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

PHASE II

MARCH 1989

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 (JICA).

The JICA and MMAJ sent to the Kingdom of Morocco a survey team headed by Mr. Jinichi Nakamura from September 13 to November 22, 1988.

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, 1989

Kensuke Yanagiya

KENSUKE YANAGIYA
Presidente
Japan International Cooperation Agency

Junichiro Sato

JUNICHIRO SATO
Presidente
Metal Mining Agency of Japan

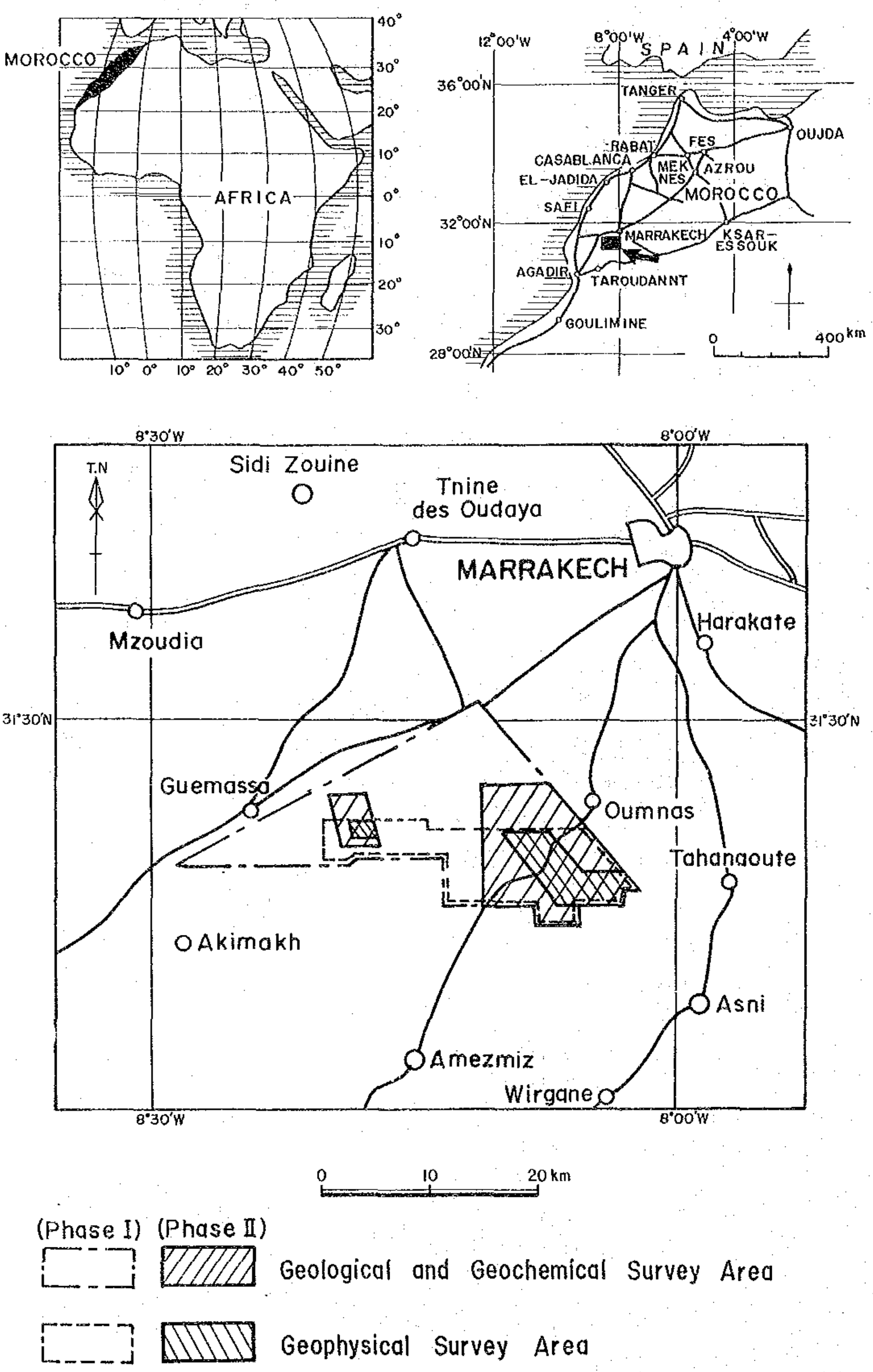


Fig. I Location Map of the Survey Area

SUMMARY

This report contains the Second 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 through the elucidation of geological phenomena in the Haouz Central Area.

In this year, the following surveys were carried out in the Eastern Area and Western Area which were selected for the prosperous areas in the First Phase survey:

Geological and geochemical survey:

The Eastern Area : surveyed area: 34 km^2, surveyed route: 170 km geochemical rock samples: 207 pcs.

The Western Area : surveyed area: 12 km^2, surveyed route: 60 km, geochemical rock samples: 75 pcs.

Geophysical survey:

IP method : survey lines: 13 lines, total length of survey line: 26.6 km, survey points: 1070 pts.

Gravity method : surveyed area: 40 km^2, survey points: 745 pts.

The survey results are described below.

(1) Geological and Geochemical Survey

The detailed geological and geochemical survey was carried out in the Hajar horizon of the Eastern Area and in the Frizem horizon of the Western Area. In both horizons mineral indications had been found by the First Phase surveys.

The Eastern Area:

Several gossan outcrops were found in the Hajar horizon and geochem-

ical anomalies indicated by Pb-Zn-Cu elements in rock samples were found around the gossans. The host rock of the gossans was mostly acidic tuff. The mineral indications occurred in the acidic tuff or in the vicinity of the acidic tuff which was distributed always in the Hajar horizon.

On the other hand, the inner structure of the Hajar ore deposit was studied in detailed. It becomes clear that the Hajar ore deposit exists in the acidic tuffaceous green rock and consists of two parts that are bedded orebody at the upper part concentrated with lead-zinc-silver-copper-iron minerals and a network orebody at the lower part associated with copper-zinc-iron minerals. These characteristics of the Hajar ore deposit are belonging to the sedimentary deposit originated in the submarine volcanic activity.

The Western Area:

It was clarified that gossans were distributed around the acidic volcanic rock and geochemical anomalies indicated by Pb-Zn-Cu elements in rock samples were distributed in the limited area with the acidic volcanic rock as the center. The gossans located to the upper horizon (eastern side) of the acidic volcanic rock are massive or disseminated type ores and found separately at 6 places. While, the gossans to the lower horizon (western side) are vein type ores developed sporadically in fault fractures. Each type is believed to have been formed in connection with the submarine acidic volcanism.

The relation of the Both Areas:

Two stages of the submarine acidic volcanisms are confirmed in this area. The isotopic age of the acidic volcanic and pyroclastic rocks shows 294 - 303 ± 15 million years in the Eastern Areas and that of the acidic volcanic rock in the Western Area shows 328 ± 16 million years.

It shows exactly that the volcanism in the Hajar horizon is of early stage and the volcanism in the Frizem horizon is of latter stage. It is estimated that the generation age has been reserved well in the volcanic rocks in this area, though the rocks suffered intensive deformation and alteration.

(2) Geophysical Prospecting

Several low resistivity anomalies were discovered in this area by the First Phase CSAMT prospecting method. And the rock sample measurements of the Hajar ores yielded the values of the resistivity, FE and density of about 20 ohm-m, 15% and 4.25 g/cm^3 respectively. Due to the significant differences of these values compared to the corresponding background values, IP and gravity methods were introduced for the Second phase prospecting techniques.

As the survey line above the Hajar ore deposit, the apparent resistivity of as low as 20 ohm-m and IP anomaly of 6.6% maximum were obtained by the IP method. And the same low resistivity and strong IP anomalies were discovered at Lamrah and Frizem. The apparent resistivity and FE values of the former were 20 ohm-m and 3 to 4% respectively, and those of the latter were 20 to 30 ohm-m and 5 to 6% respectively. And the locations of the low resistivity anomalies obtained by the dipole-dipole array of electrodes were well coincide with those of the low resistivity anomalies from the Phase I CSAMT method. Therefore, ore deposits are expected for both Lamrah and Frizem. Due to the severe fluctuations of measured resistivity values in the survey area, it was difficult to detect the locations of the sulfide ore bodies only from the low resistivity anomalies, but IP method was effective to distinguish them in the low resistivity anomalies.

From the gravity survey, several high gravity anomaly zones were detected. One of them was the area from the south of Akhlij to the north of Tiferouine, and considered to be corresponding to the Hajar horizon. Because of the corresponding low IP and high apparent resistivity anomalies, the high gravity anomaly zone seemed to be representing the shallow basement. Inasmuch as the disseminated ore deposits were found from the drilling survey at the north of Tifferouine, it is possible that this gravity high zone is corresponding to the disseminated ore deposit. The other gravity high zone of maximum 1.5 mgal at the *north of Akhlij was found, and corresponding slight high FE* values of 2.5 to 3% were recognized in addition to the near by magnetic anomalies and CSAMT low anomalies.

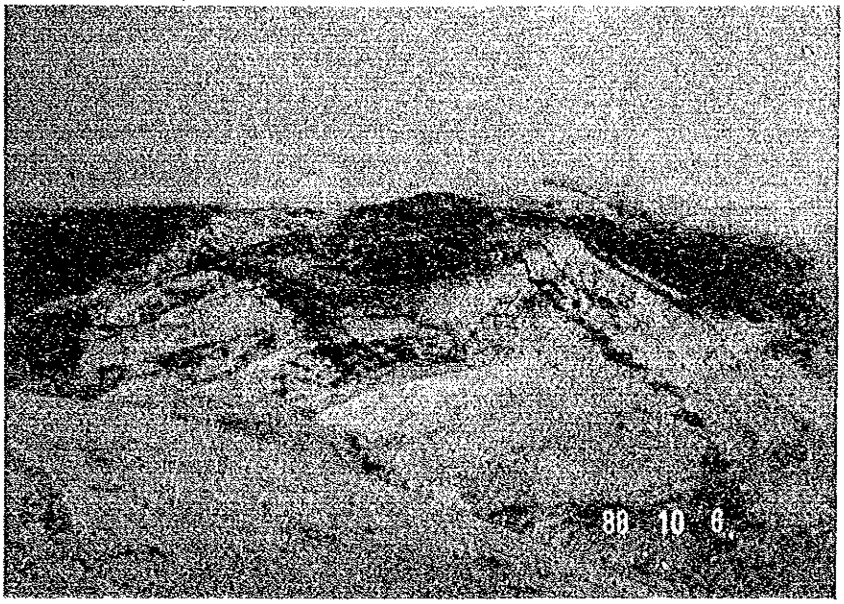
At Lamrah block, where low resistivity and strong IP were observed, no significant gravity anomalies were detected. Therefore, it may be difficult to expect Hajar type massive ore deposits but the possibility of the existence of disseminated ore deposits still remains.

Following prospectings are proposed for the Third Phase :

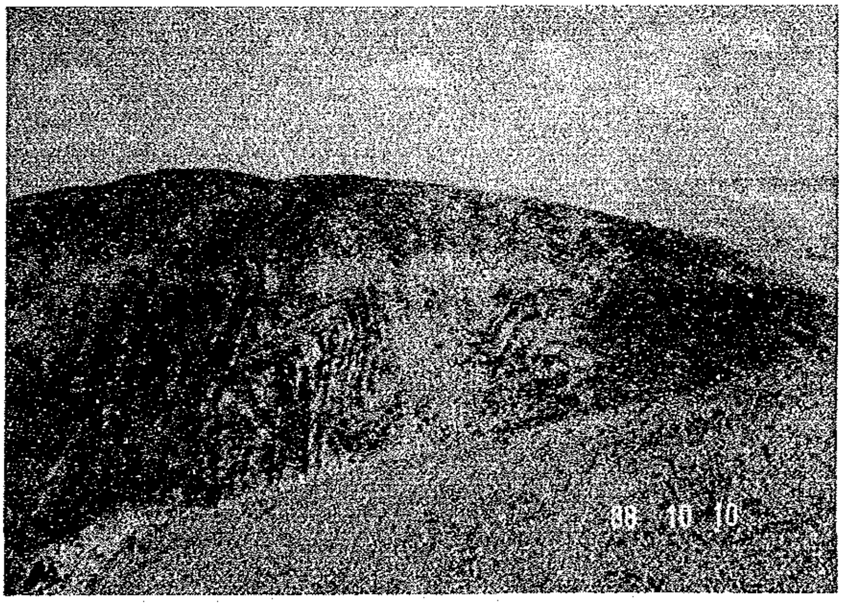
(1) IP method for the underlying Hajar horizon (Connecting Lamrah-Akhlij-Hajar mine) in the Eastern Area

(2) IP method for the Frizem block to investigate the structure of the detected low resistivity and high IP zones

(3) Drilling to the low resistivity and high IP anomalies detected at Frizem and Lamrah



Schistosity Fault and Drag Fold in the Marly Schist, Frizem Area



Overfold Structure in the Alternation of Sandstone and Mudstone, Frizem Area.

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GENERAL REMARKS

CHAPTER 1 INTRODUCTION

1-1 Background of the Survey

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

The Cooperative Mineral Exploration in the Haouz Central Area has been selected and agreed between the Bureau de Recherches at de Participations Mineres (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 Exploration Survey carried out in the Haouz Central Area, is to elucidate the detailed geological structure and mineralization.

The survey of this year is corresponding to the Second Phase. In the First Phase survey, geological and geochemical survey in 350 km^2 area with 215 samples, and geophysical prospecting by CSAMT method in 150 km^2 area with 302 measurement points were carried out and two specific prosperous areas - the Eastern Area and the Western Area were picked up to enforce the detailed survey in the Second Phase.

1-2 Conclusion and Recommendation of the First Phase Survey

1-2-1 Conclusion of the First Phase Survey

(1) Geological and Geochemical Survey

1) It was indicated that the Hajar ore deposit was a sedimentary sulfide deposit and at the same time there existed a large possibility of the occurrence of the Hajar type ore deposits in the area.

2) It was clarified that there were two important mineralized horizons, the Hajar horizon and the Frizem horizon, in which there were high

potentialities of the occurrence of ore deposits.

(2) Geophysical Prospecting (CSAMT method)

1) The areas, bearing similar patterns of the resistivity structure in comparatively shallow portion to the pattern found in the Hajar ore deposit area, were extracted in extracted in west of Taguennza, Lamrah, east of Barrage Cavagnac, southeast of Oukhribane and south of Oukhribane. These areas are concentrated in a zone representing the Hajar horizon with the approximate width of 3 km extending in NW-SE direction from west of Taguennza to Oukhribane through Lamrah. Each of them shows a correlation to the magnetic anomalies.

2) Same pattern of resistivity structure was detected in an area west of Frizem.

3) The extension of the low resistivity anomaly was recognized in the area southeast of the Hajar ore deposit, where a high gravity anomaly had ben detected.

Based upon the survey results, three areas the Hajar mine area, the Hajar horizon area including Taguennza, Lamrah and Oukhribane, and the Frizem horizon area were picked up for the prosperous areas of further exploration.

1-2-2 Recommendation of the First Phase Survey

The ore deposits in this area was emplaced in the basement rocks concealed under the thick sediments of Quaternary and Neogene. The exploration target in near future would be focused on the mineralized horizons comparatively shallow underground.

Accordingly, the following surveys were proposed for the Second Phase survey.

1) Detailed geological survey on the Hajar and Frizem horizons.

2) Geophysical prospecting in the areas of the Hajar and Frizem horizons.

1-3 Outline of the Second Phase Survey

1-3-1 The Survey Area

The Haouz Central Area is a trianglar-shaped area of 350 km located in the west central part of the Kingdom of Morocco, about 330 km south-southwest of Rabat.

As the results of the First Phase survey, two important areas have been extracted for the extensive exploration target of next stage. They are the Eastern Area (the Hajar-Amzourh Area) about 100 km^2 including the Hajar mineralized horizon and the Western Area (the Frizem Area) about 20 km^2 including Frizem Mineralized zone (Fig. 1).

1-3-2 Purpose of the Survey

The purpose of the survey is to clarify the details of geological successions and structure of mineralized horizons and the features of mineralization, and to confirm geophysical anomalous zones that suggest the existence of concealed orebodies.

1-3-3 Method of the Survey

The adopted survey methods are geological and geochemical survey and geophysical prospecting by means of IP method and gravimetric method. The details are as follows:

(1) Field Survey

	Geological and Geochemical Survey			Geophysical Survey				
	Area (km²)	Surveyed Route (km)	Geochemical Samples (pcs)	Gravity Method		IP Method		
				Area (km²)	Number of Stations	Number of Lines	Number of Stations	Length of Line (km)
Eastern Area	34	170	207	40	745	11	910	22.6
Western Area	12	60	75	–	–	2	160	4
Total	46	230	282	40	745	13	1070	26.6

(2) Laboratory Test

Geochemistry (Ag-Cu-Pb-Zn) = 282 pcs,

Thin section = 20 pcs

Polished section = 10 pcs

X-ray diffraction = 20 pcs

Whole rock analysis (13 elements) = 10 pcs

Ore analysis (Ag-Cu-Pb-Zn) = 10 pcs

Dating in K-Ar method = 4 pcs

Measurement of AR and FE values = 24 pcs

Measurement of density = 30 pcs

1-3-4 Organization of the Survey Team

The members of the Second Phase survey team are as follows:

	Japan Side		Morocco Side	
Leader	Jinichi NAKAMURA	(MINDECO)	Assou LLHATOUTE	(BRPM)
			Ali BENNANI	(BRPM)
			Ahmed LOUALI	(BRPM)
			Hassan SEQQAT	(BRPM)
			Allal TIJANI	(BRPM)
Geol.Geoch	Ryohei OTSUBO	(MINDECO)	Abdelaziz MELLAL	(BRPM)
Geol.Geoch.	Kazuhiro ADACHI	(MINDECO)	Abderrahim QALBI	(BRPM)
Geophysic	Akira SAITO	(MINDECO)	Mohamed BERRADA	(BRPM)
Geophysic	Kazushige WADA	(MINDECO)	Said QASRI	(BRPM)
Geophysic	Tadashi OHASHI	(MINDECO)		
Geophysic	Tatsuo YAMAZAKI	(MINDECO)		
Geophysic	Hirokazu MUTO	(MINDECO)		

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

1-3-5 Survey Schedule

—— In Morocco ------ In Japan

	1988 Sep.	Oct.	Nov.	Dec.	1989 Jan.	Feb.
Mobilization & Arrangement	13 — 21		9 — 22			
Field Survey (Geol. & Geoch.)	17 →		→ 13			
Field Survey (Geophysics)	22 →		→ 10			
Laboratory Work			1 ···→		···→ 31	
Report Preparation			20 ···→			···→ 10

CHAPTER 2 OUTLINE OF THE SURVEY AREA

2-1 Geography

Refer to the report of Phase I.

2-2 The Past Exploration

February 1988, the CMG (Companie Miniere des Guemassa) financed by both BRPM and ONA (Omnium Nord Africain) has been established to open the Hajar Mine and a pilot plant is now under construction.

As for the detailed progress, refer to the report of Phase I.

CHAPTER 3 GENERAL GEOLOGY

The Haouz Central Area is located in the Paleozoic geosynclinal belt developed along the marginal parts of the Mauritanian Craton. The Carboniferous to Permian systems are cropped out partly in the survey area, although the greater part of the basement rocks is covered extensively by the Quaternary and Neogene sediments.

The Carboniferous to Permian systems are mainly composed of pelitic and marly schist and semischist intercalated with acidic volcanic beds. Numerous schistosity faults and drag folds are developed in the schist and semischist. Although the geological structure is intensively deformed and complicated, the general trend of the formation is NNE-SSW or NW-SE directions dipping to the east.

Ore deposit in the survey area is emplaced in the Carboniferous to Permian systems and represented by the Hajar ore deposit in the Eastern Area and the Frizem mineralized zone in the Western Area. The Hajar ore deposit is a bedded sulfide deposit concealed in the ground at the depth of 150m to 500m below the surface. The Frizem mineralized zone is a lenticular and massive disseminated zone and carbonate - quartz veins associated with sulfide minerals.

The mineralization in this area is intimately related to acidic volcanic activities and the ore deposits occurred in some specific horizons. The most important mineralization horizons are the Hajar horizons are the Hajar horizon corresponding to the alternation of acidic volcanic and pyroclastic rocks, siltstone, sandstone, tuffaceous mudstone and limestone, and the Frizem horizon corresponding to acidic volcanic and pyroclastic rocks.

CHAPTER 4 SYNTHETIC EXAMINATION

4-1 Geological Structure and Mineralization

(1) The Eastern Area

1) The Hajar Horizon

The indications of mineralization in the Eastern Area are found to be converged in the Hajar horizon impregnated with rock.

The Hajar horizon characterized by tuffaceous rock is exposed sporadically on the surface elongated about 20km to the E-W direction. The rock faces of the Hajar horizon are various depended upon each Block.

2) The Hajar Ore Deposit

The Hajar ore deposit located at the eastern end of the survey area is a massive to bedded-type ore deposit composed mainly of galena, sphalerite and pyrrhotite. The ore deposit carries network and vein-type orebodies comparatively rich in copper and zinc at the lower parts.

The Hajar ore deposit had been formed at the uppermost part of the tuffaceous green rock and covered by mudstone intercalated with limestone beds in which mineralization is not observed. Main alterations related to mineralization are silicification and argillization.

Although it is difficult with the naked eye to distinguish the tuffaceous green rock from the green schist originated in mudstone, the tuffaceous green rock abounds K and Mg elements and has high ratio of K/Na, usually more than 8.

3) The Oukhribane Block

In the Oukhribane Block located at about 13 km west of the Hajar mine, the Hajar horizon is composed of fine alternation of tuff and calcareous siltstone, tuffaceous green stone, alternation of sandstone and tuffaceous mudstone, tuffaceous mudstone, acidic volcanic rocks, and alternation of limestone and mudstone, in the ascending order from lower

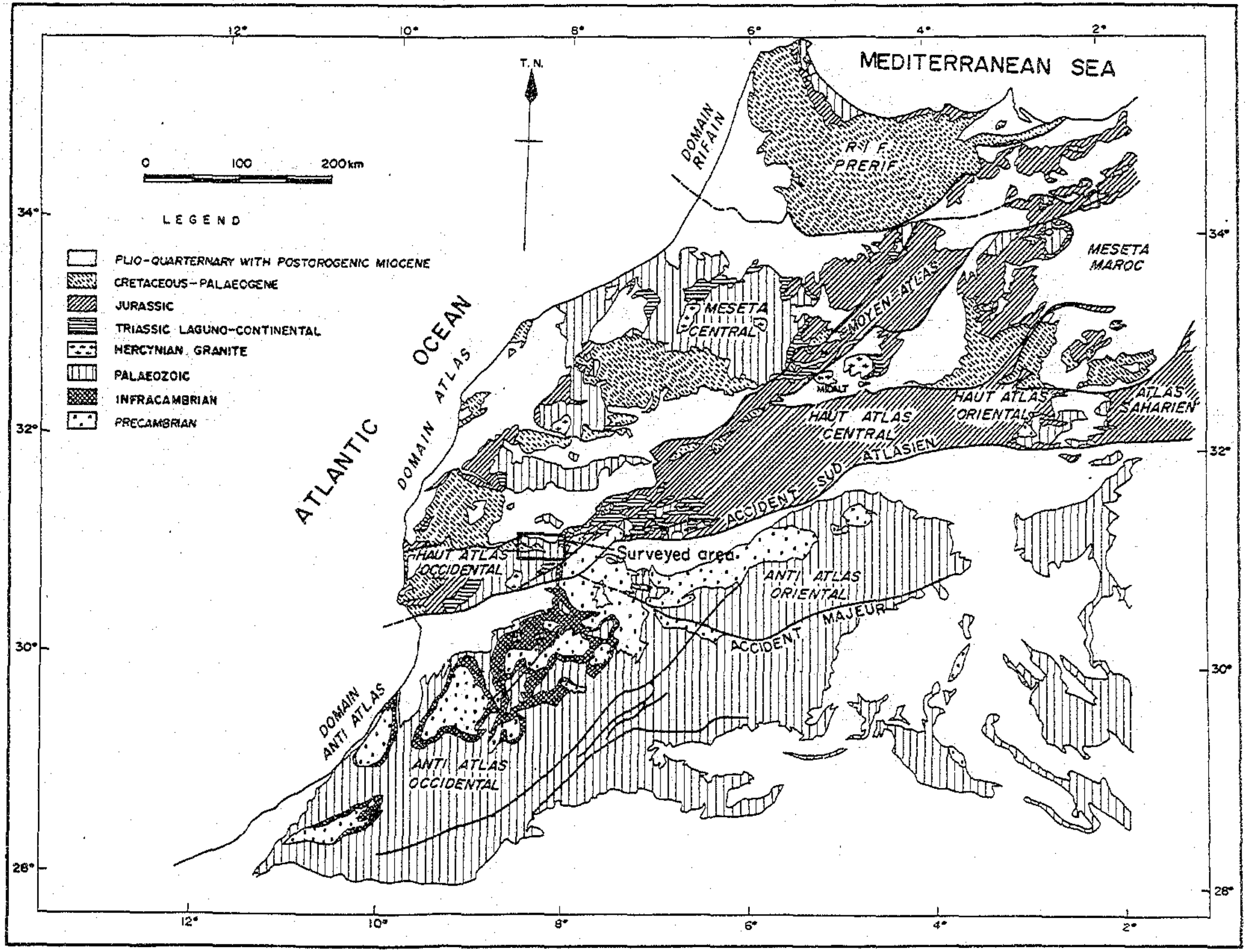

Fig. 2 Geotectonic Map of Northern Morocco

to upper. The bed of conglomerate is found in the lowermost part in the fine alternation. Remarkable mineral indications and geochemical anomalies of Pb-Zn-Cu are converged in the tuffaceous green rock.

Two mineralized zones about several meters in scale are found in the tuffaceous green rock about 0.4km and 1.0 km northwest of Oukhribane village. Both of the mineralized zone are network-type orebodies accompanied with iron oxide-quartz veinlets containing copper and zinc and accompanied with the alternation of silicification and argillization. These mineralized zones are considered to be the same type of the network-type orebody of the Hajar ore deposit.

4) Amzourh Block

In the Amzourh Block located at about 10 km of the Oukhribane Block, the Hajar horizon is composed of alternation of sandstone and tuffaceous mudstone, tuffaceous mudstone, acidic volcanic rocks, and alternation of limestone and mudstone in the ascending order. The tuffaceous fine alternation and the tuffaceous green rock were turned to thin beds and were wiped out to the west. In return, the limestone alternation of the uppermost part increase its thickness.

The mineral indications in the Amzourh Block are found in the inside of the acidic volcanic rocks and in the lower formations below the acidic volcanic rocks. They are pyrrhotite-pyrite-quartz veinlets or gossan masses in fault fractured zones. Both of them are small-scale and disseminated with green copper.

5) The Hajar Horizon and Mineralization

The alternation formation indicating the Hajar horizon is considered to have been formed in the period of the submarine volcanic activity which erupted large volume of pyroclastic rock on the sea floor.

The occurrence of ore deposits in this area is estimated to be an episode involved in the submarine volcanic or exhalative activity.

The result of the age determination by K-Ar method on the acidic volcanic rocks and tuffaceous green rock in the Eastern Area is 294 - 303 ± 15 million years. This isotopic age is corresponding to the upper part of the Carboniferous and coincides to the age of the sedimentation in this area.

(2) The Western Area

The indications of mineralization in the Western Area are lenticular-shaped brecciated gossans in the eastern part and vein-type gossan in the western part. The geochemical anomalies of Pb-Zn-Cu together with mineral indications are distributed around the Frizem horizon that is compose of acidic volcanic and pyroclastic rocks.

The eastern gossan outcrops were explored by drilling and under the outcrops, a low-grade dissemination-type of ore was confirmed occurring in the marly-muddy schist directly upper of the acidic pyroclastic rock. The brecciated gossan found on the surface is, in possible, a secondary fragmental ore separated and removed from the primary disseminated ore.

The western vein-type gossan is found sporadically in the fault fracture developed in the psammitic-pelitic schist.

The Frizem horizon composed acidic volcanic rock is lacking in the accumulation of large volume of the pyroclastic rock. From this point of view, the Frizem horizon is different from the Hajar horizon. The ore deposits in the Frizem horizon are mainly dissemination-type or vein-type which are estimated to have been formed in connection with the submarine acidic volcanism.

The isotopic age of the acidic volcanic rock in the Frizem Horizon is 328 ± 16 million years. This age is corresponding to the middle part of the Carboniferous which is a little older than the age of the Hajar horizon.

4-2 Results of Geophysical Prospecting and Ore Deposit

(1) IP Method

In the Second Phase Survey, IP method was adopted in the selected areas where the low resistivity structures were found by CSAMT method. As the result, remarkable low resistivity and high IP anomalies were detected in the following three areas.

Hajar mine area : AR = 20 - 30 ohm-m, FE = 5 - 6%

Frizem area : AR = 30 ohm-m, FE = 5 - 6%

Lamrah area : AR = 20 - 30 ohm-m, FE = 3 - 4%

Each geophysical anomaly of low resistivity and high FE value shows concealed-shape which suggests the existence of concealed sulfide ore-body.

(2) Gravity Method

Several high gravity anomaly zones were detected and density cross sections were analyzed by the gravity method.

The high gravity anomaly zone revealed along the NW-SE direction around Oukhribane was corresponding to the high resistivity and week IP area and to uplift and outcrops of the basement rocks corresponding to the Hajar horizon. Therefore, it may be difficult to expect large massive orebody but there is a possibility of the existence of the disseminated ore deposits, which were found nearby the drilling survey.

Since the high gravity anomaly zone at the north of Akhlij was associated with high FE values, and also coincided with the CSAMT low resistivity anomaly, further investigations are anticipated.

At the low resistivity and strong IP anomaly area found in Lamrah, no gravity anomalies were detected. Inasmuch as the CSAMT low resistivity anomaly and magnetic anomalies were found in this area, the possibility of disseminated ore deposit remains.

4-3 Potentiality of Ore Deposit

1) It is estimated that the ore deposits in this area have been formed to be caused by the submarine volcanic or exhalative activity. The silver-lead-zinc-copper orebodies in such type as sedimentary massive to bedded-type are expected occurring in the specific horizon in this survey area.

2) In the Eastern Area, the ore deposits are originated intimately in the tuffaceous green rock which is distributed to the northern part from the line connected the Hajar mine, Oukhribane and the point of about 2.5km north of Cavagnac. Restricting the development area in the near future within the comparative shallow underground, the target area of exploration is limited to about 5km north of the above mentioned line (Fig. 3).

3) The target area of exploration in the Western Area is the extent of 5km length in the north to south direction and 2.5km width in the east to west direction with the acidic volcanic rock as the center, in which the sites of mineral indications and geochemical anomalies are included (Fig. 3).

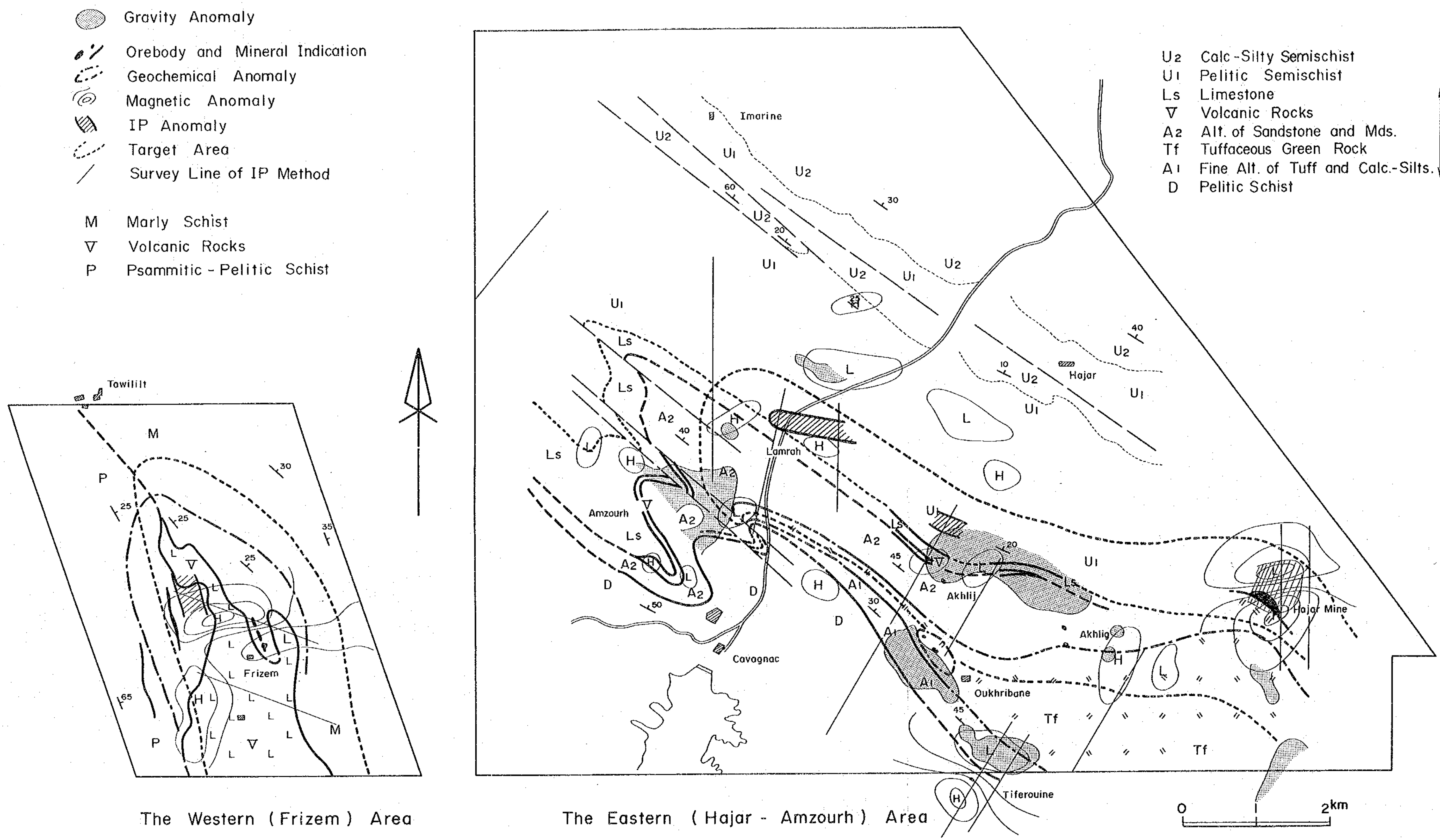

Fig. 3 Synthetic Map of Exploration

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5-1 Conclusion

(1) Geological and Geochemical Survey

1) It is confirmed in The Second Phase Survey that the ore deposits in this area are embedded in the two specific geologic horizons, namely Hajar horizon in the Eastern Area and Frizem horizon in the Western Area. The former is composed of acidic volcanic and pyroclastic rocks, siltstone, tuffaceous mudstone and limestone. The latter is composed of acidic volcanic and pyroclastic rocks.

2) The ore deposits represented by the Hajar ore deposit are submarine sedimentary type, formed in relation to the acidic volcanic activities. In the Hajar ore deposit, a large-scale and high-grade massive bedded orebody, concentrated with lead, zinc, copper and silver has been formed at the upper part. And at the lower part of the mineralized horizon, a stockwork and vein type orebody containing zinc and copper has been formed. It is concluded that there is a good possibility for the occurrence of the other ore deposits of the same type with Hajar orebody in the specific geologic horizons mentioned above.

(2) Geophysical Prospecting

1) By detecting the Hajar ore deposit as a low resistivity and strong IP zone, IP method has proved to be an effective technique for the exploration in this area.

2) The same low resistivity and strong IP anomalies were detected in the Lamrah and Frizem areas.

3) Several high gravity anomaly zones were detected and density cross sections were analyzed by the gravity method.

4) The gravity high anomaly zone seemed to be corresponding to high

resistivity and week IP area. It is difficult to expect large scale massive ore deposit but the possibility of disseminated ore deposit remains.

5) At the low resistivity and strong IP anomaly area found in Lamrah, no gravity anomalies were found. Inasmuch as the CSAMT low resistivity anomaly and Magnetic anomalies were found in this area, the possibility of disseminated ore deposit exists.

6) High resistivity and strong IP anomaly zone was found at Frizem FZ-1. The possibility of the ore deposit other than Hajar type exists.

5-2 Recommendation for the Third Phase Survey

From the results of the Second Phase Survey, several recommendations are posted for the Third Phase Survey as follows:

1) Detailed IP survey in the Frizem area to find out the structure and extension of the low resistivity and strong IP anomaly zone.

2) IP survey at the northern part of the line connecting the Hajar mine, Akhlij, and Lamrah, where Hajar horizon is concealed below the surface. (The Second Phase IP survey was carried out in the area where the Hajar horizon was exposed on the surface.)

3) Drilling exploration for the low resistivity and strong IP anomaly zones in Frizem and Lamrah.

PARTICULARS

PART I

GEOLOGICAL AND GEOCHEMICAL SURVEY

CHAPTER 1 OUTLINE OF THE SURVEY WORK

1-1 Field Work

The surveyed area is widely covered by Quarternary sediments and exposures of the basement rocks on the surface are sporadic. It is difficult in this area to distinguish original rock types of the basement rocks because they were metamorphosed to schist and semischist. In addition, the geological structure of the basement rocks is very complicated through the influence of intense dynamic movement.

Considering the above mentioned condition, the geological and geochemical survey route, 230km in total length, was set up so as to cover all important outcrops of the basement rocks. Geological mapping was carried out using the topographical maps of the scale of 1 to 5,000 prepared by BRPM. In the mapping, careful attention was paid to the distinction of petrological characteristics, the observation of schistosity and bedding plane, the confirmation of faults and folding structure, and the inquiring of the relation between stratigraphic succession and mineralization.

About 40 samples of rocks and ores were collected for laboratory test and examinations and total 282 samples of rocks and gossans were collected for the geochemical exploration.

In the Eastern Area, a check survey of the drift and drilling core in the Hajar mine was performed in order to study the relationship of orebody and host rock. In the Western Area, a field check survey outside of the area was performed in order to clarify the details of stratigraphic successions.

The base camp for the survey was kept at the city of Marrakesh and jeeps were used for the transportation to and from the surveyed area. The period of the field survey was 57 days from September 17, 1988 to November 13, 1988.

The details of the field survey classified by areas are as follows:

	The Eastern Area (Hajar-Amzourh Area)	The Western Area (Frizem Area)
Surveyed area (km^2)	34	12
Surveyed rout (km^2)	170	60
Geochemical samples (pcs)	207	75

1-2 Laboratory Work

Total 282 pieces of geochemical samples and total 10 pieces of whole rock samples were analyzed at the Chemex Labs Ltd. in Canada. Total 4 isotopic dating samples were analyzed at the Teledyne Isotopes in USA by K-Ar method. Preparation and microscopic observation of thin sections of 20 rock samples and polished sections of 10 ore samples, as well as X-ray diffraction test for 20 samples and chemical analysis of 10 ore samples were carried out in Japan.

CHAPTER 2 GEOLOGY AND ORE DEPOSIT

2-1 The Eastern Area (Hajar-Amzourh Area)

The Eastern (Hajar-Amzourh) Area is located in the southeastern part of the Haouz Central Area. The area is approximately 100 km^2 (Fig. I-1, Fig. I-2, Fig. I-3, Fig. I-5).

The exposure of the basement rock is sporadic in this area, which is represented by Imarine-Hajar Block, Akhlij Block, Oukhribane Block, Amzourh Block and Cavagnac Block. At the southeastern end of this area, the Hajar ore deposit is recognized.

2-1-1 Stratigraphy (Fig. I-6, Fig. I-7)

The basement rocks of the Hajar-Amzourh Area are correlated to Permian-Carboniferous systems, and are composed mainly of schist and semi-

Age	Rock			Thickness (m)
Quaternary ~ Neogene	Alluvium, diluvium		(Q)	0 ~ + 120
	Calcareous-silty semischist		(IIc)	+ 400
	Pelitic semischist		(IIp2)	± 900
Paleozoic	Alternation of limestone and mudstone		(IIal)	100 ~ 400
Permian	Acidic volcanic rock	Hajar	(IIap)	0 ~ 100
~	Pelitic schist	Hz	(IIap)	± 100
Carboniferous	Alternation of sandstone and mudstone		(IIas)	0 ~ 200
	Acidic volcanic and pyroclastic rock		(IIat)	0 +200
	Fine alternation of tuff and calcareous siltstone		(IIaa)	0 ~ 250
	Pelitic schist		(IIpl)	+500

schist originated from calcareous pelitic rocks. The stratigraphy of the beds in this area is as follows. The general trend of the beds if NW-SE, and the upper succession is distributed in the northeast. The Hajar horizon is impregnated with acidic volcanic and pyroclastic rocks.

(1) Pelitic Schist (IIpl)

The pelitic schist stratigraphically occupies the lowest portion of the basement found in the Eastern Area, and is correlated to the uppermost beds in the Western Area. This pelitic schist is distributed in the Cavagnac Block and in the southwestern part of the Amzourh Block.

The beds are constituted by dark grey slaty pelitic schist, with some inserted marl, siltstone and limestone layers. On the surface, they often show themselves in greenish grey to pale grey color. The main constituent minerals are chlorite, sericite and quartz.

The schistosity of the beds is in WNW-ESE direction, and the dip is 70 degrees to the north. The bedding planes are disturbed by the schistosity but it is estimated that the strike of the bedding is NW-SE with the dip of 30°-60° as a whole trend. The thickness of this pelitic schist is more than 500 m in this area.

(2) Fine Alternation of Tuff and Calcareous Siltstone (IIaa)

This alternation bed is distributed in the Oukhribane Block. This alternation is characterized by the fine alternation of dark green layers and greyish white layers of the thickness of 1 to 10 cm. The dark green layers are composed mainly of chlorite and are thought to have been originated from tuff. The greyish white layers are silty and cherty, but in places calcareous. In some part of the alternation, there are abundant siliceous nodules. The diameter of the nodules is usually 10 to 20 cm. The lowermost part of this alternation is marly and contains silty pebbles, the diameter of which is usually less than 10 cm.

As a whole this alternation is disseminated with hematite, and the surface exposure looks dark brown in color. The strike of the beds in this alternation is NW-SE and the dip is 30° - 40° NE. The thickness of this alternation is approximately 250 m. In the Amzourh Block in the western part the distribution of this alternation, the exposure is limited and the thickness is rather thin. The alternation is thought to have been developed in the vicinity of submarine activity, related to it.

(3) Acidic Volcanic and Pyroclastic Rock (IIat)

This acidic volcanic and pyroclastic rock is recognized to be the host rock of the Hajar ore deposit. It is distributed in thick beds, underlying the ore deposit. The rock is what is called green rock. By the results of the drill core logging or by the observation in the underground, the rock is dark green, fine grained, homogeneous and slaty as a whole, with very fine foliation. In places, white phenocrysts of 1 to 2 mm in diameter are recognized. Under microscope, the rock is composed mainly of chlorite, biotite sericite and quartz. They are recognized to be distributed to form banding structure. The white phenocrysts are completely replaced by the aggregate of very fine quartz. The green rock which contains white phenocrysts is thought to have been originated from volcanic rocks or pyroclastic rocks, while that without the white phenocrysts is thought to have been originated from tuff. The former is found mainly in the lower portion of this unit, and the latter is recognized distributed in the upper portion of it. In the green rock, network veinlets composed mainly of pyrite, pyrrhotite and quarts are remarkably developed.

A tuff correlated to the green tuff hosting the Hajar ore deposit is distributed in the northeastern part of the Oukhribane Block. Gossan-quarts networks are developed in this rock at the points 0.,4 km and 1.0 km northwest of Oukhribane. Mineralization and alternation such as silicification and argillization are recognized associated with them. The extension of this rock toward the west has not been confirmed. The thickness is estimated to be 0 m to over 200 m. The K-Ar isotopic age of this rock is 297 ± 15 Ma (Tab. I-15).

(4) Alternation of Sandstone and Mudstone (IIas)

The alternation bed of sandstone and mudstone is distributed in the northeastern part of the Oukhribane Block and in the northern part of the Amzourh Block. The thickness of the respective layers composing the alternation is usually 10 to 60 cm and the proportion of the sandstone against the whole is approximately 50 to 60%. The sandstone is pale grey, fine grained and siliceous. Very fine bands showing grading structure are well developed in this sandstone. In some places complicated interformational folding is developed. The mudstone is tuffaceous.

This alternation is disseminated by iron sulphide minerals as a whole, and the surface exposure looks dark brown in color. The general trend of the alternation is NW-SE with the dip to the northeast, though the dipping angle varies from 0° - 90° or even reverses in some places. In the Amzourh Block, drag folds and parallel-to-schistosity faults are well developed and this alternation forms imbricate structure. The thickness of this alternation is about 200 m at the largest, and the thickness decreases toward the west where the lithological character of this formation varies to silty phases.

(5) Pelitic Schist (IIap)

Overlying the above alternation of sandstone and mudstone, the pelitic schist is distributed. The pelitic schist found in the Oukhribane Block and in the Amzourh Block is dark grey to dark green in color and tuffaceous to some extent. The thickness is less than 100 m.

(6) Acidic Volcanic Rock (IIav)

The acidic volcanic rock is recognized to form distinct homoclinal syncline with the overlying limestone-mudstone alternation in the southern part of the Amzourh Block. The bearing of the syncline axes is N40° W and the inclination of the axis planes is 70° - 80° NE. The plunge of the axes is in northeast direction. This thickness of this acidic volcanic rock is as much as 100 m but this formation can be traced more than 2.5 km in distance. Small exposure of this formation is recognized at the west end of the Akhlij Block.

By the observation of the fresh part of this rock, it is dark grey and has porphyritic texture with the phenocrysts of feldspar (5 mm in diameter at the largest). The surface exposure of the rock looks pale grey to dark brown and the schistosity due to the metamorphism to form crystalline schist is well recognized. The relation of this formation with the overlying and underlying formations is not simple, as the physical form and the thickness of this formation varies so much, but it can be said that the relation is conformity as a whole.

Under microscope, this rock has phenocrysts of plagioclase, K-feldspar and quartz, which are observed to have been replaced by such secondary minerals as montmorillonite, biotite and calcite. The K-Ar isotopic age is 294 ~ 303 ± 15 Ma (Tab. I-15).

(7) Alternation of Limestone and Mudstone (IIa1)

Overlying the acidic volcanic rocks in the Amzourh Block, the alternation of limestone and mudstone is well developed. The limestone is grey and crystalline, having the thickness of 10 to 40 cm. This alternation is seen to form homoclinal syncline with the underlying acidic volcanic rocks and its apparent thickness is more than 200 m.

The northwestern extension of this formation is recognized to expose at the small outcrop about 2 km northwest of the Amzourh Block, and the total thickness in this area is estimated to be more than 500 m. As a part of the eastern extension, there is a small exposure of this alternation at the west end of the Akhlij Block. At the Hajar mine, a limestone layer is recognized in the pelitic schist overlying the ore deposit (1 m in thickness about 10 m above the ore deposit).

(8) Pelitic Semischist (IIp2)

The pelitic semischist is distributed in the Akhlij Block, above the Hajar ore deposit, at the lower portion of the Imarine-Hajar Block and at a small outcrop south of it.

By the observation of the fresh rock of this formation, the rock is dark grey in color and relatively massive, but on the surface the rock easily becomes soft and weak, where it shows pale green or pale grey color with distinct schistosity. This formation is pelitic as a whole, but in some places it is silty or marly and has insertion of limestone layers. In this pelitic semischist, barite veins and siderite veins in addition to quartz veins are recognized.

Schistosity faults and drag folds are complicatedly developed in this formation. The general trend of the pelitic semischist is estimated to be NW-SE, with the shallow dip to the northeast. This thickness of the formation is approximately 900 m, estimated from the general geological structure in this area, though the estimation is fairly difficult due to sporadic exposure of this formation.

(9) Calcareous-Silty Semischist (IIc)

Calcareous-silty semischist is exposed on the Imarine-Hajar Block in the largest scale in the Eastern Area. The outcrop is divided to parallel two mountain rows extended about 8 km in NW-SE direction with width about 2 km.

There observed two types of rock faces, a massive one and a banded one. The fresh part of this rock shows black to dark grey color, while at the surface of the outcrops it changes to dark brownish. The schistosity is N 60° W dipping steeply to the northeast. The bedding structure is gentle as a whole in the repetition of synclines and anticlines with the axises of NW-SE direction and in the northeastern parts it dips 30° to 40°degree to the northeast.

Geostructurally this semischist comprises the uppermost part of the basement rocks in the survey area. The thickness of the formation is estimated to be more than 400 m.

By the microscopic observation, detrital material represented by quartz are cemented with carbonate minerals in this semischist.

(10) Alluvium and Diluvium (Q)

Approximately 80% of the Eastern Area is covered with the Neogene and Quarternary sediments. There sediments are mainly composed of terrestrial conglomeratic sandstone, most of which are estimated to be flood sediments. The thickness reaches over 120 m.

2-1-2 Intrusive Rocks

In the Hajar-Amzourh Area, the sheet rhyolite in the Cavagnac Block and the pipe-dyke rhyolite in the Akhlij Block are recognized to be the intrusive rocks belonging to the igneous activities prior to the metamorphism in this area. As the intrusive rocks intruded after the metamorphism, dacite breccia dyke, andesite dykes and pipe rhyolite are found in the Imarine-Hajar Block.

(1) Sheet Rhyolite

The sheet rhyolite is found to have intruded into the pelitic schist at around the Cavagnac dam-site. The rock looks grey in color and has phenocrysts of quarts and plagioclase. Pyrrhotite-quartz veins are associated. It takes sheet-like form and has been affected by the metamorphism to form schist. The width of the rock body is about 200 m and the extension is more than 1.5 km. It is thought that rock represents a root of the acidic volcanic rock distributed in the Amzourh Block.

(2) Pipe-Dyke Rhyolite

The pipe-dyke rhyolite is recognized to have intruded sporadically into the pelitic schist, with the sizes of 10 m x 100 m at the largest, in the Akhlij Block. The rock, greyish white in color, is remarkably siliceous and crystalline, containing secondary biotite. Overlying this rock, a bed with abundant thin limestone layers is recognized, which shows the probability that this pipe-dyke rhyolite is an eastern extension of the acidic volcanic rocks found in the Amzourh Block.

Under microscope, this rock has porphyritic texture, with the phenocrysts mainly of plagioclase. The matrix is composed of quartz, plagioclase and K-feldspar. secondary minerals such as sericite, calcite and chlorite are recognized.

(3) Dacite Breccia Dyke

The dacite breccia dyke is found as a sheet breccia dyke intruded into the calcareous-silty semischist, parallel to the schistosity, found at about 1 km west-northwest of Hajar. Four dykes are recognized, with the width of 1 to 2 m, extending more than 1 km in the direction or WNW-ESE.

The rock contains abundant breccias, and usually more than 50% of the mass is occupied by the breccias. The breccias are mainly silty or pelitic schist and the diameter is 30 cm at the largest. The matrix is dacitic rock and in some places chilled margin is recognized.

(4) Andesite Dykes

The andesite dykes are found crosscutting the Imarine Hajar Block at a point about 3 km west of Hajar. The trend of the dykes is NNE-SSW, which is almost perpendicular to the schistosity. Total three dykes have been found. The width is 2 to 8 m, and the extension is more than 1 km.

(5) Pipe Phyolite

The pipe rhyolite is recognized to have intruded into the calcareous silty semischist at about 1.2 km east-south-east and at about 1.0 km north of Hajar. The form of the intrusion is circular. The diameter of the former is 1.5 km, and that of the latter is 1.0 km.

The rock is leucocratic and silliceous, with network of quartz veins. By the observation under microscope, this rock contains phenocrysts of quartz about 1 mm in diameter. The matrix is composed of quartz and plagioclase as fine as under 2 mm, associated with the secondary minerals such as sericite and chlorite.

2-1-3 Geological Structure

The geological structure in the Hajar-Amzourh Area has been formed under the influence of the schistosity of the trend of WNW-ESE and the inclination of 60° - 80° to the northeast. The schistosity accompanies schistosity faults and drag folds, which has disturbed the geological structure. The degree of the disturbance is small in the upper portion of the succession and heavier in the lower portion of it (Fig. I-9, Fig. I-10).

The geological structure of the Imarine-Hajar Block, where the layers belonging to the uppermost portion of the succession are distributed, is monoclinal to the northeast with the repetition of gentle wavy folds as a whole, but in the vicinity of the schistosity faults, drag fold are well developed with steep angles.

In the Akhlij Block and Oukhribane Block, though more intense drag folds are developed, still monoclinal structure dipping to the northeast is predominant as a whole. In the Amzourh Block, steeply folding homoclinal synclines are well developed in the southern part, while imbricate structure is recognized to have been formed by the numerous schistosity faults and drag folds in the northern part.

2-1-4 Ore Deposit

The mineral indications in the Eastern Area are centralized in the Hajar horizon in which the Hajar ore deposit is representative one.

(1) Hajar Ore Deposit

For the Hajar ore deposit, after the surface drilling and the shaft sinking by BRPM were completed, CMG is now carrying out detailed exploration works by tunnel driving. The excavation levels are -225 m level and -195 m level. the tunnel of the -235 level is crosscutting the center of the orebody. By the observation of the orebody along the wall of the tunnel, the occurrence of the orebody is as follows (Fig. I-15).

1) The orebody is emplaced in the green rock, and it is classified into two types, bedded orebody and vein-type orebody. The green rock is dark grey in color and rather slaty, but as white phenocrysts are recognized in places, it is thought that the green rock has been originated from tuffaceous rock and volcanic pyroclastic rocks. The trend of the schistosity is approximately N40°E and the dip is 60° to 70° ME. However, it is thought that the bedding plane is represented by the fine foliation structure recognized at the point about 40 m from the shaft, which shows the strike of N45°W and the dip of 35°NE.

2) The bedded orebody is emplaced in the uppermost portion of the green rock and is divided into two layers. Pyrrhotite is abundant in both of them. In the upper orebody, galena and sphalerite are concentrated. The lower orebody contains comparatively rich chalcopyrite. The part between the upper orebody and the lower one contains disseminated ore developed in the silicified rock. The assay result of the samples col-

lected continuously along one side of the tunnel wall is shown as follows:

	Depth of Drift (m)	Width (m)	Pb (%)	Zn (%)	Cu (%)	Ag g/t	Fe (%)
Bedded Ore	212-222	10	4.50	8.25	0.14	112	11.5
Bedded Ore	192-212	20	9.83	19.39	0.23	209	35.3
Dissem. Ore	177-192	15	1.78	3.10	0.13	29	7.8
Bedded Ore	145-177	32	2.31	8.33	0.58	36	31.9
Network	121-131	10	0.15	0.08	0.53	4	8.6
Vein	67- 73	6	0.58	4.12	0.40	6	28.8

(data by BRPM)

3) The vein-type orebody is emplaced below the bedded orebody. Silicified rock is recognized along the bottom (between 145 m and 106 m) of the lower bedded orebody, where network veins are developed. Below this silicified rock with the network veins (between 106 m and 0 m), there are ore veins in the green rock. These ore veins are composed mainly of pyrrhotite and quartz, associated with sphalerite, chalcopyrite and pyrite. The width of the ore veins is usually under 1 m, though it is over 6 m at the largest.

4) The pelitic rock overlies the upper bedded orebody, bounded by a schistosity fault (215 m) of the direction of N45°W. This pelitic rock has an inserted layer of limestone (width 1 m). The strike varies from N10°W to N80°W and the dip from 40° to 70° NE. No mineralization has ever been recognized in the pelitic rock overlying the orebody, which suggests that the ore deposit would be sedimentary ore deposit.

5) By the microscopic observation of the polish sections (No.910, No.913, No.915), the ores of the Hajar deposit consist mainly of sphale-

rite, galena and pyrrhotite associated with subordinate amounts of chalcopyrite, pyrite and marcasite. Sphalerite and pyrrhotite are of euhedral grains. Galena is of subhedral to anhedral grains filling interstices between sphalerite and pyrrhotite. Chalcopyrite is of subhedral grains filling interstices of sphalerite and coexisting with pyrite. Pyrite is of euhedral and subhedral grains filling interstices of sphalerite. Marcasite replaces a part of pyrite especially the margine of the grains. As for the sequence of crystalization, it is considered that sphalerite and pyrrhotite have crystallized in the early stage and galena, chalcopyrite and pyrite have crystallized in the later stage.

6) The green rock is composed mainly of chlorite and quartz associated with sericite and biotite. The alterations related to the mineralization are silicification, argillization, chloritization and sericitization.

(2) Tiferouine Magnetic Anomaly

Tiferouine is located about 5 km southwest of the Hajar ore deposit, and a remarkable bipole magnetic anomaly, remarkable next to that at Hajar, has been detected in Tiferouine. In this magnetic anomaly area, BRPM carried out three holes of surface drilling totalling 1,313 m.

By the result of the drilling, it has turned out that the Quarternary sediments are there down to the depth of 80 m, where the underlying basement appears. The basement is composed mainly of chlorite schist with inserted limestone layers. Small indications of mineralization are recognized in the form of dissemination and veinlets of pyrrhotite, pyrite, magnetite and chalcopyrite.

It is thought that these indications of mineralization were emplaced in the lower horizon than Hajar horizon in the surrounding area of the Hajar ore deposit.

(3) Oukhribane-East Mineralization zone (Fig. I-16)

This mineralization zone is located about 0.4 km west of Oukhribane. Remarkable indications of mineralization, which occur in the green rock, are found within a distance of 70 meters in east and west direction. Predominant alteration is siliciffication and argillization. Hematite-quartz network associated with numerous gossans has been developed. The width of the quartz veinlets is usually less than 10 cm, and their direction is dominantly N80°W and N70°W. Gossan-quartz veinlets contain some amount of copper and zinc but the grade is only as much as Cu 0.4% and Zn 0.1%.

The assay result of the mineralized veinlets and gossans is as follows:

Sample No.	Intv. (m)	Cu	Pb	Zn	Ag	
634	0.05	1800	1	890	0.1	(vein)
635	0.10	356	5	1000	0.5	(vein)
636	0.10	3350	94	160	9.5	(vein)
637	3.50	29	1	180	0.1	(network)
638	0.10	270	1	310	0.1	(host rock)
639	0.10	166	14	410	0.1	(host rock)

(unit=ppm)

This network contains Cu, Zn and Fe minerals and is thought to reflect the condition of the mineralization beneath the high grade bedded ore deposit. It is thought that the bedded ore deposit supposed to overly the network would have been eroded out already or would lie at the depth in the northeast.

(4) **Oukhribane-West Mineralization Zone** (Fig. I-17)

This mineralization zone is located about 1.0 km northwest of Oukhribane. The size of the mineralization and alteration zone is 30 m x 40 m. The zone is controlled by the quartz veins trending N70°E and N60°W, and has gentle inclination to the east as a whole. The main ore minerals are hematite and goethite associated with chalcopyrite and sphalerite in small grains on rare occasion. The host rock of this mineralization zone is the green rock with the foliation shown mainly by sericite, biotite and quartz (No. 336, Phase I). This host rock is thought to have been originated from tuffaceous rock. The assay result of the gossans is as follows:

Sample No.	Intv. (m)	Cu	Pb	Zn	Ag	
640	6.0	448	1	73	0.1	(network)
641	1.0	140	1	160	0.1	(hostrock)
642	6.2	980	1	134	0.5	(network)
643	7.0	480	1	61	0.2	(network)
644	1.0	171	1	128	0.1	(hostrock)

(unit=ppm)

This mineralization zone is represented by the dissemination zone controlled by the quartz veins which contain comparatively high amount of Cu and Zn minerals. This fact shows the characteristics of the mineralization in the surrounding area of the mineralized center. The center is estimated to be located in the east of it.

(5) **Akhlij Mineralization Zone**

For the slight magnetic anomaly detected about 200 m west of Akhlij located about 3 km west of the Hajar mine, BRPM carried out one hole of drilling to the depth of 417 m, and caught an indication of lead-zinc mineralization at the approximate depth of 300 m. The mineralization is recognized along the core of 3 meters in length, where sphalerite, galena and pyrrhotite are disseminated layer by layer. The average grade assayed of the whole 3 m core is to be Zn 0.6%, Pb 0.2%, Cu 0.01% and Ag 7g/t. The mineralized part is overlain by siliceous silt and underlain by tuffaceous rock. Viewing from the facts that the mineralized part is stratigraphically situated above the tuffaceous rock and that the mineralization contains mainly Pb-Zn minerals, it is thought that subsurface bedded ore deposit would be expected in this area.

(6) Amzourh Magnetic Anomaly

In the Amzourh area, the acidic volcanic rock layer is distributed in the form of syncline, underlying the bed of the alternation of limestone and mudstone. This volcanic rock layer is distributed in the form of syncline, underlying the bed of the alternation of limestone and mudstone. This volcanic rock bears magnetite-quartz veinlets and is discontinuously gossaneous on the surface. For the small magnetic anomaly detected in this area, 2 holes of drilling, total length of which is 551 m, was carried out by BRPM. However, favorable mineralization was not caught by the drilling, although the acidic volcanic rock was recognized underlying the limestone. It is thought that the acidic volcanic rock layer would represent the volcanic activity at the last stage of the mineralization. The assay result of the gossan samples in this area is as follows:

Sample No.	Intv. (m)	Cu (%)	Pb (%)	Zn (%)	Ag (g/t)
778	1.0	0.31	1.04	1.37	20
928	1.0	0.50	0.30	0.77	4
311	0.4	0.01	0.01	0.19	0.4
314	0.2	0.44	0.84	0.03	2.4

(unit=ppm)

The outcrops of gossan are usually small scale formed in fault fracture. Main ore minerals are hematite and geothite associated with fine grains of chalcopyrite.

2-2 The Western Area (Frizem Area)

The Western (Frizem) Area is located in the southwest part of the Haouz Central area, composing a part of the Geumassa Block. The area is 12 km^2. (Fig. I-1, Fig. I-4, Fig. I-5)

2-2-1 Stratigraphy (Fig. I-6, Fig. I-8)

In the Frizem Area, the schist of calcareous mudstone origin is predominantly distributed, which is thought occupy rather lower portion of the schist and semischist succession developing in the Hajar-Amzourh Area. The geological stratigraphy in this area is as shown below, including that in the surrounding area. The general trend of the formations is NNW-SSE and the further in the eastnortheast, the upper beds are distributed. *The Frizem horizon is composed of acidic volcanic* rock.

Age	Rock			Thickness (m)
Quanternary ∿ Neogene	Alluvium, diluvium		(Q)	0 ∿ 10
	Pelitic schist		(Ip)	+1,000
	Marly schist and pelitic schist		(Imp)	± 250
Paleozoic	Alternation of sandstone and mudstone		(Ism)	± 70
Permian	Marly schist with limestone thin bed		(Isl)	± 700
?	Alternation of siltstone and mudstone		(Ipm)	100 ∿ 300
Carboniferous	Marly schist		(Ic)	± 500
	Acidic volcanics	Frizem Hz	(Ivv Ivt)	0 ∿ 200
	Psammitic-pelitic schist		(Ips)	+1,000

(1) Psammitic-Pelitic Schist (Ips)

The rocks belonging to this formation are distributed in the area west of Frizem and regarded stratigraphically as the lowest formation in the Haouz Area. The main constituent minerals of this rock are sericite, chlorite, quartz and plagioclase. The rock is grey in color, but in silty parts where content ratio of sericite and quartz increases, it is pale grey. The schistosity is NNW-SSE, dipping 40° to 80° to the east. The thickness of this formation is more than 1,000 m. Numerous veins of quartz and carbonate minerals are well developed parallel to the schistosity, parts of them are gossaneous.

(2) Acidic Volcanics (Ivv, Ivt)

The acidic volcanics are distributed around Frizem in two layers with the apparent width of 0.8 km at the largest, overlying the psammitic-pelitic schist. The sizes of the formation decreases toward the north and increases toward the south where it is covered with the Quarternary sediments. The acidic volcanics show very irregular form, which is thought to be formed by the influence of the dynamic metamorphism and distortion after sedimentation, in addition to the reason coming from the comparatively gentle inclination of the formation (20° - 30°E).

The rock is pale grey to dark brown in color. It is composed of the lava phase (Ivv) where the rock is comparatively massive and shows porphyritic texture of quartz and plagioclase and the tuff phase (Ivt) where foliation structure is developed. The K-Ar isotopic age of this rock is 328 ± 16 Ma (Tab. I-5).

(3) Marly Schist (Ic)

The marly schist is distributed in the north of Frizem. The fresh part of this rock is dark grey in color while it looks pale grey on the surface. Where the rock is weathered, there occurs white clay composed mainly of calcareous ingredient. The constituent minerals of this marly schist are clacite, sericite, chlorite, quartz and plagioclase.

Many schistosity faults are developed in this rock with several ten meters' spacing (trend is NNW-SSE, dip is 40° - 30°E). The schistosity faults are filled with carbonate-quartz veins usually of the width of 1 m around. In the marly schist divided into numerous blocks by the schistosity faults, very complicated drag folds are developed. In some places microfolds of the size of several 10 cm are recognized.

The general trend of this marly schist is inferred to be NNW-SSE with the dip of 20° - 30°E, taken as parallel to the general trend of the schistosity. The apparent width of the rock in the area of its distribution is approximately 1,000 m, but the real thickness is estimated to be less than 500 m.

(4) Alternation of Siltstone and Mudstone (Ipm)

The alternation of siltstone and mudstone is distributed in the northeast of Frizem, forming a band. The width of the band is 200 to 600 m. The siltstone is pale grey in color and composed mainly of fine or coarse quartz grains. The width of alternation varies from 5 cm to 80 cm, the average of which is about 30 cm. The strike of the bedding planes is NW-SE and the dip is 20° - 60°NE. The relation of this alternation to the overlying and underlying formations is mostly fault, though in some places comformable relation is recognized. The siltstone contained in this alternation becomes calcareous in the western extension. The thickness of this alternation is estimated to be 100 to 300 m.

(5) Marly Schist with Limestone Thin Beds (Iml)

This marly schist with limestone thin beds is distributed from the north of Frizem toward the east down to Mkhalif. The limestone thin beds are usually 5 - 40 cm in thickness and the marly layers or pelitic part is 20 cm - 2 m. The limestone is grey in color and crystalline, but where weathered, it looks brown.

The schistosity of the formation is NW-SE, with the dip of 60° - 70° NE. This formation is also divided into numerous blocks by the schistosity faults which develops with several 10 cm spacing, and drag folds peculiar to each blocks are recognized. The apparent width of the rock in the area of its distribution is approximately 1,400 m, but the real thickness is estimated to be 700 m, more or less.

(6) Alternation of Sandstone and Mudstone (Ism)

The alternation of sandstone and mudstone is distributed about 3 km northeast of Frizem, in a narrow band occupying topographically high hills, in the direction of NW-SE. The apparent width is 100 m, but the real thickness is about 60 m. The extension of distribution is over 6 km.

The sandstone in this alternation is medium grained and siliceous. The thickness of a single sandstone bed is 20 - 80 cm while that of the mudstone is 10 - 60 cm. This alternation is lithologically the most competent of all the rocks distributed in this area, and as it is the rock least affected by alteration and deformation, it makes itself a keybed most useful for the analysis of geology and stratigraphy in this area.

In spite of the fact that this alternation is the most competent and least affected by deformation in this area, complicated drag folds are there developed with the acute angles of V-shape folding. Due to such overfold, the strike and dip of the bedding in this formation varies greatly, but the general trend is estimated to be NW-SE, with the dip of 20° - 40° NE. The relation of this alternation to the overlying and underlying formations is usually fault.

(7) Marly Schist and Pelitic Schist (Imp)

The marly schist and pelitic schist is distributed with the apparent width of more or less 500 m in the northeastern side of the alternation of sandstone and mudstone. On the surface, the marly schist is white in color while the pelitic schist looks dark grey. The width of the alternation of these schists is several 10 meters. The real thickness of this formation is estimated to be approximately 250 m.

(8) Pwlitic Schist (Ip)

The pelitic schist is distributed in wide area to the northeast of Frizem. This schist is dark grey or black in color and intercalated occasionally with thick beds of limestone. Total thickness of this formation is estimated to be more than 1,000 m.

(9) Alluvium and Diluvium (Q)

The basement rocks are covered by Alluvium and Diluvium in the northwestern and southern parts of the Frizem Area.

2-2-2 Intrusive Rocks

In the Frizem Area, several dolerite dykes are found along the schistosity faults developed in the marly schist to the north of Frizem. The width of dyke is varied from 1 m to 10 m. This rock is dark grey