivity values of over 1,000 Ωm, while the rock samples with no alteration , such as the samples Nos. 7, 14, 15. 16, 17 and 18 presented values below 100 Ωm.

The chargeability values determined in the samples ranged from 1.0 to about 450mV/V. Massive sulphide rocks presented very high chargeability values of above 300 mV/V, while massive magnetite containing pyrite, or rocks with intense pyrite dissemination presented high chargeability values between 50 to 100 mV/V. Rocks containing no pyrite presented low chargeability values, however, rocks containing big amounts of pyrite are likely to present high chargeability values.

2-5-2 Ghuzayn Area

(1) Lines location

A total of 11 lines, from 1000E to 1000W, along N14° direction were surveyed around the main gossan during the 1995 field survey season. During this Phase I (1997) survey, the line 1000W of the previous 1995 field survey was extended by 500m towards the north of the station No. 20, while five more lines of 2.5 km each, were placed on the western side. Five additional lines of 2.0 km each were located on the western side.

The location of the above mentioned lines are indicated in Fig. II-2-4.

(2) Results

Contour sections of apparent resistivity, chargeability and metal factor values are presented in the Figs. II-2-5 to II-2-7 for the lines on the west side and in the Figs. II-2-8 to II-2-10 for the lines located on the east side. Compiled contour maps of apparent resistivity, chargeability and metal factor for N=1 to 4 are presented in the Figs. II-2-11 to II-2-14.

West Side:

As can be seen in Fig. II-2-12, apparent resistivity distributions detected in the west side of the area show resistivity values higher than 100Ωm in the south part, but lower than 100Ωm in the north part. Between the boundary of these high and low resistivity distributions, a low resistivity zone below 20Ωm can be clearly seen along the line 1800W around the stations 14 and 15. As shown in the apparent resistivity sections of Fig. II-2-5, this low resistivity anomaly zone is more remarkable than the low resistivity zone detected during the 1996 field survey around the ore body No.2 (line 800W around the station No. 7), indicating that the scale of this anomaly is bigger and/or shallower than the anomaly reflected by the ore body No, 2. The fact that the south side of this low resistivity zone suddenly shows bigger resistivity values, permits to infer that a discontinuity in resistivity takes place below this zone. Furthermore, the line 2000W shows about the same depth, almost same anomaly but in small scale, suggesting the possibility that the source of this anomaly can be extended around the line 2000W.

As presented in the Fig. II-2-11, chargeability values of about 15 mV/V are seen from N=1, indicating that the source of the anomaly (mineralization) reflects high chargeability distribution from surface to depth. Judging from the chargeability and apparent resistivity sections of Fig II-2-6, the chargeability values are distributed wider with a probable extension to the north towards depth. The anomaly distribution at deeper levels (N=3 to 4) indicates its continuation in several directions.

In relation to the metal factors, high values of about 50 are seen (Fig. II-2-11) from shallow levels (N=1), however maximum values of about 80 are seen at deeper levels (N=3) indicating values higher than the ones detected around the ore body No.2. The chargeability values of the lines 2000W and 1600W present rather similar values, for which a continuation is seen at deeper levels but with somewhat smaller values.

At the south edge of the lines 1800W and 2000W values higher than 20 mV/V are seen, however, as these values are seen at the end of the line, its distribution can not be clearly assumed.
Since low resistivity values detected in the north part are located in low chargeability zones of less than 5 mV/V , no massive sulphide distribution can be inferred in this zone.