REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE UMM AD DAMAR AREA
THE KINGDOM OF SAUDI ARABIA

CONSOLIDATED REPORT

MARCH 2001

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

In response to the request of the Government of the Kingdom of Saudi Arabia, the Japanese Government decided to conduct a Mineral Exploration Project consisting of analysis of existing data, geological survey, and IP geophysical survey and other relevant work in the Umm ad Damar area to clarify the potential of mineral resources, and entrusted the survey to Japan International Cooperation Agency (JICA). The JICA entrusted the survey to Metal Mining Agency of Japan (MMAJ), because contents of the survey belong to a very specialized field of mineral exploration.

The Government of the Kingdom of Saudi Arabia appointed the Saudi Geological Survey to execute the survey as a counterpart to the Japanese team.

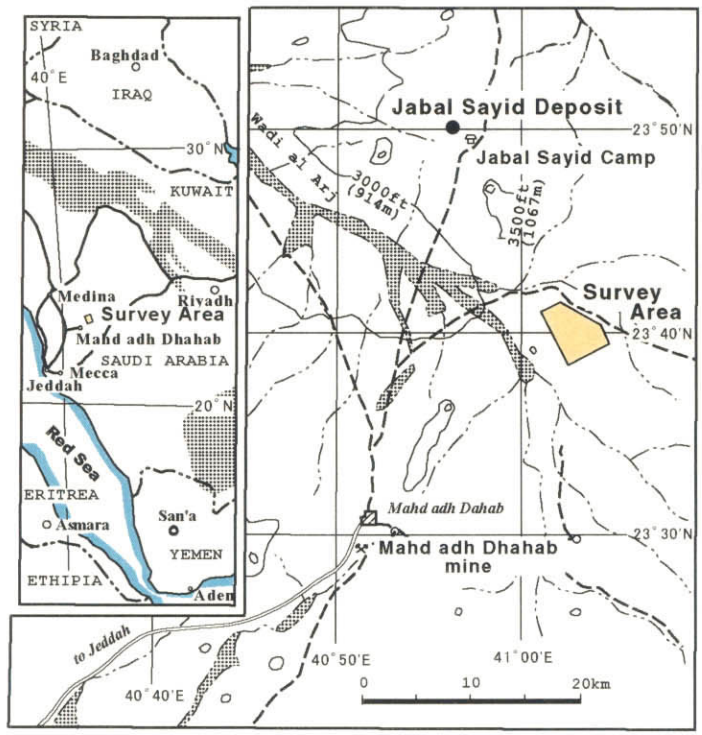
The survey was carried out in the Umm ad Damar area during three years from 1998. This consolidated report hereby submitted summarizes the results of the survey.

We wish to express our deep appreciation to the persons concerned of the Government of the Kingdom of Saudi Arabia, the Ministry of Foreign Affairs of Japan, the Ministry of Economy, Trade and Industry, the Embassy of Japan in Saudi Arabia and the authorities concerned for the close cooperation extended to the team.

March 2001

Kunihiko SAITO
President
Japan International Cooperation Agency

Naohiro TASHIRO
President
Metal Mining Agency of Japan



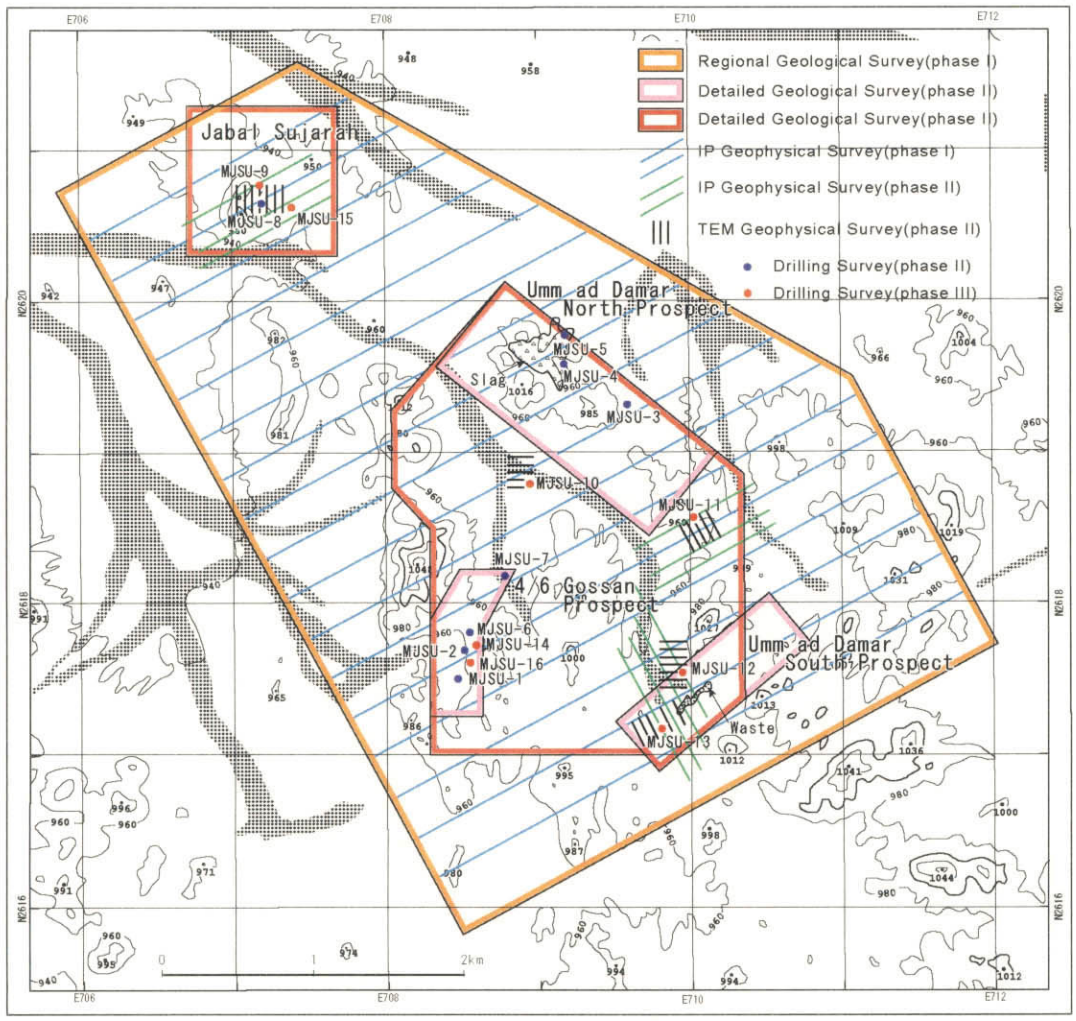


Fig. 1-1 Location Map of the Survey Area

SUMMARY

Mineral exploration was carried out in the Umm ad Damar area during the past three years from 1998. The work carried out included analysis and interpretation of existing data, geological survey, geophysical surveys (IP and TEM methods), and drilling (16 drill holes, total length of 4,492m). The results of the above surveys are summarized as follows.

1. The geology of the survey area consists mainly of rhyodacite, dacite, and andesite and their pyroclastic rocks belonging to the Late Proterozoic Arj Group, and these units are accompanied by jasper. These units are intruded by diorite, quartz diorite, tonalite, andesite, dacite, rhyodacite, and basalt. Andesite and andesitic pyroclastic rocks of Late Proterozoic Mahd Group overlies the above units unconformably in the western margin of the survey area. Of the above units, jasper and dacitic breccia occur near Jabal Sujarah in the northwestern part of the survey area. Granitic rocks occur throughout the survey area, but they are concentrated in the zone from the Umm ad Damar North Prospect to the Umm ad Damar South Prospect.

2. Mineralization containing Cu and Zn occur in four localities of this area. They are Jabal Sujarah district, Umm ad Damar North Prospect, Umm ad Damar South Prospect, and 4/6 Gossan Prospect. The mineralization in the Jabal Sujarah district, 4/6 Gossan Prospect, and a part of Umm ad Damar North Prospect is volcanogenic massive sulfide Cu-Zn mineralization. Also Cu vein mineralization occurs in Umm ad Damar North Prospect and Cu-Zn vein mineralization in Umm ad Damar South Prospect.

3. Chargeability anomalies have been extracted by IP survey in areas other than the above prospects. But only pyrite dissemination and veinlets occur in the high chargeability anomalies, and the Au, Cu, and Zn contents are low.

4. The mineralization in the Jabal Sujarah district is the volcanogenic massive sulfide Cu-Zn type and it occurs in dacitic breccia of the Arj Group. The orebodies consist of massive and pebbly ores and are accompanied by pyrite dissemination. The highest chargeability anomaly (over 30mV/V, 800m elevation) of the entire survey area occurs in this district, and it occurs over an areal extent of 200×200m. These chargeability anomalies are caused by thick pyrite dissemination in the footwall of the massive and pebbly ores. This pyrite disseminated zone consists solely of pyrite and the Au, Cu, and Zn contents are negligible.

There are several layers of massive and pebbly ores and the total thickness of the mineralized zones including the intercalated pyrite dissemination is around 6m. The extent of the mineralized zones

containing massive and pebbly ores is around 200m in the strike direction and longer than 250m in the dip direction. Although there are parts rich in Cu and Zn, most of the massive and pebbly ores consist mostly of pyrite and is of low grade.

5. In the Umm ad Damar North Prospect, five rows of Cu vein zones are inferred to occur. They are named No. 1 ~ No. 5 Mineralized Zones. Drilling was carried out for three of these zones. The veins and network ores confirmed by these drill holes consist of chalcopyrite-pyrite hosted by dacite and dacitic pyroclastic rocks of the Arj Group. There are few gangue minerals. Au and Ag grades are low and the margins of the ore veins are strongly chloritized.

Five holes were drilled during the past for No.1 Mineralized Zone, and it is 4.8m thick in average and the grade is Cu !.40%. For No.2 Mineralized Zone, two holes were drilled and the occurrence of two to three mineralized layers of veinlets and dissemination have been confirmed. These are 3.5m thick in average and the grade is Cu 2.38%. For No.3 Mineralized Zone, four holes were drilled and in UAD-11 hole the ore layer is 3.1m thick and Cu 1.87%. The length of the Nos. 1 and 2 Mineralized Zones is estimated to be 400~500m in the strike direction, and that of No.3 Mineralized Zone about 300m. The grades of metals other than Cu, namely Au and Zn, are both low.

Nos. 4 and 5 Mineralized Zones have not been drilled, but the length in the strike direction is estimated from the surface manifestations to be about 200m and 400m respectively.

Aside from these Cu vein-type mineralization, a volcanogenic massive sulfide-type mineralized zone was confirmed by MJSU-5, but similar mineralized zones have not been found in drill holes in the vicinity and thus this is considered to be of small scale.

6. One row of vein-type Cu-Zn mineralized zone occurs in the Arj Group of Umm ad Damar South Prospect. Eleven hole were drilled for this zone in the past and four of them confirmed the existence of the mineralized zone. Vein-type mineralized zone was not encountered by the drilling carried out to the southwest of the mineralized zone during the present survey. Thus the scale of this mineralized zone is estimated to be 2.1~6.9m thick, 300m in the strike direction, at most 130m in the dip direction. The Cu grade of this zone is 1.99~2.93%. In some drill holes, Au grade of 0.3~1.1g/t and Zn grade of 0.2~3.1% have been obtained.

7. The mineralization observed in 4/6 Gossan Prospect is volcanogenic massive sulfide-type Cu-Zn mineralization in rhyodacitic tuff of the Arj Group. This mineralized body consists of massive, siliceous,

and pebbly ores and the ore minerals are chalcopyrite, sphalerite, and pyrite.

Three ore layers occur in this mineralized zone. They occur both above and below (apparent) a basaltic tuff horizon intercalated in the rhyodacitic tuff. The mineralized body below the basaltic tuff is largely divided into two parts. The mineralized body immediately below the basaltic tuff is the thickest in MJSU-2 where the thickness is estimated to be about 3.7m. The grade of this part is Au 0.4g/t, Cu 0.96%, and Zn 2.17%.

The mineralized body in further deeper horizon is also thickest in MJSU-2 and is estimated to be about 9.3m. The grade here is Au 0.4g/t, Cu 1.00%, and Zn 3.67%.

Mineralized body also occurs above the basaltic tuff horizon. This is observed only in the MJSU-6 hole. The average grade is Au less than 0.1g/t, Cu 0.69%, and Zn 3.99% and the thickness is estimated to be around 2.5m.

The size of the two mineralized bodies below the basaltic tuff is estimated to be about 100m in the strike direction and the lengths of the dip direction more than 60m and 120m respectively. The body above the basaltic tuff was confirmed only in one drill hole and the length in both the strike and dip directions is estimated to be around 100m.

8. Three prospects (Umm ad Damar North Prospect, Umm ad Damar South Prospect, and 4/6 Gossan Prospect) have been known in this survey area for many years, and various exploratory work have been carried out in limited parts of these prospects sporadically since 1966. But final assessment had not been made. Because of this situation, comprehensive assessment of the mineral potential of the total area was carried out during this cooperative exploratory project integrating the results of geological survey, geophysical surveys, and drilling. These work was based on the results of the past surveys and emphasis was laid on confirming the extent of the known ore bodies and on finding new ore deposits.

By drilling the geophysical anomalies extracted by IP geophysical prospecting, new Cu-Zn mineralized zones partly accompanied by Au were discovered in three prospects including the hitherto unknown Jabal Sujarah district. It became clear, however, that the mineralized zones observed in this survey area do have high-grade parts, but they either converge or disperse in their lateral and downward extension and thus are of small scale. Therefore it is deemed difficult to develop these mineralized zones under the present economic conditions. Also the results of the geophysical surveys indicate that the possibility of locating mineralized zones larger than the known orebodies with further detailed surveys is small.

CONTENTS

CONTENTS

PART II DETAILED DISCUSSIONS

FIGURES

Tables

Appendices

PART I OVERVIEW

PART I OVERVIEW

CHAPTER 1 INTRODUCTION

1-1 Background and Objectives

This is the consolidated report regarding the Cooperative Mineral Exploration of Umm ad Damar area carried out under the "Scope of Work" signed on 6 July 1998 by the Metal Mining Agency of Japan (MMAJ) and the Deputy Ministry for Mineral Resources (DMR) of Kingdom of Saudi Arabia.

The objective of this survey was to discover new mineral deposits by clarifying the geology and mineral occurrences of the area.

During the first year of this project, 1998, the work consisted of preparation of topographic maps, analysis and interpretation of existing data, photogeologic analysis and interpretation, geological survey, and regional IP geophysical survey. Photogeologic analysis and interpretation was done with the purpose of clarifying the regional geologic structure including faults, lineations, bedding and lithofacies distribution. Geological survey was carried out in order to understand the relation of mineralization and geology・geologic structure. Regional IP geophysics was done for the whole survey area and the objective was to extract the IP anomalies related to mineralization and geologic structure. The work carried out is shown in Table 1-1.

During the second year of this project, the work consisted of detailed geological survey, drilling (8 drill holes, total length 2,152.05m), detailed IP survey, and TEM survey. Drilling was done in promising zones extracted by geological survey and regional IP survey, and the objective was to clarify the detailed distribution of Au, Cu, and Zn. Detailed IP survey was made in promising zones extracted by the geological and IP surveys of the previous year, and the purpose was to extract IP anomalies related to mineralization and geologic structure. TEM survey was targeted on anomaly zones of extracted by detailed IP, and the objective was to determine the existence-or-absence of volcanogenic massive sulfide mineralized zones and to estimate their location and shape. Geological survey was carried out for parts of the IP anomalies extracted by detailed geophysical work and the purpose was to clarify the relation between mineralization and geology・geologic structure.

Work of the third year of the project, Fiscal 2000, consisted of drilling (8 drill holes, total length 2,340.65m). The targets of the drilling was mineralization in deeper subsurface zones, particularly the

details of Au, Cu, and Zn distribution of the promising zones extracted by geological, geophysical (IP and TEM) surveys and drilling carried out during the first and second years of this project.

The flow of the surveys carried out during the three years is shown in Figures 1-2 and 1-3.

1-2 Location of the Survey Area

The survey area is located in the western part of Saudi Arabia. The areal extent of the survey area is 18 km^2 (Fig. 1-1). The survey area is in the central part of the Proterozoic region in the western margin of the Arabian Peninsula.

1-3 Members of the Survey Team and Duration

Duration of the survey and members of the survey teams are shown in Table 1-2.

Table 1-1 Amount of Work

First Phase

Survey Method	Amount		
Topographic map (scale 1:10,000)	Areal extent	100	km^2
Topographic map (scale 1:5,000)	Areal extent	9	km^2
Photogeological interpretation	Areal extent	90	km^2
Geological survey	Area extent	18	km^2
	Laboratory works		
	Thin section	25	samples
	Polished section	8	samples
	X-ray diffraction analysis	10	samples
	Ore assay (Au,Ag,Cu,Pb,Zn,Fe)	33	samples
	Fluid inclusion		
	Homogenization temperature	14	samples
	Salinity	14	samples
Geophysical survey (IP method)	Length of survey lines	55.0	km
	Number of stations	1,962	points
	Measurement of rock resistivity and chargeability	36	samples

Second Phase

Survey Method	Amount		
Geological survey	Area extent	6	km^2
	Laboratory works		
	Thin section	13	samples
	Polished section	10	samples
	X-ray diffraction analysis	10	samples
	Ore assay (Au,Ag,Cu,Pb,Zn,S)	13	samples
Drilling exploration	Number of drill holes	8	holes
	Total drilled length	2,152.05	m
	Laboratory works		
	Thin section	73	samples
	Polished section	27	samples
	X-ray diffraction analysis	28	samples
	Ore Assay (Au,Ag,Cu,Pb,Zn,S)	419	samples
Geophysical survey (IP method)	Length of survey lines	10.0	km
	Number of stations	260	points
	Measurement of rock resistivity and chargeability	34	samples
Geophysical survey (TEM method)	Number of stations	319	points

Third Phase

Survey Method	Amount		
Drilling exploration	Number of drill holes	8	holes
	Total drilled length	2,340.65	m
	Laboratory works		
	Thin section	32	samples
	Polished section	20	samples
	X-ray diffraction analysis	60	samples
	Ore Assay (Au,Ag,Cu,Pb,Zn,S)	455	samples
	Measurement of rock resistivity and chargeability	50	samples

Table 1-2 Duration of Survey and Participants

Phase	Works	Duration	Name	
			Japanese Side	Saudi Arabian Side
First	Mission for Scope of Work Consultation	1998. 6.25～1998. 7.8	Takeru SASAGUCHI[4] Hiroyuki OKAJIMA[2] Tatsuya TAKAHASHI[1] Takafumi TSUJIMOTO[4] Noboru FUJII[4] Nobuyasu NISHIKAWA[4]	Mohammed TAWFIQ[6] Ghazi ABDULHAY[6] Mohamad SAHL[6]
	Field Supervisor	1999. 3. 9～1999. 3 16 1999. 1.30～1999. 2. 7 1999. 3. 5～1999. 3.16	Taro KAMIYA[3] Takafumi TSUJIMOTO[4] Hiroshi SHIBASAKI[4]	
	Geological Survey	1999. 1.30～1999. 3.17	Yoneharu MATANO[5] Yoshihiro KIKUCHI[5]	Ghazi ABDULHAY[6] Mohamad SAHL[6] Abdullah AL-JEHANI[6]
	Geophysical Survey	1999. 1.30～1999. 3.17	Takashi YAMAISHI[5] Shin-ichi SUGIYAMA[5] Saburo TACHIKAWA[5] Satoshi HIROOKA[5] Tadanori IWASAKI[5]	Ahmad ZAMZAME[6]
Second	Field Supervisor	2000. 2.26～2000. 2 28	Hiroshi SHIBASAKI[4]	
	Drilling Exploration	1999. 9. 5～1999.11.18	Yoshihiro KIKUCHI[5]	Ghazi ABDULHAY[6] Mohamad SAHL[6] Abdullah AL-JEHANI[6] Ghazi KATTU[5]
	Geological Survey	2000. 1.25～2000. 2.28	Yoshihiro KIKUCHI[5]	Ghazi ABDULHAY[6] Mohamad SAHL[6] Abdullah AL-JEHANI[6]
	Geophysical Survey	2000. 1.25～2000. 2.28	Toshihisa ISHIBASHI[5] Saburo TACHIKAWA[5] Mitsuyoshi SAITO[5]	Ahmad ZAMZAME[6]
Third	Field Supervisor	2000.11.10～2000.11 15	Yasunori NUIBE[4]	
	Drilling Exploration	2000. 9. 1～2000.11.15	Yoneharu MATANO[5]	Ghazi ABDULHAY[6] Abdullah AL-JEHANI[6] Zaben AL-GHIDANY[6] Yahya AL-MUFAREEH[6] Yasser AL-GHANMY[6] Ayman NADERAH[6] Ahmad SARHAN[6]

[1]: Ministry of Economy, Trade and Industry, [2]: Ministry of Foreign Affairs of Japan, [3]: Japan International Cooperation Agency, [4]: Metal Mining Agency of Japan, [5]: Nikko Exploration and Development Co., Ltd., [6]: Deputy Ministry of Mineral Resources (actually Saudi Geological Survey)

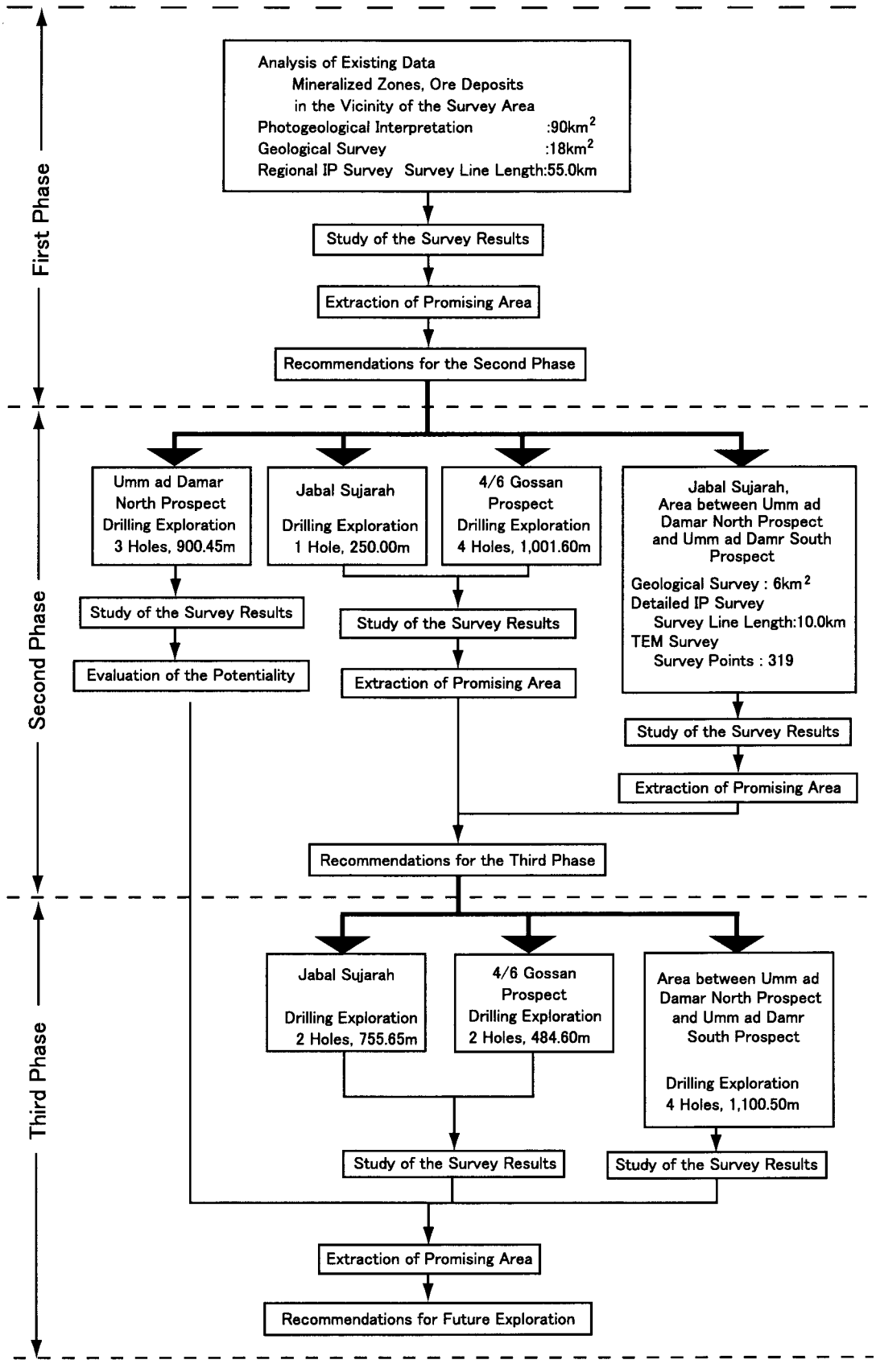


Fig.1-2 Flowsheet of Survey

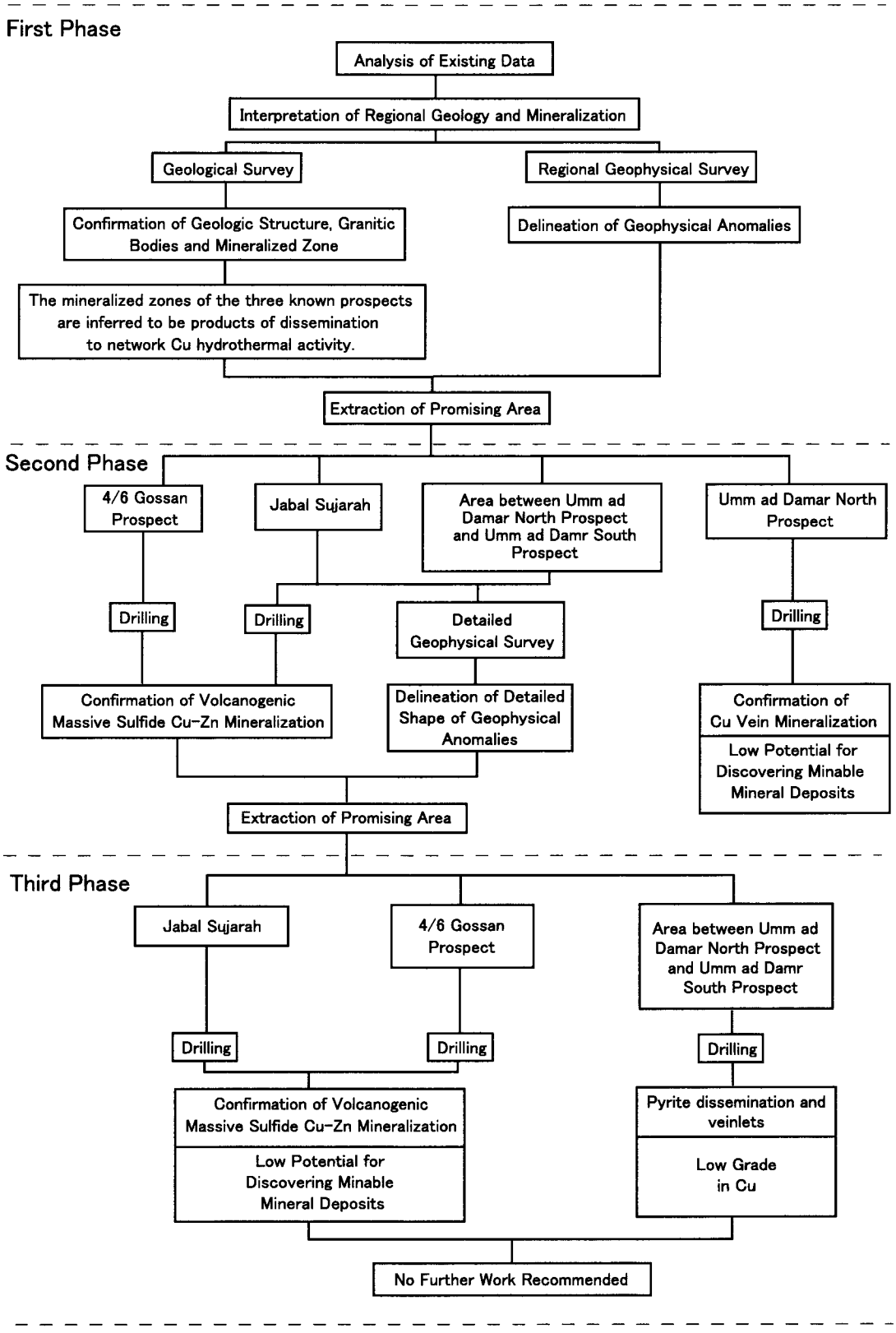


Fig.1-3 Exploration Flowsheet

CHAPTER 2 GEOGRAPHY OF THE SURVEY AREA

2-1 Location and Access

The survey area is located about 300-km northeast of Jeddah. DMMR camp near the Jabal Sayid deposit was used as the base camp (shown in Fig. 1-1). This is located about 20-km northwest from the survey area. The survey area is about 30-minute drive from the base camp.

2-2 Topography and Drainage

The topography of the region including the survey area consists, from the west; the Red Sea, coastal plain of the Red Sea – hilly zone, the Hijaz Mountains, Harat Rahat (basalt plateau), sabkha zone, and low-relief mountainous zone. And the survey area is located at the easternmost part with low-relief mountains. The altitude gradually increases eastward from the Red Sea, the Hijaz Mountains are 1,200−2,300 m high, the highest part of the Harat Rahat is 1,500 m, the altitude of the sabkha zone and the low-relief mountains are 1,000−1,200 m.

The low-relief mountains including the survey area are a part of the Najd Plateau located to the east of the Hijaz Mountains. The topography of the survey area consists of flat zone with altitude of about 900 m with hills and small mountains ranging in relative height from 50 m to 100 m.

Hills and mountains in the survey area generally are elongated in the N-S and NW-SE directions, and those in the southeastern part of the survey area are elongated in the NE-SW direction.

In the survey area, permanent rivers do not exist. Wadis in the survey area become lower in elevation to the north or northwest, and join Wadi al Arj at a location northwest of the survey area.

2-3 Climate and Vegetation

Saudi Arabia is located at the central part of the great tropical desert, which extends from northern Africa to Asia. In the highlands, the day time temperature exceeds 40 ° C , but it often drops to near 0 ° C at night in winter. The average annual precipitation at Mahd ad Dhahab is 62 mm.

Vegetation is sparse in the survey area with only acacia growing along wadis.

CHAPTER 3 PREVIOUS EXPLORATION WORK

Three prospects are known in the survey area; namely Umm ad Damar North, Umm ad Damar South, and 4/6 Gossan (henceforth the North Prospect, the South Prospect, and the 4/6 Gossan, respectively). The range of these prospects has been drawn in various ways by past surveys. In these prospects, disseminated to network pyrite-chalcopyrite mineralized parts occur intermittently in lens-form within the sheared zones. In this survey, the belt containing the linearly distributed mineralized lenses is called the mineralized zone.

The North and South Prospects have been explored in the past by various methods, including airborne geophysical survey, ground geophysical survey, geological survey, and drilling. The organizations concerned with these surveys were; DGMR (1936-1965), BRGM (1966-1971), SEREM (Societe d'Etudes de Recherches et d'Exploitation Minieres)/US Steel (1976-1977), and Riofinex (1981-1983). Regarding the 4/6 Gossan, Riofinex carried out trenching, geochemical survey, IP geophysical survey, and other types of exploration during 1982 to 1983, and Riofinex conducted drilling in 1983.

Ground geophysical survey was carried out intermittently from 1961 to 1983, but the area surveyed is not clear except for the work done by Riofinex during 1982 and 1983. The latter survey included the above three prospects and IP and geomagnetics were used. Although there are some exceptions, the chargeability anomalous zone exceeding 12.5 mV/V of Riofinex, mostly coincides with the mineralized zone.

A total of 27 holes were drilled in the survey area and the sum of the hole lengths attains 4,821 m. Of the 27 holes drilled, 12 holes were in the North Prospect and 11 in the South Prospect. It is seen that drilling was concentrated in these two prospects and only 2 holes were drilled in the 4/6 Gossan.

CHAPTER 4 REGIONAL GEOLOGICAL SETTING

4-1 Regional Geology

The geology of the survey area, Jabal Sayid deposit and Mahd adh Dhahab mine (the above area will be called "this area" in this section) will be reported below (Fig. 1-4) based on Kemp et al. (1982).

The Late Proterozoic Arj Group, Mahd Group, and Ghamr Group, in ascending order, occur in this area. These units are intruded by Dhukur Tonalite, Fufayriyah Tonalite, Bari Granodiorite, and granites of the Raghiyah Suite.

The Arj Group is the lowermost unit of this area, and the base of this Group is not known. The Arj Group in this area consists of Sayid Formation (asa in Fig. 1-4) composed of silicic volcanic rocks, Jabal Azlam Formation (ajz) composed of pyroclastic rocks and andesite, and undifferentiated rocks (asz). The main component of Sayid Formation is dark gray to green massive silicic rocks accompanied by sedimentary rocks. The lower part of the Jabal Azlam Formation consists of basaltic to andesitic breccia-tuff breccia and andesite, and the upper part of this formation is composed of breccia, sandstone, and conglomerate. This Group is unconformably overlain by the Mahd Group.

The Mahd Group in this area consists of Tulaymisah and Haf Formations. Tulaymisah Formation is divided into pyroclastic rock unit (mtv) and volcanic rock unit (mt). Haf Formation is further divided into Juraysiyah Member (mhj), Zur Member (mhz), and undifferentiated rocks (mh). The Juraysiyah Member consists of basalt, andesite, and rhyodacite, while the Zur Member is composed of rhyolite and sedimentary rocks.

Ghamr Group in this area consists of Tuff Member (ggt) and Kharzah Formation. Kharzah Formation is further divided into mafic unit (gka), silicic unit (gkr), and sedimentary unit (gks).

Dhukhr Tonalite (dt) consists of gabbro – trondhjemite・granodiorite, and mostly of quartz diorite – tonalite. The relation between Dhukhr Tonalite and Arj Group is not clear. The age of the tonalite was measured by U-Pb (zircon) method and is reported to be 816±4 Ma.

The composition of the Fufayriyah Tonalite (ht, 760±10 Ma) is that of quartz diorite – tonalite.

Bari Granodiorite (bg) intruded into the Mahd Group, and the latter is contact metamorphosed. The

Granodiorite is covered by unmetamorphosed Ghamr Group. The composition of the Bari Granodiorite is the same as that of tonalite – trondhjemite.

Raghiyah Suite is divided into Dayahin Granite (rda, 582±26 Ma), Assharah Granite, and Dumah Granodiorite. Assharah Granite is further divided into monzogranite (rag, 573±22 Ma and 575±28 Ma) and red granite – microgranite (ram). Dumah Granodiorite is divided into granodiorite (rdg), and quartz monzodiorite (rdd).

Of the above geologic units, Sayid and Jabal Azlam Formations of the Arj Group occur in the survey area.

4-2 Geological Structure

In this area, the distribution of the Arj Group is limited to near the Jabal Sayid deposit and in the survey area. The Group in the survey area has triangular distribution, and it is bounded; to the northeast by NW-SE trending Wadi al Aqiq strike-slip fault, to the south by Bari Granodiorite and Dhukhr Tonalite, and to the west by the Mahd Group.

4-3 Mineralization

The Jabal Sayid deposit occurs about 20 km northwest and the Mahd adh Dhahab mine is about 25 km southwest of the survey area.

The Jabal Sayid deposit is a stratabound massive sulfide deposit consisting of four orebodies. It is accompanied by a stockwork orebody below. The orebodies occur in the upper part of the silicic rocks of the Sayid Formation. These are overlain by chemically precipitated chert – carbonate formation. The sulfide minerals constituting the massive sulfide orebodies are mainly; pyrite, pyrrhotite, sphalerite, and chalcopyrite. The sulfides of the stockwork body are mainly pyrite and chalcopyrite with smaller amount of sphalerite. The pyroclastic rocks, the host of the stockwork body, are chloritized. The results of the feasibility study carried out by BRGM in 1985 show the combined reserves of Orebodies No.1 and No.2 to be 19.93 million tons (Cu 2.68 %).

Mahd ad Dhahab mine has been mined since ancient times (3,000 BP), and it is still being mined underground. The mineralization, which formed the deposit of this mine, was a vein-type Au-Ag-Cu-Zn hydrothermal activity. The age of this mineralization is 649 Ma. The deposit occurs in andesitic tuff,

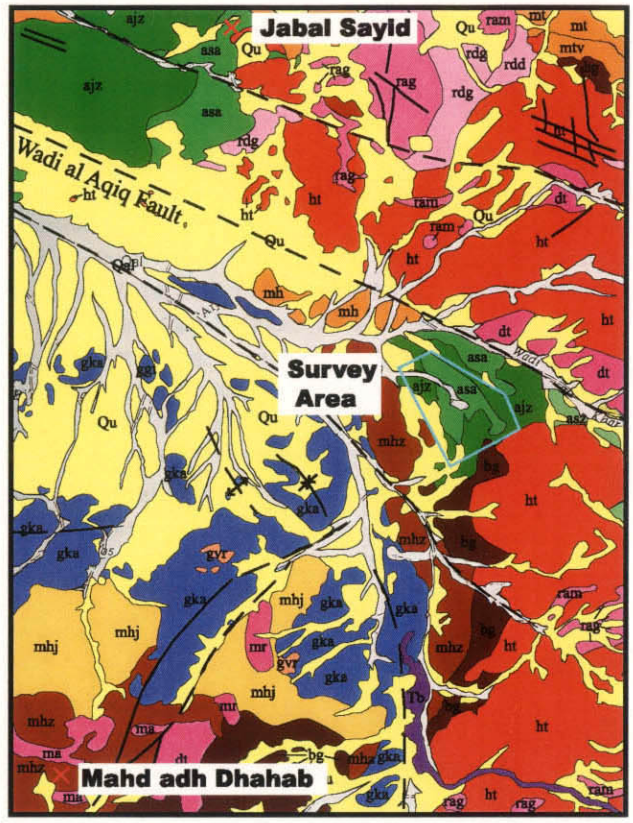
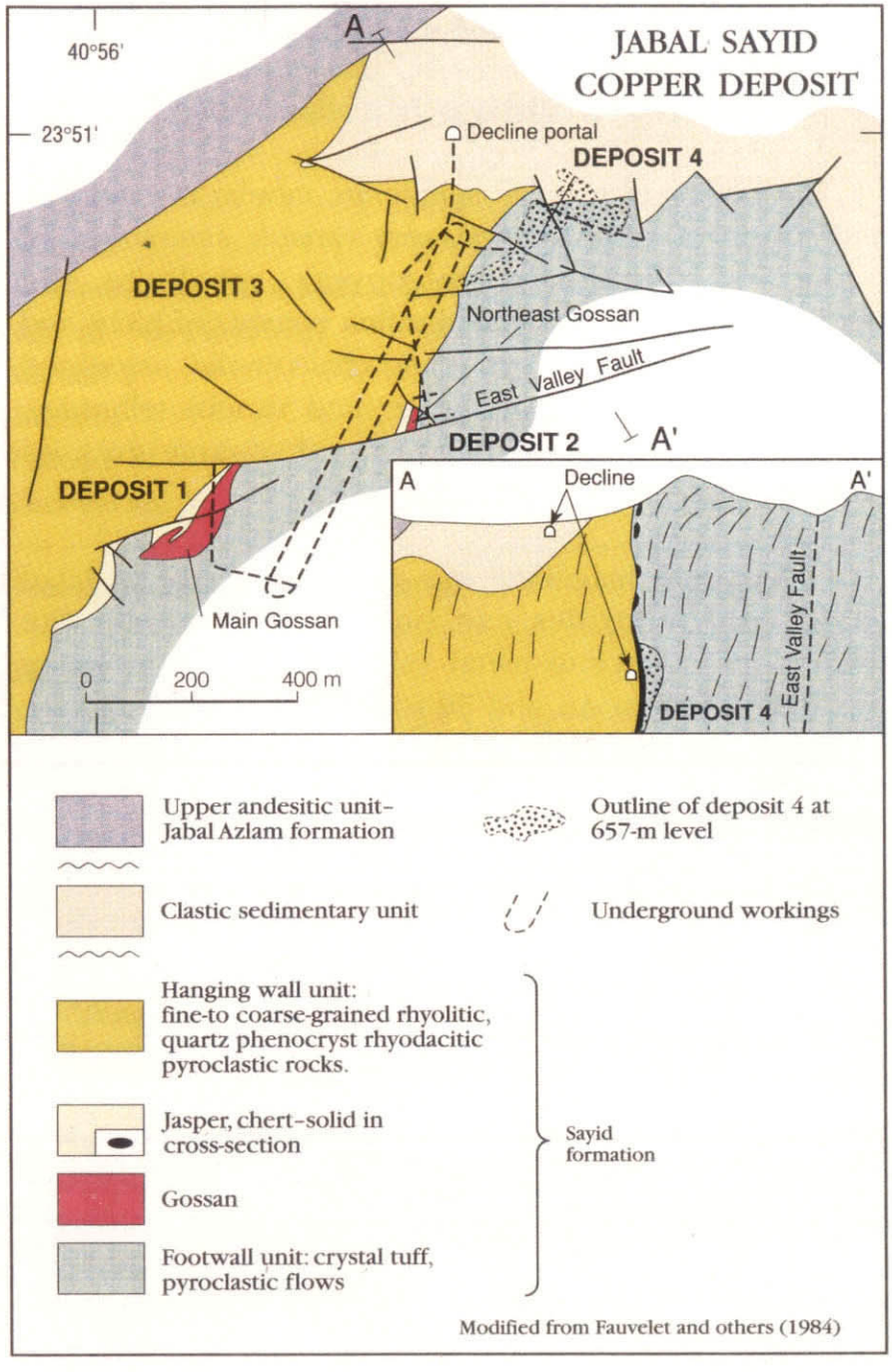
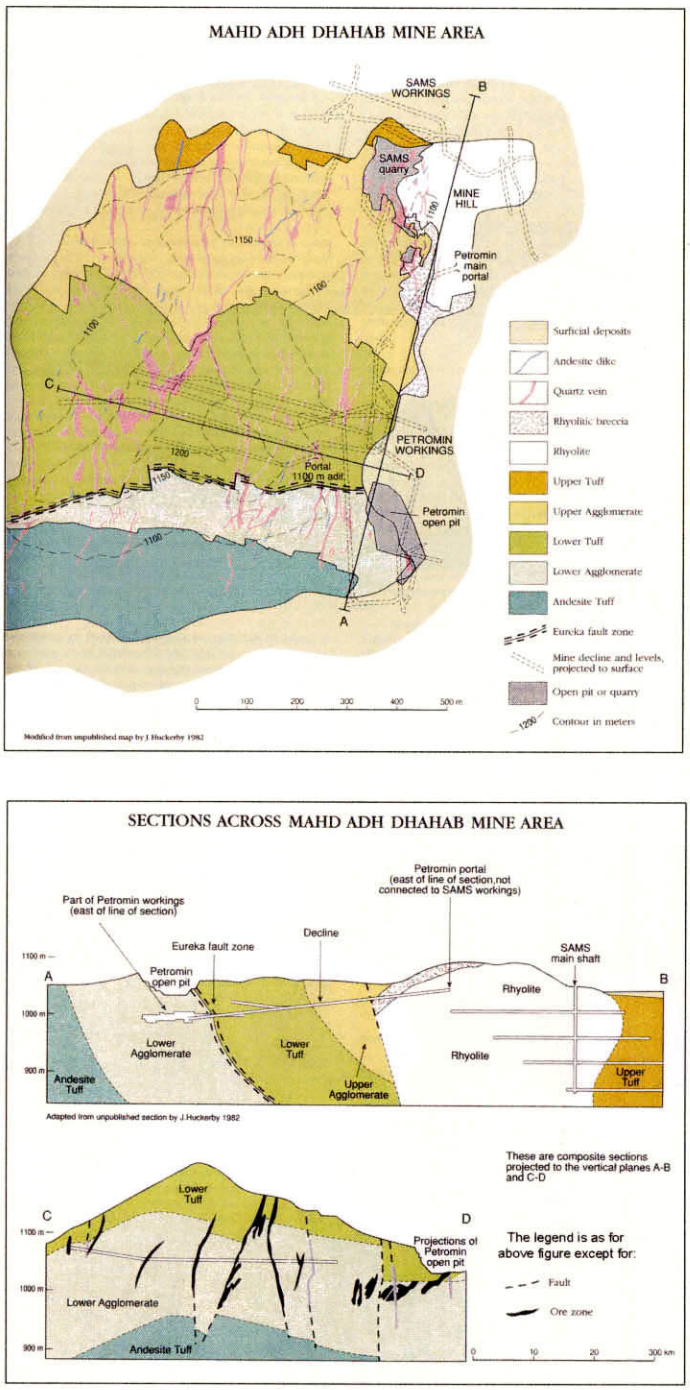


Fig.1-4 Regional Geology of the Survey Area



DGMR(1994)

Fig1-5 Geological Map of the Jabal Sayid Deposit



DGMR(1994)

Fig.1-6 Geological Map of the Mahd adh Dhahab Mine

andesite, agglomerate, and sandstone of the Haf Formation. The main ore minerals are; chalcopyrite, galena, sphalerite, and pyrite. The gangue minerals are quartz and chlorite. The host rock is silicified, chloritized, and potash-metasomatized. The ore reserves of the mine as of 1992 are 1.14 million tons (Au 31.8 g/t, Ag 167 g/t, Cu 0.87 %, Zn 3.24 %).

CHAPTER 5 GEOLOGY AND MINERALIZATION OF THE SURVEY AREA

5-1 Geology

Simplified geological map of the survey area is shown in Figure 1-7.

The geology of the survey area consists mainly of; rhyodacitic lava and pyroclastic rocks ("Ar" in Fig. 1-7), dacitic lava and pyroclastic rocks (Ad), breccia (Adb), andesitic lava and pyroclastic rocks (Aa), and jasper (Aj) belonging to the Late Proterozoic Arj Group. This group is intruded by diorite/ quartz diorite (D), tonalite (T), andesite/ porphyritic andesite (a), dacite/ porphyritic dacite (d), rhyodacite (r), and basalt/ porphyritic basalt (b) bodies.

Of the above rocks, jasper and dacitic breccia occur mostly near Jabal Sujarah in the northwestern part of the survey area. Granitic rocks occur throughout the area, but are concentrated in the area from the Unnad Damar North Prospect to Umm ad Damar South Prospect.

These units are covered unconformably by Late Proterozoic andesitic lava and pyroclastic rocks (Ha) of the Mahd Group in the western edge of the survey area. The rocks of the Arj Group are regionally chloritized and epidotized, and schistosity is partly developed.

The strike of the Arj Group is NE at the South Prospect and the eastward, but it is NW – N in other parts of the survey area. The dip of the formations of this group is steeper than 60°. The attitude of the Mahd Group is NNW and 20 – 40° W.

NE-SW system faults are predominant in the survey area. The existence of a NW-SE fault, almost parallel to Wadi al Aqiq Fault is inferred in the northeasternmost part of the survey area.

5-2 Mineralization

The existence of Cu, and Zn mineralization have been confirmed in the following four prospects of the survey area. Jabal Sujarah, the Umm ad Damar North Prospect, the Umm ad Damar South Prospect, and the 4/6 Gossan Prospect (Fig. 1-9).

Volcanogenic massive sulfide-type Cu-Zn mineralization exists in Jabal Sujarah, the 4/6 Gossan Prospect, and a part of the Umm ad Damar North Prospect. Also vein-type Cu mineralization is confirmed in the Umm ad Damar North Prospect, and vein-type Cu-Zn mineralization occurs in the Umm ad Damar South Prospect.

The ore minerals of these prospects are oxidized to depths of 30−40m and thus only gossan containing oxidized copper minerals, limonite, and hematite occur on the surface.

Mineralization of these prospects is reported below.

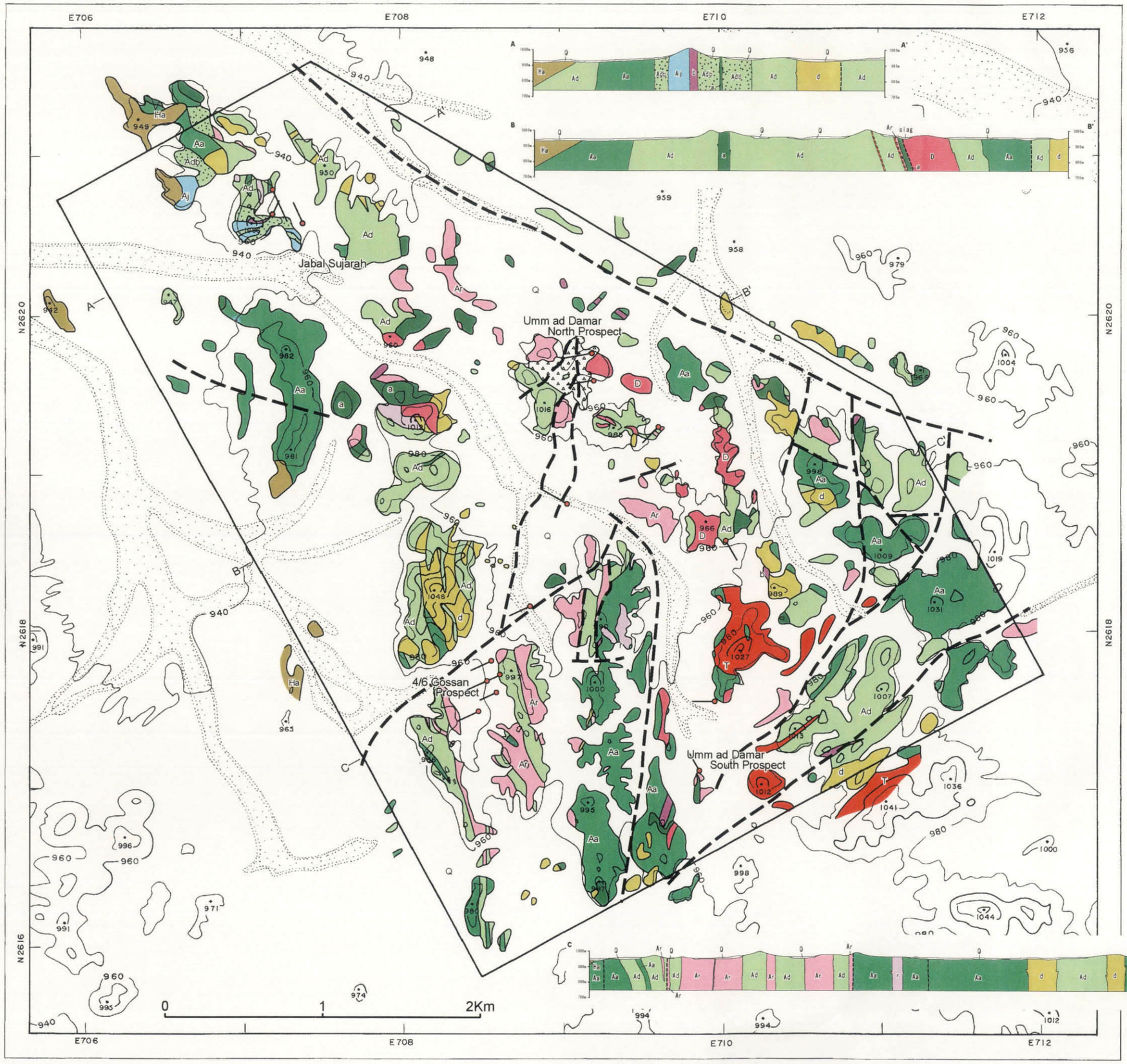
(1) Jabal Sujarah

As feature of mineralization and alteration at the surface of this district, strongly carbonatized silicic breccia only crops out at the southwestern part of Jabal Sujarah, and ancient pits or gossans are not observed.

The mineralization found in this cooperative works is volcanogenic massive sulfide-type Cu-Zn mineralization.

(2) Umm ad Damar North Prospect

A large amount of slag occurs at the Umm ad Damar North Prospect, and many ancient pits are distributed in the small hills to the west and southeast of this slag zone. The hill to the southeast was named "Southeast Hill" during the present survey and the one in the west "West Hill". Ancient workings are also distributed in the hills to the southeast of the Southeast Hill. The major geologic units near this prospect are rhyodacite and dacite of the Arj Group, and are elongated in the NW-SE direction. Diorite bodies have intruded into the Arj Group in the northeastern part of this prospect. Mineralization occurs only in the Arj Group and is not observed in the diorite bodies.



AGE		SEDIMENTARY AND VOLCANIC ROCKS	INTRUSIVE ROCKS
CENOZOIC	QUATERNARY	Q Sand, Gravel	
LATE PROTEROZOIC	MAHD GROUP (Haf Foramtion)	Ha Andesite, Andesitic pyroclastic rocks, Conglomerate	
			T Tonalite
			BARI GRANODIORITE, HUFAYRIYA TONALITE — D Quartz diorite, Diorite
			b Basalt, Porphyritic basalt
			a Andesite, Porphyritic andesite
			d Dacite, Porphyritic dacite
			r Rhyodacite
	ARJ GROUP (Jabal Azlam & Sayid Formations)	Aa Andesite,Andesitic pyroclastic rocks	
		Ad Dacite, Dacitic pyroclastic rocks (Adb:Breccia)	
		Ar Rhyodacite,Rhyodacitic pyroclastic rocks	
		Aj Jasper	

Fault

MMAJ drill hole(1999 & 2000)

Fig.1-7 Geological Map of the Survey Area

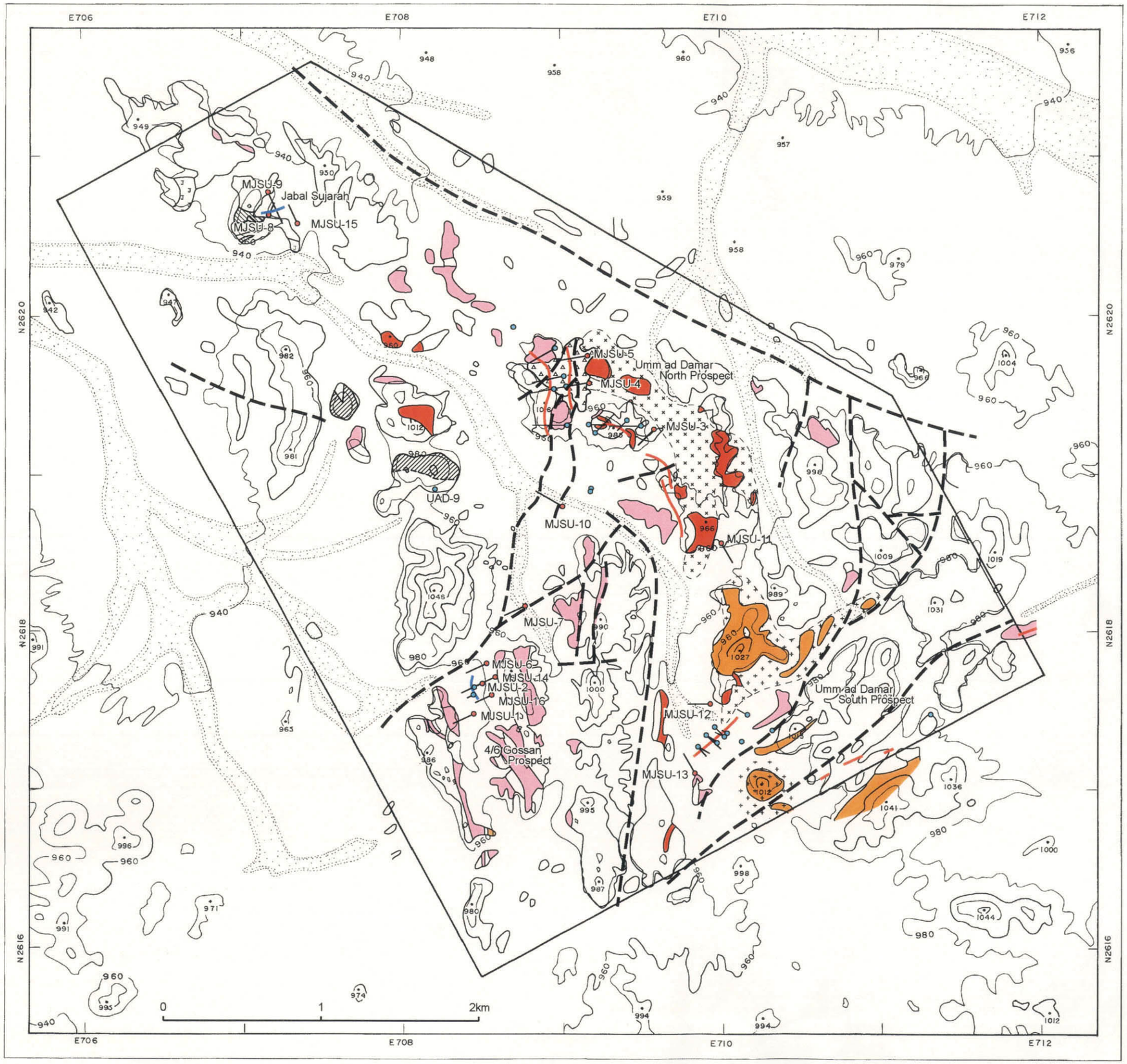


Fig.1-8 Mineralization Map of the Survey Area

IP anomaly (chargeability > 15mV/V)
IP anomaly (chargeability > 24mV/V)
Conductive plate estimated from TEM survey
Quaternary gravel & sand
Arj Group rhyodacite ,rhyodacitic pyroclastic rocks
Major plutonic bodies
Other rocks
Slag

Fault
Carbonatization
Silicification
Vein-type mineralization
Massive sulfide-type mineralization
Previous drill hole
MMAJ drill hole (1999 & 2000)
IP survey line (1998)
IP survey line (1999)
TM-27 TEM survey (1999)

Fig.1-9 Integrated Interpretation Map

A total of five main mineralized zones are inferred to exist from the following observations; namely, the distribution of the ancient pits and gossan in trenches, and the results of drilling carried out in the past.

(3) 4/6 Gossan and the vicinity

The geology of this prospect is composed mainly of rhyodacitic pyroclastic rocks with intercalation of basaltic tuff.

Two holes have been drilled here in 1983, and the mineralized zone encountered in UAD-14 is 2.1 m wide and contains Au 16.1 g/t, Ag 449.8 g/t, Cu 1.15 %, Pb 1.02 %. However this zone is secondary enrichment and the description of mineral assemblage and occurrence is not available. The grab samples collected in the trenches during the first-phase survey contain Au 3.7 g/t and Au 1.6 g/t.

It was clarified by this cooperative drilling works that the mineralization of this prospect was divided into volcanogenic massive sulfide Cu-Zn mineralization and vein-type Cu-Ag mineralization, and the latter type is of small.

(4) Umm ad Damar South Prospect

The major geologic units near this prospect are rhyodacite, andesite, andesitic tuff, and dacitic tuff.

Seventeen ancient pits are confirmed in this prospect. The number of the main mineralized zone of this prospect is inferred to be one, from the distribution of ancient pits containing oxidized-copper minerals and gossan in trenches. Eleven holes including UAD-4 have been drilled for this mineralized zone, and ore zone encountered in UAD-2 is 6.9 m wide and Cu 1.99 %. However Au grades of mineralized parts of cores are not known. Two grab samples collected at the surface during the first-phase survey contain Au 6.2 g/t and Au 3.0 g/t. Thus this Cu mineralization is believed to be accompanied by Au contrary to that of the North Prospect.

CHAPTER 6 CONCLUSIONS

6-1 Results of the Survey

Mineral exploration was carried out in the Umm ad Damar area during the past three years from 1998. The work carried out included analysis and interpretation of existing data, geological survey, geophysical surveys (IP and TEM methods), and drilling (16 drill holes, total length of 4,492m). The results of the above surveys are summarized as follows.

1. The geology of the survey area consists mainly of rhyodacite, dacite, and andesite and their pyroclastic rocks belonging to the Late Proterozoic Arj Group, and these units are accompanied by jasper. These units are intruded by diorite, quartz diorite, tonalite, andesite, dacite, rhyodacite, and basalt. Andesite and andesitic pyroclastic rocks of Late Proterozoic Mahd Group overlies the above units unconformably in the western margin of the survey area. Of the above units, jasper and dacitic breccia occur near Jabal Sujarah in the northwestern part of the survey area. Granitic rocks occur throughout the survey area, but they are concentrated in the zone from the Umm ad Damar North Prospect to the Umm ad Damar South Prospect.

2. Mineralization containing Cu and Zn occur in four localities of this area. They are Jabal Sujarah district, Umm ad Damar North Prospect, Umm ad Damar South Prospect, and 4/6 Gossan Prospect. The mineralization in the Jabal Sujarah district, 4/6 Gossan Prospect, and a part of Umm ad Damar North Prospect is volcanogenic massive sulfide Cu-Zn mineralization. Also Cu vein mineralization occurs in Umm ad Damar North Prospect and Cu-Zn vein mineralization in Umm ad Damar South Prospect.

3. Chargeability anomalies have been extracted by IP survey in areas other than the above prospects. But only pyrite dissemination and veinlets occur in the high chargeability anomalies, and the Au, Cu, and Zn contents are low.

4. The mineralization in the Jabal Sujarah district is the volcanogenic massive sulfide Cu-Zn type and it occurs in dacitic breccia of the Arj Group. The orebodies consist of massive and pebbly ores and are accompanied by pyrite dissemination. The highest chargeability anomaly (over 30mV/V, 800m elevation) of the entire survey area occurs in this district, and it occurs over an areal extent of 200×200m. These chargeability anomalies are caused by thick pyrite dissemination in the footwall of the massive and pebbly ores. This pyrite disseminated zone consists solely of pyrite and the Au, Cu, and Zn contents are negligible.

There are several layers of massive and pebbly ores and the total thickness of the mineralized zones including the intercalated pyrite dissemination is around 6m. The extent of the mineralized zones containing massive and pebbly ores is around 200m in the strike direction and longer than 250m in the dip direction. Although there are parts rich in Cu and Zn, most of the massive and pebbly ores consist mostly of pyrite and is of low grade.

5. In the Umm ad Damar North Prospect, five rows of Cu vein zones are inferred to occur. They are named No. 1 ~ No. 5 Mineralized Zones. Drilling was carried out for three of these zones. The veins and network ores confirmed by these drill holes consist of chalcopyrite-pyrite hosted by dacite and dacitic pyroclastic rocks of the Arj Group. There are few gangue minerals. Au and Ag grades are low and the margins of the ore veins are strongly chloritized.

Five holes were drilled during the past for No.1 Mineralized Zone, and it is 4.8m thick in average and the grade is Cu 1.40%. For No.2 Mineralized Zone, two holes were drilled and the occurrence of two to three mineralized layers of veinlets and dissemination have been confirmed. These are 3.5m thick in average and the grade is Cu 2.38%. For No.3 Mineralized Zone, four holes were drilled and in UAD-11 hole the ore layer is 3.1m thick and Cu 1.87%. The length of the Nos. 1 and 2 Mineralized Zones is estimated to be 400-500m in the strike direction, and that of No.3 Mineralized Zone about 300m. The grades of metals other than Cu, namely Au and Zn, are both low.

Nos. 4 and 5 Mineralized Zones have not been drilled, but the length in the strike direction is estimated from the surface manifestations to be about 200m and 400m respectively.

Aside from these Cu vein-type mineralization, a volcanogenic massive sulfide-type mineralized zone was confirmed by MJSU-5, but similar mineralized zones have not been found in drill holes in the vicinity and thus this is considered to be of small scale.

6. One row of vein-type Cu-Zn mineralized zone occurs in the Arj Group of Umm ad Damar South Prospect. Eleven hole were drilled for this zone in the past and four of them confirmed the existence of the mineralized zone. Vein-type mineralized zone was not encountered by the drilling carried out to the southwest of the mineralized zone during the present survey. Thus the scale of this mineralized zone is estimated to be 2.1-6.9m thick, 300m in the strike direction, at most 130m in the dip direction. The Cu grade of this zone is 1.99-2.93%. In some drill holes, Au grade of 0.3-1.1g/t and Zn grade of 0.2-3.1% have been obtained.

7. The mineralization observed in 4/6 Gossan Prospect is volcanogenic massive sulfide-type Cu-Zn mineralization in rhyodacitic tuff of the Arj Group. This mineralized body consists of massive, siliceous, and pebbly ores and the ore minerals are chalcopyrite, sphalerite, and pyrite.

Three ore layers occur in this mineralized zone. They occur both above and below (apparent) a basaltic tuff horizon intercalated in the rhyodacitic tuff. The mineralized body below the basaltic tuff is largely divided into two parts. The mineralized body immediately below the basaltic tuff is the thickest in MJSU-2 where the thickness is estimated to be about 3.7m. The grade of this part is Au 0.4g/t, Cu 0.96%, and Zn 2.17%.

The mineralized body in further deeper horizon is also thickest in MJSU-2 and is estimated to be about 9.3m. The grade here is Au 0.4g/t, Cu 1.00%, and Zn 3.67%.

Mineralized body also occurs above the basaltic tuff horizon. This is observed only in the MJSU-6 hole. The average grade is Au less than 0.1g/t, Cu 0.69%, and Zn 3.99% and the thickness is estimated to be around 2.5m.

The size of the two mineralized bodies below the basaltic tuff is estimated to be about 100m in the strike direction and the lengths of the dip direction more than 60m and 120m respectively. The body above the basaltic tuff was confirmed only in one drill hole and the length in both the strike and dip directions is estimated to be around 100m.

6-2 Evaluation of the Survey Area

Three prospects (Umm ad Damar North Prospect, Umm ad Damar South Prospect, and 4/6 Gossan Prospect) have been known in this survey area for many years, and various exploratory work have been carried out in limited parts of these prospects sporadically since 1966. But final assessment had not been made. Because of this situation, comprehensive assessment of the mineral potential of the total area was carried out during this cooperative exploratory project integrating the results of geological survey, geophysical surveys, and drilling. These work was based on the results of the past surveys and emphasis was laid on confirming the extent of the known ore bodies and on finding new ore deposits.

By drilling the geophysical anomalies extracted by IP geophysical prospecting, new Cu-Zn mineralized zones partly accompanied by Au were discovered in three prospects including the hitherto unknown Jabal

Sujarah district. It became clear, however, that the mineralized zones observed in this survey area do have high-grade parts, but they either converge or disperse in their lateral and downward extension and thus are of small scale. Therefore it is deemed difficult to develop these mineralized zones under the present economic conditions. Also the results of the geophysical surveys indicate that the possibility of locating mineralized zones larger than the known orebodies with further detailed surveys is small.