REPORT
ON
THE MINERAL EXPLORATION
IN
THE HAOUZ CENTRAL AREA
KINGDOM OF MOROCCO

PHASE I

MARCH 1988

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Kingdom of Morocco, the Government of Japan decided to conduct a Mineral Exploration Project in the Haouz Central Area and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to the Kingdom of Morocco a survey team headed by Mr. Jinichi Nakamura from September 23 to December 13, 1987.

The team exchanged views with the officials concerned of the Government of the Kingdom of Morocco and conducted a field survey in the Haouz Central 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 Kingdom of Morocco for their close cooperation extended to the team.

February, 1988

Kensuke Yanagiya
President
Japan International Cooperation Agency

Junichiro Sato
President
Metal Mining Agency of Japan

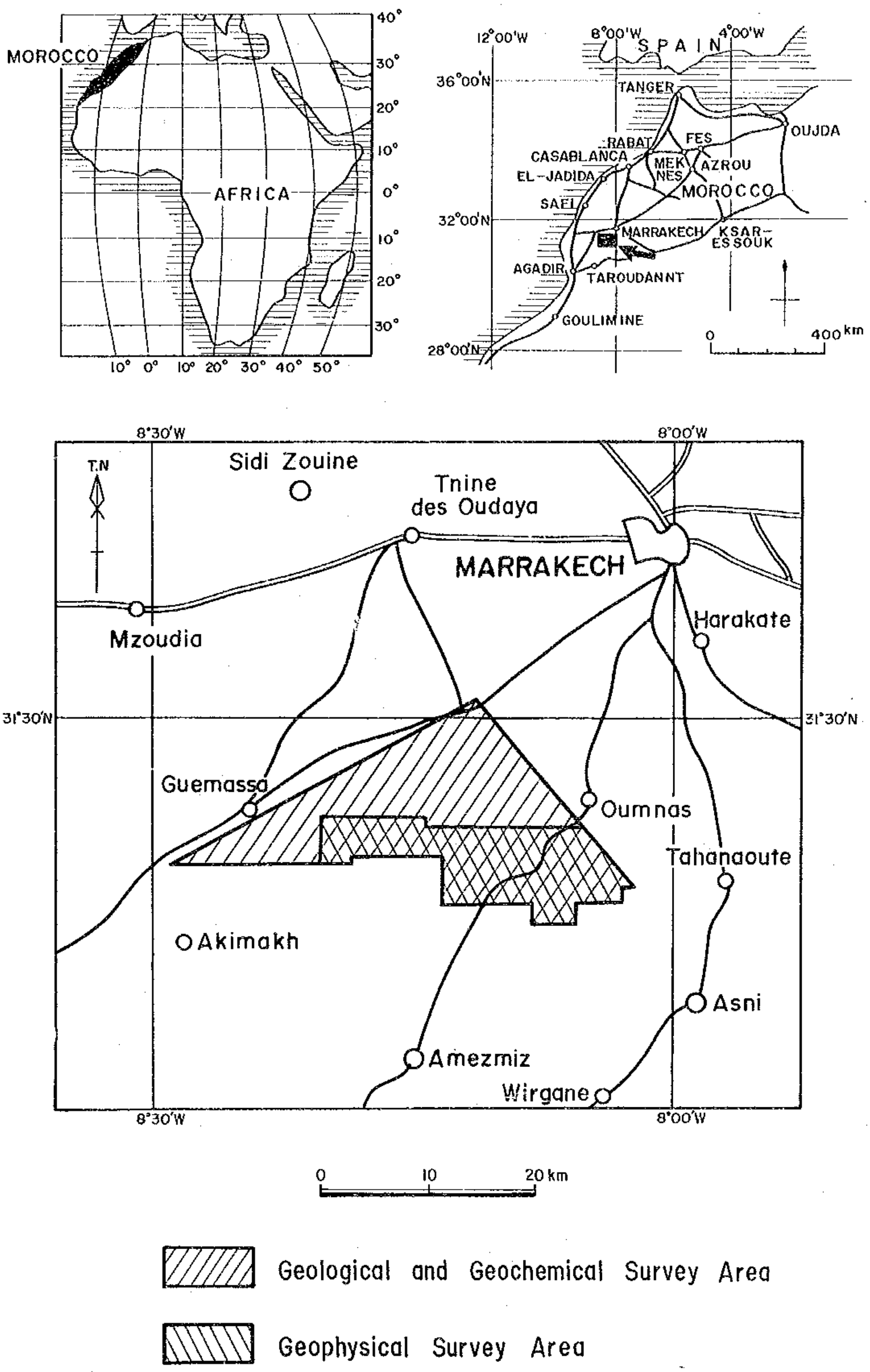

Fig. 1 Location Map of the Survey Area

SUMMARY

This report contains the First Phase survey results of the Cooperative Mineral Exploration in the Haouz Central Area in the Kingdom of Morocco. The purpose of this survey is to obtain comprehensive information on the condition of emplacement of mineral ore deposits by the elucidation of geological phenomena in the Haouz Central Area.

The surveys carried out in this year are geological survey in 350 km^2, geochemical exploration with 215 samples and geophysical prospecting by CSAMT method in 150 km^2 with 302 survey points.

The results of the surveys are summarized as follows.

(1) Geological Survey and Geochemical Survey

The basement rocks in this surveyed area are composed of Carboniferous to Permian systems of the Paleozoic Era, and pelitic and marly schist and semischist are principally distributed. But the exposures of these basement rocks are sporadic due to extensive covering of the Quaternary sediments. The pelitic and marly schists are the rocks intensely metamorphosed. Numerous drag folds, intrafolial folds and schistosity faults are developed and the mineral composition as well as the bedding structures of the original rocks have been remarkably altered and deformed.

As to the mineralization in the surveyed area, are noteworthy the Hajar copper-lead-zinc-pyrrhotite ore deposit in the eastern part of the area, the mineralization zones in Oukhribane block and in Amzourh block, and the Frizem mineralization zone in the western part. It is thought that these indications of mineralization are of the type of sedimentary ore deposit related to submarine acidic volcanic activity. The host rock of the Hajar ore deposit is the green rock originated from acidic volcanic rocks and pyroclastic rocks, and the Frizem mineralization is constituted by vein-dissemination ore deposits around acidic volcanic rocks. The indications of mineralization in the Oukhribane block and in the Amzourh block are recognized to be emplaced in the successions belonging to the horizon of the Hajar ore deposit.

Through the lithological differentiation of rocks apparently poor in variation and through the elucidation of the complicated geological structures by the surveys in this year, it has become possible to correlate stratigraphically the basement rocks in different blocks which are sporad-

ically distributed. It is evident that the most important horizon related to the mineralization is the Hajar horizon, followed by the Frizem horizon, but these two horizons are thought to be different to some extent in view of the age and the characteristics of mineralization.

The Hajar horizon is mostly covered with the Quaternary sediments. It is estimated that this horizon extends in ESE direction to the Souktana Block in the east, while it extends toward the Rial area by changing the direction to the north after it extends to the Oukhribane block and the Amzourh block in the west. The acidic volcanic rocks of the Frizem horizon shows a tendency to increase their volume to the southeast, where it is covered with the Quaternary sediments.

(2) Geophysical Prospecting (CSAMT method)

Based on the survey results of the geophysical prospecting by CSAMT method, resistivity circumstance in relation to the mineralization and alteration has been elucidated. Through the correlation of the results with the existing data and information from the past geophysical prospecting results, the following areas are extracted warranting further exploration.

1) As to the resistivity structure, the mineralization and alteration zone in and around the Hajar ore deposit has been caught as a low resistivity anomaly in the resistivity basement. An area west of Taguennza, an area near Lamrah, an area east of Barrage Cavagnac, an area southeast of Oukhribane and an area south of Oukhribane are listed as the areas where the same pattern of the resistivity structure is recognized in the successions of the Hajar horizon. All of them show strong correlation to the magnetic anomalies and are found in the successions belonging to the Hajar horizon distributed in NNW-SSE direction from the west of Taguenzza to Oukhribane through Lamrah.
2) The same pattern of resistivity structure is recognized in an area west of Frizem, which is corresponding to the remarkable magnetic anomaly.
3) Viewing from the fact that the extension of the low resistivity anomaly can be recognized in the area southeast of the Hajar ore deposit, where high gravity anomaly has been also detected, this area in the southeast of the Hajar ore deposit, is thought to warrant

further investigation.

By the above-mentioned survey results, the areas bearing the highest potentiality of mineralization have been extracted. They are the area around the Hajar ore deposit and the area where the successions of the Hajar horizon are distributed in NNW-SSE direction including the Oukhribane block and the Amzourh block. The Frizem horizon is also significant.

For future exploration, it is necessary to carry out investigation by the pursuit of the successions of the Hajar horizon and the Frizem horizon, where mineral ore deposits are expected to be seated. It is desirable to employ such method of investigation by which the characteristics of the mineralization and the environment of emplacement of ore deposits can be grasped comprehensively through the integration of the existing data and informations obtained from the past exploration surveys.

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GENERAL REMARKS

CHAPTER 1 INTRODUCTION

1-1 Circumstances and Purpose of the Survey

The Kingdom of Morocco is rich in mineral resources and enforces a policy to develop mineral resources.

In the Kingdom of Morocco, three areas, Anti Atlas area (1974-1976), Haute Moulouya area (1978-1980), and Haut Atlas Occidental area (1983-1985) had been taken up for the Cooperative Mineral Exploration Projects.

The Cooperative Mineral Exploration in the Haouz Central Area has been selected and agreed between the Bureau de Recherches et de Participations Minières (BRPM), the official organization of the Kingdom of Morocco, and the Project Finding Mission on November, 1986 and the Preliminary Survey Team on June, 1987, dispatched by the Government of Japan in response to the request of the Government of Morocco.

The purpose of the Mineral Exprolation Survey carried out in the Haouz Central Area, is to elucidate the detailed geological sturcture and mineralization.

1-2 Outline of the Survey

The Haouz Central Area is a triangular shaped area holding 350 km^2. And it is located in the west central part of the Kingdom of Morocco about 330 km south-southwest of Rabat.

Geological survey, geochemical survey and geophysical prospecting by means of CSAMT Method were applied as for the First Phase survey.

Priority theme in the geological and geochemial survey is to elucidate the relationship between geological structure and mineralization, and to select the specific mineralized beds and zones.

Priority theme in the geophysical prospecting is to pick up the electric conductivity anormalous zones and to make clear the horizontal and vertical extentions.

The applied methods and specifications are as follows.

(1) Geological and Geochemical Survey

1) Field survey

Surveyed area:	350 km^2
Surveyed rout:	350 km
Geochemical sampling:	215 pcs

Mapping scale:	1/10,000
Compiled scale:	1/25,000 and 1/50,000

2) Laboratory test

Geochemical analysis (Ag·Cu·Pb·Zn):	215 pcs
Thin section:	20 pcs
Polished section:	10 pcs
X-ray diffraction:	20 pcs
Rock analysis (12 elements)	20 pcs
Ore analysis (Ag·Cu·Pb·Zn)	10 pcs

(2) Geophysical Prospecting (CSAMT method)

1) Field survey

Surveyed area:	150 km^2
Measured point:	302 pts

2) Laboratory test

Electric resistivity measurement:	24 pcs

1-3 Organization of the Survey Team

(1) Survey Planning and Negotiation

The Preliminary Survey Team was dispatched to the Kingdom of Morocco from June 3, 1987 to June 13, 1987, in order to negotiate and agree the Phase I survey plan for the cooperative mineral exploration in the Haouz Central Area.

The member of the team is as follows:

	Japan Side	Morocco Side
Leader	Minoru FUJITA (MMAJ)*	Assou LHATOUTE (BRPM)*
Staff	Nobuyoshi TAKABE (MFA)*	Ahmed LOUALI (BRPM)
Staff	Hideo TAKANO (MITI)*	Hassan SEQQAT (BRPM)
Staff	Ichiro KIKUSHIMA (MMAJ)	Allal TIJANI (BRPM)
Staff	Takashi KAMIKI (JICA)*	

* JICA: Japan International Cooperation Agency
MMAJ: Metal Mining Agency of Japan
MFA : Ministry of Foreign Affairs
MITI: Ministry of International Trade and Industry
BRPM: Bureau de Recherches et de Participation Miniéres

(2) Phase I Survey

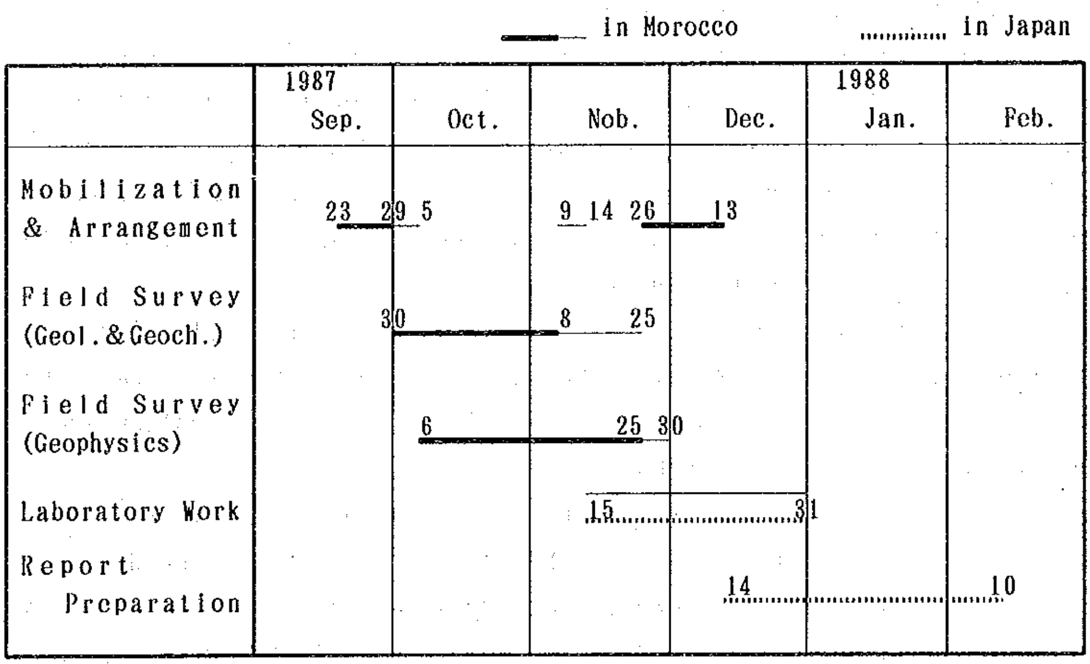
The schedule of the Phase I field survey was from September 23, 1987 to December 13, 1987. The member of the Field Survey Team and the detailed survey schedule are as follows:

Field Survey Team

	Japan Side		Morocco Side	
Coodination	Yosuke SUZUKI	(MMAJ)	Assou LHATOUTE	(BRPM)
Coodination	Fumiko TSUCHIDA	(MMAJ)	Ahmed LOUALI	(BRPM)
Coodination	Ichiro KIKUSHIMA	(MMAJ)	Hassan SEQQAT	(BRPM)
Coodination	Natsumi KAMIYA	(MMAJ)	Allal TIJANI	(BRPM)
Leader	Jinichi NAKAMURA	(MINDECO)*	Abdelaziz MELLAL Mohamed BERRADA	(BRPM) (BRPM)
Geol. Geoch.	Eitaro SATO	(MINDECO)	Abderrahim QALBI	(BRPM)
Geol. Geoch.	Ryohei OTSUBO	(MINDECO)		
Geophysic	Kazuhiko KINOSHITA	(MINDECO)	Said QASRI	(BRPM)
Geophysic	Kazushige WADA	(MINDECO)		
Geophysic	Tadashi OHASHI	(MINDECO)		

* MINDECO: Mitsui Mineral Development Engineering Co., Ltd.

Survey Schedule



CHAPTER 2 OUTLINE OF THE SURVEY AREA

2-1 Location and Transportation (Fig.1)

The Haouz Central area is located at the north latitude between 31°20' and 31°30' and at the west longitude between 8°8' and 8°23' in the central western part of the Kingdom of Morocco. The Haouz Central area lies about 30 to 40 km southwest of the Marrakech city, and in term of the administrative division, it belongs to Marrakech province of the State of Marrakech.

Railway and paved roads are available for the access to the area, and it takes about 4 to 5 hours from Rabat, the capital, to the township of Marrakech. The distance is about 330 km. The access to the surveyed area from the township of Marrakech is convenient because the roads are available to Barrage Cavagnac at the southeast corner of the surveyed area (about 35 km from Marrakech) as well as to Ait Daoud at the northernmost part of the area (about 25 km from Marrakech).

2-2 Geography

The surveyed area is located geographically on a hilly land at the elevation of 500 to 800 meters above sea level along the northern side of the Haut Atlas Range. In the area, the Paleozioc basement and the Cenozoic sediments are distributed. The land in the area is comparatively undulating and small streams, where water-flow can be recognized only in the rainy seasons, are well developed irregularly.

The climate in this area is continental, having big difference of temperature. It registers more than 40°C in summer time and less than 0°C in winter season. Annual rainfall is about 300 mm but the rain is used to be concentrated in the periods of October to November and April to May. Except the rainy seasons, it is dry and is like a desert, with the vegetation seen only along the streams.

The inhabitants are Berber. They have gathered in small villages along the main rivers. They can have water supply from the wells. They live on the pasturing of sheep and on the farming of olive cultivation and on the corn crops in rainy seasons.

The Marrakech city has as long history as almost 1,000 years, as a center of the commodity exchange with the people in the Sahara desert area in the southwest. Nowadays, the city is active as a place for sightseeing in addition to the function the town has as a commercial center for agricultural products and industrial art objects. The population is 330 thousand, being ranked as third in the Kingdom of Morocco.

2-3 The Past Exploration

In the Hajar area at the easternmost corner of this surveyed area, existence of an ore mineral deposit composed of silver-copper-lead-zinc sulphide ores has been confirmed in the Paleozoic beds which are overlain by the Quaternary sediments distributed on the surface.

Concerning the full-scale exploration works in the surveyed area, Geoterrex Ltd., Canada carried out, in 1968, the aeromagnetic and the electromagnetic surveys under the contract with the Ministry of Energy and Mining. Through these surveys, many magnetic anomalies were confirmed. In 1984, the data collected in these surveys were analysed again and re-consideration was given to the results by the cooperation of B.R.G.M. (Bureau de Recherches Geologiques et Minieres), French governmental organization. Diamond drilling was carried out for the remarkable magnetic anomalies by BRPM in 1985, and the Hajar ore deposit was ascertained to lie underground at the depth of 200 to 400 meters by this drilling.

For this Hajar ore deposit, diamond drilling of total 27 holes was carried out, and a shaft and adits are being opened toward the ore body at present.

The ore reserve of this Hajar ore deposit is estimated to be about 16 million tons with the grade of Ag 74 g/t, Cu 0.86 %, Pb 2.78 %, and Zn 9.45 %, respectively.

In 1985, Hunting Geology and Geophysics Ltd., England carried out aero-magnetic survey, electromagnetic survey and radiometric exploration in the surrounding area, by the investment of the Arab Mining Co.

In the other areas than the Hajar area, surface geophysical surveys and diamond drilling were carried out in 1985 and 1986, in the areas where the principal magnetic anomalies were recognized, in areas such as Frizem, Amzourh, Tiferouine, and Mjed, etc. However, nor significant ore deposit has been found.

The details of the past exploration is shown in Tab.1.

2-4 Regional Geology in Morocco (Fig.2)

Most part of the African continent has been kept stable since the begining of the Paleozoic Era, when it was cratonized. But the northern marginal area of the West African craton including Moroccan territory was left as a mobile zone, where geosynclinal activities and orogenic movements were active after the Paleozoic Era.

The territory of the Kingdom of Morocco is divided into southern and northern parts by the Atlas Range which is composed of mountaneous land at the elevation of 3,000 to 4,000 meters above sea level extending about 2,000 km in east to northeast direction. The rocks of the Atlas Range are composed of Mesozoic geosynclinal sediments accumulated on the Paleozoic basement, and the range was formed by the uplift during the period of Alpine orogenic movement in Tertiary. The Moroccan territory is divided into three parts in term of geosynclinal structure, Atlas zone in the central part, Anti-Atlas zone in the south and Rif zone in the north. The Atlas zone is again sub-divided into three zones, the Haut Atlas zone extending in west to northwest direction, the Moyen Atlas zone branched from the Haut Atlas zone in north-western direction and the Meseta zone expanding in the east and in the west of the Moyen Atlas zone. The central part of the Atlas zone is composed of the Jurassic sediments accumulated with the marine transgression of the Tethys Sea, while the Meseta zone is composed of the Paleozoic sediments. The surveyed area is located at about the junction of the Meseta zone with the Haut Atlas zone. The folding structure of this Atlas zone is characterized by the repetition of acute-angled anticlines and shallow synclines.

The Anti Atlas zone is composed of the sediments accumulated in the Paleozoic geosyncline, which developed along the marginal area of the Pre-Cambrian craton. This geosyncline was uplifted during the period of Hercynian orogenic movement at the end of Paleozoic Era or at the begining of Mesozoic Era. In the central part of this uplifted zone, lower Paleozoic metamorphic rocks are distributed with the core of the Pre-Cambrian system.

The Rif zone is composed of the sediments accumulated in the Mesozoic to Tertiary geosyncline with the Paleozoic basement. Many nappe structures from north to south were formed during the period of the Alpine orogenic movement.

2-5 Mining Industry of Morocco

Main industries in the Kingdom of Morocco are the mining mainly of phosphates and the agriculture in which about 50 % of the labor force are engaged. The total ore reserve of the phosphate in this country is said to be 63 billion tons, the largest reserves in the world. The phosphates production is almost 20 million tons per annum and the export amount of the phosphates and phosphate fertilizer is more than 40 % of the total amount of export from the Kingdom of Morocco.

As to the balance of trade, the import has been excessive owing to the rise of oil payment and to the descent of phosphates price, since the oil crisis in 1973. Export covering ratio (export/import in amount) has remained as low as 50 % and the balance of international payments in this Kingdom is habitually in deficit which has been compensated by the transfer account and the capital account.

The financial position of the Kingdom has been placed in the red figure owing to the increase of food import due to draught as well as to the war-time expenditure for the Sahara melee which has been protracted since 1975. The accumulation of international debt reached some 13 billion dollars, which is almost the same amount as the Gross Domestic Production of the Kingdom, and the country has faced financial embarrasment.

Concerning the foreign relation, they have most intimate relation to the European countries, no need to say about the relation to France who used to have suzerainty over the Kingdom.

The trade relation between the Kingdom and Japan show the excess of export from the Kingdom of Morocco. Total amount of import and export is 200 to 300 million dollars annually, among which the amount to and from Japan occupies 2 or 3 %. About 70 % of the commodities exported to Japan are composed of fishery products as octopus and squirrel while the export of phosphates occupies a little less than 30 %. Most of the imported commodities from Japan are machinery.

In the Kingdom of Morocco, they produce and export such minerals containing lead, copper, zinc, silver, manganese, iron and barite, etc. in addition to the phosphates. It is known that there are some ore deposits in this country containing any of the ore minerals of cobalt, nickel, chrome, uranium and fluorite. The promotion of mining industry is one of the most important policys together with the development of agriculture.

Tab. 1 List of the Past Exploration in the Haouz Central Area

Area	Date	Survey Method	Concerned Party	Result
Overall Area	1968	Aero-magnetic·electromagnetic sv.	Geoterrex-MEM	Bipole magnetic anomalies were found
	1984	Reinterpretation of aero survey	BRGM-BRPM	
	1985	Geological survey (1/50,000)	BRGM-BRPM	
Surrounding Area	1985	Aero-magnetic·VLF·radiometric sv.	Hunting-AML·BRPM	
Hajar	1985	Terrestrial magnetic·gravimetric·elec. sv.	BRPM	
	1985	Drilling (27 holes)	BRPM	High-grade sulfid orebody was confirmed
	~1987	Shaft (235 m)·Adit	BRPM	
Frizem	1978	Drilling (1 hole)	BRPM	
	1986	Geol. sv., magnetic·SP VLF·grav. sv.	BRPM	
		Drilling (9 holes)	BRPM	Low-grade ore
Amzourh	1985	Geol. sv., magnetic · SP survey	BRPM	
		Drilling (2 holes)	BRPM	Pyrrhotite diss.
Tiferouine	1986	Magnetic·gravimetric survey	BRPM	
		Drilling (3 holes)	BRPM	Pyrrhotite diss.
Mjed	1986	Magnetic·gravimetric survey	BRPM	
		Drilling (1 hole)	BRPM	Pyrrhotite diss.
El Haloudi	1986	Magnetic·gravimetric survey	BRPM	

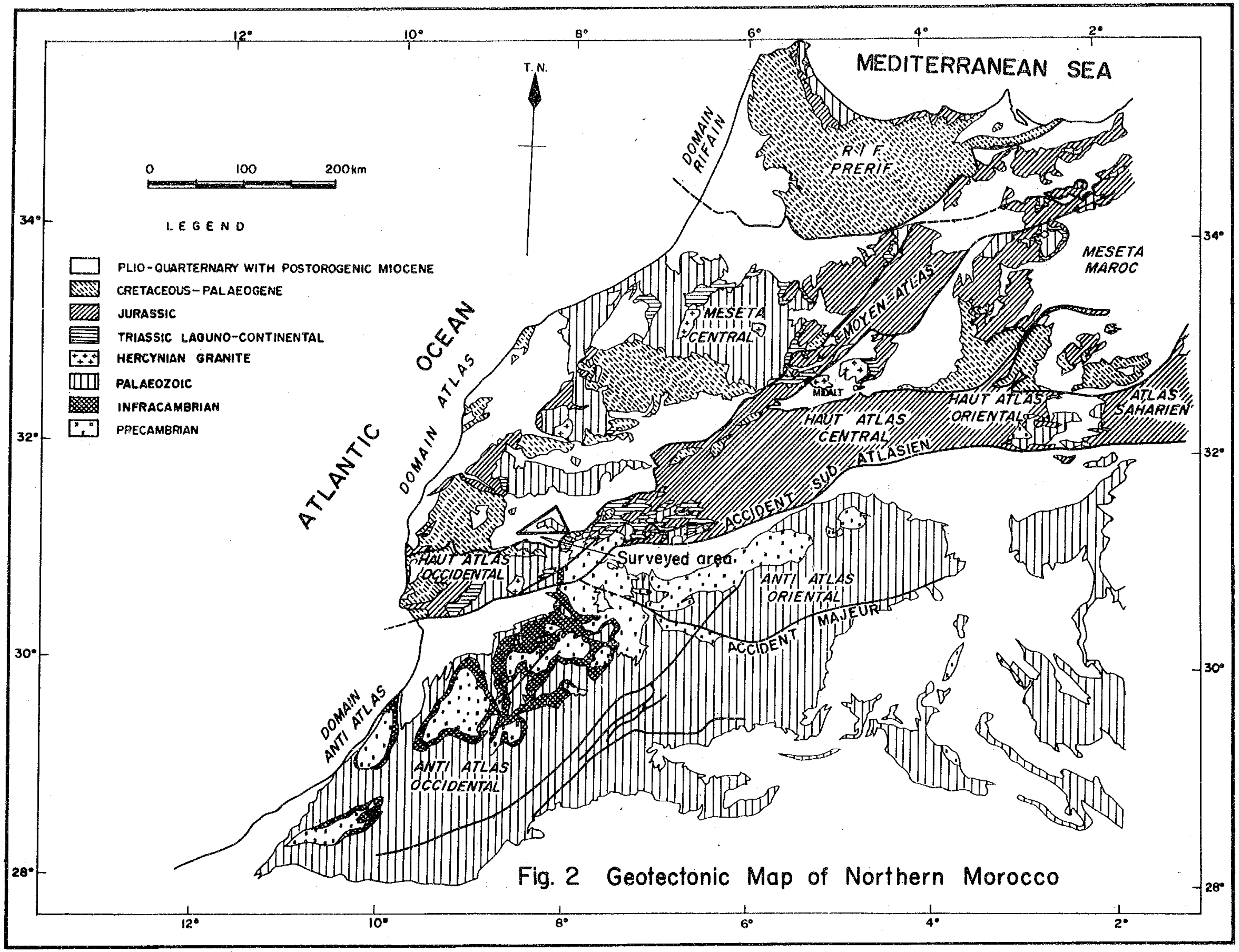


Fig. 2 Geotectonic Map of Northern Morocco

CHAPTER 3 OUTLINE OF THE SURVEY RESULTS

3-1 Geological and Geochemical Survey Results

(1) Stratigraphy

The basement rocks of the surveyed area are composed of pelitic and calcareous schist or semischist with occasional occurrences of acidic volcanic layers. Their age is Carboniferous or Permian. The schist and the semischist are composed mainly of chlorite, sericite, biotite, quartz and calcite, and they are thought to have originated from mudstone, marlstone, siltstone, and limestone. On the surface, is extensively recognized the distribution of the Pliocene to Quaternary sediments, covering the basement rocks which are only sporadically outcropped. The stratigraphical order and the thickness of the basement rocks are shown below from the upper to the lower, as follows.

(Western Area)	(Eastern Area)
	marly semischist (+400 m) IIc
	pelitic semischist (±900 m) II_{p2}
	alternation zone (±500 m) IIa
pelitic schist (+1000 m) I_p	pelitic semischist (+1000 m) II_{p1}
calcareous, pelitic schist (±1500 m) $I_{pm} \cdot I_p$	
acidic volcanic rocks (±400 m) Iv	
pelitic schist (+1500 m) I_{ps}	

The alternation zone in the eastern area is composed of an alternation of acidic volcanic rocks, acidic pyroclastic rocks, limestone, siltstone and slate. The Hajar ore deposit is emplaced in this alternation zone. The volcanic rocks in the western area are composed of acidic volcanic rocks and acidic pyroclastic rocks. The Frizem mineralization zone is associated with them.

(2) Geological Structure

The surveyed area is located at a point where the Meseta Central Zone extending in NNE-SSW direction is put together as a junction with the Haut Atlas Zone which extends in WSW-ENE direction. The lower Paleozoic system extensively distributed in this surveyed area has been metamorphosed into schists by the intense dynamic metamorphism through the Hercynian orogenic movement and the Alpine orogenic movement. Many drag folds, intra-folial folds and schistosity-faults are observed to have been developed, dividing the terrain into many minute blocks where composite folding structures have been formed.

The Guemassa fault, which occurs cross-cutting the Guemassa block in the western area, is recognized to run in the direction of WNW-ESE. The apparent horizontal dislocation by this fault is as much as 10 km. The general trend of the beddings in this area is different in the north side of the Guemassa fault and in the south side of the fault, that is, NNW-SSE in the north of the fault against NW-SE in the south.

(3) Ore Deposit

The ore deposits in the surveyed area are represented by the Hajar ore deposit which has been emplaced in the alternation zone in the eastern area and by the Frizem mineralization zone related to the acidic volcanic rocks in the western area.

The Hajar ore deposit is a massive ore deposit, which is composed mainly of sphalerite and pyrrhotite with some galena and chalcopyrite. The ore deposit is hosted by the green rocks, which are estimated to have been originated from acidic volcanic rocks, acidic pyroclastic rocks and tuffaceous mudstone. The Hajar ore deposit is associated with marine volcanic activities and is emplaced in beds belonging to a certain horizon. It is classified genetically as submarine sedimentary ore deposit.

The beds belonging to the Hajar horizon are outcropped sporadically in the Oukhribane block and in the Amzourh block. Each of them contains remarkable indications of mineralization. The succession of the Hajar horizon are thought to have high mineral potentiality for the emplacement of the same type of ore deposits. Therefore, it is thought to be one of the most important elements for the future exploration to carry out fullscale investigation for the successions of the Hajar horizon.

The Frizem mineralization zone is composed of ore-vein-like gossans around the acidic volcanic rocks and characteristically it contains copper and lead in addition to zinc. The center of the acidic volcanic activity is in further southeastern area and as the Hajar type ore deposits are expected to exist there, it is necessary to extend the investigation to the southeastern part.

(4) Result of Geochemical Exploration

Geochemical anomalies of the heavy metal elements such as Ag, Cu, Pb, and Zn, etc. are concentratedly distributed around the successions belonging to the Hajar horizon in the eastern area and around the Frizem mineralization zone in the western area.

The geochemical content of the heavy metal elements of Cu-Pb-Zn is high in the volcanic rocks in the Frizem area and the content of Zn is obviously high in the beds of the Hajar horizon compared with the other layers. The upper part of the succession of the Hajar horizon has less amount of the heavy metal elements except for Pb, which is thought to have been concentrated during the period of their sedimentation. Therefore they are thought not to have been affected by the later mineralization. This can be an evidence for the fact that the Hajar ore deposit might be syngenetic ore deposit.

3-2 Geophysical Prospecting Result

By the geophysical prospecting by CSAMT method carried out in this area, the following results are confirmed of the resistivity.

(1) Results of the Measurement of Rock Property

The measured results of the resistivity, density and magnetic susceptibility of the pieces of rock samples collected in this survey are as follows.

1) As to the basement rocks, resistivity and density are remarkably high, but magnetic susceptibility is low.
2) As to the Quaternary sediments, resistivity and density are comparatively low, and magnetic susceptibility is also low.
3) As to the pieces of ore samples collected from the Hajar ore deposit, they have remarkably low resistivity, high density and high magnetic susceptibility, which are quite characteristic compared with other rocks composing the geology in this area.

(2) Outline of the Resistivity Structure

The resistivity structure in this area is, on the whole, constituted by three layers. The first layer, from the top, is the one bearing low resistivity including resistivity variation zone near the surface. It is correlated to the covering layers of the Pliocene to Quaternary sediments. The second layer is the resistivity basement with very high resistivity, which is correlated to the upper part of the basement rocks composed of Carboniferous to Permian systems. The third layer is the one bearing comparatively low resistivity, which is thought to be correlated to the low resistivity beds of the lower part of the basement rocks.

The resistivity structure has an extension in the direction of NW-SE, reflecting the bedding trend, but the appearance of resistivity structure is quite different in the western part and in the central to eastern part.

In the western part, the resistivity basement bearing very high resistivity and homogenuity is extensively seated in the shallow part below the surface. On the other hand, in the central to eastern part, the resistivity structure has ups and downs of the resistivity basement, reflecting extent of exposures of the basement rocks.

The first low resistivity layer in the central to eastern part is as thick as under 100 meters where the thickness is rather thin, while it is as thick as more than several 100 meters where the layer develops well and the variation of resistivity is recognized, which is thought to be by the effect of underground water. In this area, fairly wide range of the variation of resistivity in the resistivity basement can be observed and the low resistivity anomalies forming depression of the resistivity basement have been recognized in many places.

(3) Correlation with the Results of the Past Geophysical Prospecting

The following relations have been confirmed by the correlation of the resistivity structure with the results of the magnetic survey and the gravity survey carried out in this area.

1) The magnetic base in the western part is quite different from the anomalies in the other parts in view of the period of formation and the magnetic susceptibility. Also, the gravity base is rather shallow. These facts are coincident with the point that the structure of the high resistivity basement in this area is different from that in the other area.
2) In the central to eastern part, the extension in the direction of NW-SE can be seen with both of the magnetic anomalies and the resistivity anomalies with which the extension of the high gravity anomalies is in

good harmony.

3) Correlation is recognized between the high magnetic bodies and the low resistivity anomalies and between the high gravity anomalies and the high resistivity distribution.

4) At the southernmost part of the surveyed area, there is a remarkable low resistivity anomaly. As a depression of the low gravity anomaly is recognized corresponding to this resistivity anomaly, it is thought that the covering sediments of low density containing aquifer are distributed.

5) Typical magnetic anomaly and a high gravity anomaly have been detected in the area corresponding to the location of the Hajar ore deposit. As to the resistivity structure, it has been caught as the relatively low resistivity portion (depression) in the resistivity basement.

(4) Relation between the Resistivity Structure and the Mineralization

In the low resistivity structure in the area where the Hajar ore deposit is found, the mineralization and alteration zone in and around the ore deposit is recognized to form a low resistivity anomaly (depression) in the resistivity basement. The areas where the same pattern of the resistivity structure is recognized have been extracted in an area west of Taguennza, in an area near Lamrah, in an area east of Barrage Cavagnac, in an area southeast of Oukhribane, in an area south of Oukhribane and in an area west of Frizem. It is recognized that all of them are showing strong correlation to the magnetic anomalies, and they are thought to have mineral potentiality for the emplacement of the type of the Hajar ore deposit.

The areas where the above low resistivity anomalies (depression) are detected are distributed, except the area west of Frizem, in a zone with the approximate width of 3 km extending in NNW-SSE direction to connect west of Taguennza ∿ Lamrah ∿ Oukhribane. It is estimated that this zone is representing the area of high potentiality for the emplacement of ore deposits.

Also, in the area southeast of the Hajar ore deposit, low resistivity depressions in the resistivity basement are connected and a high gravity anomaly has been detected. Therefore, this area in the southeast of the Hajar ore deposit is thought to warrant further exploration.

3-3 Synthetic Explanation (Fig.3)

Fig. 3 illustrates the results of integrated analysis of informations of geological survey, geochemical survey and geophysical survey. The figure includes aero-magnetic anomalies, distributions of Hajar ore deposit horizon and Frizem horizon, ore deposit and mineral indications and conductive zones in concaves of the resistive basement, and a prospective area of mineralization inferred by geophysical informations.

The results of integrated analysis is as follows:

(1) Area of Hajar Horizon Distributed

Hajar horizon runs NW-SE direction in the central part of the survey area, the east of Souksou to the north of Amzourh and to Oukhribane. Hajar horizon shows mineral indications on the ground surface in around Oukhribane and Amzourh and dips 30 to 40 degrees to northeast.

Most of conductive zones in concaves of the resistive basement detected by CSAMT survey are in the Hajar horizon and its northeast slope. Those conductive zones are: the northeast of Souksou, the west of Taguennza, around Lamrah, around Akhlij, the east of Barrage Cavagnac the southeast of Oukhribane, and the south of Oukhribane.

Hajar horizon, mineral indications and the conductive zones are in the area of 3 km wide and 10 km long centered by Lamrah to Oukhribane indicated in Fig. 3.

Air-borne magnetic survey indicates distributions of many small anomalies aligned in NW-SE direction in the area. Most of the aforementioned conductive anomalies and mineral indications correspond to magnetic anomalies.

Therefore ore deposits similar to those of Hajar mine can be expected in the shallow part of the aforementioned 30 square km in the central part of the survey area.

(2) Area of Frizem Horizon Distributed

Frizem horizon is distributed in N-S direction in the west to the south of Frizem, the western part of the survey area. Frizem horizon dips 40 to 60 degrees east with mineral indications.

A conductive anomaly is detected in Frizem horizon in the west of Frizem and corresponds to remarkable magnetic anomalies.

Many remarkable magnetic anomalies are in the western part of the survey area, but the ones with mineral indications and conductive anomalies are only in Frizem horizon.

(3) Area around Hajar Mine

Typical bipolar magnetic anomaly is found at Hajar ore deposit and conductive anomaly in the resistive basement is also detected at and around Hajar ore deposit extending toward southeast. The extent of the conductive anomaly indicates that mineralization extends widely.

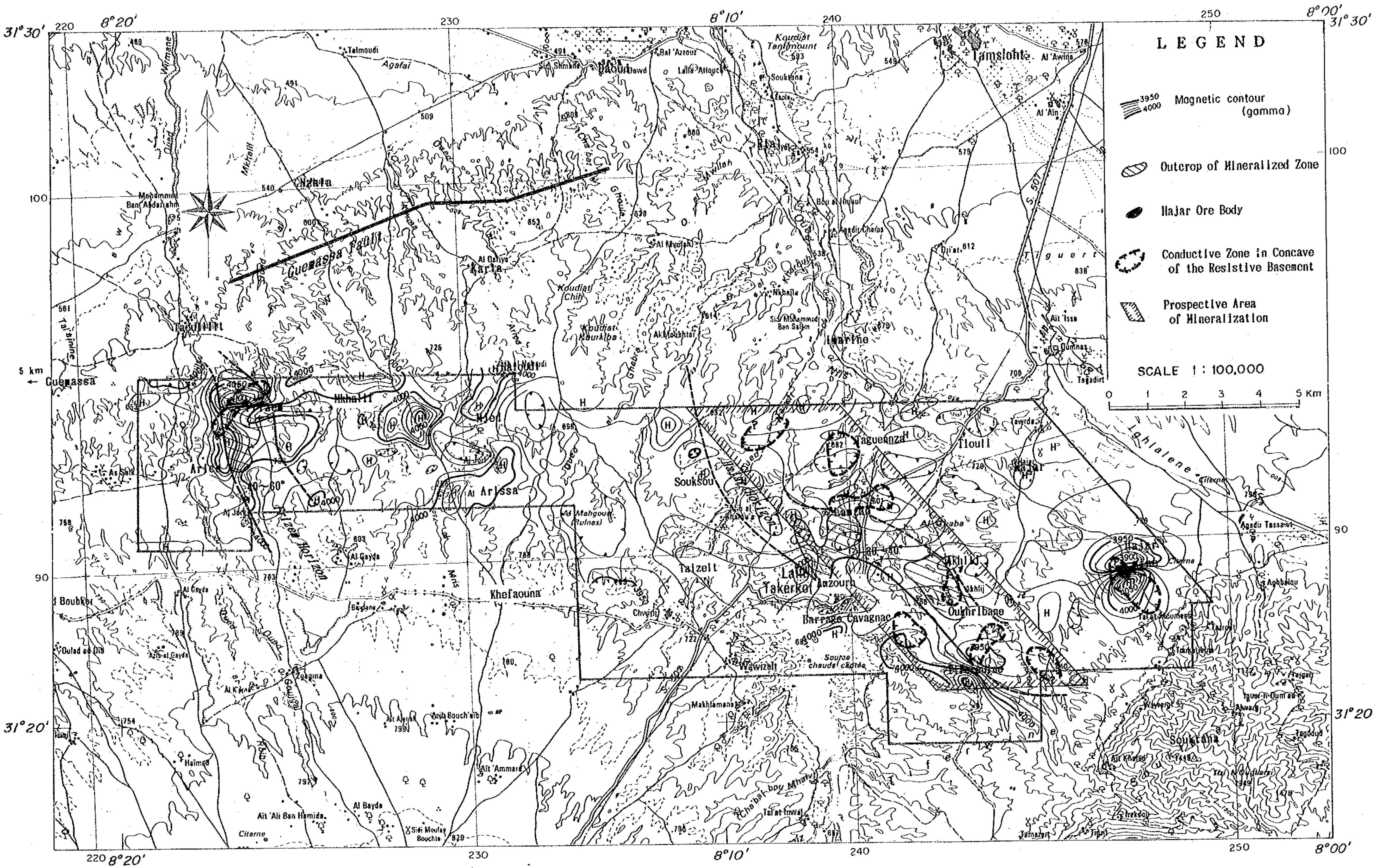


Fig. 3 Generalized Results of the Survey

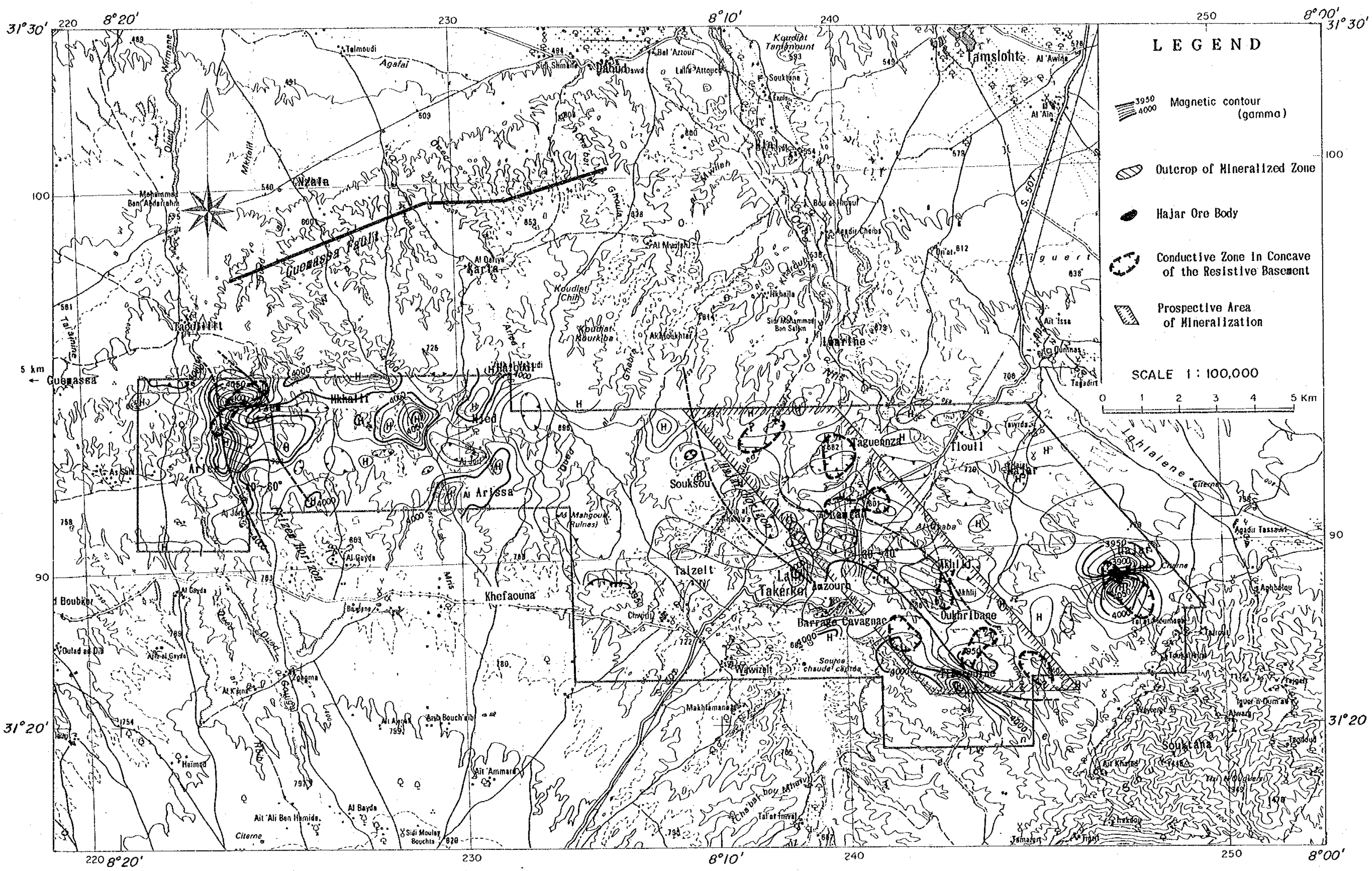


Fig. 3 Generalized Results of the Survey

CHAPTER 4 CONCLUSION AND RECOMMENDATION

4-1 Conclusion

The conclusion from the survey is as follows.

(1) Geological Survey and Geochemical Exploration

1) In this surveyed area, the Carboniferous to Permian systems are distributed, which are composed mainly of pelitic and marly schist and semischist. These systems are constituting the basement of this area. However, the exposures of these basement rocks are sporadic due to the extensive covering of the Pliocene to Quaternary sediments.
2) The ore deposits in this area are intimately associated with the acidic volcanic rocks and pyroclastic rocks which are contained in the succession of mudstone and marlstone of the Carboniferous to Permian systems. In the Hajar ore deposits, the metal elements such as silver, copper, lead and zinc are recognized to be concentrated with great deal of sulphide minerals, and the ore deposits are classified into submarine sedimentary ore deposit, genetically.
3) There are two remarkable horizons of mineralization in the area, which are the Hajar horizon and the Frizem horizon. Exploration surveys by the pursuit of mineralization along these horizons is the most important subject for future investigation.

(2) Geophysical Prospecting (CSAMT method)

1) The areas, bearing the same pattern of the resistivity structure in the Hajar horizon in comparatively shallow portion as that found in the Hajar ore deposit area, have been extracted in an area west of Taguennza, in an area near Lamrah, in an area east of Barrage Cavagnac, in an area southeast of Oukhribane and in an area south of Oukhribane. These areas are concentrated in a zone representing the Hajar horizon with the approximate width of 3 km extending in NNW-SSE direction to connect west of Tanguennza to Oukhribane through Lamrah. Each of them shows strong correlation to the magnetic anomalies, and because a remarkable magnetic anomaly has been detected in the area where the Hajar ore deposit is located, these areas are thought to warrant further exploration.
2) Same pattern of resistivity structure has been detected in an area

west of Frizem. Further exploration will be necessary in this area as it corresponds to a remarkable magnetic anomaly.

3) The extension of the low resistivity anomaly is recognized in the area southeast of the Hajar ore deposit, and as a high gravity anomaly has been detected there, it is necessary to carry out further mineral exploration in this area southeast of the Hajar ore deposit.

Based on the above survey results, it can be pointed out that the areas bearing high potentiality for the emplacement of ore deposits are the area around the Hajar ore deposit, the area where the Hajar horizon is distributed in a zone extending in NNW-SSE direction to connect west of Taguennza ∿ Lamrah ∿ Oukhribane, and the area where the Frizem horizon is distributed.

4-2 Recommendation for the Second Phase Survey

The ore deposits in this area are emplaced in the basement rocks which are covered with the recent sediments more than 100 meter thickness.

Accordingly, for the exploration and investigation in this area, it is necessary to employ appropriate survey methods having many phases and to analyse and integrate the survey results comprehensively. In addition to the surveys for the thickness of the covering sediments, for the confirmation of the depth of the basement rocks, and for the confirmation of anomalous area of the property of materials, the analysis of the geological structure and the geological environment for the emplacement of ore deposits are essential.

The most important target for the future exploration is placed in the Hajar horizon and the Frizem horizon. Considering the characteristics of the geology and mineralization, the following surveys are recommended.

(1) Geological Survey

Detailed geological survey on the Hajar and Frizem horizons in order to explecate the details of the mineralized beds.

(2) Geophysical Prospecting

Detailed geophysical prospecting on the Hajar horizon in order to explore ore deposits and elucidate the geological structure in which ore deposits are emplaced.

(3) Drilling Survey

Exploration under the mineralized and altered zone of the Oukhribane area and additional exploration of the magnetic anomalous zone of the Tiferouine area.

PARTICULARS

PART Ⅰ

GEOLOGICAL AND GEOCHEMICAL SURVEY

CHAPTER 1 OUTLINE OF THE SURVEY WORK

1-1 Field Work

The area for the survey is about 350 km^2. As most of the central and the eastern part of the surveyed area are underlain by Quaternary sediments, survey routes for the geological reconnaissance work were established in the area where the basement rocks are distributed. The length of the survey routes is 350 km.

For the survey, the topographycal maps of the scale of 1 to 10,000 prepared by BRPM were fully used together with the topographical map of 1 to 50,000, which was utilized after enlarged in copying.

A geological map of the scale of 1 to 50,000 is available, which has been prepared by BRPM. However, on this map, rock types are not distinctly differentiated and the geological structure has not been analized sufficiently. The reason why the rock differentiation and the structure analyses are insufficient is thought to be that the rocks distributed in this surveyed area are recognized to have been severely metamorphosed into schists through dynamic crustal movement accompanying intense metamorphism.

Therefore, in this survey, careful attention was paid especially to the distinction of petrological characteristics and to the observation of stratigraphical succession, so that the correlation might be possible among the different blocks.

For laboratory test and examinations, about 50 samples of rocks and ores were collected. Parallel with the geological survey, total 215 rock samples were collected for the geochemical exploration.

Having the base camp for the survey at the townsite of Marrakech, jeeps were fully used for the transportation to and from the surveyed area. The period of the field survey was 57 days from September 30, 1987 to November 25, 1987.

1-2 Laboratory Work

Total 215 pieces of rock samples for the geochemical exploration were analysed at the BRPM laboratory. Analysis was carried out with 4 elements of Ag, Cu, Pb and Zn, by the atomic absorption method. The limit of precision of the analysis is 0.1 ppm for silver and 1 ppm for copper, lead and zinc. Preparation and microscopic observation of thin sections of 20 rock samples and polish sections of 10 ore samples, as well as the application of X-ray diffraction method for 20 samples were carried out in Japan, together with the analysis for 20 rock samples and 10 ore samples. Aerophotographs were utilized for the interpolation of the geological structure.

CHAPTER 2 GEROLOGY AND GEOLOGICAL STRUCTURE

2-1 Outline of Geology (Fig. I-1)

The surveyed area is located at a junction where the Meseta Central Zone extending in NNE-SSW direction is put together with the Haut Atlas Zone which extends in WSW-ENE direction. The basement rocks are widely distributed in this area, which are composed of Carboniferous to Permian systems of the Paleozoic Era.

On the surface, the Pliocene to Quaternary sediments are distributed covering the basement rocks which can be found sporadically in blocks such as Guemassa block in the western area, Hajar-Imarine block, Akhlij block, Oukhribane block, Amzourh block and Barrage Cavagnac bock in the eastern area of the surveyed area.

Geologically, the basement rocks are composed mainly of pelitic rocks and marly sediments with thin inserted layers of siltstone and limestone. Volcanic rocks and volcanic pyroclastic rocks are observed to have been developed partly. These sediments were metamorphosed to schists and semi-schists in the form of chlorite schist, sericite schist and calcareous schist, through the intense metamorphic activity during the period of the Hercynian orogeny and the Alpine orogenic movement. The degree of the metamorphism is generally weak in the eastern area and strong in the western area.

2-2 The Eastern Area (Fig. I-2)

Stratigraphical order of the basement rocks in the eastern area is pelitic semischist, alternation zone, pelitic semischist and marly semischist from the lower to upper. The Quaternary sediments are dominant in this area covering more than 80 percent of the surface.

(1) Hajar-Imarine Block ($IIc \cdot II_{p2}$)

The Hajar-Imarine block is recognized to be exposed in large scale in the eastern part of the surveyed area (about 8 km in NW-SE direction and about 2 km in width). The block is composed of two almost parallel rows of mountaneous lands extending from northeast to southwest. The main part of this block is composed of carbonatic and marly semischist while the lower part of the mountaneous lands is composed of slate or pelitic semischist.

The carbonatic semischist is mainly calcareous to dolomitic marl, with occasional alternations with cherty layers and pelitic layers. The surface of the outcrop of these rocks is seen in color of brownish grey, while at the outcrops of fresh rocks they look in dark color. The strike of the schistosity is N60°W, dipping steeply to the northeast. The bedding planes are gently dipping as a whole. Repetition of syncline and anticline is observed with the axes in WNW-ESE direction. At the northeastern corner of this block, they have a trend dipping 30°-40° to the northeast. Geo-structurally, this carbonatic semischist composes the uppermost part of the basement in this surveyed area. The thickness of this semischist is estimated to be more than 400 meters.

Dissemination of fine grain pyrite, which is thought to be primary, is recognized in this semischist. Occasionally, siderite veins and barite veins are developed. Rhyolite stocks and diorite dykes are recognized as the intrusive rocks.

Faults of WNW-ESE system, which is parallel to the trend of the schistosity, and the faults of NNE-SSW system almost perpendicular to the above are well developed. It is recognized that the former faults caused vertical dislocation while the latter caused lateral dislocation, principally.

By the observation under microscope, detrital materials represented by quartz are cemented with the carbonate minerals in this carbonatic semi-schist (No.360).

(2) Akhlij Block (II_{p2})

The Akhlij block is located at the west of Akhlij. The outcrops of this block can be observed to extend discontinuously more than 2 km in east and west direction. The block is composed mainly of slate or pelitic semischist, with the inserted layers of limestone. Alternation of slate and siltstone developes occasionally.

Slate or pelitic semischist is dark grey, bluish grey and greenish grey in color. On the surface, it is usually weathered and looks pale green in color. The schistosity is N40°W, dipping steeply to the northeast, while the trend of the bedding structure is N50°W with the dip of 10°-30° to the northeast, though some variations are observed with gentle folding structure. The limestone beds inserted in this semischist are usually 1 to 5 meters thick and are pale grey in color. It is estimated that this slate or pelitic semischist, having approximate thickness of 900 meters, is overlain by the formerly-stated carbonate semischist, and that the series of this semischist forms covering layers against the succession belonging to the horizon of the Hajar ore deposit.

(3) Oukhribane Block (IIa)

The Oukhribane block is exposed discontinuously over 2.5 km in the direction of NW-SE from the west of Akhlij to Oukhribane.

This block is characteristically composed of the alternations, alternation of limestone and slate (thickness of each layer less than 1 meter), alternation of siltstone and slate (thickness of each layer less than 1 meter) and semischist of tuffaceous mudstone, etc.

The tuffaceous mudstone composes main part of this block. It is dark greenish grey in color and usually massive, but occasionally some banded structure of muddy band and siliceous band is observed with the thickness of each band to be several centimeters. The schistosity is vertical with the trend of N40°W. The whole trend of the bedding planes is N40°W with the dip of 20° to 40° to the northeast. Folding structure has been developped well with the axis in N40°W direction which is same as the trend of the schistsity. The folding structure is accompanied by the faults parallel to the schistosity.

Small outcrops of gossans are seen contained in this tuffaceous mudstone, as a whole. The gossans, remarkably reddish brown in color, which is thought to have been formed through the alteration associated with mineralization are recognized at the localities about 1 km and 0.4 km northwest of Oukhribane. They are concentrated in the layers composing the upper part of this tuffaceous mudstone. The size of each gossan is 10 to several ten meters. According to the X-ray diffraction test, the main component minerals are hematite, goethite and quartz.

(4) Amzourh Block (IIa)

The Amzourh block is outcropped in an area of 2 km x 1.5 km in the north of Amzourh. The block is composed of the semischist, which is constituted mainly by dacite, dacitic tuff, tuffaceous mudstone, alternation of limestone and slate (thickness of each layer less than 1.0 meter), alternation of siltsone and slate (thickness of each layer less than 1.0 meter) and slate. They are correlated stratigraphically to the succession found in the Oukhribane block.

The dacite layer in this block occupies a stratigraphical position between the overlying limestone-slate alternation and the underlying sandstone-slate alternation. The layer shows discontinuous linear distribution over 3 km with the approximate width of several ten meters, being observed at the outcrop of this layer.

They form isoclinal folding structures, in which the dacitic bed is intensely folded into V-shape together with the overlying and underlying layers. The rocks are dark greenish grey in color. Phenocrysts of feldspars are recognized. Under microscope, the rock (No.322) shows porphyritic texture with phenocrysts of plagioclase, potash-feldspar and quartz which are partly replaced by secondary minerals such as nontronite, chlorite and carbonates. Dark brown gossans are observed in and around this rock. Green copper dissemination is occasionally recognized.

The schistosity in this block is mostly N40°W dipping steeply to the northeast. The bedding planes show the trend of N40°W with the dipping of 40° to 60° to the northeast, although they are almost flat in some occasion.

The geological structure in this block is characterized by the acute-angled isoclinal folding and by the development of faults parallel to the schistosity. To describe it more in detail, synclinal axes, anticlinal axes and schistosity faults are combined together to divide each layer into pieces of minute blocks, forming "saw-like" isoclinal folding structure.

The alternation of limestone and slate observed in the small outcrops about 3 km to the northwest of Amzourh and the alternation of limestone and slate and of siltstone and slate observed in the small outcrops about 3 km to the southwest of Rial are correlated lithologically to the rocks of the Amzourh block, that is belonging to so-called alternation zone and the horizon of Hajar ore deposit.

(5) Cavagnac Block (II_{p1})

The rocks in the Cavagnac block are exposed along the downstream of the Barrage damsite along the N'Fis river. The block is composed mainly of thick layers of slates, which are the base of the successions found in the Oukhribane block and in the Amzourh block. The rocks in this block composes the lowest succession of the eastern part of the surveyed area.

The slate looks dark grey to dark in color. It is weathered on the surface, where the color changes to grey to greenish grey with distinct schistosity. In some occasion, calcareous layers are inserted. The trend of the schistosity is approximately N40°W, with steep inclination to the northeast. Most of the bedding planes have trend of N60°W with the dip of

30° to 50° to the northeast. The total thickness of the slate is estimated to be more than 1,000 meters.

A pair of anticline and syncline is found at the Barrage damsite. Along the axes of these folds, intrusion of diorite is observed.

(6) Horizon of Hajar Ore Deposit (Alternation Zone) (IIa)

The surface of the area where the Hajar ore deposit has been discovered is completely covered with the Pliocene to Quaternary sediments, the thickness of which reaches 120 meters.

By the results of the observation of the existing drill cores and the underground tunnels, the layers overlying the Hajar ore deposit are mainly grey pelitic rock, which can be correlated to the slate or pelitic semi-schist found in the Akhlij block.

The layers emplacing the ore deposit are underlain by dark green tuffaceous or pelitic rock. Partly the rock contains white phenocrysts and it is estimated that the rock could be originated from some acidic volcanic rocks or pyroclastic rocks.

Under microscope, the constituent minerals of this rock are mainly fine grain quartz, chlorite, biotite and sericite associated with some carbonate minerals and muscovite. The minerals are oriented in the same direction and sometimes they form fine banding structure. The white phenocrysts have been replaced by the aggregate of micro-crystals of quartz. In the sphalerite ore (No.302), talc was detected together with chlorite and sericite as gangue minerals by X-ray diffraction test.

The green rock in which the Hajar ore deposit is emplaced is considered to be equivalent to the lithological series of Oukhribane block composed of tuffaceous mudstone, alternation of limestone and slate, and alternation of siltstone and slate, and also to that of Amzourh block composed of acidic volcanic rock, tuffaceous mudstone, alternation of limestone and slate and alternation of siltstone and slate. Those lithological series distributed in the above three places is defined as the alternation zone or the Hajar horizon characterized by the alternation of tuffaceous rock, limestone siltstone and slate.

2-3 The Western Area (Guemassa Block) (Fig. I-3)

The Guemassa block is exposed in an area occupying 20 km in east and west and 4 to 8 km in north and south. In the central part of this block, is recognized to run a fault of the ENE-WSW system. The apparent dislocation caused by this fault reaches approximately 10 km, and so the movement of this fault would have influenced the surrounding terrain greatly. The strike trend of the Paleozoic system varies bounded by this fault. In the north of the fault the trend is NNE-SSW while it is NW-SE in the south of the fault.

The stratigraphic succession in the block is given, from the lower sequence, as follows.

(1) Pelitic Schist (I_{ps})

The pelitic schist is distributed in the area west of Frizem. This schist composes the lowest succession in this surveyed area. The pelitic schist is grey in color and is composed mainly of sericite, chlorite and quartz.

In the Guemassa area in the east, this pelitic schist is observed to form alternation with siltstone layers. Composite anticlinal structure is recognized. The general trend in the east of the anticline axis is NW-SE, with the dip of 30°-50° to the northeast. The thickness of this pelitic schist is estimated to be more than 1,500 meters. In the west side of the anticlinal axis, the trend is varied and yet generally E-W with the dip of 30°-50° to the south.

(2) Acidic Volcanic Rocks (Rhyorite Layers: Frizem Horizon) (Iv)

The rhyolite layers are distributed near Frizem in two beds in the upper succession of the pelitic schist. They are exposed in apparent width of 0.8 km. The distribution is characteristically irregular and the number of their exposures decreases toward the northwest. Size and scale of their outcrops are apt to increase in the southeastern area, where they are covered with Tertiary beds. The center of the activities of this rhyolite is thought to be in further south.

The rhyolite is pale grey in color, and some phenocrysts of quartz are recognized. Schistosity is well developed. In some occasion it looks like volcanic tuff.

Dark brown gossans are found sporadically distributed around this rhyolite. Under microscope, the rock (No.187), mainly composed of quartz and plagioclase, is replaced by sericite and chlorite, and disseminated by magnetite, hematite and goethite. Actually, the gossans are sporadically located along the schistosity faults in the pelitic schist underlying the rhyolite. The area where the gossans are distributed is about 1 km x 1.5 km.

The size of the gossans is approximately 60 m x 150 m in maximum.

This rhyorite layers is defined as the Frizem horizon being accompanied with mineralization.

(3) Calcareous and Pelitic Schist ($I_{pm} \cdot I_p$)

The calcareous schist is distributed in an area from Frizem to the east of Mkhalif in the southern side of the Guemassa fault while it is found around Daoud in the northern side of the fault.

The fresh calcareous schist looks dark grey in color, but where the rocks are weathered, the schist is soft and it has been argillized in white color. The component minerals of this calcareous schist are calcite, sericite, chlorite, quartz and plagioclase. This calcareous schist is thought to have been originated from marl. The schist is alternated with calcareous pelitic schist with the interval of several 10 meters and several 100 meters. In the area near Mkhalif, the schist is found in the alternation with siltstone.

The drag folds are well observed with the wave-length of several 10 meters in this calcareous schist, where synclines and anticlines are repeated. Many fissures and faults parallel to the schistosity are found, which have caused step dislocation to the layers.

The general trend of this rock is in NW direction with the dip of 40°-50° to the northeast in the southern side of the Guemassa fault, while the strike is NNE and the dip is toward the east in the northern side of the fault.

The total thickness of this calcareous schist is estimated to be approximately 1,500 meters.

(4) Pelitic Schist (I_p)

The pelitic schist is distributed in the area east of the Mjed mountain in the southern side of the Guemassa fault. The pelitic schist is greenish grey, dark grey or dark in color, and the main component minerals of this schist are chlorite, sericite and quartz. The intrafolial folding of the strata and the dislocation by the schistosity faults, caused by the metamorphism which formed the schist are the remarkable characteristics of this rock. Bedding structures are scarcely reserved. The trend of the schistosity is NNW and the dip is steep. The pelitic schist composes the uppermost succession of the basement rocks found in the eastern part of the surveyed area.

The lower succession of this pelitic schist is represented by the rocks which are distributed in the area from the Mjed mountain to Karia, where inserted layers of limestone are recognized in the pelitic schist. The limestone is grey in color and the thickness varies from several 10 centimeters to over 10 meters. It has poor continuity and is recognized in the forms of echeron or fragmental masses. The limestone layers are thought to have been pulled in the direction of the schistosity at the period of metamorphism and torn to pieces by step dislocation by the schistosity faults. The limestone layers contain lots of fossils of Crinoidea.

This pelitic schist is thought to dip toward ENE direction in the form of composite folding structure including intense intrafolial folds, by the estimation through the geological structure of the inserted limestone layers.

The pelitic schist observed in the small outcrops at the east of Mjed and Arissa has insertion of limestone layers, and it is correlated to the pelitic schist distributed in the area from the Mjed mountain to Karia.

(5) Intrusive Rocks

Concerning the intrusive rocks in the western part of the surveyed area, rhyolite (about 1.5 km and about 3 km north of Mkhalij), diorite (about 0.5 km northwest of Mkhalij and about 3-4 km east of Guemassa) and gabbro (about 1 km northeast and about 2 km northwest of Karia) have been found, all of which are dykes intruded along the schistosity or bedding plane. The width of the dykes is 1 to twenty meters.

All of these intrusive rocks are intensely metamorphosed and altered both in texture and mineral assemblages. Under microscope, porphyritic texture are usually observed and the assemblages of phenocryst minerals are composed of plagioclase and quartz in rhyolite, plagioclase, pyroxene and hornblende in diorite, and olivine and plagioclase in gabbro.

(6) Pliocene to Quaternary Sediments

About two thirds of the surveyed area is covered with Quaternary and partly Pliocene sediments. The sediments are mainly continental conglomeratic sandstone, and the thickness is more than 100 m meters.