REPORT ON THE MINERAL EXPLORATION
IN THE RAKAH AREA
SULTANATE OF OMAN (PHASE 1) FEBRUARY 1989

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JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the Government of the Sultanate of Oman, the Japanese Government decided to conduct a Preliminary Feasibility Study for Mine Development Project in Rakah Area and entrusted the survey to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to the Sultanate of Oman a survey team headed by Mr. Takehiko Nagamatsu from September 25, 1988 to January 16, 1989.

The team exchanged views with the officials concerned of the Government of the Sultanate of Oman and conducted a field survey in the Rakah area. After the team returned to Japan, further studies were made and the present report has been prepared.

We hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

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

February, 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Junichiro Sato

Junichiro Sato
President
Metal Mining Agency of Japan

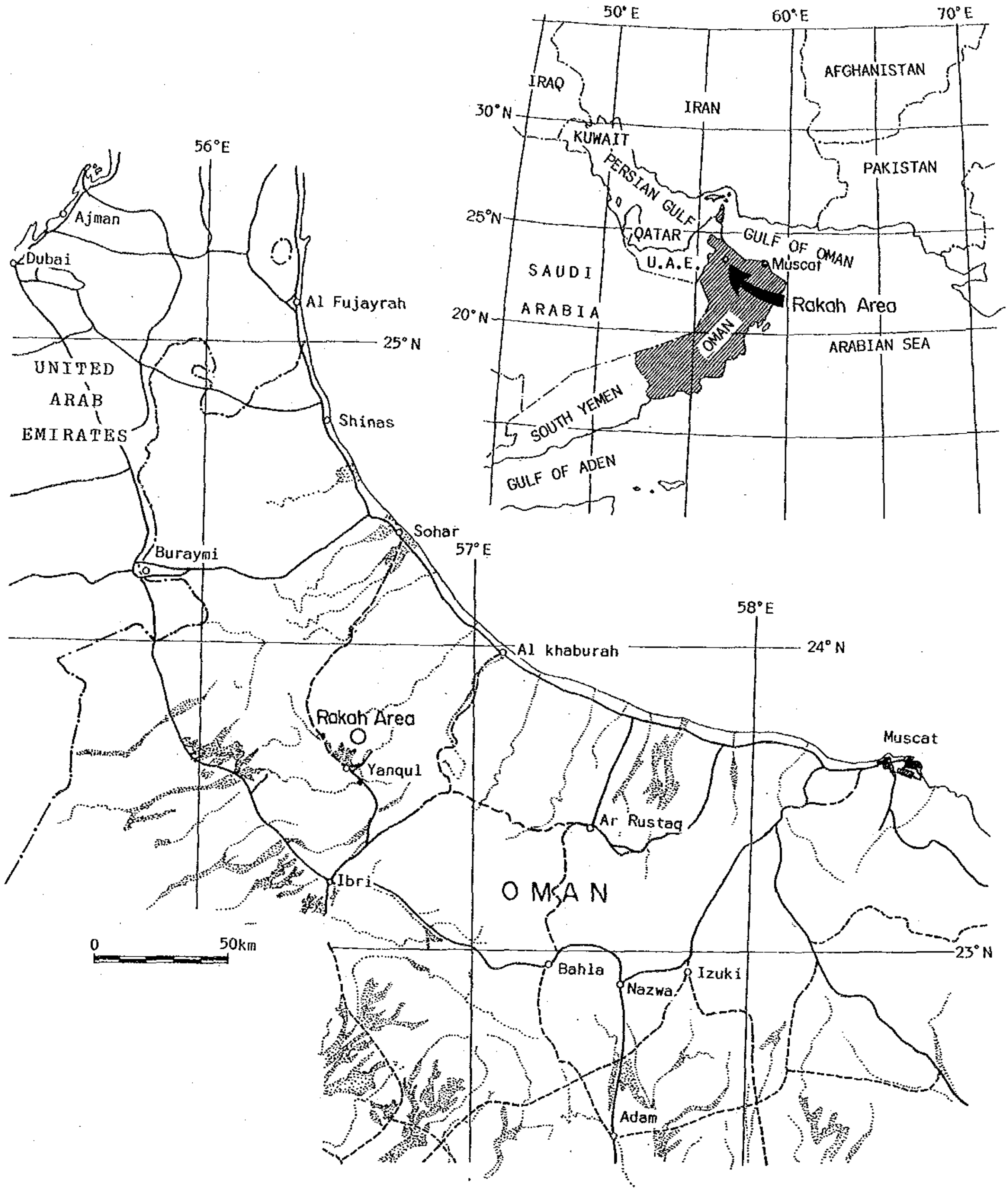


Fig. 1 Location Map of the Rakah Area

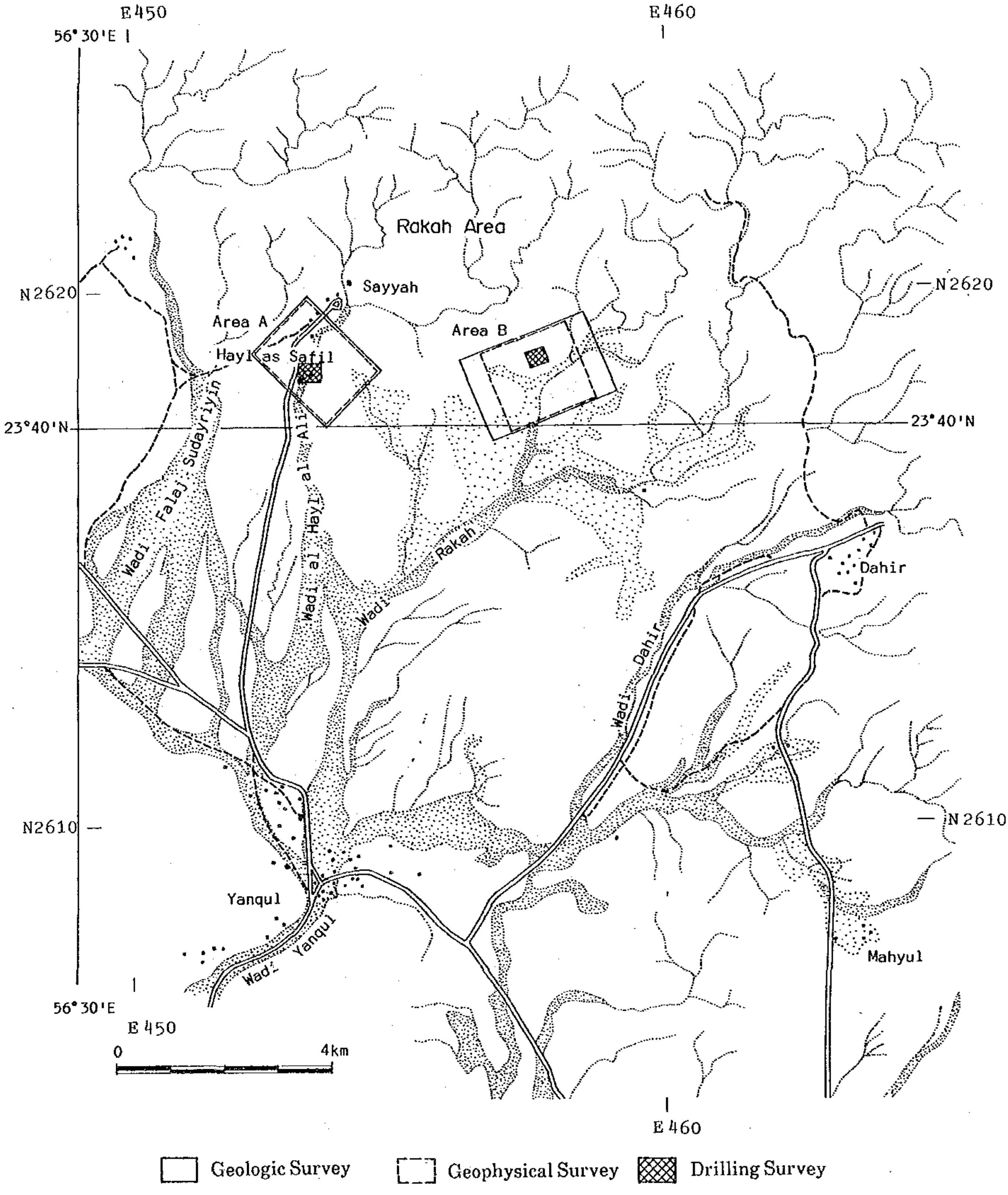


Fig. 2 Location Map of Survey Areas

ABSTRACT

Objectives of "the Mineral Exploration in the Rakah Area, Sultanate of Oman" are to clarify the potential for known two ore deposits and to conduct a preliminary feasibility study for mine development to these ore deposits. The project consists of two years of Phase I and II, and this year is the first year of the project. Geologic, geophysical and drilling surveys were conducted to clarify the potential in the area. In addition, data collection and reconnaissance site inspection for the preliminary feasibility study were carried out in this year.

The Rakah area is situated in Samail Nappe. Geology in the area consists of Samail Ophiolite and overlying Supra-ophiolite Sediments. The Samail Ophiolite consists of Tectonites, Cumulate Sequence, High-level Gabbro, Sheeted-dyke Complex and Samail Volcanic Rocks in ascending order. Geologic structure in the area is represented by thrust faults related with obduction of the Samail Ophiolite and lower formations are found topographically at the upper part due to imbrication structure.

Two ore deposits classified to be Cyprus type massive sulfide deposits are known in the area and are found in the Samail Volcanic Rocks. The ore is classified into stockwork, massive and siliceous ores, and are represented by thick stockwork ore zones. Mineralized zones in Area A, Hay las Safil deposit and gossan zones, were interpreted to be formed at the same time as one orebody and then dislocated by fault movement.

Geophysical survey results in Area A show further extensions of the Hayl as Safil deposit. Results of the geophysical survey in Area B delineate the Rakah deposit very clearly with some extensions.

Drilling in the Hayl as Safil deposit area confirmed western extension of the known ore deposits. The intersections gave an average of 0.73 g/t Au and 1.27% Cu over a thickness of 43.60 m and expected ore reserves for the extensions are approximately 3 Mt. Drilling results in the Rakah deposit area clarify two mineralized zones of lower and upper, and also show the drilling work is insufficient for the lower mineralized zone. A drill hole confirmed a highly gold concentrated zone, 18.30 m thick grading 8.96 g/t Au and 13.3 g/t Ag, in the northwestern part of the deposit area.

Based on the above-mentioned results, followings were delineated as the targets for further exploration work,

Area A: Deeper part of the southern half of Main Gossan, south of Main Gossan, and northeast and southeast of the Hayl as Safil deposit.

Area B: Lower mineralized zone, and southwest and east of the Rakah deposit.

The gold concentrated zone in the Rakah deposit is thought to be very important to evaluate the Rakah deposit. Detailed geologic survey including gossan zones and drilling for gold concentrated zone should be carried out in the Area B.

Necessary data for the preliminary feasibility study were mostly collected in the survey. Suitable site for mine facilities and transportation route for materials and copper concentrates were tentatively selected. These results shall be used for the preliminary feasibility study including ore reserve estimation and beneficiation test in Phase II.

CONTENTS

PART II SURVEY RESULTS

PART III CONCLUSIONS AND RECOMMENDATIONS

PART I GENERAL

Gossan Zone

Drill Hole Done in This Survey

Previous Drill Hole

Mineralized Zone by CP Method

Thin or Deep Mineralized Zone by CP Method

Ore Boundary by Driling Survey

Fig. I-1-1 Compilation Map of Survey Results in Area A

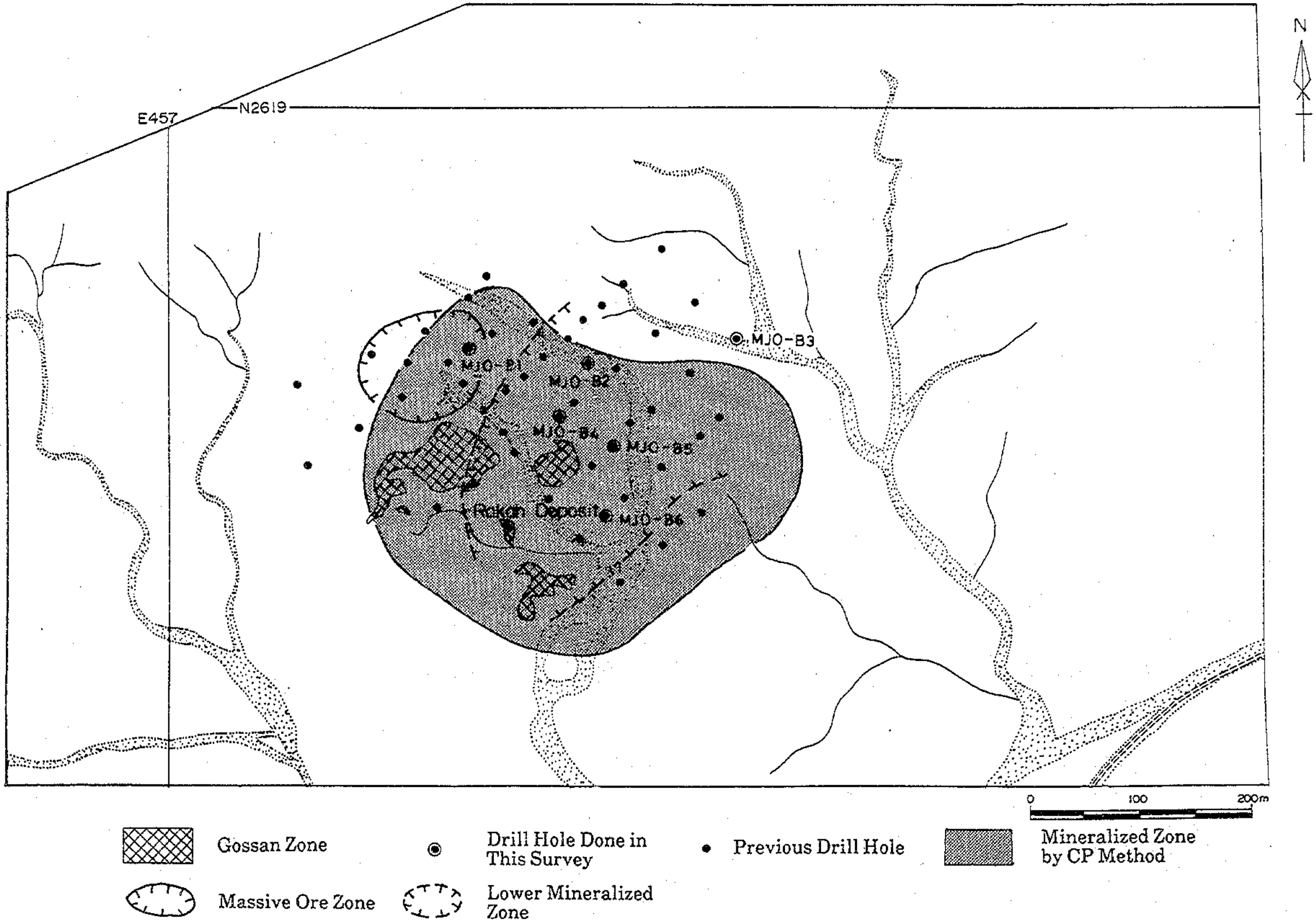


Fig. I-1-2 Compilation Map of Survey Results in Area B

Chapter 1 Introduction

1-1 Background and Objectives

The Oman Mountains in the northern part of the Sultanate of Oman is famous district for ancient copper producing center in the Middle East. Modern mining activity for the Oman Mountains region was started in 1970's. Oman Mining Company LLC (OMCO) which is wholly owned by the government started the operation for Sohar Smelter and Mine in 1983. About 15,000 tons refined copper have been produced annually to date. Copper is important export commodity for Oman and account for 28 percent of whole export excluding crude oil.

However, the Sohar mine will be mined out by early 1990's due to limited ore reserves. Because of economic impact to the Sohar region and trade balance, the Government of Oman must find new source of copper ore. The Ministry of Petroleum and Minerals (MPM), Sultanate of Oman, thought the two ore deposits, Hayl as Safil and Rakah deposits, have possibility to be developed.

Therefore, the Government of Oman requested to the Government of Japan to confirm the potential and to carried out preliminary feasibility study for these two ore deposits. In response to the request, the Government of Japan send a mission consisting of Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ). The both government agreed two years project in the Rakah area and signed the Scope of Work on 7th July 1988.

Objectives for the survey in the first year (Phase I), are to clarify the nature and shape of the mineralized zone and potential of the two known ore deposits through the geologic, geophysical and drilling surveys. In addition, reconnaissance survey and data collection were also planned for the preliminary feasibility study in the second year (Phase II).

1-2 Descriptions of Work in the First Year

The Rakah area consists of two survey areas of Area A and Area B as shown in Fig. 2. The Area A and B are located centering the Hayl as Safil and Rakah deposits respectively. Geologic, geophysical and drilling surveys were completed for both of the areas.

The geologic survey was carried out to clarify geology and geologic structure related to formation of massive sulfide mineralization, and to confirm the potential in the area.

The geophysical survey of charged potential method was carried out to clarify the extensions of the known ore deposits and to find new targets for further exploration work.

Drilling work was completed to confirm the extensions and to clarify the nature of the mineralization for the known two ore deposits.

In addition to the above-mentioned surveys, data collection and site inspection were undertaken to obtain necessary data for preliminary feasibility study which planned as the second year program.

The work amounts completed in Phase I are as follows:

(i) Area A

Geologic survey	:	Area 4 km^2. Route length 20.2 km.
Geophysical survey	:	Charged potential method. Area 4 km^2, 611 stations.
Drilling	:	6 holes, 898.70 m in total (MJO-A1 ~ MJO-A6).

(ii) Area B

Geologic survey	:	Area 3 km^2. Route length 39.2 km.
Geophysical survey	:	Charged potential method. Area 2 km^2, 402 stations.
Drilling	:	6 holes, 811.45 m in total (MJO-B1 ~ MJO-B6).

(iii) Others

Thin section	: 30 samples	Polished section	: 38 samples
X-ray diffraction analyses	: 11 samples	Whole rock analyses	: 30 samples
Minor element analyses	: 33 samples	Ore assaying	: 265 samples
EPMA analyses	: 12 points	Physical property test:	24samples

1-3 Organization of Survey Team

The members, who participated in the planning and consultations on the survey as well as in the field survey, are as follows:

Planning and Consultation (From 30th June 1988 to 9th July 1988)

Japanese Counterparts		Omani Counterparts	
Takeshi Izumi	MMAJ	Mohammed H. Kassim	MPM
Mayuri Jibiki	Ministry of Foreign Affairs	Salim O. Ibrahim	MPM
Mamoru Yamazaki	Ministry of International Trade and Industry (MITI)	Hilal M. Al – Azri	MPM
		Saif A. Al – Rashidi	MPM
Hideo Hirano	MMAJ	Harib H. Al – Hashmi	MPM
Yoshiyuki Kita	JICA	Munir A. Haddadin	MPM
		Omer Al – Amin	MPM

Field survey

Japanese Counterparts			Omani Counterparts	
Takehiko Nagamatsu	Leader		Saif A. Al-Rashidi	
	Geologic and drilling surveys	BEC	Data collection	MPM
Mikio Kajima	Geologic survey	BEC	Abdulla H.S. Al-yahya'Ey	
Susumu Sasaki	Geophysical survey	BEC	Geologic survey	MPM
Kohei Sugawara	Geophysical survey	BEC		
Hiroshi Hyodo	Geophysical survey	BEC		
Toru Otani	Data collection	BEC		
Hayao Nakayama	Data collection	BEC		

BEC: Bishimetal Exploration Co., Ltd.

1-4 Survey Period in Oman

From 25th September 1988 to 16th January, 1989

Chapter 2 Geography of Survey Area

2-1 Location and Access

The Sultanate of Oman is the second largest country, about 300,000 km^2, in the Arabian Peninsular, lying at its southeast corner, south of the Strait of Hormuz. It is bordered to the west by the United Arab Emirates, Saudi Arabia and the People's Democratic Republic of Yemen, while the coastline faces the Gulf of Oman and Arabian Sea (Fig. 1). Population in Oman is about 1.5 million.

The north of Oman is dominated by the Hajar mountain range (the Oman Mountains), reaching a height of over 3,000 m. The Rakah area is in the western flank of the Oman Mountains and is approximately latitude 23°36'N and longitude 56°24'E.

The Rakah area consists of two survey areas: Area A (3 km^2) and B (4 km^2) as shown in Fig. 2. These areas were located centering two known ore deposits. These are the Hayl as Safil deposit in Area A and the Rakah deposit in Area B. Area B is approximately 4 km east of Area A.

Access to the area is made by vehicle from Muscat (capital city) along well-maintained asphalt road to Yanqul through Izuki, Nazwa and Ibri, then along gravel road from Yanqul to the Area A. Access between Area A and B is made by four-wheel drive vehicle. Muscat to Yanqul is about 370 km (4.5 hours driving), and Yanqul to Area A is 13 km.

Base camp for this project was established in Sayyah, 1 km north of Area A. Three bedroom house was rented. Water was supplied by a tank truck and electric power was supplied by a generator.

2-2 Topography and Drainage System

The Rakah area is situated between steep mountainous range to the north and flat plain to the south.

Area A is characterized by a isolated large gossan hill in widespreaded terrace. Mountainous zone is limited at the northeastern corner of the area where Tectonites outcrop. The large gossan hill is named "Main Gossan", and is about 90 m high from the surface of the terrace. Northwestern flank of the Main Gossan, an another gossanized zone outcrops and is called "Small Gossan". Terrace can be distinguished into lower and middle terraces. Difference of elevation between these two terraces are from 3 to 8 m (Plate II-1-1).

Wadis run from north to south. Main wadi in the area is Wadi al Hayl al Ali. Small wadis, tributaries of Wadi Falaj Sudayriyin, are in the west and tributaries of Wadi Rakah are run to south in the east (Fig. 2, Plate II-1-1).

Area B is situated in the middle between mountainous zone and widespreaded terrace, and is in low hill land. Several gossan zones are observed in the center of the area and forms steep topography. Some gossan zones show strange shape due to old working. Slags and gossan dump are found in many places in the area. Western part of the area is characterized by flat topography of upper terrace.

Wadi Rakah runs in the middle of the area to southwest. Several tributaries of Wadi Rakah run from north to south.

2-3 Climate and Vegetation

The Batinah plain, between the Oman Mountains and coast line of the Gulf of Oman, is intensively cultivated. But the south and west of the mountains is an extensive desert of stony plain and sand dunes.

The Rakah area is located at the boundary between the stony plain and the mountains. Small villages including Sayyah, Dahir and Falaj Sudayriyin are found in the surroundings of the project area. Palm tree, wheat and several kinds of vegetable are farmed in the villages. Water is supplied from water well or water way (falaj) of several kilometers long used since old times.

Oman is extremely dry country and annual average precipitation is 104.3 mm. The Rakah area is situated in inland and may have lesser precipitation than the average in Oman. A temperature change through a year in the capital area is given below. The Rakah area may have a more temperature change between winter and summer.

January	22°C	May	33°C	September	33°C
February	25°C	June	37°C	October	31°C
March	27°C	July	36°C	November	26°C
April	32°C	August	35°C	December	22°C

Chapter 3 Available Information on Survey Area

3-1 Summary of Previous Survey Results

Two ore deposits, Hayl as Safil and Rakah deposits, have been discovered in the area by previous comprehensive exploration work. The exploration work completed in the Rakah area can be summarized as below.

3-1-1 Area A (Hayl as Safil Deposit)

During the course of BRGM's mapping program in the Northern Oman Mountains between the years 1983 - 1985, two siliceous caps (Main Gossan and Small Gossan) with noticeable gold content were discovered near the village of Hayl as Safil, about 4 km west of Rakah.

MPM awarded BRGM a contract to explore for copper and associated precious metals in, and around, thirteen promising prospects. Hayl as Safil was one of the prospects. Exploration work in the Hayl as Safil area was carried out systematically by BRGM. The work included: detailed geologic mapping, geophysical surveys, geochemical survey as well as drilling (percussion and diamond). The work results are summarized below.

Geology : The gossans overlie hydrothermally altered and silicified Lower Volcanics. Jasper and boxworks, found within the gossan, suggest a former silica-sulfide deposit at the top of the Lower Volcanics. Many fault zones affected the area and the mineralized outcrops, with a major fault (NE-SW) separated the two gossans.

Geophysics : Magnetic and IP surveys were completed in the area. The magnetic survey delineated two well-marked dipole anomalies. One was located east of the main gossan and was interpreted to have a deep origin. The other was located southwest of the small gossan and it suggested the presence of shallow magnetic body.

Geochemistry : Systematic channel sampling of the two gossans were conducted. The results showed good relation between Cu-Mo-As and Au, confirming the possible existence of former gold rich sulfide zone. The maximum reported assay for gold was 11 g/t and average content was 0.4 g/t.

Drilling : Based on the above survey results, a total of eight drill holes (from HS-1 to HS-8) were completed in the gossan areas (Fig. II-1-10). The most encouraging results were those obtained from the hole HS-6 in the Main Gossan area and hole HS-7 in the Small Gossan area. HS-6 results gave

2.29% Cu, 1.67 g/t Au and 14.6 g/t Ag over a thickness of 4.70 m. The top 8 m of a deeper stockwork zone gave 1.70% Cu with minor amount of Au and Ag. Hole HS-7 in the Small Gossan area intersected massive sulfide zone and gave an average 3.69% Cu over a thickness of 13.70 m.

Based on the encouraging results, follow-up drilling program was conducted by MPM during December 1986 to June 1988. The exploration effort was concentrated to confirm further extension of the massive sulfide bodies which encountered by holes HS-6 and HS-7. The work was successfully carried out and resulted to find following geologic ore reserves in the southeastern part of the Main Gossan area.

2,086,000 tons, 2.09% Cu, 0.97 g/t Au, 6.86 g/t Ag

A total of 33 drill holes (4,463.30 m in total) was completed before starting this project (Table II-1-6). Among the holes, five were percussion drill holes and remainings were diamond drill holes. A total of 23 holes (3,551.15 m in total) were in the Main Gossan area and 10 holes (912.15 m in total) were in the Small Gossan area (Fig. I-1-1).

3-1-2 Area B (Rakah Deposit)

The gossan of Rakah prospect was discovered in October 1973 by Prospection Ltd. helicopter reconnaissance. During 1973 to 1974, Prospection Ltd. also carried out comprehensive exploration work including geologic, geochemical and geophysical surveys for the Rakah prospect. Based on the surveys results, Prospection Ltd. conducted intense drilling work and a total of 42 drill holes (5,493.32 m in total) were completed during April 1976 to October 1977 (Fig. I-1-2, Table II-2-2). From the drilling data, Prospection Ltd. estimated 4.15 Mt of ore grading 1.31% Cu and 0.24% Zn.

These ore reserves were re-evaluated by I. G. Pettitt (OMCO) in 1980. The ore reserves were also evaluated by L. Carlson (MPM) in 1981, based on higher cut-off grade.

Re-interpretation of the Rakah prospect was conducted by BRGM in 1985. Evaluation of the ore reserves was also made by BRGM based on the newly introduced classification. The re-interpretation work by BRGM delineated the northwestern part of the Rakah area as the potential area for massive sulfides.

Follow-up surveys including geophysics and drilling were carried out by BRGM based on the re-interpretation results. The Rakah orebody is well-marked by a large SP anomaly extending southwestward. A north-dipping conductive body was detected by dipole-dipole, IP and self-potential profile. Three diamond drill holes (445.00 m in total) were completed in the prospect in order to examin the nature of the geophysical anomalous body. One of the hole (RA-1) encountered an 8 m thick of massive sulfide body (0.55% Cu, 0.09% Zn, 9.6 g/t Au and 20 g/t Ag) but the other two holes failed to confirm significant mineralized zones.

3-2 General Geology of the Rakah Area

The allochthonous units in the Oman Mountains consist of Hawasina Nappes and overlying Samail Nappe and form two layers structure. The Rakah area is located in the area of the Samail Nappe and consists of Samail Ophiolite and overlying Supra-ophiolite Sediments. Samail Ophiolite consists of Tectonites, Cumulate Sequence, High-level Gabbro, Sheeted-dyke Complex and Samail Volcanic Rocks in ascending order. Supra-ophiolite Sediments consist mainly of Batinah Olistostrome.

Cupriferous massive sulfide deposits formed in Samail Volcanic Rocks are found in the Oman Mountain region and are classified as the Cyprus type massive sulfide deposit. The Samail Volcanic Rocks can be stratigraphically divided into Lower, Middle and Upper Volcanic Rocks in ascending order. The Lower Volcanic Rocks also be subdivided into Lower Extrusives I and Lower Extrusives II in ascending order. Two known massive sulfide deposits under operation, Lasail and Bayda deposits in the Sohar area, are situated at the top of the Lower Extrusives I and are covered by the Lower Extrusives II. Stratigraphic location of Hayl as Safil and Rakah ore deposits in the project are similar to those known ore deposits in Sohar Area. Therefore, the ore deposits in the area may be formed in the similar geologic environment to those in the Sohar area.

3-3 Brief History of Mining Activity in the Rakah Area

Copper production in Oman can trace back to 5,000 years ago. The ancient name 'Magan' was given to Oman by the Sumerians who used the Omani copper exported to Mesopotamia during the 3rd Millennium B.C. The Sumerian Kings of Ur in Mesopotamia were probably the biggest buyer of copper in accordance with the written record of 4,400 years ago. The copper production in Magan is recorded up to 860 or 940 A.D.

Magan is probably the Sohar mine area between Buraymi and Sohar. Plenty of slag and ancient smelter sites are observed in the Sohar mine area. About twenty thousand tons and old smelter sites are also found in the Rakah area. Mining and smelting operation in the Rakah area were possibly conducted in the similar period of those in the Sohar mine area. After the time, no mining work was recorded in Oman. The survey results for the Rakah deposit show the old working reached to at least 38 m in depth.

Chapter 4 Interpretation and Evaluation of Survey Results

4-1 Characteristics of Geologic Structure and Mineralization

Structual development in the Rakah area can be divided into three stages of formation of Samail Ophiolite, obduction of Samail Ophiolite and after enplacement. Samail Ophiolite was formed in the spreading ridge from Early to Middle Cretaceous and obducted onto the Arabian Platform in Late Cretaceous time. Many thrust faults and folds related to the obduction are found throughout the Oman Mountains. The thrust faults in the Rakah area trend NW-SE to E-W and dip to the north. Although each thrust sheet shows normal succession, the succession appeares to be formed by overturn due to imbricated structure (Fig. II-1-9).

Massive sulfide deposits are situated in Samail Volcanic Rocks of Samail Ophiolite. The Samail Volcanic Rocks in the Rakah area are stratigraphically divided into Lower and Middle Volcanic Rocks. The Lower Volcanic Rocks are also subdivided into Lower Extrusives I and II in ascending order. Both of the Hayl as Safil and Rakah deposits are found at the top of the Lower Extrusives I and are covered with the Lower Extrusives II (Fig. II-1-7). The Lasail and Bayda deposits in the Sohar area were formed in the same stratigraphic location in the Lower Volcanic Rocks to those in the Rakah area, and are classified as Cyprus type massive sulfide deposit. Because of the same stratigraphic location and similar sedimentary textures observed in massive ore, the ore deposits in the Rakah area can be classified as Cyprus type deposit. The mineralization in the Sohar area shows close relation with volcanic activity of the Lower Extrusives II. The thick Lower Extrusives II in the Rakah area suggests that the volcanic activity have some relations with the formation of ore deposits in the Rakah area. Results of petrochemical study suggest that the Lower Extrusives II was originated from more earlier stage of magma compared with the Lower Extrusives I. Similar tendency can be observed for the Lower Extrusives II in the Sohar Area.

As mentioned above, the deposits in the Rakah area show similar nature to those in the Sohar area. However, the deposits have different shape, nature of ore and alteration.

(1) Hayl as Safil Deposit

The survey results show following characteristics for the Hayl as Safil deposit.

(i) Mineralized zones in the area cover an area of 900 m by 300 m (Fig. I-1-1). These were probably formed at the same time as one orebody. After obduction, the zone was separated to the Hayl as Safil deposit, Main Gossan and Small Gossan (Fig. II-1-24).

(ii) Ore consists of stockwork, massive and siliceous ores. A thick stockwork ore zone is found in the central part of the deposits and rather thick massive sulfide ore zone surrouds the stockwork zones (Fig. II-1-11).

(iii) Strong silicification and brecciation of several times can be observed in the stockwork zone. Many quartz stockwork veins and quartz-hematite breccia are recognized throughout the stockwork zone. The zone shows similar occurrence from the top to the bottom.

(iv) Ore minerals are pyrite and chalcopyrite with minor sphalerite, bornite, chalcocite and covellite. Secondary enrichment for copper is also observed at the deeper part (Table II -1-7).

The mineralized zones in the area arranged in a NW-SE direction. The direction is similar to the trend of Sheeted-dyke Complex and also to the general trend of Samail Ophiolite. The stockwork ore zone, which forms the most part of the deposit, shows intense brecciation and the central part of the deposits has thin massive sulfide zone at the top. These facts may suggest that the most ore minerals were precipitated in the matrix of breccia before reaching the sea floor, because the repeated brecciation keep high polocity in the mineralizend zone. In case of the Lasail ore deposit, quartz-hematite zones are observed at the marginal part of the hanging wall side, but the quart-hematite breccia can be observed throughout the stockwork ore zone in the Hayl as Safil deposit. This fact may also suggest that intermittent brecciation occured in the mineralized zone. The stockwork ore zone rapidely reduces the thickness at the southeastern part of the known ore deposit area. This fact indicates the stockwork zone is formed limitted zone with some width.

(2) Rakah Deposit

Following characteristics are recognized in the Rakah deposit.

(i) The ore deposits consist of two mineralized zones of the lower and upper zones. Volcanic rocks with weak pyrite disseminations are found between these two mineralized zones. At the eastern part of the ore deposits, the volcanic rocks pinched out and form one zone (Fig. II-2-5).

(ii) The mineralized zone consists of stockwork ore which subordinate massive and siliceous ores. Both of the massive and siliceous ores are found in the area of sedimentary rocks mainly consisting of chert (Fig. II-2-5). The siliceous ore may originate from chert.

(iii) Host rock of the stockwork ore zone is pillow lavas and brecciated, silicified and strongly chloritized. The mineralized zones are clearly bounded with volcanic rocks by chlorite zones at the top and bottom.

(iv) Ore minerals include pyrite and chalcopyrite with subordinate sphalerite, covellite, chalcocite, bornite and rare native gold (Table II-2-3). The stockwork ore in the Rakah deposit shows lesser quantity of sulfide minerals compare with that in the Hayl as Safil deposit (Fig. II-2-14). However the ratio of chalcopyrite to pyrite is higher than the Hayl as Safil deposit. The massive ore composed of pyrite with subordinate supergene copper minerals and Au enrichment of Au is also observed in the ore.

Matrix of breccia and pillows are filled with sulfide minerals in the stockwork ore zone and the zone is also cut by pyrite-chalcopyrite veins. However, intense silicification and brecciation found in the Haylas Safil deposit are not observed and fewer quartz veins are found in the stockwork ore zone. The marginal parts of the ore deposit show very weak alteration and mineralization, and volcanic texture can be observed under the microscope (Table II-1-2). These fact may suggest that the ore deposit was formed with quiet hydrothermal activity and deposited centering the known ore deposit.

The massive ore occurs at the eastern end of sedimentary bed which is situated at the boundary between the Lower Extrusives I and II in the northeastern part of the known ore deposit area. This sediments interbeds brecciated massive sulfide layers. The siliceous ore found hanging wall and footwall sides of the massive ore originates from chert. Therefore, the sedimentary rocks may have close relation for the formation of the massive ore.

4-2 Potential of the Rakah Area

Area A is covered with thick and widespreaded terrace deposits. The poor exposure make it difficult to evaluate the potential geologically in the area. Results of geophysical survey by CP method show no potential area other than the known mineralized zones and the surroundings in Area A.

Volcanic rocks of the Lower and Middle Volcanic rocks occur for the southeast of the Rakah deposit, but no mineralization is found at the boundary between the Lower Extrisives I and II of the Lower Volcanic Rocks (Plate II-2-1). No potential areas were deliniated by the geophysical survey except the Rakah deposit area. These many suggest the potential areas in Area B are limitted in the Rakah deposit and the surroundings.

(1) Hayl as Safil Deposit

Results of geologic survey show that mineralized zones observed in the Small Gossan, Main Gossan and Hayl as Safil deposit are formed originally as one orebody and later faults movement separated the zones. Drilling results confirmed the Hayl as Safil deposit under Main Gossan with low angle fault contact (Fig. II-1-11). Drill hole done at the immediate south of Main gossan encountered gossanized zone in the depth. This fact may indicate that most part of Main Gossan is completely gossanized. Geophysical survey results located more wide potential area compare with the survey results completed by BRGM and MPM. These are under Main Gossan, South of Main Gossan and from southeastern to northeastern parts of the Hayl as Safil deposit.

These survey results deliniated the following targets which require further exploration work in Aera A

(i) Beneath the southern half of Main Gossan and south of Main Gossan

(ii) Northeastern and southeastern extensions of the Hayl as Safil deposit.

(2) Rakah Deposit

Geologic and drilling survey results confirmed two mineralized zones of lover and upper in the Rakah deposit. The results also suggest no enough drilling were completed for the lower mineralized zone (Fig. II-2-5). Geologic sections constructed by existing drilling data and surface geology suggest some extensions of the ore deposit to the southwest and east. A drill holes completed in the nothwestern part of the area encountered massive sufide orebody with high Au contents. Potential of Au is thought to be high in Area B. Geophysical survey results reflect the faults and delineated the Rakah deposit clearly. Some extensions are also shown in the survey results.

The servey results in Area B deliniated following targets for further explaration work.

(i) Lower mineralized zone

(ii) Southwestern and eastern estensions of th known ore deposits

(iii) Masive ore zone and the surroundings for Au potential.

4-3 Preliminary Feasibility Study

In order to carried out preliminary feasibility study in Phase II, it is very important to clarify the size, shape and ore resurves for the ore deposits in the Rakah area. Base on these results, mining method and locations of mine facilities shall be decided. The ore resurves are also very important for the economic evaluation of the deposits. However, drill holes completed to date are not sufficient for the detailed estimation of ore resurves. Additional drilling work are required to examine the thckness and grades of the deposits.

The previous drill holes and 12 holes completed in the project gave followining idea for the ore *resorve estimation:*

(i) Ore reserve estimation made by MPM for the Hayl as Safil deposits gave 2,086,000 tons grading 0.97 g/t Au and 2.09% Au. Five drill holes excluding MJ0-A4 were completed in the western extension of the Hayl as Safil deposit and gave 43.60 m in average thickness grading 0.73 g/t Au and 1.27% Cu. The extension covers approximately an area of 150 m by 150 m and about 3 Mt of additional ore reserves can be expected for the extensions.

(ii) Ore reserve estimation had been made several times for the Rakah deposit. This survey result, revealed that the high grade zone in the mineralized zone form irregular shope. This occurrence make difficult to mine only high grade zone without great amounts of drilling work. Therefore, ore reserves made by Prospection Ltd. and OMCO which estimated 4 Mt to 5 Mt with 1.28% to 1.31% Cu, are seemed to be the most reasonable ore reserves for mining. The average grades of five holes except MJ0-B3 which encountered weak mineralized zone, are 1.18 g/t Au and 1.15% Cu in case of cutt-off grade of 0.25% Cu. Among the drill holes, MJ0-B1 encountered massive ore with high concentration of Au (18.30 m, 8.96 g/t Au, 13.3 g/t Ag). Average Au grade of the stockwork ore zone is 0.31 g/t Au. Because of the high concentration of Au, it is necessary to confirm the ore reserves of high Au zone.

Data collection and site inspection for the preliminary feasibility study in Phase II gave following results.

(i) Suitable sites for mine facilities are found in both Area A and B. Final locatoin of the mine facilities shall be dicided after ore reserves are confirmed. However, in order to dicide exact location of the mine facilities and to estimate the cost, topographic maps should be prepared for the area covering both Area A and B.

(ii) It is possible to use the existing road for the transportation of construction and operation materials, if small improvement are made between Yanqul and Area A (Fig. II-4-1).

(iii) Existing road have possibility to be used for the transportation of copper concentrates between the Rakah area to the Sohar Smelter.

(iv) It is cheaper to get the electric power from MEW compare with the power from newly constructed diesel generator.

(v) Communication to the outside is possible if wire telephone line is installed between Yanqul and planned mine site.

Smelting and refining cost of the Sohar Smelter could not be obtained in the survey. Because this cost is very inportant to evaluate this projet, it should be clarified. Survey for water source is required in the project because of no work has been carried out in the area. Most date for the preliminary feasibility study in Phase II were obtained in the survey of this phase.

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

The survey results completed in Phase I can be conclusively summarized as below:

(i) The Rakah area is situated in Samail Nappe and the geology consists of Samail Ophiolite and Supra-ophiolite Sediments. The Samail Ophiolite includes Tectonite, Cumulate Sequence, High-level Gabbro, Sheeted-dyke Complex and Samail Volcanic Rocks in ascending order.

(ii) Thrust faults formed in the stage of obduction are found in the area. Each thrust sheet shows normal succession but it looks overturn due to imbrication structure.

(iii) Samail Volcanic Rucks is divided into Lower Volcanic Rocks and Middle Volcanic Rocks in th area. The Lower Volcanic Rocks is subdivided into Lower Extrusives I and II in ascending order. Hayl as Safil and Rakah deposits occur at the top of Lower Extrusives 1 and are overlain with Lower Extrusives II. These deposits are classified to Cyprus type mossive sulfide deposit.

(iv) Mineralized zones including the Hayl as Safil deposit, Main Gossan and Small Gossan, in Area A are interpreated to be formed as one orebody. The zone consists of stockwork, massive and siliceous ores, and is dominated with thick sotockwork ore zone. The stockwork ore zone show intense brecciation repeated several times and silicification.

(v) Geophysical survey by CP method in Area A delineated wider potential area to the outsides of the known ore deposits.

(vi) Drill holes completed in Area A confirmed western extension of the known ore deposit with an average of 43.60 m in thickness grading 0.73g/t Au and 1.27% Cu. Approximately 3 Mt of additional ore resurves can be expected in the extensions.

(vii) The Rakah deposit consists of two mineralized zones of lower and upper mineralized zones except the eastern part of the deposit. The ore deposits consist of stockwork, massive and siliceous ores and are dominated with stockwork ore. The occurrences of massive and siliceous ores show close relation wirh sedimentary rocks consisting mainly of chert.

(vii) Geophysical survey by CP method in Area B delineated the known ore deposits very clearly and some extensions of the deposits for outside are expected.

(ix) Geologic sections made by drilling data in Area B suggest that insufficent drilling work has been completed for the lower mineralized zone. Good ore zones are also expected to continue outward in some places. Massive ore zone with high Au contents (18.30 m 8.96 g/t Au, 13.3 g/t Ag) is very important to evaluate the Rakah deposit.

Based on the above mentioned survey results, following parts are delineated as the patential area for further exploration work.

Area A: Beneath the southern half of Main Gossan and south of Main Gossan. Northeast and northwest of the Hayl as Safil deposit.

Area B: Lower mineralized zone. Southeastern and eastern extensions of the Rakah deposit. Massive ore zone and the surroundings with high Au concentration.

Data collection and site inspection for the preliminary feasibility study resulted to collect enouth date for the study, to find suitable sites for mine facilities, and to select transportation roads for construction and operatoin materials and copper concentrates to the Sohar Smelter. The samples for beneficitation test were also collected in the survey. Based on these date and results, preliminary feasibility shall be completed in Phase II.

5-2 Recommendations for Phase II Survey

Based on the results of surveys completed in Phase I, following work are recommendable for Phase II work.

(i) Drilling in Area A

Purpose : Confirmation of the expensions of the Hayl as Safil deposit.

Drill sites: Beneath the southern half of Main gossan. South of Main Gossan. Northeast and southeast of the Hayl as Safil deposit.

(ii) Drilling in Area B

Purpose : Confirmation of the extensions of the Rakah deposit, exploration of the Lower mineralized zone and confirmation of Au concentrated zone.

Drill sites: Southwestern and eastern extensions. Presumed center of the lower mineralized zone. The massive sulfide zone of the Rakah deposit.

(iii) Detailed geologic survey in the Rakah deposit area.

Purpose : Exermine the Au contents in gossan and gossan dump.

Ore reserve estimation, beneficiation test and a preliminary feasibility study are programed in Phaes II. Following points should be consider to carried out these works.

(i) Ore reserve estimation should be made using 0.20 to 0.25% Cu as the cutt-off grade and be calculated for each level and block. Highly Au concentrated zone should be calculated separately.

(ii) Beneficiation test should be carried out based on the difference of nature of ore.

(iii) In order to made fineal decision for the location of underground the mine facilities, road, power line and water pipe etc., topographic maps covering these locations are required in Phase II.

(iv) Because of no data for water sources in the area, survey for water sources should be carried out in Phase II.

PART II SURVEY RESULTS

Chapter 1 Area A

1-1 Survey Methods

Area A covers an area of 3 km^2 centering Hayl as Safil deposits. The survey methods and amounts utilized in the Area A are below:

Geologic Survey:	3 km^2 (1 : 2,000 in scale)
Geophysical Survey:	Charged potential method. 3 km^2 611 stations
Drilling:	6 holes 898.70 m in total

The samples collected for laboratorial studies are shown in Table II-1-1.

The survey results of these work are given below.

1-2 Geologic Survey

1-2-1 Geology

1. General Geology

The Oman Mountains, forming a part of the Alps-Himalaya orogenic belt, consist of autochtonous and allochthonous units. The autochtonous units form the Arabian Platform and are Pre-cambrian to Mesozoic formations. The allochthonous units, overthrusted onto the autochtonous units, consist of Hawasina Nappes and overlying Samail Nappe. The Hawasina Nappes are made up of Hawasina Sediments and the Samail Nappe is divided into Samail Ophiolite and Supra-ophiolite Sediments.

The Rakah area is situated at southwestern flank of the central part of the Oman Mountains. Geology of the area consists of the Samail Ophiolite including Tectonites, Cumulate Sequence, High-level Gabbro, Sheeted-dyke Complex and Samail Volcanic Rocks in ascending order, and the Supra-ophiolite Sediments (Fig. II-1-1). Tectonostratigrapohic section is shown in Fig. II-1-2.

Area A is situated in the west part of the Rakah area. Geology in the area consists of the Samail Ophiolite and Supra-ophiolite Sediments. Outcrops of these rocks are limited and scattered because of widespreaded thick terrace deposits. The geologic maps for Area A are given in Fig. II-1-3 and Plate II-1-1, and cross sections are given in Plate II-1-2.

Tectonically, the area is marked by two thrust faults trending a E-W direction. The area is also characterized by imbrication structure and stratigraphically lower units of ophiolite can be observed at the upper part.

Two fault systems of NW-SE and NE-SW are found in the area. Stractual map of Area A is given in Fig. II-1-4.

Table II-1-1 Number of Samples for Laboratorial Studies in the Project

Area \ Method		Thin Section	Polished Section	Whole Rock Chemical Analyses	Minor Elements Chemical Analyses	X-ray Diffraction Analyses	Ore Assay (Au, Ag, Cu, Pb, Zn)	EPMA	Physical Properties Measurement
Area A	Surface	7	-	7	8	-	-	-	5
	Drilling	5	18	6	7	5	132	2	8
Sub-Total		12	18	13	15	5	132	2	13
Area B	Surface	9	-	9	9	-	-	-	-
	Drilling	9	20	8	9	6	133	10	11
Sub-Total		18	20	17	18	6	133	10	11
Total		30	38	30	33	11	265	12	24
Remarks		Table II-1-2	Table II-1-7 (Area A) Table II-2-3 (Area B)	Table II-3-1	Table II-3-3	Table II-1-8 (Area A) Talbe II-2-4 (Area B)	Appendix 4 (Area A) Appendix 8 (Area B)	Table II-2-5	Table II-1-3

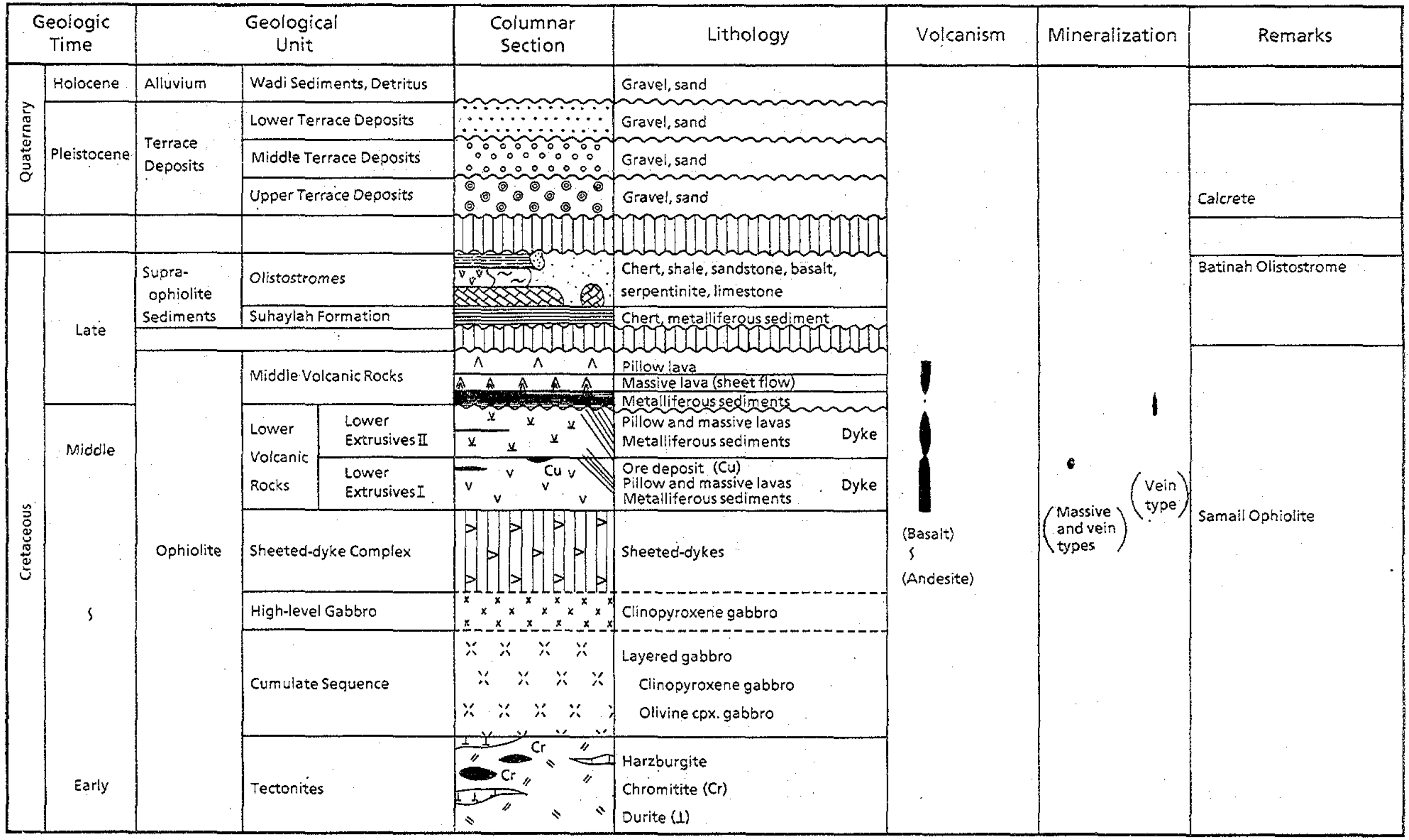
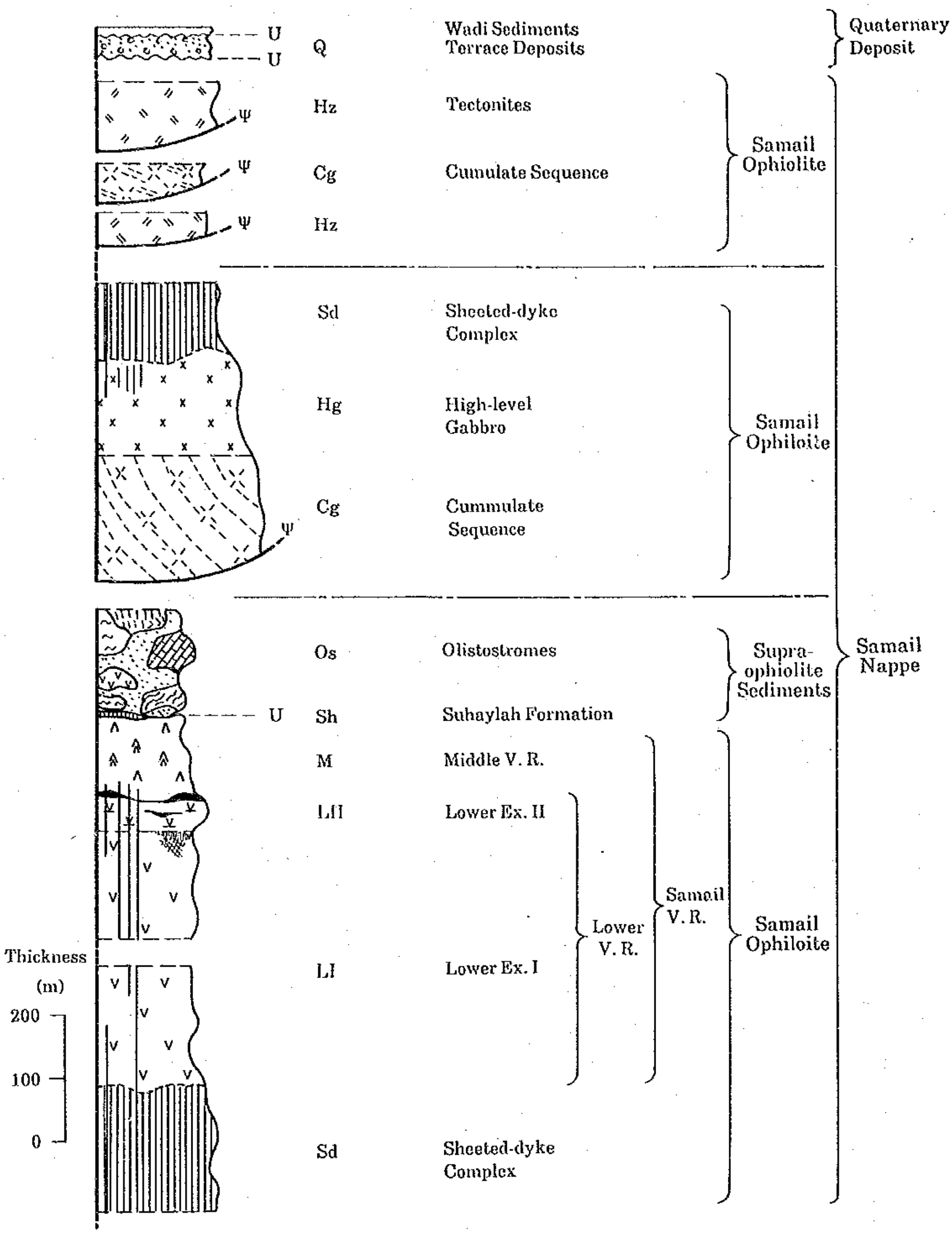


Fig. II-1-1 Stratigraphic Columnar Section of the Rakah Area



Ψ	: Thrust fault	Q	: Quaternary	Sd	: Sheeted-dyke Complex
U	: Unconformity	Os	: Olistostromes	Hg	: High-level Gabbro
V.R.	: Volcanic rocks	Sh	: Suhaylah Formation	Cg	: Cumulate Sequence
Ex.	: Extrusives	M	: Middle Volcanic Rocks	Hz	: Harzburgite
		LII	: Lower Extrusives II		
		LI	: Lower Extrusives I		

Fig. II-1-2 Tectonostratigraphic Section of the Rakah Area

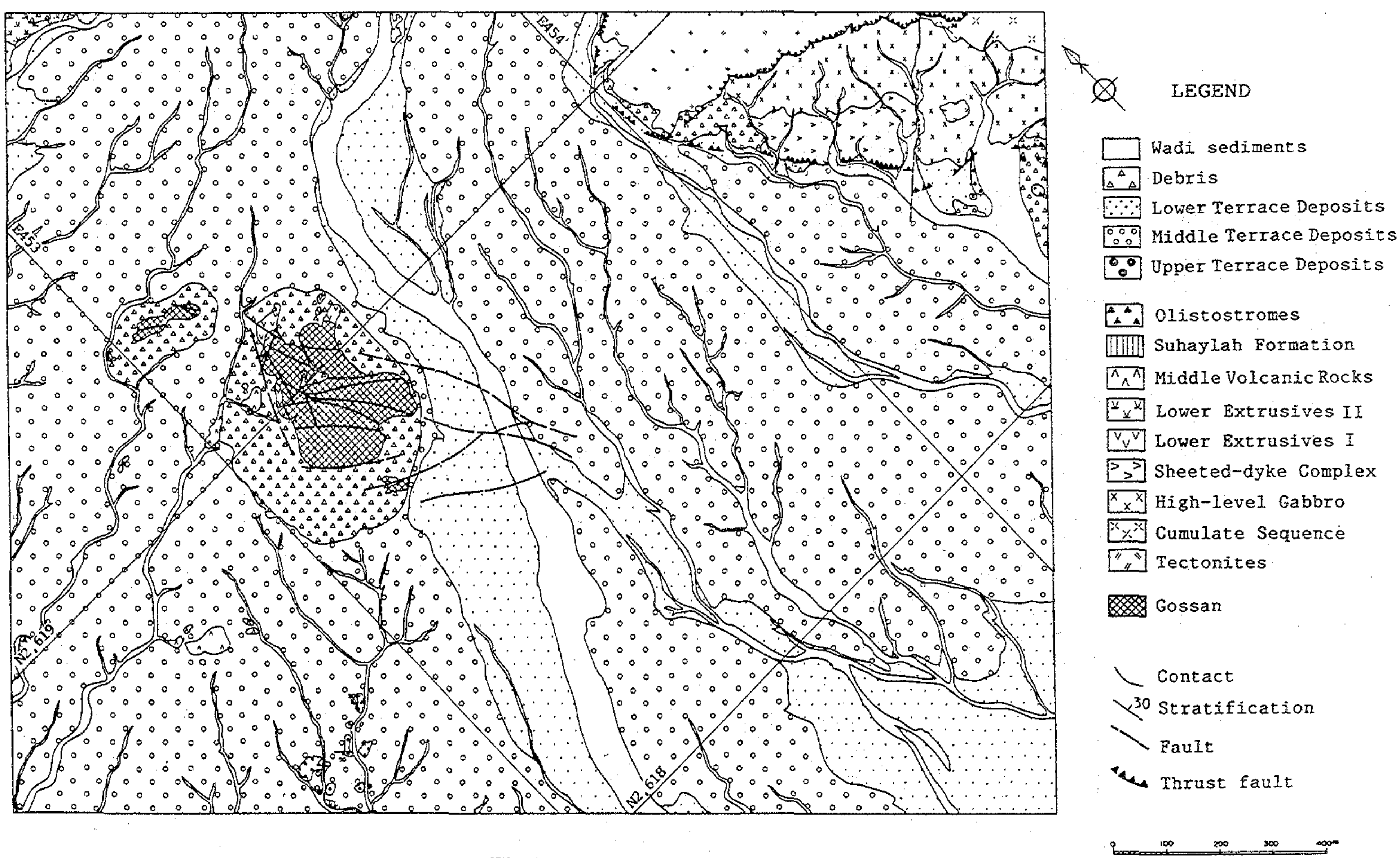


Fig. II-1-3 Geologic Map of Area A

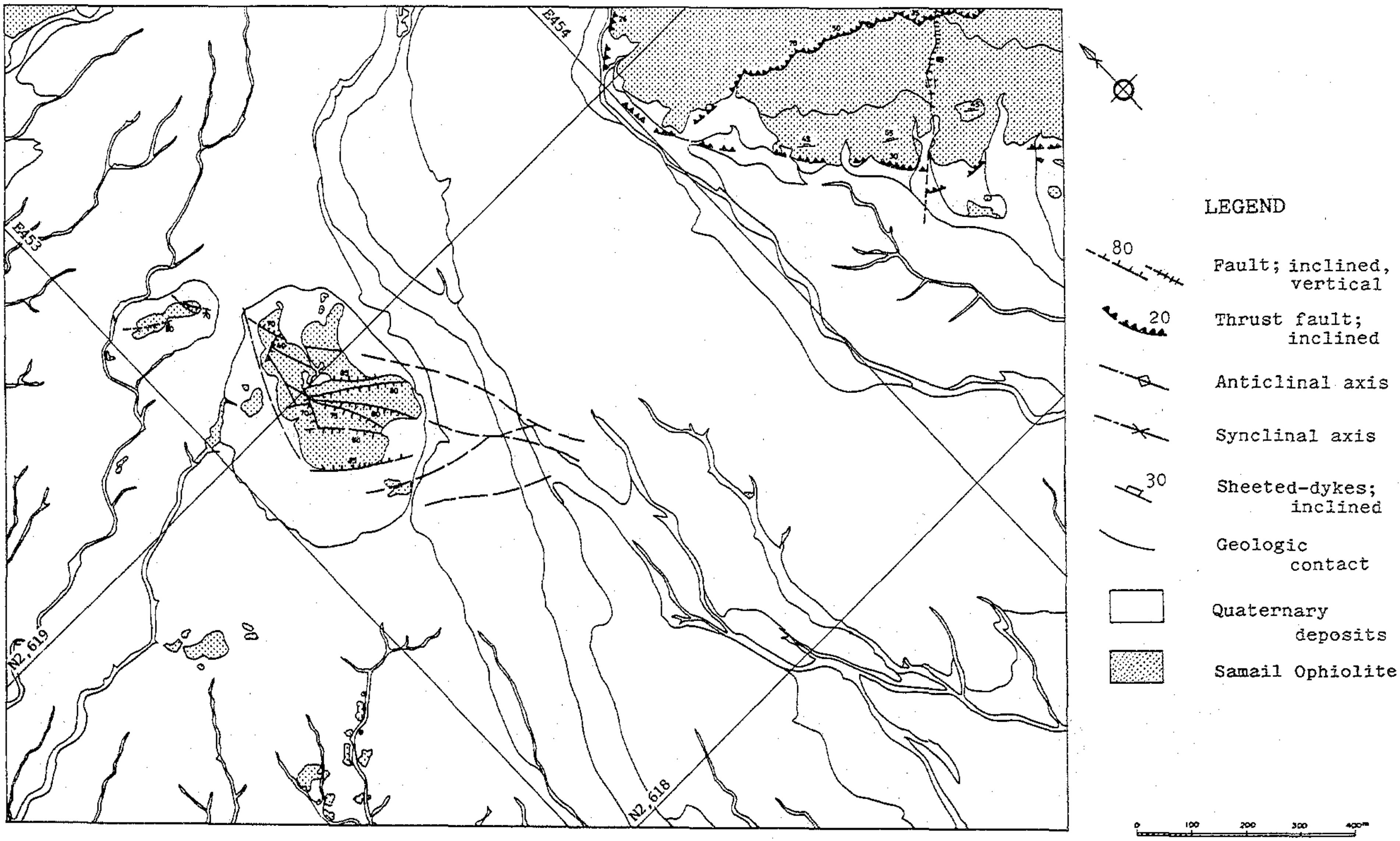


Fig. II-1-4 Structural Map of Area A

2. Stratigraphy

(1) Samail Ophiolite

The Samail Ophiolite in the area consists of Tectonites, Cumulate Sequence, High-level Gabbro, Sheeted-dyke Complex and Samail Volcanic Rocks in ascending order.

(a) Tectonites

The Tectonites form a mountainous zone in the northeastern corner of the area with a E-W direction. The rocks consist of harzburgite with subordinate dunite, gabbro, chromitite and orthopyroxenite dyke. The Tectonites show a WNW-ESE direction as a whole, but internal structures are generally invisible. The rocks have more than 80 m thick in the area. The relationship between the Tectonites and Cumulate Sequence is fault contact.

Harzburgite (Hz)

Harzburgite is dark brown to dark green and is composed of olivine and bastitized orthopyroxene. A banded structure is observed in places in the lower part of the Tectonites. The rock is marked by strong serpentinization. Foliation is generally invisible, but is weak. Foliation striking NNW-SSE and dipping 60° to the east, is measured in the west part of the Tectonites. Mumerous magnesite veins, ranging in thickness from 1 cm to 10 cm and in strike length from 1 m to 5 m, are found in the Tectonites. These veins strike N 60° ~ 80° W and dip steeply to the east.

The lowest part of the Tectonites is sheared along a thrust fault with width of several meters. (Fig. II-1-5).

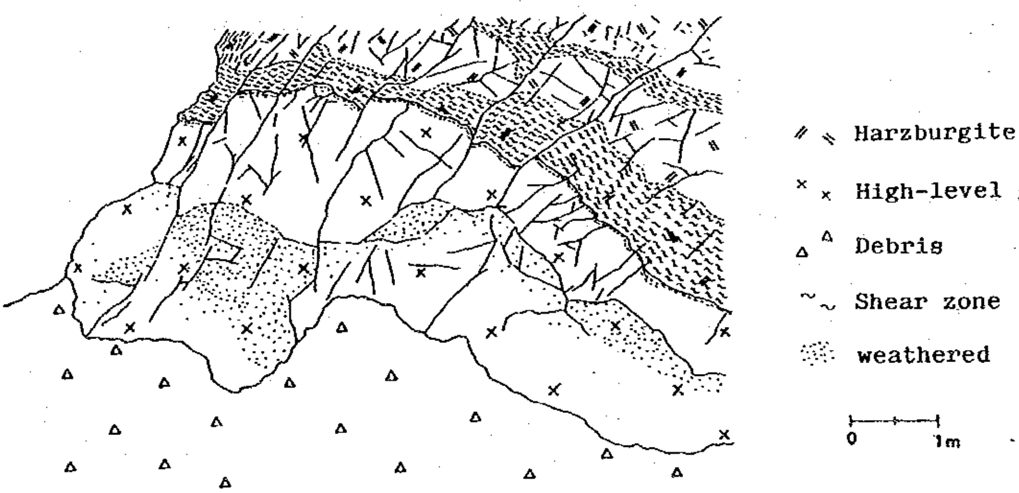


Fig. II-1-5 Sketch of Thrust Fault between Tectonites and High-level Gabbro

Results of microscopic observation are as below:

Sample No.: M008

Rock name: Harzburgite (Tectonites)

Texture: Porphyroclastic and mesh textures

Descriptions: The rock consists of olivine and subordinate orthopyroxene and chromite. Olivine is completely altered to serpentine and magnetite and exhibites mesh texture. Subhedral and anhedral orthopyroxene (enstatite) is 0.4 to 3 m/m in grain size and is present exsolution lamellae of clinopyroxene. Orthopyroxene is mostly altered to serpentine, chlorite and small amounts of magnetite and tremolite.

Results of microscopic aboservation for thin sections are shown in Table I-1-2.

Dunite (Du)

Dunite is found as small lenticular bodies in harzburgite. The bodies range in thickness from 1 m to 10 m and in length from several to a hundred meters. They strike N 10° ~ 40° W and dip 30° to the east. The boundary between dunite and harzburgite is not clear and gradational change is observed in some places. Four chromitite showings were found within the dunite.

Chromitite (Cr)

Four chromitite (Cr) showings were discovered in Area A. These showings were found in the lower part of Tectonites. Chromitite show gradational change to dunite and has fault contact with harzburgite. Gabbro is locally accompanied with chromitite. Chromitite bodies show lenticular shape and 3 m in width and several meters to 20 m in length. Chromite ore is compact and massive ore to disseminated ore. Fig. II-1-6 shows the occurrence of chlomitite.

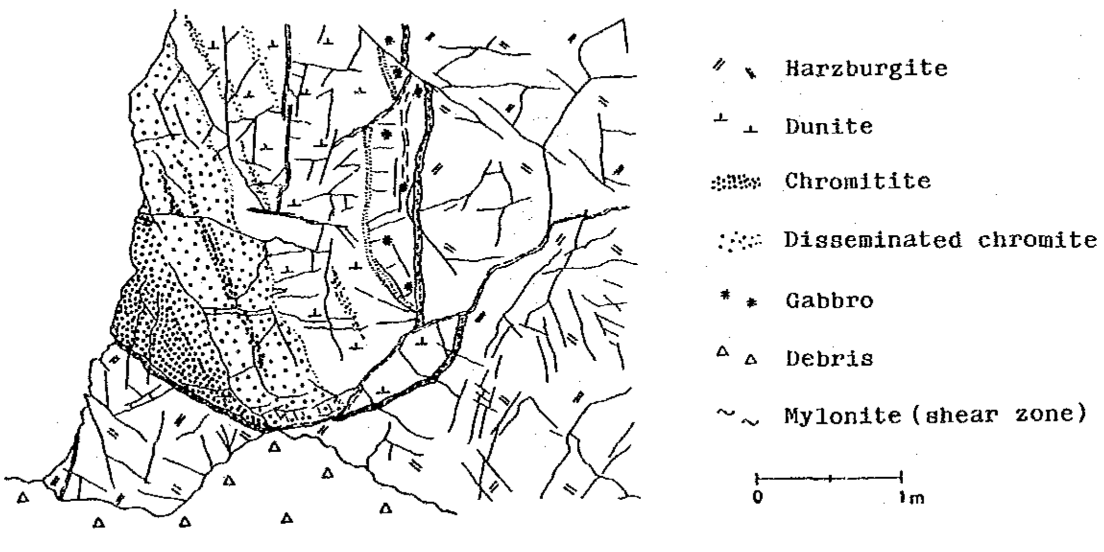


Fig. II-1-6 Sketch of Chromitite Showing

Orthopyroxene Gabbro (Ga)

The rocks are found locally in harzburgite. The bodies show small lenticular or oval shap ranging in width from several tens centimeters to one meter. They trend NW-SE in general and

Table II-1-2 Observation Results of Thin Sections

Ser. No.	Sample No.	Coodinates N (km)	Coodinates E (km)	Geol. Unit	Rock Name	Texture	Phenocrysts Qz	Ne	Ap	P	Kp	Pl	Bi	Ho	Au	Hy	Ol	Cr	Op	Groundmass Qz	Pl	Bi	Ho	Hy	Au	Ol	Mt	Op	Gl	Secoundary Minerals Qz	Ab	Sr	Cc	Cl	Ep	Ho	Zo	Sh	Pr	Tr	Sm	Se	Lm	Hm	Op	Remarks
1	M003	2,618.723	453.108	Me	basalt	intergranular						○			○						◎			•	●			●					◎	○	○						○				●	Ti-augite
2	M005	2,619.150	452.857	Me	dolerite	ophitic						◎			○				●		○				○			●					◎	○	○			•			○					
3	M011	2,618.724	454.245	Hg	hb-cpx gabbro	porphyritic			•			◎		○	○				●		○									○		○		○	○	○		●		●				•		
4	M012	2,618.638	454.222	Sd	dolerite	–						○																					●	○	◎			•							●	altered
5	M015	2,619.830	453.344	LII	andesite	glomeroporphyritic						○			●				●		○								○					○	◎						○			•		devitrification
6	M016	2,617.975	457.542	Sd	andesite	intergranular						◎									○				●			●					○	○	○			●								altered
7	M017	2,618.985	457.200	Cg	cpx gabbro	ortho-cumulate			•			◎			○				●													○	●	●		○										poikilitic
8	M018	2,618.950	457.236	L'	andesite	–																								◎				◎	◎			●					•		●	altered
9	M020	2,618.365	457.172	LII	basalt	hyalopilitic									○				●										○	○			○	○				●			○					devitrification
10	M022	2,618.938	458.642	Me	andesite	ophitic						◎			○													●		○		○	○	◎	○						○				●	
11	M023	2,618.440	458.925	Me	basalt	intergranular						○			○						○					●		●				●	◎	○	○			●								
12	M024	2,618.314	458.596	LI	basalt	intersertal						○									◎				○			●	○			●	○	○	○			●								argillization
13	M031	2,618.249	457.534	L'	dolerite	subophitic						○			○						○				○			●				●	○	○	●			●								
14	M032	2,617.977	457.502	LI	andesite	intersertal						●							●											○			●	◎	○			●			○					
15	M034	2,619.127	453.198	LI	andesite	–						●																		◎				○							○			●		altered
16	MJO-A4 44.20	2,618.676	453.458	LII	andesite	intersertal						●			●						◎				○			●	●				●	◎				•				•				brecciated
17	MJO-A4 143.70	2,618.676	4 53.458	LI	basalt	intersertal, vesicular									●						○				◎			●	○				●	◎	○		○	•							○	
18	MJO-A1 63.70	2,618.742	453.434	LII	basalt	intersertal									○						◎				○			●	○	○				◎	●											
19	MJO-A1 172.00	2,618.742	453.434	LI	basalt	variolitic, vesicular									●						●				○			•		○				◎				•	●		○					chloritization
20	MJO-B5 23.50	2,618.700	457.404	LII	basalt	hyalopilitic									●						●				○				●	○			○	○											○	
21	MJO-B5 79.20	3,618.700	457.404	LI	basalt	hyalopilitic									●						●				●				○	◎			○	○				•							○	
22	MJO-B5 136.10	2,618.700	457.404	LI	basalt	intersertal						●			●						◎				○			●		○				◎	○			●								
23	MJO-B3 55.20	2,618.784	457.526	LII	basalt	intersertal, vesicular									○						◎				○			●		○			○	○				•	○							
24	MJO-B3 147.70	2,618.784	457.526	LI	basalt	intrsertal						●			●						○				○			●					○	◎	○			●					●	●		chloritization
25	MJO-B4 101.20	2,618.723	457.358	LI	basalt	hyalopilitic									○						●				○					○			○	◎	●											chloritization
26	MJO-B6 85.90	2,618.631	457.405	LI	basalt	intersertal						○			●						◎				○			•	○	○			○	◎	●			●							●	chloritization
27	N 011	2,618.782	453.194	LII	andesite	variolitic									○						●				○				●	◎				○									●		○	silicification
28	MJO-B2 52.20	2,618.772	457.385	LII	andesite	hyalopilitic									●						●				○				○	◎			●	◎	●										●	
29	MJO-B3 125.90	2,618.770	457.526	LI	basalt	–																								◎			○	◎				●						●	○	altered
30	MJO-A5 17.50	2,618.796	453.299	LII,	basalt	intergranular						◎			○						◎				○			●		●				◎	●			•			○					

◎ abundant ○ common ● rare • very rare

Me : Middle Volcanic Rocks
LII : Lower Extrusives II
LI : Lower Extrusives I
Sd : Sheeted-dyke Complex

Hg : High-level Gabbro
Cg : Cumulate Gabbro
L' : Late dykes

Ab : albite
Ap : apatite
Au : augite
Bi : biotite
Cc : calcite

Se : sericite
Cl : chlorite
Cr : chromite
Ep : epidote
(Gl) : (glass)

Mt : magnetite
Ne : nepheline
Ol : olivine
Op : opaque minerals
Pl : plagioclase

Pr : prehnite
Qz : quartz
Sh : sphene
Sm : smectite
Sr : sericite

Tr : tremolite
Zo : zeolite

dip 40° to 60° NE. Harzburgite surrounding the clinopyroxene gabbro is marked by serpentinization and the boundary between these two rocks are not clear.

Orthopyroxenite (D')

The rock is obseved as dykes in harzburgite. The dykes show irregular and undurate shape and have width ranging from several centimeters to several tens centimeters. The dykes strike NW-SE to NNW-SSE and consist of greenish gray and coarse-grained orthopyroxene.

(b) Cumulate Sequense

The rocks are found locally in the eastern edge of the area, and have a thrust fault contact with Tectonites. The rocks are more than 150 m thick and show gradational change to the High-level Gabbro.

The rocks consist of clinopyroxene gabbro with subordinate olivine gabbro and present distinct layered structure ranging in width from several milimeters to several tens centimeters. The layering strikes N-S to NNW-SSE and dips 30° to 50° eastward.

The clinopyroxene gabbro is light greenish gray to dark gray and shows medium to coarse-grained texture. Clinopyroxene forms lamination in the rock. The olivine gabbro has a 20 cm to 30 cm in thickness and is dark brownish green. Olivine in the olivine gabbro altered to serpentine and limonite, and show brownish gray in color. Pyroxene is also altered mostly to chlorite. Numerous veinlets of prehnite, carbonates and epidote et al. are found in this unit.

(c) High-level Gabbro (Hg)

High-level Gabbro (Hg) occurs in the eastern part of the area and the thickness is 100 m to 150 m. This unit is overlain the Cumulate Sequence with gradational contact and is underlain the Sheeted-dykes Complex with transition zone of about several tens meters. Numerous dykes of dolerite and basalt ranging in width from 30 cm to 1 m intrude in the upper part of the unit. Dolerite stocks of 5 m to 10 m wide are also found locally in the unit.

The unit consists of light greenish gray to greenish gray clinopyroxene gabbro with subordinate hornblende-bearing gabbro. It show fine-grained texture in the upper part and medium to coarse-grained texture in the lower part. Gabbroic pegmatite with several meters wide are found in places in the lower part. Chloritization and epidotization are observed in the unit, especially along dykes. Weak mineralized zones with hematite, limonite and green copper minerals are also locally observed. Results of microscopic observation are as follows:

Rock name:	Clinopyroxene gabbro
Sample Number:	N011
Texture:	Porphyritic texture
Descriptions:	The rock consists of plagioclase, hornblende, augite and subordinate apatite and opaque minerals. Numerous euhedral to subhedral plagioclase grains are 0.2 to 1.5 m/m in size and are marked by

sericitization. Green euhedral to subhedral hornblende, 0.3 to 2.5 m/m in grain size, is altered locally to chlorite. The rock is strongly altered and present chlorite, amphibole, sericite, epidote, sphene, hematite and limonite.

(d) Sheeted-dyke Complex

The sheeted-dyke Complex is found locally in the eastern part of the area. The relation with the underlying High-level Gabbro is gradational and the upper part is cut by faults. This unit is estimated at least more than 100 m thick. The dykes generally strike N 40°~70° W and dip 35° ~ 75° to the north.

More than 70% of the unit is composed of dark gray and greenish gray dolerite to basalt and basaltic andesite. The dykes have chilled margin of serveral centimeters wide. Width of each dyke ranges from 30 cm to 1 m. Fine-grained clinopyroxene gabbro occurs in the matrix of the lower part. Strong epidotization is recognized in the unit.

Shear zone with several meters wide is found in the southwestern edge of the exposure. The shear zone trend a NW-SE direction and dips 30° NE which is possibly thrust sheet. Pillow lavas and dykes are observed beneath the shear zone and the rocks may correspond to the lower part of the below-mentioned Samail Volcanic Rocks.

(e) Samail Volcanic Rocks

The Samil Volcanic Rocks can be divided into Lower Volcanic Rock, Middle Volcanic Rocks and Upper Volcanic Rocks (Bishimetal, 1987) in ascending order. The Lower and Middle Volcanic rocks are found in the survey area. The Lower Volcanic Rocks can be subdivided into Lower Extrusives I and Lower Extrusives II based on the different nature of pillow lavas. Stratigraphic correlation of Samail Volcanic Rocks between the northern part of the Oman Mountains and the Rokaha area is shown in Fig. II-1-7.

Lower Extrusives I (LI)

The rocks are found in the northwestern corner and northern immadiate frank of Main Gossan. The weakly altered Lower Extrusives I shows dark greenish gray to light brownish green in color, but the strongly altered zone shows dark green to light brown and no volcanic texture can be observed. The rocks consist of pillow lavas with subordinate massive lavas. Pillow shows oval shape with diameter ranging from 60 cm to 100 cm. Some vesicles are observed and are filled with calcite and quartz. Hyaloclastite which forms matrix of pillow is 2 cm to 3 cm in thickness and is *accompanied with subordinate pillow breccia.*

Lower Extrusives II (LII)

The rocks are found locally in the north corner of the area and the south of Main Gossan. The thickness of this unit is more than 20 m. The rocks are purplish gray to light greenish gray and consist of pillow lavas and subordinate massive lavas. Diameter of pillow ranges from 30 cm to

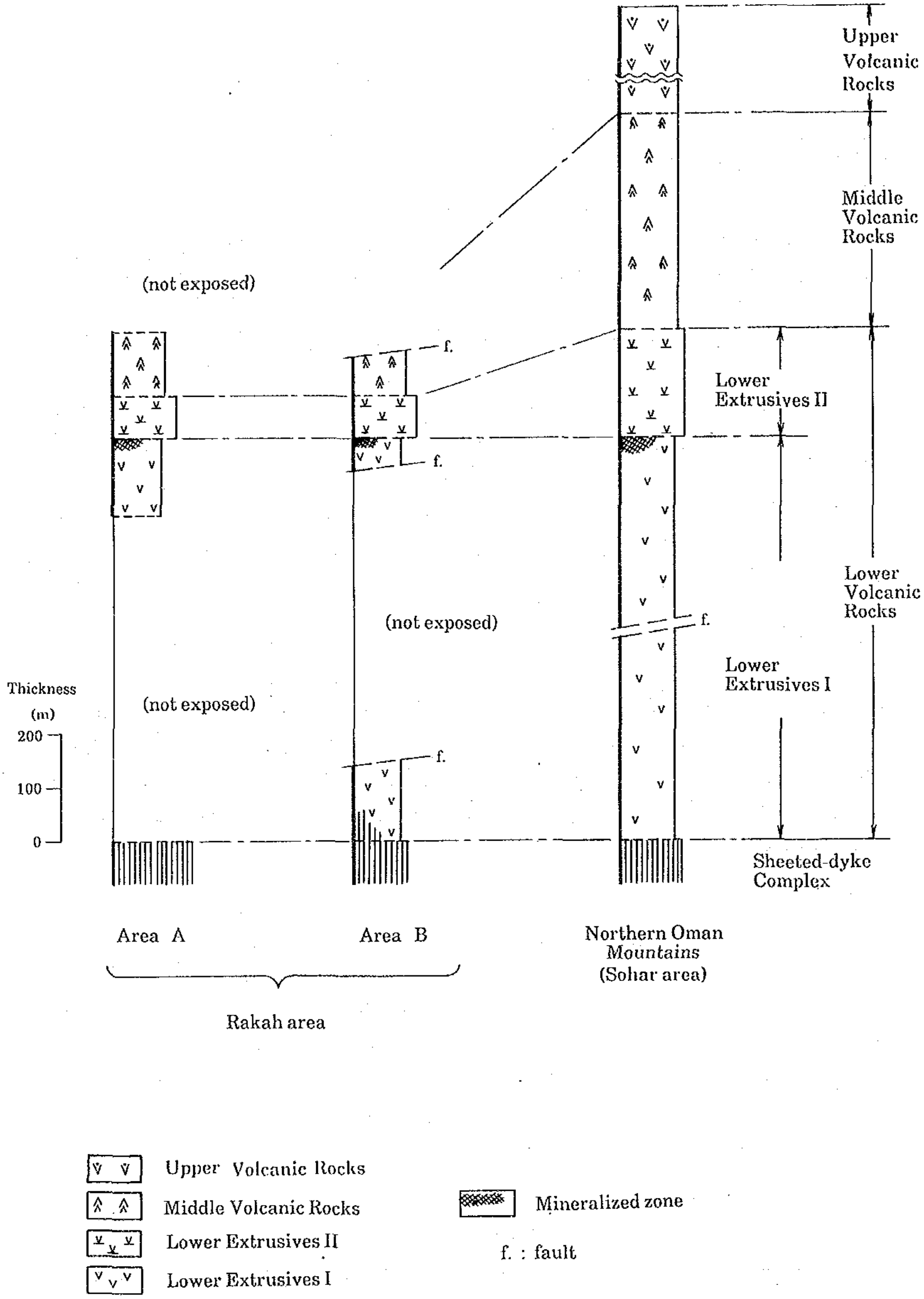


Fig. II-1-7 Correlation of Samail Volcanic Rocks

60 cm and has an amygdaloidal texture filled with zeolites, calcite, epidote and chlorite. Hyaloclastite around the pillow is relatively thin and ranges in thickness from 1 cm to 3 cm.

Three metalliferous sedimentary layers are found in this unit. These are reddish brown in color and up to 3 cm in thickness. The layers strike N 20° ~ 40° E and dip 30° to 40° toward north.

Microscopic observation gives following results:

Rock name:	Andesitic pillow lava
Sample number:	M015
Texture:	Glomeroporphyritic texture
Descriptions	Phenocrysts consist of augite and subordinate plagioclase. Euhedral to subhedral and prismatic augite, 0.4 to 0.6 m/m in grain size, shows undulatory extinction and is altered to chlorite and epidote. Euhedral plagioclase is 0.4 m/m in grain size. Groundmass consists mainly of laths of plagioclase, augite, glass and opaque minerals. Glass is altered to chlorite, epidote, albite and smectite. Opaque minerals are probably iron oxide minerals and are partly oxidized to hematite.

Middle Volcanic Rocks

The Middle Volcanic Rocks are found in the west of Main Gossan and consist of extrusive rocks and metalliferous sedimentary laysers. The extrusives are composed of dark greenish gray to greenish gray pillow lavas (Me) and massive lavas (Mms). Small but typical outcrop of the pillow lavas is found in the southeastern part of the area. The pillows are relatively large ranging the diameter from 0.6 m to 1.2 m and show irregular oval shape. The massive lavas occure at the west to southwest of Main Gossan and consist of fine to medium-grained dolerite containing chloritized pyroxene as the phenocryst.

The metalliferous sedimentary layers are interbedded in the massive lavas. The layers are dark reddish brown and have thickness ranging from 5 cm to 12 cm.

Columnar sections of volcanic rocks in Area A are shown in Fig. II-1-8. Results of microscopic observation for the rock in this unit are as below:

Rock name:	Basaltic pillow lava
Sample number:	M003
Texture:	Intersertal texture
Descriptions	Phenocrysts consist of plagioclase and augite. Euhedral plagioclase, 0.5 to 1.5 m/m in grain size, is prismatic. Small amount of euhedral to subhedral augite is 0.5 m/m in grain size. Groundmass includes plagioclase, augite and subordinate titan-augite, hyperthene and iron oxide minerals. Carbonates and subordinate chlorite, epidote and smectite are secondary minerals.

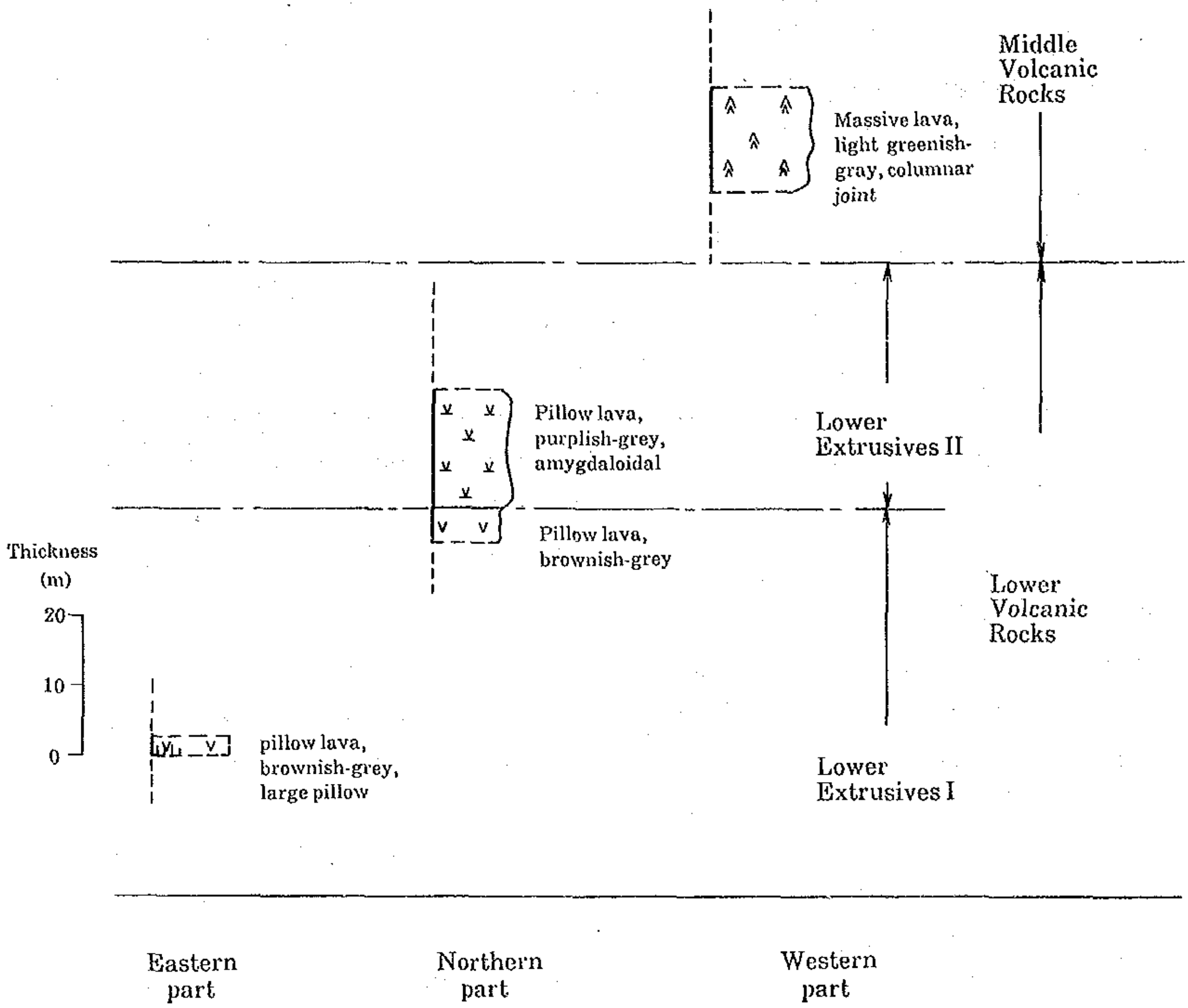


Fig. II-1-8 Columnar Sections of Volcanic Rocks in Area A

Rock name:	Doleritic massive lava
Sample number:	M005
Texture:	Subophitic texture
Descriptions	Phenocrysts consist of euhedral plagioclase, 0.5 to 2.0 m/m in grain size and subordinate euhedral to subhedral augite, 1.0 m/m in grain size. Plagioclase is altered to calcite and chlorite. Groundmass is composed of lath of plagioclase, augite and small amount of opaque minerals. Carbonetes, smectite, chlorite, sphene and epidote are the secondary minerals.

(2) Intrusive Rocks

Basaltic to andesitic dykes are found in the eastern end of the area. The dykes are dark green to greenish gray and have chilled margin with width of 2 to 3 cm. The rocks are altered and contain epidote and carbonate veinlets. The dykes have width ranging from 30 cm to 2 m and have a direction of NW-SE dipping 30° to 50° toward northeast. The direction and dip of the dykes are similar to those in the Sheeted-dyke Complex. The dykes are possibly feeder dykes of the Lower Volcanic Rocks.

(3) Supra-ophiolite Sediments

This unit is found locally in the eastern and southwestern parts of the area and consists of Olistostrome (Os). The Olistostrome present chaotic structure and contains various kind of olistoliths including red chert, reddish brown siliceous shale, dirty limestone, basalt and bedded limestone et al.

Individual olistoliths show the size ranging from several tens meters to several hundreds meters. The relationship between the Olistostrome and Samail Ophiolite is unknown because of no outcrops of the contact in the area.

(4) Quaternary

Quaternary superficial deposits are divided into terrace deposits, debris and wadi sediments.

(a) Terrace Deposits (Qt.)

Terrace is widespreaded in the area and is divided into middle and lower terraces. Upper terrace found in Area B is not observed in this area.

The middle terrace is between 680 m and 720 m above sea level and distributes widely in the area. Middle Terrace Deposits (Qtm) forming the middle terrace consist of sand and gravel, and reach the thickness up to 40 m. The gravel are mostly rounded to subrounded gabbro and harzburgite ranging the diameter from 1 cm to 60 cm. The deposits are ill sorted and occasionally intercalate thin fine to coarse-grained sand beds. The bottom of the deposits consist of granule to *coarse sand and area mostly cemental with carbonate.*

The lower terrace is situated between 675 m and 710 m above sea level and occurs along the main wadis and the surroundings. The level of middle terrace is higher from 3 m to 8 m than that of lower terrace. Lower Terrace Deposits (Qtl) are similar to those of the Middle Terrace Deposits (Qtm).

(b) **Debris (Qd)**

Debris occurs at the northeastern part of the area and the surroundings of Main Gossan and Small Gossan. The Debis (Qd) in the gossan zones have several meter thick and consists of angular gravel of siliceous gossan.

(c) **Wadi Sediments (Qw)**

The Wadi Sediments (Qw) are found along wadis and consist of rounded to subrounded gravels. The gravels are mostly gabbro and harzburgite.

1-2-2 Geologic Structure

Tectonic history in the Rakah area can be divided into three stages. These are formation of Samail Ophiolite (first stage), obduction of Samail Ophiolite (second stage) and tectonic movement of post-obduction (third stage).

In the first stage, the Samail Ophiolite was formed in the spreading ridge of the Palaeo-Tethys sea during Early to Middle Cretaceous time (Lippard et al., 1986), and Hawasina Basin was situated between the spreding ridge and Arabian Plate, as shown each situation in Fig. II-1-9 (1). Original structures within the ophiolite are preserved generally in Sheeted-dyke Complex, Cumulate Sequence and Tectonites. The Sheeted-dyke Complex in Aera A and B shows original structure, which has a direction of NW-SE. This direction corresponds with the general trend of the Samail Ophliolite, which is found broadly in the Oman Mountains.

The second stage is related to the obduction of the Samail Ophiloite onto the Oman Platform, which is located southwestern edge of the Arabian Plate, following detatchment from sea-floor and deposition of the Supre-ophiolite Sediments. The obduction of Samail Ophiolite is considered to be of Late Cretaceous age (Coleman, 1981 and Lippard et al., 1986) (Fig. II-1-9 (2)). Thrust faults and folds trending NNW-SSE to NW-SE, which is related to the obduction, are found widely in the Oman Mountains. In the Rakah area, several thrust faults trending NW-SE to E-W are found. Although internal structures of the individual thrust sheets show normal stratigraphic sequence, upper part of the sequence is tectonically overlain by lower part of the sequence as just like reversed structure. This feature is thought to be imbricated structure resulted by the formation of several thrust faults (Fig. II-1-9 (3), (4) and (5)).

The third stage is post-obduction and shows a variation in different localities. In Area A, two thrust faults trending NNW-SSE and dipping gently to the north, are found in the northeastern part of the area. These thrust faults are situated between High-level Gabbro and Sheeted-dyke

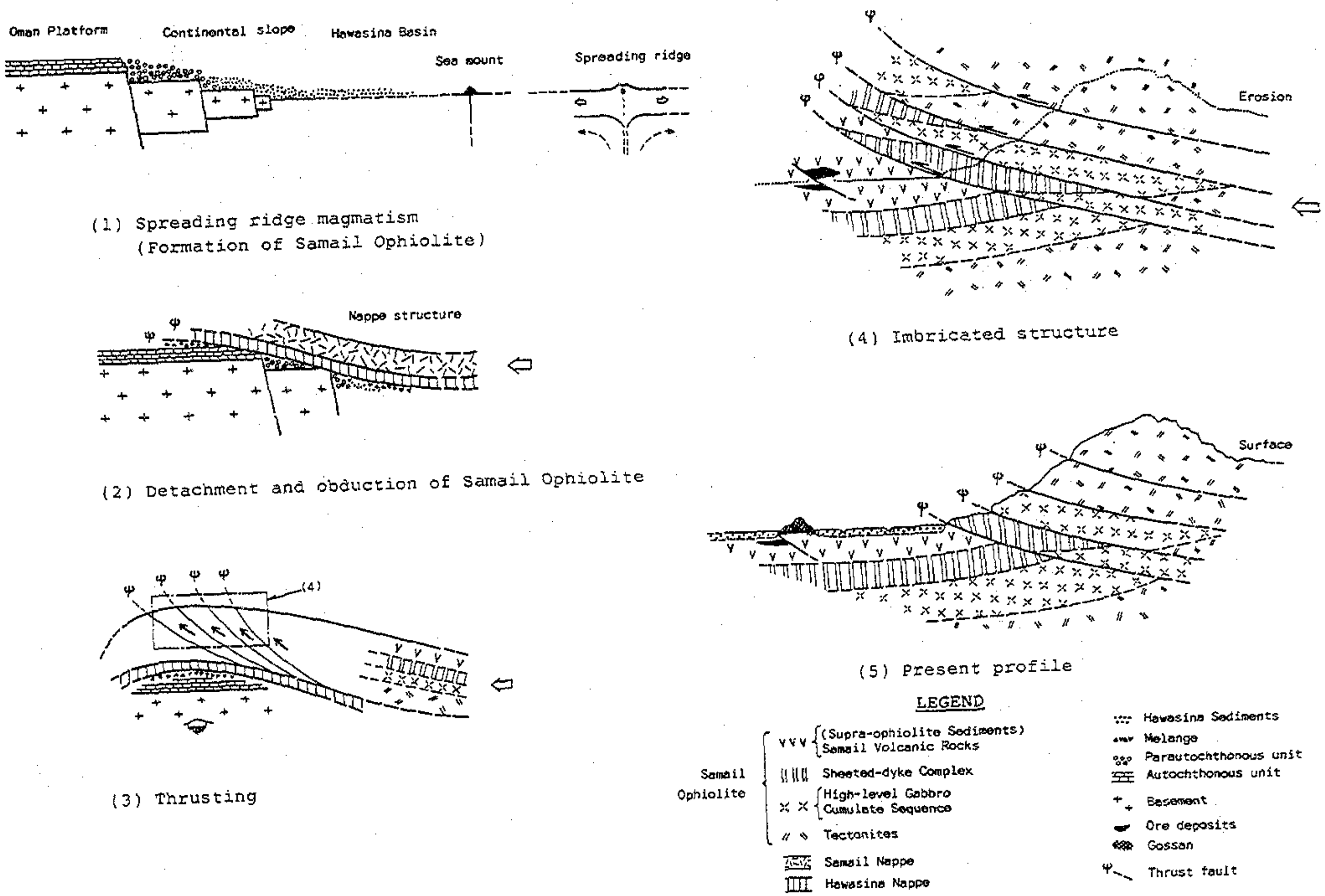


Fig. II-1-9 Tectonic History of Samail Ophiolite in the Rakah Area

Complex on the upper part and between Sheeted-dyke Complex and Volcanic Rocks on the lower part. Faults consist of three directoions of faults, including N-S, NE-SW and NW-SE. Most of faults are high angle (70° ~ 90°), but low angle (40° ~ 50°) faults are inferred locally. The tectonic map of Area A shows in Fig. II-1-4.

1-2-3 Mineralization

1. General

Mineralized zones in Area A consist of four zones including Hayl as Safil deposit, Main Gossan, Small Gossan and the north of Small Gossan (north orebody) from southeast to nothwest. Among the mineralized zones the Hayl as Safil deposit and the north orebody were discovered by drilling. Many additional drill holes were completed for these two depostis and resulted to estimate ore reserves of 2,086,000 tons grading 2.09% Cu, 0.97 g/t Au and 6.86 g/t Ag (Haddadin, 1988) for the Hayl as Safil deposit.

Previous survey results for the Hayl as Safil deposit and Main Gossan were interpreated to be formed separately. The servey results show these were formed as one orebody and later fault movement separated them. The mineralized zone is situated at the top of the Lower Extrusives I with overlying Lower Extrusives II. The ore can be classified into stockwork ore, massive ore and siliceous ore in ascending order. The gossanized zones consist of intensely weathered stockwork ore and siliceous ore in part. A detailed geologic survey and six drill holes were completed in the Hayl as Safil deposit area including gossan zones. Based on the survey results geologic map and sections were made as shown in Fig II-1-10 and Fig. II-1-11.

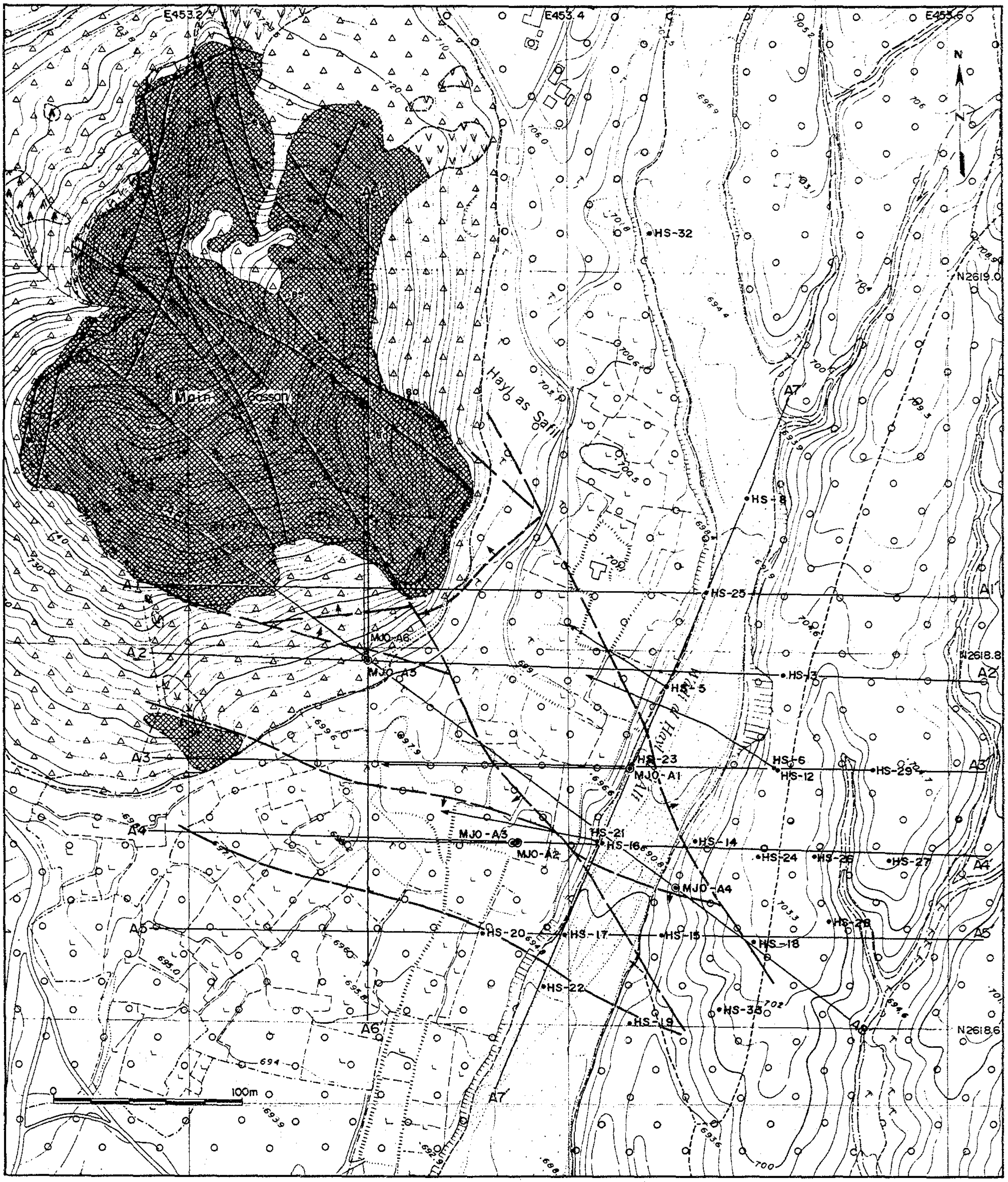
2. Mineralized Zones

(a) Main Gossan

Main Gossan occupies over an aera of 300 m (N-S) by 240 m (E-W) in the center of Area A and form a hill about 90 m high from the surface of terrace. The thickness of the gossan zone is estimated more than 50 m. The zone strikes ENE-WSW and dips 10° to 20° southward. Boundary between the gossan zone and underlying Lower Extrusives I is observed at the northern edge of Main Gossan. The boundary is clear due to different intensity of alteration. A small gossan outcrops about 60 m south of Main Gossan. Lower Extrusives II occurs between these gossan outcrops. Middle Volcanic Rocks are found at the west of Main Gossan.

Several normal faults trending NW-SE are found in the gossan zone. The Lower Extrusives II found in the south of Main Gossan may have fault contact with gossan zones. A sheared zone with 1 to 2 m thick is found at the southern end of Main Gossan.

No sulfide minerals are found in Main Gossan due to intense weathering. This mineralized zoned is characterized with intense brecciation and silicification with quartz stockwork veins.



LEGEND

Wadi Sediments

Debris

Terrace Deposits

Middle Volcanic Rocks

Lower Extrusives II

Lower Extrusives I

Gossan

Fault

•HS-18 Previous drill hole

◉MJO-A4 Drill hole done in this project

Fig. II-1-10 Geologic Map of the Hayl as Safil Deposit Area

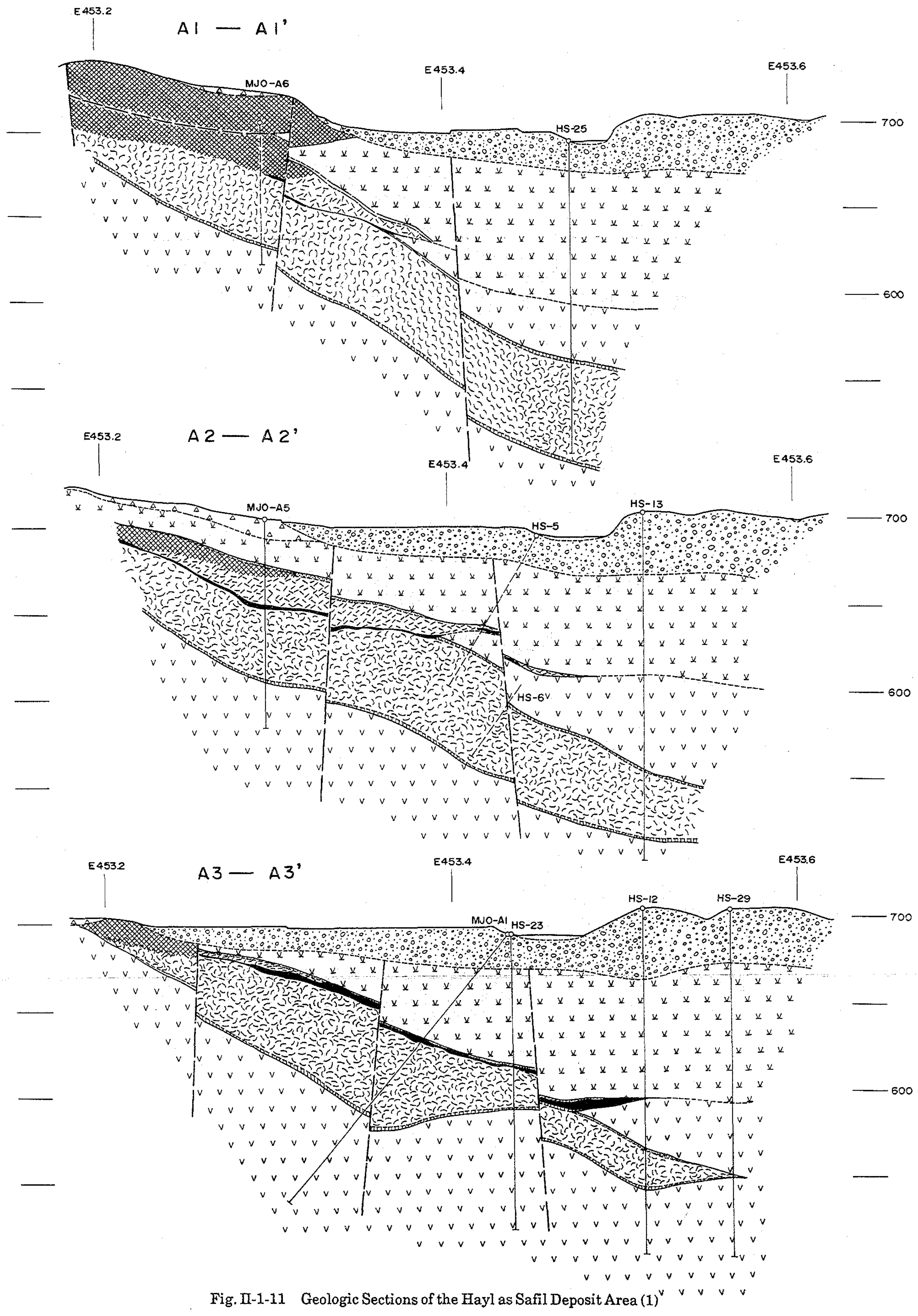
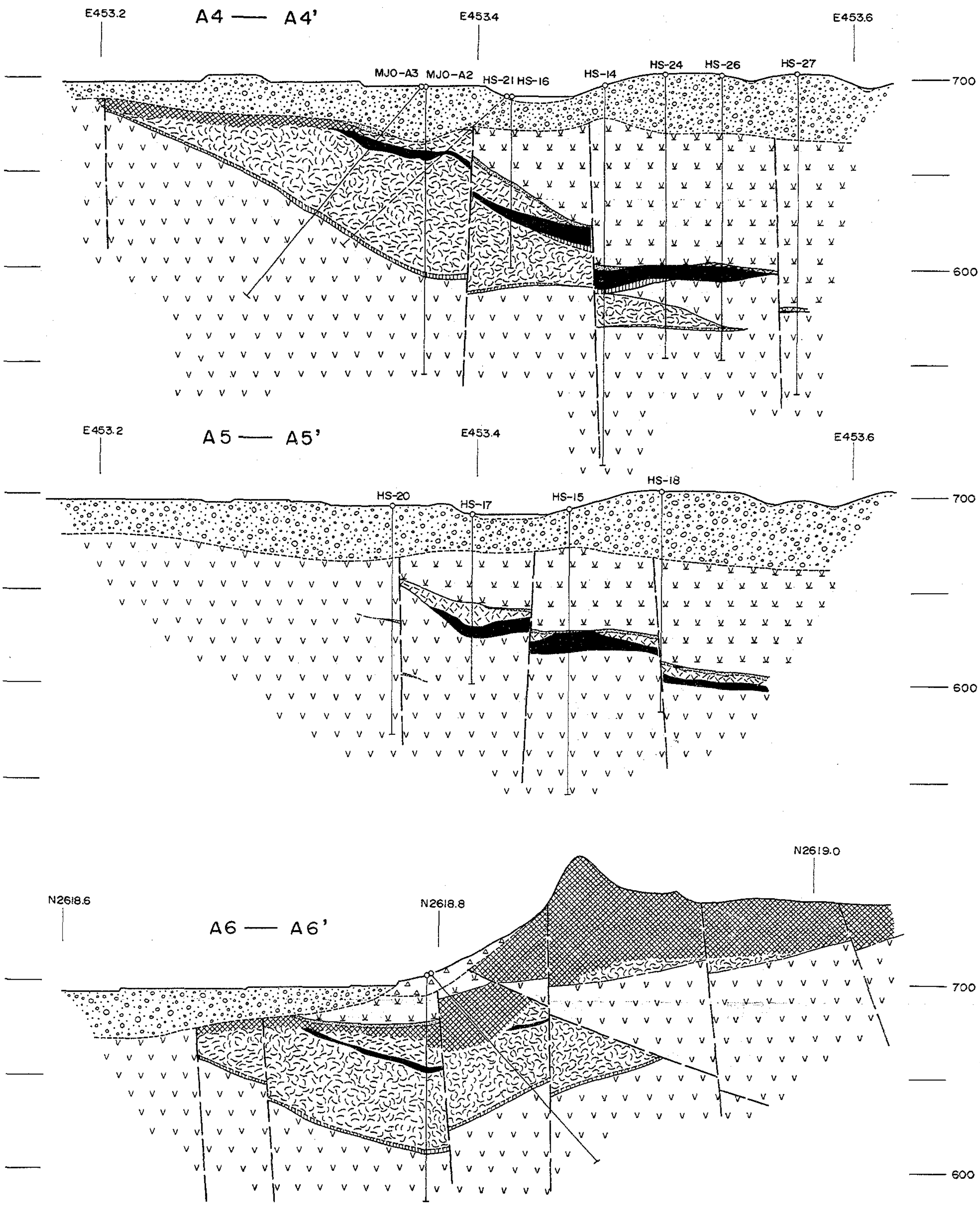
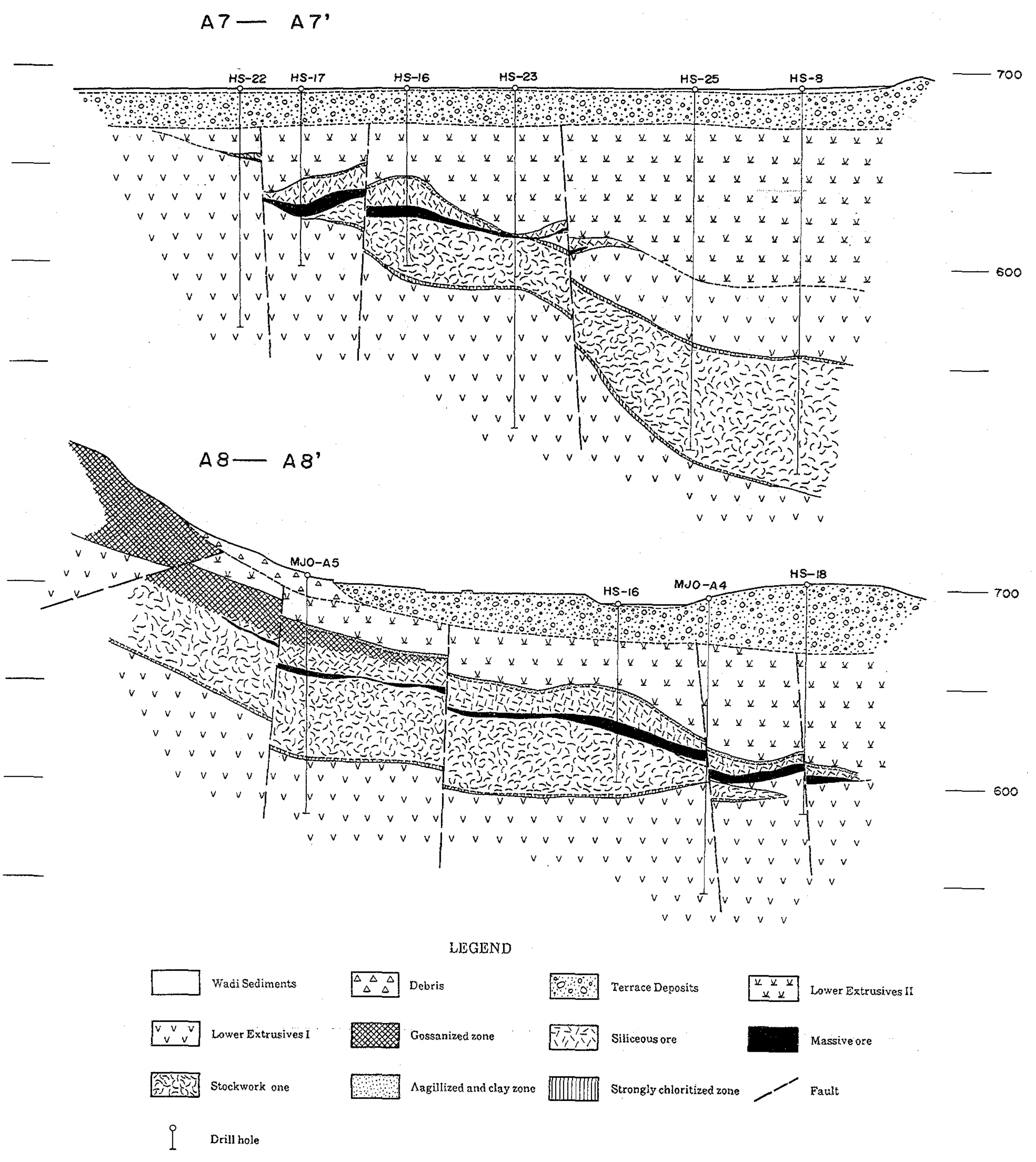


Fig. II-1-11 Geologic Sections of the Hayl as Safil Deposit Area (1)


A4 — A4'
E453.2
E453.4
E453.6
MJO-A3
MJO-A2
HS-21
HS-16
HS-14
HS-24
HS-26
HS-27
700
600
A5 — A5'
E453.2
E453.4
E453.6
HS-20
HS-17
HS-15
HS-18
700
600
A6 — A6'
N2618.6
N2618.8
N2619.0
700
600

(2)


A7 — A7'
HS-22
HS-17
HS-16
HS-23
HS-25
HS-8
700
600
A8 — A8'
MJO-A5
HS-16
MJO-A4
HS-18
700
600
LEGEND
Wadi Sediments
Debris
Terrace Deposits
Lower Extrusives II
Lower Extrusives I
Gossanized zone
Siliceous ore
Massive ore
Stockwork one
Aagillized and clay zone
Strongly chloritized zone
Fault
Drill hole

(3)

The breccia consists of silicified volcanics, quartz-hematite, quartz, limonite, goethite and hematite. Brecciation occured at least three or four times because re-brecciated breccia were found in many places. Matrix of the breccia is reddish brown and is mainly filled with hematite. Barren quartz veins of the latest stage cut the breccia. No difference are found throughout the gossan zone for the intensity of brecciation and composition of breccia. Quartz-hematite breccia tend to occur at the upper part, but some quartz-hematite breccia is also found in the middle and lowr parts of the gossan zone. Oxide copper minerals are found locally at the lower part.

(b) **Hayl as Safil Deposit**

A total of 23 holes (3,551.15 m) were completed for the Hayl as Safil deposit before starting this project. Six drill holes totalling 898.70 m were carried out in this survey. No outcrops are found due to thick terrace deposit in the Hayl as Safil deposit area.

Drilling results show the ore deposits are at the top of the Lower Extrusives I and is covered with the Lower Extrusives II. Previous drilling confirm the extension of the ore deposits over an area of 200 m (N-S) by 180 m (E-W). The survey results in this project confirmed that the ore deposits extend westward and reach to Main Gossan.

The ore deposits consist of stockwork, massive and siliceous ores in ascending order. Strongly chloritized zones with a few meter thick are found at the boundary between the ore deposits an footwall volcanic rocks. Argillized zone with gray clay are occurs at the top of the deposits. The ore deposits are clearly bounded with these zones at the top and bottom. No sulfide minerals are found in the hanging wall and footwall volcanic rocks. The mineralized zone with maximum thickness of more than 70 m, also extend to the northeast. The zone reachs surface at the southwest and is eroded.

The Hayl as Safil deposit consists mainly of stockwork ore and no difference of occurrences, and ore and gangue minerals are observed throughtout the stockwork zone except the marginal part. The stockwork ore consists of strongly silicified, pyritized and chloritized breccia of volcanic rocks, and the matrix containing quartz and quartz-hematite veins with cholcopyrite and pyrite. This ore zone is re-brecciated and chalcopyrite-pyrite and quartz veinlets are found along fractures. Further more, sphalerite-pyrite-quartz veinlets cut the brecciated stockwork ore. The barren quartz veinlets of later stage also cut the ore zone. Occurrence of stockwork zones also show a few time brecciation occured in the stockwork zone. Minor quartz-hematite breccia are found throughout the stockwork zone.

Massive ore in the center of the orebody have gradational change to the stockwork ore zone. But volcanic rocks are intercalated between the massive and stockwork ore zone in the marginal part of the ore deposits. The thickness of the massive ore is a few meter in the center and more than 10 m at the marginal part, and the grade of Cu is very high (more than 6% Cu). Massive ore also shows more concentration of Au. A part of the massive ore encountered by the hole of HS-14 shows more than 7 g/t Au. Massive ore consists of breccia containing medium to fine grained pyrite and the matrix filled with pyrite-chalcpopyrite. Colloform pyrite is obsereved under the microscope.