KINGDOM OF MOROCCO

REPORT ON GEOLOGICAL SURVEY OF THE ANTI ATLAS AREA

PHASE III

(VOL. III)

September 1977

METAL MINING AGENCY

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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PREFACE

The Government of Japan, in response to the request of the Government of the Kingdom of Morocco, decided to conduct a geological survey for mineral exploration in the Anti-Atlas area of the Kingdom of Morocco, and commissioned its implementation to the Japan International Cooperation Agency.

The Agency, taking into consideration of the importance of technical nature of the survey work, in turn sought the Metal Mining Agency of Japan for its cooperation to accomplish the task within a period of three years.

This year was for the third phase survey, and as for this current year, a survey team was formed consisting of thirteen (13) members headed by Mr. Kensuke Wakabayashi, MESCO, Inc., and sent to the Morocco on February 4, 1977. The team stayed there for sixty four days (64) from February 4, 1977 to April 8, 1977. During the period of its stay, the team, in close collaboration with the Government of the Kingdom of Morocco and its various authorities, was able to complete survey works on schedule.

This report submitted hereby summarized the results of the survey performed for the third-phase survey, and it will be also formed a portion of the final report that will be prepared with regard to the results obtained in the first, the second, and the third phases.

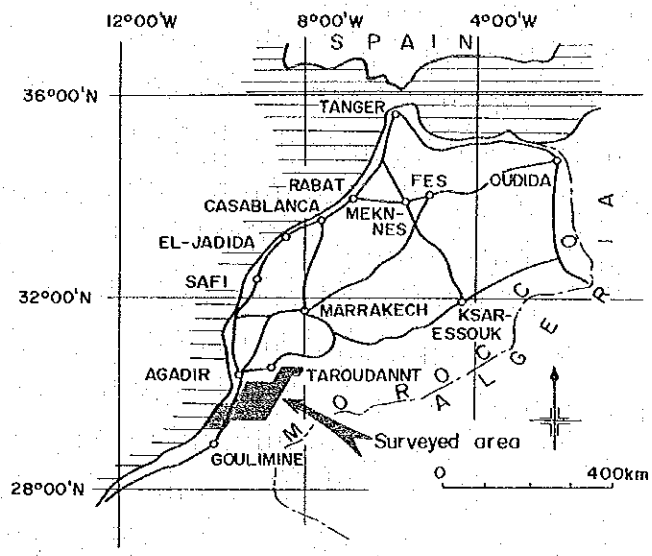
We wish to take this opprtunity to express our heartfelt gratitude to the Government of the Kingdom of Morocco and the other authorities concerned, as well as to these Japanese authorities of Ministry of International Trade and Commerce, Ministry of Foreign Affairs, Embassy in the Kingdom of Morocco, and the others concerned, for thier kind cooperation and support extended to the Japanese survey team.

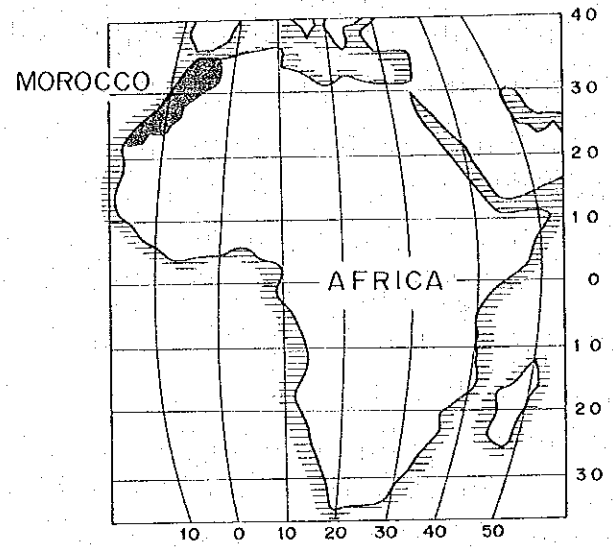
September, 1977

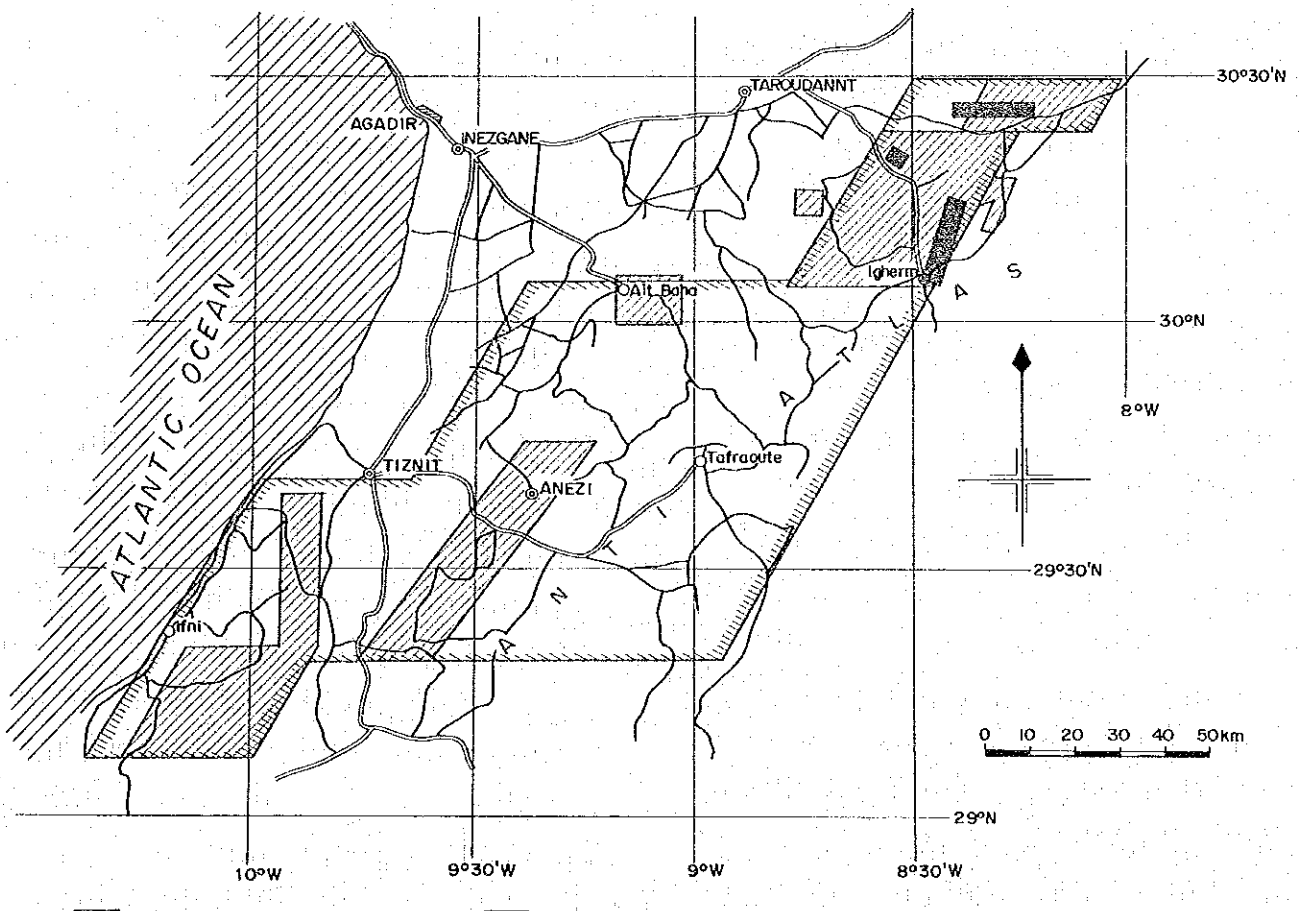
Shinsaku Hogen
President
Japan International Cooperation Agency

Yasuaki Hiratsuka
President
Metal Mining Agency of Japan

Fig. I-1 Distribution map of published reports







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ABSTRACT

The present survey has been performed for the selected areas as most promising in possible existence of ore deposits, being extracted from the initially projected area of about 11,500 km^2 through the survey operations of the first and second year phases in the Anti-Atlas region, the Kingdom of Morocco.

Based upon the recommendations of the report of the second year phase, the present survey consists of;

1. the detailed geological survey for the purpose to establish stratigraphy and accurate relation with igneous activity and geological structure of the surveyed areas of 119.3 km^2, containing the known ore deposits or promising mineralized zones (H Area: Amdouz & I Area: Igherm).
2. the detailed survey on ore deposits for the purpose of getting acquainted with the natures of ore deposits and to select the areas of higher possibility in ore existence (4 areas of 26.6 km^2, J Area: Talat-n-Sous, K Area: Assif Imider, L Area: Tizirt, & M Area: Aniloul).
3. the geochemical survey by rock samples for the purpose to investigate the distribution of metallic elements and their sources (for the entire areas with 2,913 samples collected; elements assayed, Cu, Pb, and Zn).
4. the geophysical survey by IP method to investigate the natures of ore deposits and distribution of concealed ore deposits (in J & K Areas with total length of surveyed lines 62.4 km).
5. the structural boring for the purpose to investigate the natures of FE anomalous zone detected by the IP survey of the second year phase (in Alous Area with the depth of 150 m + 150 m).

Digests of the survey results will be given in the following paragraphs.

[H and J Area]

(1) Geology in these areas is composed of the Pre-Cambrians distributed almost eastwesterly from Amdouz to Talat-n-Sous and of the Infra-Cambrians overlying the former unconformably, distributed in the south and northwest sides of the Pre-Cambrians.

(2) The Pre-Cambrian formations consist of PII-III formation principally consisted of rhyolitic tuffs with association of andesite, sandstone, and shale, and of PIII formation mainly consisted of andesitic conglomerate with intercalation of rhyolite and andesite, being inclined gently to the south as a whole.

The Infra-Cambrian formations form an almost conformable succession of the formations in ascending order of Basal Series consisting of conglomerate, sandstone, and dolomite, Tamjout Dolomite Formation, and Lower Calcareous Series, of which sedimentological environments are indicated by a graduation from meta-stable facies in the lower part to stable facies in the upper part. They form a dome structure with eastwesterly axis passing through near the central part.

(3) There are numerable metallic ore deposits or mineral indications in this district, among which major ones are;

1. copper mineralization in the rhyolites of PII-III and PIII formations.
2. copper mineralization in the Pre-Cambrian formations directly below Basal Series (Talat-n-Sous).
3. copper dissemination in the conglomerates of Basal Series (Amdouz).
4. feeble dissemination of pyrite and malachite in the sandstone of Basal Series.

(4) According to the results of geochemical survey, indicator elements of Cu and Zn showed nearly similar behavior, while Pb showed a slightly different behavior from them. Especially, Cu behavior had a close relation with mineralization in this district, being represented by these anomalies recognized in the rhyolites of PII-III and PIII formations, on the surface of paleotopography of the Pre-Cambrian formations directly below Basal Series, in the conglomerates of Basal Series, near the lower and upper parts of the sandstone of Basal Series, and near the faults and fractured zones.

(5) High FE anomalies from (Rt-1) to (Rt-3) were detected in the sandstone of Basal Series in the western part of J Area as the results of IP survey. They are interpreted to have been derived by existence of pyrite, weak copper mineralization, and alteration minerals in the said layer. An FE anomalous zone (Rt-5) was also detected, stretching eastwesterly in the southeastern part

of the area. Geologically speaking, this anomaly is assumed in the ground directly below Basal Series, and is considered to have been caused either by the andesite of PIII formation containing iron mineral (specularite), copper mineralization concentrated in the fractured zones in the upper part of PIII formation, or copper mineralization in the conglomerate in Basal Series. A very weak FE anomaly was detected around Talat-n-Sous, the known mineral indication, and another small FE anomaly (Rt-4) was detected in the shallow ground of southwestern part of the former. This may be attributed to feeble and small scaled existence of copper sulphides in the surficial parts of PIII formation.

[I, L and M Areas]

(6) Geology of these areas is composed of Pre-Cambrian System (PII, PII-III, and PIII formations), and Infra-Cambrian System consisted of Basal Series, Tamjout Dolomite, and Lower Calcareous Series, overlying the former unconformably.

(7) Forming the basement of this district, PII formation is distributed in Small patches like islands. Being consisted of quartzites, schists, and green stones, limestones, it is characterized by intense metamorphism and folding. PII-III formation is distributed in the eastern half of the district and consists mainly of volcanic conglomerates, intercalating thin layers of sandstone and being intruded by rhyolite dykes. PIII formation occupies western half of the district, and consists of thick layer of sandstone, and lavas and pyroclastics of andesite and rhyolite, overlying the PII-III unconformably.

Basal Series is distributed in the northwestern and southwestern extremities of the district, and consists of conglomerate, sandstone, overlain by the thick succession of calcareous layers of Tamjout Dolomite Formation and Lower Calcareous Series. They, as a whole, form a synclinal structure with northsouthward axis. Among the faults, the Igherm Fault Zone in the northwestern side of the district is prominent in a direction of NE-SW.

(8) Many mineral indications are recognized in this district, but they are all too low graded to be worked out. But the following types of mineralization are recognized, which are considered very important from the point of geology

of ore deposits;

1. copper mineralization in the rhyolite dykes in PII-III and in the conglomerate within the distribution of the PII-III (Tadenst).
2. copper mineralization accompanied by the rhyolite and andesite of PIII formation (Aniloul).
3. bedded copper deposits in the sandstone and siltstone of Basal Series.
4. copper dissemination near the Igherm Fault Zone.

(9) The results of geochemical survey disclosed the behaviors of indicator elements similar to those in H Area. Mineralization in these areas has been shown clearly by the indicator element of Cu to have close relation with the igneous activities of rhyolite and andesite, as Cu anomalies have been detected conforming to the geological results such as rhyolite in L Area and andesite in M Area.

[K Area]

(10) Geology of this area consists of the Pre-Cambrian PIII formation and the Infra-Cambrian Basal Series overlying the former unconformably.

(11) Forming the basement of this area, PIII formation is observed in small exposures in the central and southeastern parts of the area. It consists mainly of andesite and andesitic tuff and a fractured zone of NE-SW system is found near the Assif Imider Ore Deposit in the center.

Basal Series consists mostly of dolomite intercalating marly sandstone and thin layers of conglomerate and sandstone in its lowermost and middle parts respectively. It is nearly flat-lying formation.

(12) Ore deposits and mineral indications are enumerated as below:

1. Vein type deposits of copper existing along the fractured zones in the andesite of PIII formation (Assif Imider).
2. Weak dissemination of copper and pyrite in the conglomerate and sandstone of Basal Series.

The former is now under operation by B.R.P.M., but its downward continuity has been proved only about 60 m. Perhaps this deposit may have been so formed that copper minerals initially contained in the surficial part of PIII formation, weathering zone, had been concentrated in the fractured zone

by meteoric water, and reduced into sulphides by the later hydrothermal solution.

(13) The results of geochemical survey have shown a similar tendency with the 2 areas stated above in the behaviors of indicator elements. Behavior of indicator element of Cu indicated a high anomaly over the Assif Imider Deposit as well as in the parts where copper minerals were not recognized megascopically as the intermediate anomalies detected in the conglomerate and sandstone of Basal Series.

(14) A distinct FE anomaly (Ra-1) was detected corresponding to the known ore deposit as the result of IP survey in this area. Another FE anomaly of similar type was found to continue, getting shallower to the southwest where ore deposit had not been recognized. This may be enough to expect the existence of ore deposits in this part. The strong FE anomaly (Ra-3) detected in the northeastern part of this area, having been analyzed by simulation together with the results of geological survey and geochemical survey, was found to have been caused by weak mineralization of copper and pyrite in the conglomerate and sandstone of Basal Series. On account of this, anticipation of ore existence in deeper ground was made feeble. A high FE anomaly (Ra-2) was detected in the andesite of southeastern part of this area, and anomaly was also detected in the deeper ground of the Assif Imider Deposit. At the present moment, however, any definite conclusion can not be made due to the lack of informations.

(15) The diamond boring in Alous Area was carried out for the purpose to investigate the geological factor of the FE anomaly detected by the IP survey of the second year phase. The hole was located at survey station 62 on the survey line E and aimed at the FE anomalies assumed in the shallow and deep grounds directly below the location. The results showed that the shallow FE anomaly was caused by pyrite dissemination in the sandstone of Basal Series and the deep FE anomaly by dissemination of specularite in the PIII andesite.

The results have shown the necessity of judgement to be composed after careful data nalysis generalized together with the data of geological survey and geochemical survey previously obtained, in handling the FE anomalous values in the IP survey.

(16) Considering from these results of survey, promising areas to be prospected and effective prospecting procedures desired in the future survey will be stated as below:

1. The FE anomalous zone disclosed in the south of J Area, in which a few geological factors are inferable. On account of this, detailed geological survey, geochemical survey, and IP survey (1.5 km x 10 lines) are desired to be practiced in the terrain from the Amdouz Mine in the east to the present area.
2. Along with the works above stated, one drill hole is desired to be carried out for a depth of about 300 m to solve the geological natures of this anomalous zone.
3. One drill hole of about 300 m deep is to be drilled to obtain the geological natures of the FE anomalous zone detected in Basal Series in the west of J Area.
4. The FE anomalous zone in the south of the Assif Imider Ore Deposit in K Area, which shows a possibility to continue to the south of the deposit with another existence of FE anomaly in the deeper ground. On account of this, one hole is desired to be drilled for about 200 m deep for the purpose to investigate its geological natures as well as prospecting ore deposits.
5. The FE anomalous zone and its outer zone in the southeast of K Area, which is assumed to exist in the PIII andesite. As only a part of it has been confirmed, it is desirable to practice the detailed geological survey, geochemical survey, and IP survey for more expanded area.

GENERALS

Chapter 1 Introduction

1-1 Purpose of Survey

The present survey was performed as the operations of the third year phase of geological survey for mineral resources development in the Anti-Atlas region, the Kingdom of Morocco.

The purpose of present survey was to get acquainted with geology and geological structure of the areas extracted through the survey of the second year phase, to select the areas having higher possibility of mineral emplacement through clarifying the geological environments and locations of mineral indications of importance in which emplacement of ore deposits would be anticipated, and to carry out detailed geological survey of the ore deposits and mineralized zones of which importance had been made clear by the surveys of last two years.

1-2 Outline of Operation

The terrains covered by the present survey is about 145.9 km^2 in total, which consists of detailed geological survey in H and I Areas (about 119.3 km^2) and detailed survey of ore deposits in J, K, L, and M Areas (about 26.6 km^2) as shown by Fig. I-2.

Procedures of survey employed were detailed geological survey, detailed survey of ore deposits, geochemical survey, geophysical prospecting (electrical survey by IP method), and diamond boring, which were performed by Japanese survey team with the co-operation of Bureau de Recherches et de Participacions Minieres. The field work required about two months.

1-2-1 Detailed Geological Survey

For the two areas of H and I, in which the known ore deposits and mineralized zones were contained, efforts were taken to extract some hopeful locations through making detailed study on the geological constituents and their distribution, clarifying stratigraphy and geological structure, acquiring the state of emplacement of ore deposits or mineralized zones, and through examining necessary geological environments for the emplacement of ore deposits.

Field works were performed along survey routes spaced at 200 - 500 m interval, and in surveying along each route, efforts were taken to discover mineral indications and to acquire the state of ore emplacement, by paying keen attention on stratigraphy and stratigraphical correlation, variation of rock facies, fractures, paleotopography, sedimentary environment, modes of volcanic activities, etc. Data thus obtained were compiled into geological map with a scale of 1:15,000.

1-2-2 Detailed Survey of Ore Deposits

This detailed survey was performed in the areas of J, K, L, and M, where ore deposits and mineral indications are crowded. The purpose of this survey was to acquire the relation with the known ore deposits and to discover concealed ore deposits, by paying keen attention to the detailed stratigraphy, extension of mineral indications, and relation of mineralized zones with geological structure.

Field works were performed along survey routes layed out at 150 m interval. In surveying along each route, efforts were taken to discover mineral indications and to acquire the environments of ore emplacement, with keen attention to stratigraphy and stratigraphical correlation, variation of rock facies, fractures, sedimentary environment, modes of volcanic activities, etc. Data thus obtained were compiled into geological map with a scale of 1:5,000. In addition, geophysical survey was made along the survey routes layed out in J and K Areas in common with geological survey.

1-2-3 Geochemical Survey

This survey covered the whole targetted areas of present survey, and all the geochemical samples were collected from exposed rocks. The samples were collected as a rule on the routes of detailed geological survey, and they were collected at the interval of 200 - 400 m in the areas of detailed survey, while at 150 - 200 m interval in the areas of detailed survey of ore deposits. Total samples collected amounted to 2,913.

All the geochemical samples were subjected for chemical analysis for three components of Cu, Pb and Zn.

1-2-4 Geophysical Prospecting

The purpose of this work was to obtain the informations about ore emplacement as deep as 300 m below the ground surface in these surveyed areas of J Area (about 10.7 km^2) and K Area (about 3 km^2).

Dipole-Dipole configuration of electrodes was adopted in the field practice, and the survey lines were spaced at 300 m interval, on which the survey stations were spaced at 100 m interval. The field measurements were performed on 17 survey lines of total length of 51.9 km in J Area and on 6 lines of total length of 10.5 km in K Area.

1-2-5 Diamond Boring

This work was performed for the purpose to explore underground structure indicated by the FE anomaly detected by IP survey during the operations of second year phase in Alous district, where detailed geological survey and electrical prospecting had been practiced.

The drilling work was performed by 3 engineers and 18 laborers of B.R.P.M. on 3 shift basis. The hole, one hole only, was drilled to the depth of 150 m as the work of present survey, but the drilling work was succeeded by B.R.P.M. as its own work from the depth of 150 m to 300 m.

1-3 Organization of Survey Team

Japanese members of survey team who partook the field works are listed as follows:

Head of Team	Kensuke Wakabayashi	MESCO, Inc. (Former Mitsui Kinzoku Engineering Service Co., Ltd.)
Field Manager	Terumi Ishikawa	"
Member (Geology)	Yoshinobu Wataya	"
"	Ryohei Ohtsubo	"
"	Masataka Ohuchi	"
"	Atsumu Nonami	"
"	Ikuhiro Hayashi	"

Member (Geophysical Survey) Chief	Fukujiro Miyoshi	MESCO, Inc. (Former Mitsui Kinzoku Engineering Service Co., Ltd.)
"	Akira Egawa	"
"	Eiji Tanaka	"
"	Ryo Kubota	"
"	Katsumi Sera	"
Member (Drilling)	Kazuyasu Sugahara	"

From the Moroccan side, prospectors of B.R.P.M. joined the survey, shifting from time to time, and engineers of B.R.P.M., Messrs. M. Salem and M. Baddisy joined in the field discussion.

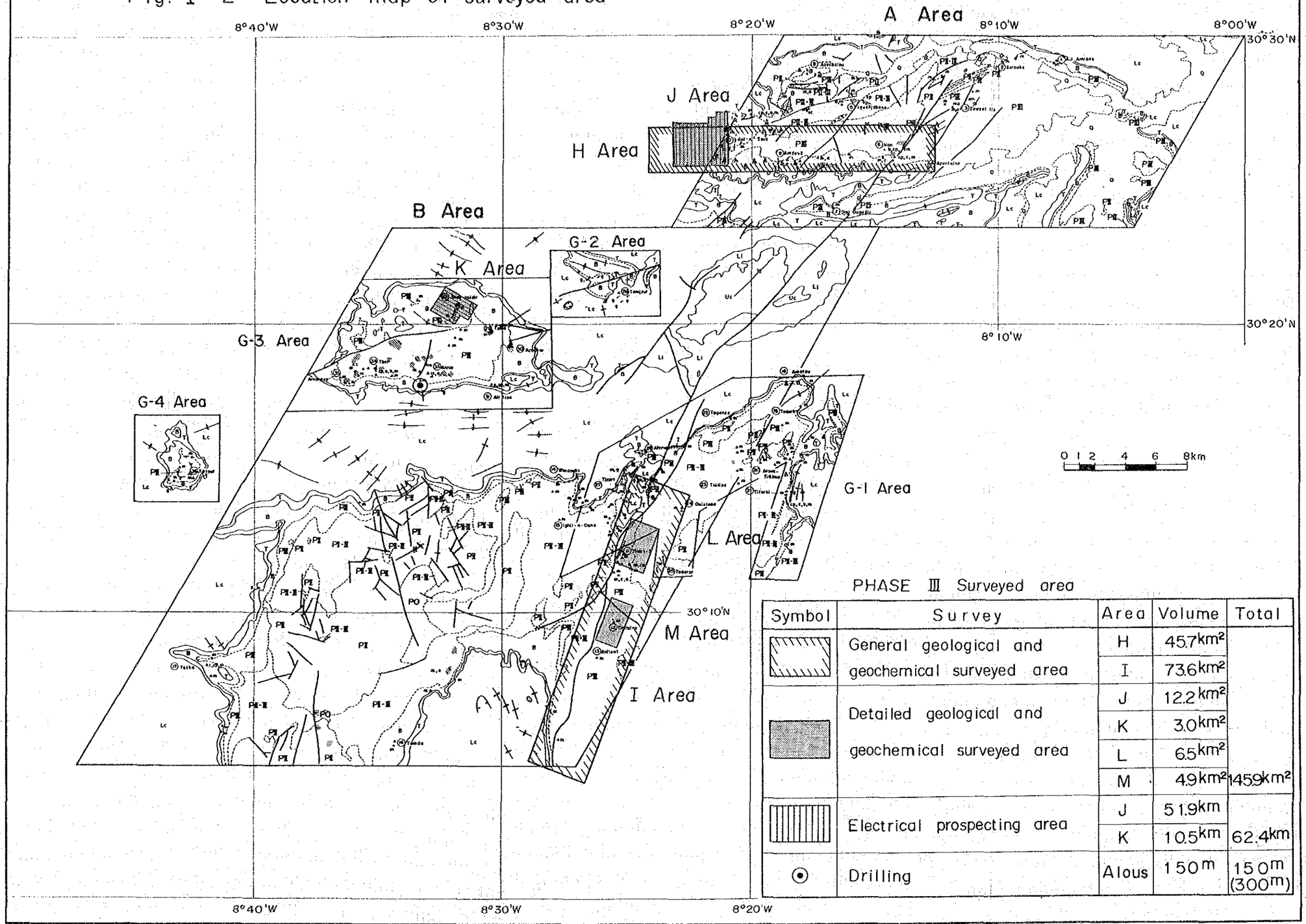
1-4 Literatures

Here are listed the additional literatures to those cited in the reports of the first and second year phases.

(1) J. Caïa (1976) : Paleogeographical and Sedimentological Controls of Copper, Lead and Zinc Mineralization in the Lower Cretaceous Sandstones of Africa, Econ. Geol., Vol.71, p. 409-422.

(2) M. Popescu (1973) : Les mineralisations Cupriferes d'Assif Imider, B.R.P.M., pp.37.

Fig. I－2 Location map of surveyed area



PHASE Ⅲ Surveyed area

Symbol	Survey	Area	Volume	Total
	General geological and geochemical surveyed area	H	45.7km²	145.9km²
		I	73.6km²	
	Detailed geological and geochemical surveyed area	J	12.2km²	
		K	3.0km²	
		L	6.5km²	
		M	4.9km²	
	Electrical prospecting area	J	51.9km	62.4km
		K	10.5km	
⊙	Drilling	Alous	150m	150m (300m)

Chapter 2 General Review

2-1 Geological Survey

The areas of present survey are situated in the northeastern part of the surveyed area of the first year phase, in which the formerly established stratigraphy was followed. In the areas of present survey, there are distributed the formations of PII, PII-III, PIII, Basal Series, and Lower Calcareous Series.

The PII formation is mainly consisted of quartzite, and is in contact with overlying formation with unconformity. The quartzites are scattered in the distributed area of the upper formations like isolated islands with projected topography, which tells that at least some of these quartzites were the land or shallow sea during the time of deposition of the upper formations.

The PII-III formation consists of conglomerate, sandstone, andesitic tuffs and rhyolitic lavas. Conglomerate has light gray or dark gray color, and contains various kinds of pebbles such as quartzite, andesites, granites, gneisses, etc. Sandstone occurs as thin layers in the conglomerate, and is generally tuffaceous.

The PIII formation is widely distributed in the surveyed areas. It is consisted of conglomerate, sandstone, rhyolitic tuffs, and andesitic lavas. Since disseminated mineralization has been recognized in these rhyolitic tuffs and andesitic lavas, intermediate to acidic volcanic activities seem to have had much to do with the copper mineralization.

The Infra-Cambrian System consists of Basal Series and Lower Calcareous Series. The upper lying Basal Series covers Pre-Cambrian formations unconformably. The Infra-Cambrian System consists of basal conglomerate, alternation of sandstone and shale, and dolomite, and copper mineralization is recognized mostly in the conglomerate, sandstone and shale.

Age determination by K-Ar method was made in the present fields. Rhyolitic tuff breccia in the PII-III formation in K Area showed 344×10^6, which corresponds to Middle Paleozoic Era. Perhaps this figure may indicate the hydrothermal alteration in the Hercynian Epoch.

Present surveyed areas can be included in the three districts of inliers of

Azerbalou, Ouaonfenerha and Igherm, and each of the inliers is consisted, in ascending order, of P0, PII, PII-III, PIII formations and Infra-Cambrians System. Each of these formations is in contact with the adjacent formations unconformably. The Pre-Cambrian System is generally dipping steeply, folded and faulted, while the Infra-Cambrians, overlying the Pre-Cambrians unconformably, show repeated gentle folds.

As stated before, the fact that conglomerate and sandstone are the main rock facies in the Pre-Cambrian PII-III and PIII formations may suggest shallow sea environment of sedimentation during the time of deposition of these formations, and the fact that volcanic rocks of intermediate to acidic are intercalated in them may suggest active volcanic activities were accompanied. In association with these volcanic activities, weak copper mineralization is recognized, and the initial mineralized zones in these volcanic rocks may have served as the source of bedded sedimentary deposits in the Basal Series.

In the important mineralized zones in the surveyed areas, there seems a tendency of copper minerals specially concentrated near faults and fractured zones, which is especially distinct in K Area. In the fractured zones in the andesites, strong copper mineralization is recognized. On the other hand, mineralized zones recognized in Talat-n-Sous are formed along the surface of unconformity. In other words, the mineralizations may roughly be classified into those of which concentration is controlled by geological structure and those controlled by sedimentary environment.

Followings are the important mineral indications made clear through the present survey.

(1) Copper dissemination in the lower part of Basal Series in Talat-n-Sous.

(2) Sedimentary copper mineralization of bedded form in the conglomerate, sandstone and shale in Basal Series.

(3) Copper dissemination recognized in the conglomerate, sandstone and rhyolitic lavas in the PII-III and PIII formations of L Area.

(4) Copper dissemination recognized in the andesitic lavas of the PIII formation in M Area and its south.

(5) Copper dissemination recognized in the andesitic lavas constituting the PIII formation in K Area.

2-2 Geochemical Survey

The data of chemical analysis of geochemical samples were analyzed by computer, and relation between indicator elements each other and relation with geology were examined about each area surveyed. According to these data analysis, high grade area could be extracted about Cu (indicator element of copper), but geological and geochemical high grade anomaly could not be extracted on Pb (indicator element of lead) and Zn (indicator element of zinc) as their contents were low, although statistical anomalies against the mean values could be extracted.

The mean value and standard deviation of each formation is shown by Tables from I-7-8 to I-7-11. As the mean value of Cu is highest in Basal Series, this formation can be estimated as the most important horizon in case all the fields are classified by formations. That is to say, to trace up the host horizon of sedimentary copper deposits will be made possible to detect by geochemical survey, and this result can serve as an important guide for future prospecting.

Followings are the fields where geochemical anomalies are found to be crowded.

(1) Mineralized zone in Talat-n-Sous and its neighbouring Basal Series.

(2) Northern part of I Area.

(3) Andesitic lavas in M Area.

(4) Andesitic lavas in K Area.

The above anomalous fields nearly coincide to the localities of mineral indications extracted through geological survey. The anomalous fields, except for the northern part of I Area, are closely related to certain rock facies. However, anomalous field in the northern part of I Area covers the distributed area of PII-III and PIII formations, by which the mineralization in this anomalous field may be considered to have been closely related to the activities of rhyolites in the PIII formation, because mineral indications have been recognized by geological survey in the rhyolitic lavas and dykes of PIII formation distributed in this anomalous field.

There is a general tendency that Pb is contained more in dolomite. PII-III and PIII formations generally contain less than 15 ppm, while dolomite contains more than 15 ppm. High contents of Pb (above 100 ppm) are those found in dolomite and the other found in the volcanic rocks in PII-III and PIII formations.

Zn as a population shows more or less logarithmic normal distribution, as shown by histograms and contents are generally low, but the anomalies are distributed in the anomalous fields of copper or dispersed around them.

2-3 Geophysical Prospecting

Geophysical prospecting by IP method in the present survey was performed in J Area: Talat-n-Sous and in K Area: Assif Imider by following the similar procedures as in the survey last year phase.

The reason why the area of Talat-n-Sous was chosen as a target of this survey was that this area was where the formation of rhyolitic tuffs with advanced mineralization was covered by Basal Series unconformably, and certain mineralization in the rhyolitic formation was anticipated to exist concealedly beneath the covering of Basal Series.

The reason why the area of Assif Imider was also chosen as a field of IP survey was that this area was where ore deposits were emplaced along the fractured zones in the andesite formation, of which extensions were covered by Basal Series, and the deposits were expected to be extended further concealedly beneath the covering of Basal Series.

Results of the IP survey in Talat-n-Sous, however, did not detect any anomaly in response to the surface mineralization and the distribution of igneous rocks in PII-III formation, the ore-hosting formation. On the other hand, FE anomalies were detected in and below Basal Series, through which FE response bodies (Rt 1-5) were disclosed (cf. Fig. II-6-1). The response bodies (Rt 1-3) are considered to indicate pyrite accumulated in sandstone and siltstone of Basal Series. The FE response body (Rt 5) was inferred to exist in the lower part of Basal Series. The response body inferable to exist in the lower part of Basal Series may possibly have been derived by (1) concentration of sulphides into the fractured zone, (2) iron oxides contained more in the andesitic rocks, (3) mineralization of copper or other sulphides in the conglomerate of Basal Series. However, as present survey has failed to conclude clearly either of which, successive prospecting is necessary to be performed in this surroundings to make the problem clear enough.

From the FE anomalies detected in the area of Assif Imider, FE response bodies (Ra 1-3) were disclosed (cf. Fig. II-8-2). A response body (Ra 1) was detected in response to the known ore deposit, indicating a small slab in shallow ground but bigger slab in the deep ground. The continuity of this response body is not strong towards northeast, but towards southwest it continues as far as the southern extremity of the surveyed field. An FE response body accompanied by a strong anomalous zone (Ra-3) was detected in the northeastern part of the field, and considering from the results of simulation and surface geological showings, this may indicate pyrite in the conglomerate of Basal Series. FE anomaly was also detected in the andesite in the southeastern extremity of the field. But the present survey is not enough to determine to what it should be attributed. Therefore, prospecting survey is necessary to be continued in this part.

2-4 Diamond Boring

The prospecting by diamond boring was carried out for the purpose to confirm the geological structure and IP anomalies, which were obtained through the detailed geological survey and electrical prospecting done in the district of Alous Mine during the survey of the second year phase.

Through the examination of cores of this boring, Basal Series of Infra-Cambrian was confirmed from 0 to 155.50 m deep, and Pre-Cambrian PIII was from 155.50 m to the bottom. This almost conforms to the geological profile of detailed survey of ore deposits in the second year phase. In spite of an anticipation of copper mineralization, as it has been recognized at the uppermost of PIII andesite through geological survey, only a dissemination of hematite (specularite) was recognized in the drill cores.

Anomalies by electrical prospecting (IP method) has been detected in this area as follows:

(1) FE anomaly in the rhyolite intrusive body of Alous Mine, probably due to sulphides in it.

(2) FE anomaly near the boundary between PIII and Basal Series.

(3) FE anomalous zone recognized in the sandstone of the lower part of Basal Series, probably due to dissemination of sulphides.

Response bodies inferred from these FE anomalies had been estimated in the shapes of horizontal slab, inclined slab, and massive.

According to examination of drill cores, the response bodies in the shapes of horizontal and inclined slabs indicate the sandstone in Basal Series accompanying weak dissemination of pyrite and hematite. The massive response body may indicate the andesite in which weak dissemination of partly of hematite and partly of specularite. In none of these response bodies, distinct copper mineralization has been recognized.

2-5 Ore Deposits

Ore deposits recognized in the surveyed areas are Talat-n-Sous and Amdouz mineralized zones in J and H Areas and the mineralization zone in the andesitic lavas in K Area.

2-5-1 Talat-n-Sous Mineralization Zone

This mineralized zone has been prospected already by B.R.P.M. with 9 trenches, 6 test pits and 8 drill holes. Detailed geological survey in a scale of 1:500 was performed in combination with simplified land survey by pocket compass.

This mineralized zone is that of network-dissemination of copper hosted in the rhyolitic pyroclastic rocks and andesitic rocks in PII-III formation underlying the dolomite of Basal Series unconformably, in which principal copper minerals are those secondary minerals of malachite, covellite and chalcocite, with rare association of chalcopyrite and chrysocolla.

The principal part of the zone is within a range of 50 m x 130 m, in which copper occurs as films along the joints and fractures developed in the rhyolite and as disseminated in the host rocks. The rhyolitic pyroclastic rocks as the host of the ore deposits have been subjected by various alterations such as distinct silicification, sericitization, etc., surrounding the kernel of mineralized zone.

This mineralized zones may have been originated by the rhyolitic activities in the time of PII-III, but many of them are considered to have been reformed by removilization and reconcentration caused by the later tectonic movements, circulation of meteoric water, etc. Such secondary enrichment or concentration is considered

to have continued for long periods, because the mineralization can be recognized in the dolomite of Basal Series overlying the PII-III.

2-5-2 Amdouz Mineralized Zone

This mineralized zone is formed by copper mineralization in the basal conglomerates of Basal Series. Dolomite formation overlies this mineralized zone, which is the same formation to the dolomite overlies the Talat-n-Sous mineralized zone. This is under exploration by B.R.P.M. by means of tunneling.

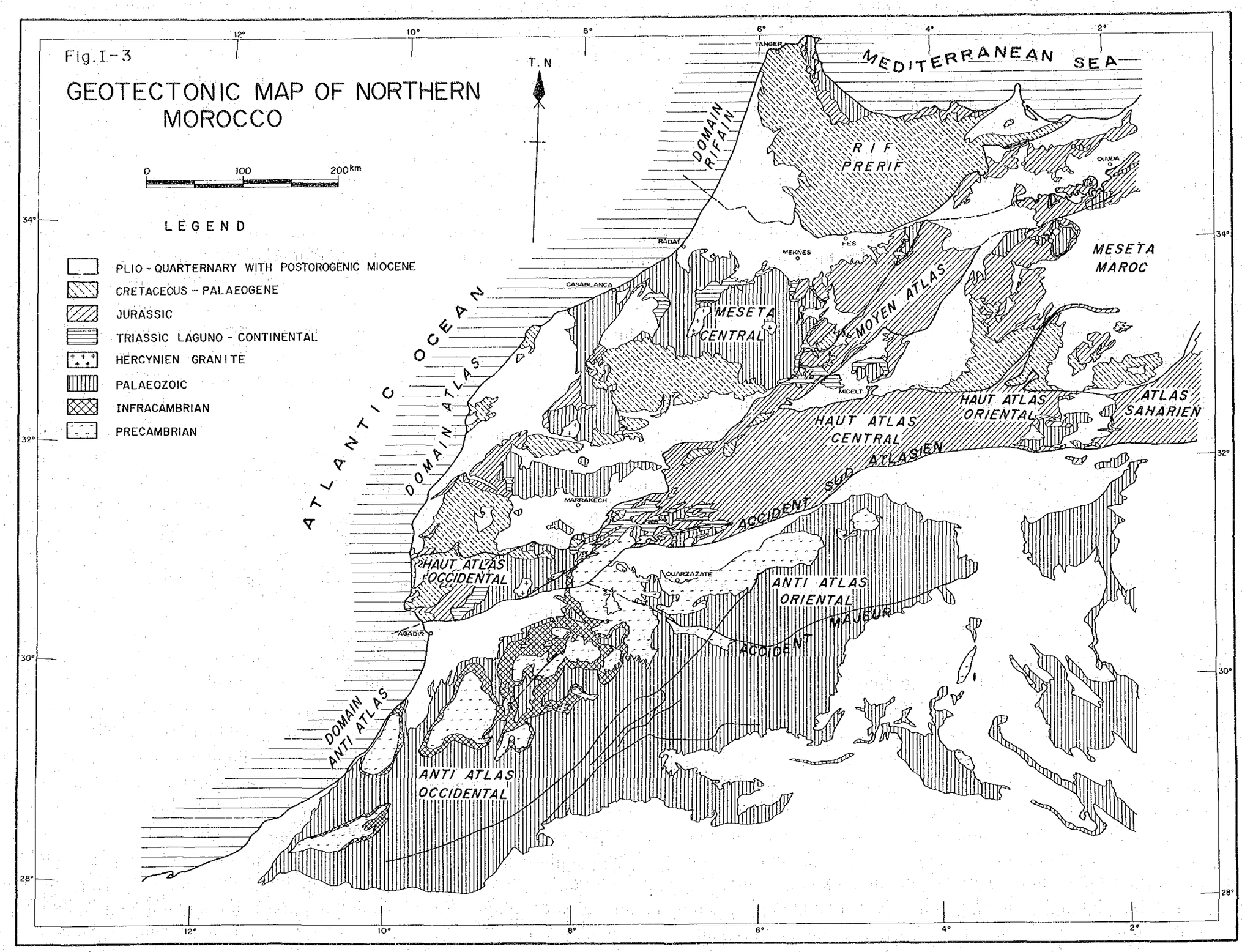
2-5-3 Assif Imider Ore Deposit

Being under operation, the Assif-Imider deposit is fissure filling and dissemination of copper along the fractured zones in the direction of NNE-SSW formed in the andesitic lavas of PIII formation, of which confirmed dimension is 5 or 6 m in width, 250 m in horizontal elongation, dip 80°E, from 50 to 85 m of dipwise extension. Its ore reserve and average grade are said to be 230,000 tons with 3.65 % Cu and 76.1 g/t Ag. Within the range of 800 m on the extension of fractured zone, copper mineralization by malachite, covellite, and bornite is recognized not only in the PIII andesitic lavas, but also in the dolomite of overlying Basal Series.

The origin of this deposit may be interpreted that copper ions initially contained in minor amounts in the rhyolitic rocks and andesitic rocks of PIII formation had been concentrated and enriched in the fractured zones.

Fig.I-3

GEOTECTONIC MAP OF NORTHERN MOROCCO



Chapter 3 Conclusion

3-1 General Summary

The present survey was performed in the 3 districts of H and J Areas, I, L, and M Areas, and K Area, isolated each other in the territory of Igherm, which is the northeastern part of the surveyed area during the first year phase. As there is slight difference in the constituent geological formations and geological structure between each area, the summary of features of each area will be given in the following paragraphs.

3-1-1 H and J Areas

a. Geology and Geological Structure

This district is consisted of the Pre-Cambrian formations of PII-III and PIII distributed almost eastwesterly from Amdouz in the central part to Talat-n-Sous, and of the overlying Infra-Cambrian formations of Basal Series, Tamjout Dolomite formation, and Lower Calcareous Series, distributed in the south and northwest sides of the Pre-Cambrian with unconformity.

PII-III formation consists mainly of rhyolitic tuffs and intercalates andesite, sandstone and shale. PII formation consists mainly of conglomerate cemented by andesitic matrix, partly intercalating the lavas of rhyolite and andesite. These formations form a monoclinal structure with gentle dips of 10° - 20° to the south.

Basal Series consists of conglomerate, sandstone and dolomite, overlying the Pre-Cambrians unconformably. The formations after Tamjout Dolomite are deposited nearly conformably, indicating graduated sedimentary environments from metastable to stable facies. The formations after Basal Series form a dome structure with its eastwesterly axis and gently dipping to the west. Major faults are the Igherm Fault of NNE-SSW system in the east and those of ENE-WSW system in the northwest.

b. Mineralization and Characters of Structural Control

The ore deposits and mineral indications in this district are copper dissemination in the rhyolite of PII-III and PIII formations, copper dissemination

in the Pre-Cambrian formations lying directly below the surface of unconformity with Basal Series (Talat-n-Sous), copper dissemination in the conglomerate of Basal Series (Amdouz), which are the prominent ones, and weak dissemination of pyrite, hematite and malachite is also recognized in the sandstone of Basal Series.

c. Relation of Results of Geochemical Survey with Mineralization

According to the results of geochemical survey by rock samples performed in this district, indicator elements of Cu and Zn showed the distribution of nearly similar tendency, while Pb showed a slightly different behavior, by which anomalies were detected in the dolomite.

Behavior of Cu shows a close relationship with the mineral indications above-mentioned, and high anomalies are indicated in the surficial parts (surface of paleotopography) of PII-III and PIII formations directly below Basal Series and in the layer of conglomerate of the lowest part of Basal Series, and intermediate anomalies exist in the lower and uppermost parts of the sandstone layer of Basal Series. High anomalies are also recognized along the faults of NNE-SSW system.

Thus, the geochemical survey by rock samples was very effective procedure in indicating out the location of mineralization and pointing out the grade of metallic contents.

d. Relation between IP Results and Mineralization

A few FE anomalies were detected as the results of IP survey parallelly performed with other survey in J Area. Considering from the results of geological survey and geochemical survey together with IP results, the FE anomalies in the sandstone of Basal Series in the west of the area (Rt-1 - Rt-3) seem to have been caused by pyrite in the said formation.

An FE anomalous zone (Rt-5) detected in the southeast, stretching almost in east-west direction, occupies the location geologically corresponding to the upper part of the layer of conglomerate of PIII formation directly below Basal Series. Causes of this anomalous zone may be interpreted in several ways such as, 1. the case of existence of hematite-bearing andesite lavas near the uppermost part of PIII formation, that is, the case similar condition with the

drill site in the southeast of the Alous Mine, 2. the case of existence of fractured zones of E-W system in PIII formation, around which copper sulphides are concentrated, for instance, existence of ore deposit of Assif Imider type, and 3. the case of existence of the lowermost conglomerate layer of Basal Series which accompanies the copper mineralization like the Amdouz Mine.

A very weak FE anomaly was detected near the known mineral indication (Talat-n-Sous) mainly of oxides and carbonates of copper in the central part of the area, and another small FE anomaly (Rt-4) was also detected in its southwest. This is considered to indicate the existence of small scaled mineralization of copper sulphides at the surficial part of PIII formation with its poor downward continuity.

3-1-2 I, L, and M Area

a. Geology and Geological Structure

Geology of this district consists of the Pre-Cambrian formations (PII, PII-III, and PIII) and the Infra-Cambrian formations (Basal Series, Tamjout Dolomite formation, and Lower Calcareous Series).

Forming the basement of this district, PII formation is distributed in small patches like islands, and is consisted of quartzites, schists, green stones, and lenticular limestones, and intensely metamorphosed and folded. PII-III formation is distributed in the eastern half of the district and in contact with PII formation with unconformity. It consists mainly of volcanic conglomerate, occasionally intercalating thin layers of volcanic sandstone and is intruded by rhyolite dykes. PIII formation occupies the west half of the district and is characterized by thick layer of sandstone. It intercalates rhyolite lavas, its tuffs, and andesite lavas.

Basal Series consists of conglomerate, sandstone, and dolomite, overlying the Pre-Cambrians unconformably and being distributed in the northwestern and southwestern extremities of the area. Being in almost conformable relation, Tamjout Dolomite and Lower Calcareous Series overlies the Basal Series and form a synclinal structure having its axis in the direction of north-south.

Main features of geological structure will be represented by intensely folded structure and weak metamorphism of PII formation and west dipping

monoclinal structure of PII-III and PIII formations. Among the faults, the Igherm Fault zone passing in the direction of NE-SW in the northwestern side of the district is a representative one.

b. Mineralization and Characters of Structural Control

The ore deposits and mineral indications in this district are copper dissemination accompanied by the rhyolite dykes of PII-III formation, copper dissemination accompanied by the rhyolitic and andesitic lavas of PIII formation, and bedded deposits of copper in the conglomerate or sandstone of Basal Series. Generally speaking, they are low graded except the bedded deposits, but it is the feature of mineralization in this area that copper mineralization is recognized in the rhyolite and andesite, which is an interesting fact in suggesting certain relationship with abundance of the bedded deposits in Basal Series in the surroundings of this district. Copper mineralization is recognized for some extent around the Igherm Fault zone, too. Thus, the characteristic of mineralization in this district is the existence of 2 types of mineralization, the ore related with the igneous activities of rhyolite and andesite, and the other of bedded type in Basal Series.

c. Relation of Results of Geochemical Survey and Mineralization

According to the results of geochemical survey performed parallelly to geological survey, indicator elements of Cu and Zn showed almost similar behaviors, while indicator element of Pb showed a slightly different behavior (existence of high anomalies in Tamjout Dolomite). Especially, the behavior of Cu showed the results to support the relation between geology and mineralization above-mentioned. For instance, the rhyolite (L Area) and andesite (M Area) showed quite a good coincidence with the geochemical anomalies, which proved the geochemical survey as an effective procedure to investigate the source of mineralization.

3-1-3 K Area

a. Geology and Geological Structure

Geological formations to construct this area are the Pre-Cambrian PIII formation (andesitic rocks) and the Infra-Cambrian Basal Series (sandy dolomite, dolomite, and conglomerate), overlying the Pre-Cambrians unconformably.

Forming the basement of this area, the andesitic rocks of PIII formation are distributed in small exposures in this area. Basal Series is nearly flatlying formation, consisting of the sandy dolomite in the bottom and the dolomite in the upper part which intercalates thin layers of conglomerate, sandstone, and shale.

b. Mineralization and Characters of Structural Control

Types of mineralization observed in this area are copper mineralization near the fractured zones of NE system in the PIII andesites (Assif Imider), and weak mineralization of copper and pyrite found in the conglomerate and sandstone of Basal Series. Although the former is under operation by B.R.P.M. at present, its downward continuity is proved only for about 60 m. Perhaps this may have been so formed that copper minerals in the surficial parts of PIII formation, in weathering zone, had been concentrated in the fractured zones by meteoric water, and were reduced into sulphides by the later hydrothermal processes.

c. Relation of Results of Geochemical Survey with Mineralization

According to the results of geochemical survey by rock samples performed in this area, indicator elements of Cu and Zn showed similar behaviors, while Pb showed different behavior similarly to other areas. Cu has shown high anomaly near the Assif Imider Ore Deposit. Other than this, intermediate anomaly was recognized in the conglomerate and sandstone of Basal Series, and the similar tendency was shown clearly even at the parts where copper minerals could not be recognized by naked eyes. This fact shows that this procedure is very effective to investigate the mineral indications.

d. Relation between IP Results and Mineralization

In response to the known ore deposit (Assif Imider Ore Deposit), an FE anomaly (Ra-1) was disclosed by IP survey. Similar type of FE anomaly was found to be continuous, getting shallower towards the southwest where ore deposit had not been discovered. This fact indicates strong possibility of ore existence in the said area.

An FE anomaly was found to exist in the PIII andesite below this ore deposit, and another one (Ra-2) was also detected in the andesite of the south-

eastern extremity of the area. Geological factor to have derived these anomalies may possibly be hematite (specularite) contained in the andesite, similarly to the FE anomalous zone in the southeast of Alous, but it can not be concluded definitely at present moment.

The strong FE anomaly (Ra-3), detected in the northeast of this area, is interpreted, as the result of simulation, to have been caused by weak copper mineralization (including pyrite) in the conglomerate and sandstone of Basal Series. On account of this, possibility is scarce to expect ore deposits below the anomaly.

3-1-4 *Diamond Boring in Alous Area*

A diamond boring was drilled about 300 m deep for the purpose to make clear the geological factor to have caused the FE anomaly in the southeast of the Alous Mine detected during the survey of the second year phase.

It has been made clear by this boring that the FE anomalies inferred in the shallow and deep grounds directly below the drill site are caused by pyrite dissemination in the sandstone of Basal Series and specularite dissemination in the PIII andesite respectively.

This fact may suggest the necessity of making comprehensive data analysis of the IP results together with the results of geological survey and geochemical survey by rock samples in handling the anomalous values in future IP survey, as well as the necessity of confirmation by enough boring to acquire the geological characteristics of anomalies.

3-2 *Future Prospecting*

Relation between mineralization and geological structure has been made clear through the survey of present year phase as stated before. In other words, the igneous activities to have derived the rhyolite and andesite in the Pre-Cambrian PII-III and PIII formations have close relation with the mineralization of the surveyed areas, and mineral indications have been recognized abundantly in the areas where these volcanic rocks are well developed. There has been found a tendency that the bedded ore deposits found in Basal Series are concentrated in the neighbourhoods of the areas where the said volcanic formations are developed or their existence is

expected. The results of geochemical survey by rock samples have enabled to detect out even the mineralization by feeble dissemination as well as to deliniate accurate range of mineralization and to make accurate determination of mineralized host rocks. For instance, high anomalies of copper or others could be detected in the surficial parts of the Pre-Cambrian formations and in faults and fractured zones, and intermediate anomalies of copper also could be detected in the conglomerate (sandstone) of Basal Series.

In view of the statement above, the followings have to be observed as the principles of future prospecting:

1. Priority of survey should be given to the areas where the rhyolites and andesites of Pre-Cambrian PII-III and PIII formations are distributed or concealed in shallow ground.

2. Attention has to be paid for the areas where the bedded deposits emplaced in the layers of conglomerate and sandstone of Basal Series will exist, especially near the existence or probable existence of the volcanic rocks above-mentioned.

3. Geological structure of the surficial parts of the Pre-Cambrian formations should be made clear, especially so in the areas where fractured zones exist.

In regard to the prospecting procedures, geochemical survey by rock samples is desirable to be made use of, as it is estimated effective procedure in enabling to correlate accurate geology to mineralization, if it will be performed systematically along with the geological survey. The IP survey is also considered an effective procedure, as FE anomalies have been detected in several areas and FE anomalies directly indicate the ore deposits have also been detected in some localities. But in the interpretation of anomalies, comprehensive data analysis including geological informations has to be made carefully, and further confirmation by boring or others is desired to be done.

Considering from the results of present survey, the practical prospecting works will be proposed as follows:

1. The detailed survey on ore deposits, geochemical survey, and geophysical survey by IP method with total length of survey lines of 15 km (1.5 km x 10 lines)

will be desired to be practiced, for the area between the Amdouz Mine to the already surveyed area, for the purpose to confirm extension of the IP anomaly (Rt-5) detected in the southeast of J Area.

2. One hole of boring is recommended to be drilled for about 300 m deep, which should be performed succeedingly to the works above stated for the purpose to confirm geological nature of the anomaly.

3. One hole of diamond boring is also recommended for about 300 m deep, for the purpose to confirm the natures of FE anomaly (Rt-3) expected to exist in Basal Series in the west of J Area.

4. The FE anomalous zone (Ra-1) detected in the south of the Assif Imider Ore Deposit in K Area may possibly indicate the southward elongation of the deposit, and another anomaly is expected to exist below the deposit. One hole by diamond boring is desirable to be done for about 200 m deep for confirmation.

5. The FE anomalous zone (Ra-2) in the same area is estimated to exist in the PIII andesite, but further detailed geological survey, geochemical survey, and IP survey are desirable to be carried out in more extended area, because the anomaly has been detected only a part of its possible extension.

PART 1

GEOLOGICAL SURVEY

Chapter 1 General Geology

1-1 Geographical Features of Surveyed Areas

The areas of present survey with overall areas of about 145.9 km^2 consist of these areas of Talat-n-Sous, Assif Imider, and Igherm, which had been extracted through the survey of second year phase.

Talat-n-Sous area contains two parts; the one is H where detailed geological survey was performed, and the other is J where detailed survey of ore deposits was practiced, while in Assif Imider, K area, detailed survey of ore deposits alone was carried out. Area of Igherm can be divided into I where detailed geological survey was done, and L, M where detailed survey of ore deposits was performed.

Talat-n-Sous area can be accessed by car from Agadir through Taloudannt and Aoulouz, but from Aoulouz only a graveled road is available along valley. It requires about 5 hours by car from Agadir for a distance of about 250 km. The land has its topographic features of plateau as a whole with altitude between 1,000 and 1,500 m S.L., but topography along some valleys is very steep. Many trails are developed for the use of pasturage and agriculture, but the development of car road is far behind and only one is available to reach to Talat-n-Sous mineralized zone. The rest of the area has to be accessed on foot.

The areas of Assif Imider and Igherm are connected by a paved road which starts from Agadir and passes through Taroudannt. Assif Imider is located between Taroudannt and Igherm, being accessed by car for 3 hours in a distance of about 150 km from Agadir. It is 4 hours trip in a distance of about 200 km from Agadir to Igherm. Both have topographical features of plateau of altitude between 1,300 and 2,000 m S.L. The lands are gently undulated, and are utilized for agricultural cultivation and for pasturage.

1-2 Sedimentary Rocks and Stratigraphy

Geology of the surveyed areas consists of Pre-Cambrian System constituting the basement and Infra-Cambrian System to cover the former.

The Pre-Cambrian System has been classified stratigraphically into, in ascending order, PO, PII, PII-III, and PIII, all of which are distributed in the surveyed

areas. PII-III and PIII are more widely distributed among them, forming the inliers surrounded by the Infra-Cambrians.

The Infra-Cambrian System has been classified into Basal Series and Lower Calcareous Series, which are widely distributed in the surveyed areas.

Ore deposits are recognized mostly in the volcanic rocks in the Pre-Cambrian PII-III and PIII formations and in Basal Series, especially, distinct copper mineralization is recognized in the rhyolitic tuffs and andesitic lavas intercalated in the sediments of PII-III and PIII formations.

1-2-1 Pre-Cambrian System

(1) PO formation, being lacked in the present survey fields, consists of metamorphic and plutonic rocks, which are estimated to construct the basement in this region. Being distributed widely in Kerdous inlier of southwestern part, results of age determination have been reported from $1,700 \times 10^6$ to $1,300 \times 10^6$ years (Rene Charlot, 1976).

This formation consists of migmatites, schists, green rocks, and granites. It has been intruded by rhyolites and granites during the time between late Pre-Cambrian to Hercynian orogenic period in late Paleozoic. The granitic rocks, having been suffered by the later hydrothermal alterations and orogenic movements, show the rejuvenated age of Hercynian orogeny. Since the Hercynian orogeny, the land has been stabilized because of the change of crustal movement into gentle up-and-down movements of epeirogenic type.

(2) PII formation forms the basement in the present fields together with PO formation, being consisted of such metamorphic rocks as green rocks, schists, and quartzites. This formation as a whole is extended in a direction of NNE--SSW, being distributed more or less parallel to the PO.

(3) PII-III formation is the principal formation to constitute the inliers, which generally consists of those sediments deposited under such unstable sedimentary environment as to form the lower seated conglomerate layers graduated to the upper seated sandstone layers. In between the two, rhyolitic and andesitic volcanic rocks are intercalated. Overall thickness of this formation is about 2,500 m.

The lower conglomerate contains abundant volcanic pebbles; a thick accumulation of volcanic pebbles is formed with its lower part rich in the pebbles of intermediate volcanic rocks and with its upper part rich in the pebbles of acidic volcanic rocks. The sediments are considered to have deposited in a slowly subsiding geosyncline with repeated transgression and regression, under prevalent neritic environment of sedimentation.

(3) PIII formation is the principal formation together with PII-III to constitute the inliers. This formation consists mainly of conglomerates, associating with acidic or intermediate volcanic rocks, and overlies the PII-III unconformably. Although most of this formation is consisted of conglomerates, but in the early part the andesitic volcanic rocks are deposited in the conglomerates, while later on, the acidic volcanic rocks has taken the place. Basic or intermediate volcanic rocks are locally intercalated in the upper part of this formation. During deposition of this formation, acidic and intermediate volcanic activities are prevalent in general. The upper part of this formation has a change of sediments from the lower conglomerate to the upper sandstone and shale, and a thin layer of dolomite is recognized in the uppermost part. This may suggest the change of sedimentary environments from neritic to deep sea.

Copper mineralization of dissemination type is recognized in the volcanic rocks of this formation. It seems stronger in the basic rocks.

1-2-2 Infra-Cambrian System

This system, overlying the basement of the Pre-Cambrian formations and being widely distributed, consists of the sediments mainly of sandstone, shale, and dolomite, which are the sediments of metastable facies without containing volcanics, deposited under transitional condition towards the stable geosyncline.

This system is in contact with the Pre-Cambrians unconformably, and is classified into Basal Series and Lower Calcareous Series in ascending order.

(1) Basal Series overlies the Pre-Cambrians in each of the surveyed areas and is distributed in a way to surround each of the inliers. It consists principally of conglomerate, sandstone, shale, and their alternations.

Dolomite occurs as thin layers intercalated in the layers of sandstone and shale. The thickness of this formation varies much by reflecting the ups and downs in the paleotopography, and it is entirely lacked in some places.

(2) Lower Calcareous Series consists mainly of dolomite and overlies the Basal Series conformably. The dolomite layers can be classified into the characteristic Tamjout dolomite and its overlying well-bedded dolomite. Tamjout dolomite consists of grayish, hard, and nonstaratified dolomite of which thickness is nearly constant as 40 - 80 m throughout the area. This formation is generally strong against erosion and steep cliffs are often forme.

The stratified dolomite which comes directly above Tamjout dolomite intercalates the layers of tuff, shale, and chert and alternates with them. This formation shows weak folding structure locally.

1-3 Volcanic Activities

The Pre-Cambrian formations in this region consist not only of sediments, but also of volcanic rocks brought about by active volcanic activities. The formation also intercalate the volcanic sediments which are related with mineralization. These volcanic rocks have their own characteristics according to their periods of volcanic activities.

PO formation consists of migmatites, schists, green rocks, gneisses, and granitic rocks. They have been formed under advanced regional metamorphism, as well as by plutonism characterized by intrusion of granitic rocks.

PII formation consists of quartzites, schists, and green rocks, characterized by intense folding and faulting and has been subjected under regional metamorphism. Igneous activity of basic rock may be considered to take place during this time, which will be represented by the green rocks.

PII-III formation consists of sandstone, conglomerate, andesite, and rhyolite. During the time of PII-III, a series of volcanic activities represented by the lowermost pyroxene andesite and upper rhyolitic rocks were repeated for several cycles, and as the results of these activities, there have been formed among the sediments pyroclastic formations consisting of andesitic volcanic conglomerates and tuffs.

The composition graduates from andesitic rocks to rhyolitic rocks. It may be estimated that the sedimentary basin was upheaved into the land after the volcalnic activities, and later on, transgressions and regressions started again to repeat.

PIII formation consists of conglomerate, sandstone, andesitic rocks, and rhyolitic rocks. The rhyolitic lavas and their pyroclastics are intercalated as layers in the formation mainly consisted of conglomerate and sandstone. Thus during the time of PIII, igneous activity mainly of rhyolitic rocks can be recognized, but the activity graduated from rhyolitic to andesitic. The effused materials show the change of composition from acidic to intermediate and also show the repetition of them for several times. Some pauses may be considered between these volcanisms, as thick layers of sandstone and conglomerate are intercalated in this formation. After the effusion of andesitic rocks at the latest stage of deposition of PIII formation, the sedimentary environment was changed into the one where dolomite and limestone were deposited, which may be enough to consider the extinction of igneous activity at least within the surveyed fields.

1-4 Geological Structure

The northern part of African Continent, in which present fields of survey are included, consists of a part of the Pre-Cambrian craton and a mobile belt, and the northwestern fringe of the craton had existed as a mobile belt for geosynclinal activities and orogenic movements since after Paleozoic Era.

Generally speaking, geological structure of Morocco shows the graded change from southern Morocco which is nearer to the Pre-Cambrian craton, towards Mediterranean Sea in the north, which can be divided into 3 tectonic belts of Anti-Atlas belt in the south, Atlas belt in the central part, and Rif belt in the north. The present survey areas are located in the western part of Anti-Atlas belt. The Pre-Cambrian formations in the west Anti-Atlas generally show anticlinal or dome structures and are exposed out as inliers, being surrounded by the Infra-Cambrian formations at their peripheries. These inliers are arranged in a direction of ENE - WSW, being controlled by the direction of main structure of Anti-Atlas belt.

The Pre-Cambrian formations in the region of Anti-Atlas correspond to the marginal part of the craton, and have been put under the influence of later crustal

movements for several times. This often makes it difficult to determine the real age of rock in the age determination on rock samples, because there is a tendency the determined age comes out younger due to the rejuvenation by the post orogenic movements.

The present areas are reported to have been affected almost successively by sedimentation and orogeny throughout the Pre-Cambrian time since Archaean. (Choubert and Faure-Muret; 1970, 1972). This is due to the location of the areas to be situated in a part of the mobile belt at the periphery of the Pre-Cambrian craton of African Continent on one hand, and on the other hand to be located in a peripheral belt of the European craton. Geosynclines have been formed; the Anti-Atlas belt may be taken as a paleozoic geosyncline formed above the Pre-Cambrian basement, of which formations had been deposited in the periphery of Pre-Cambrian cration. Later on, this belt was turned into craton by Hercynian orogeny from late Paleozoic to early Mesozoic, which was later brought up into land by the Tertiary Alpen orogeny

1-5 Ore Deposits

In the present survey, which was made in the areas extracted through the survey of last year phase, efforts were taken to make clear the natures of ore emplacement through emphasized inquiry about ore bearing horizons and relations of ore deposits with igneous activities and geological structure. The ore-hosting horizons in these areas are PII-III, PIII, and Basal Series.

In PII formation, there has not been found any distinct mineralization, except for deposits of malachite. They occur in the faulted zones and fractures branched out from the faults as disseminated or films, but they are generally poor in continuity. This is the secondary mineralization permeated in the fissures produced by faulting movements.

Mineralization recognized in PII-III formation is copper mineralization by malachite, chalcocite, covellite, etc., in the forms of dissemination or films in the rhyolitic lavas. Aside from this, copper mineralization is recognized in the rhyolitic dykes, which is shown by the occurrence of malachite, chalcocite and chalcopyrite in the state of dissemination.

The main part of PIII formation consists of andesitic and rhyolitic lavas and tuffs which are the products of active volcanic activities. In some parts of the rhyolitic lavas, dissemination of malachite, chalcocite and pyrite is recognized, and in other parts of the andesitic lavas and their tuffs, dissemination of malachite, chalcocite, and chalcopyrite is recognized, too. Although the primary mineralization accompanied by these volcanic rocks was made by the minor contents or copper in them, feeble as it was, the enriched ore bodies recognized at present may be considered to have been caused by reconcentration of primary copper contents during the time of faulting. Especially around the larger scaled fractured zones by faulting movements, the dissemination of oxide copper minerals has reached as deep as 100 m below the surface. The concentration of copper minerals found along the surface of unconformity with the overlying Basal Series can be considered the residual deposits by weathering.

Mineralization in Basal Series is generally feeble, and malachite, chalcocite, and covellite are deposited occasionally in a state of layers in the conglomerate and in the alternation of sandstone and shale. In view of such occurrence, the deposits can be considered as sedimentary deposits.

No distinct mineralization can be found in Lower Calcareous Series.

1-6 Relation between Ore Deposits and Geological Structure

Among the ore deposits stated before, all the superior ones can not be considered primary, but are considered to be secondary judged from their natures. Especially, the mineralized zones in Talat-n-Sous are developed along the unconformity surface where PIII and PII-III formations are in contact with the overlying Basal Series, and such occurrence may be attributed to the secondary concentration of copper initially contained in minor amounts in the andesites and rhyolites of PIII and PII-III. As the concentration is limited around the unconformity, they are considered to be supergene residual deposits due to weathering.

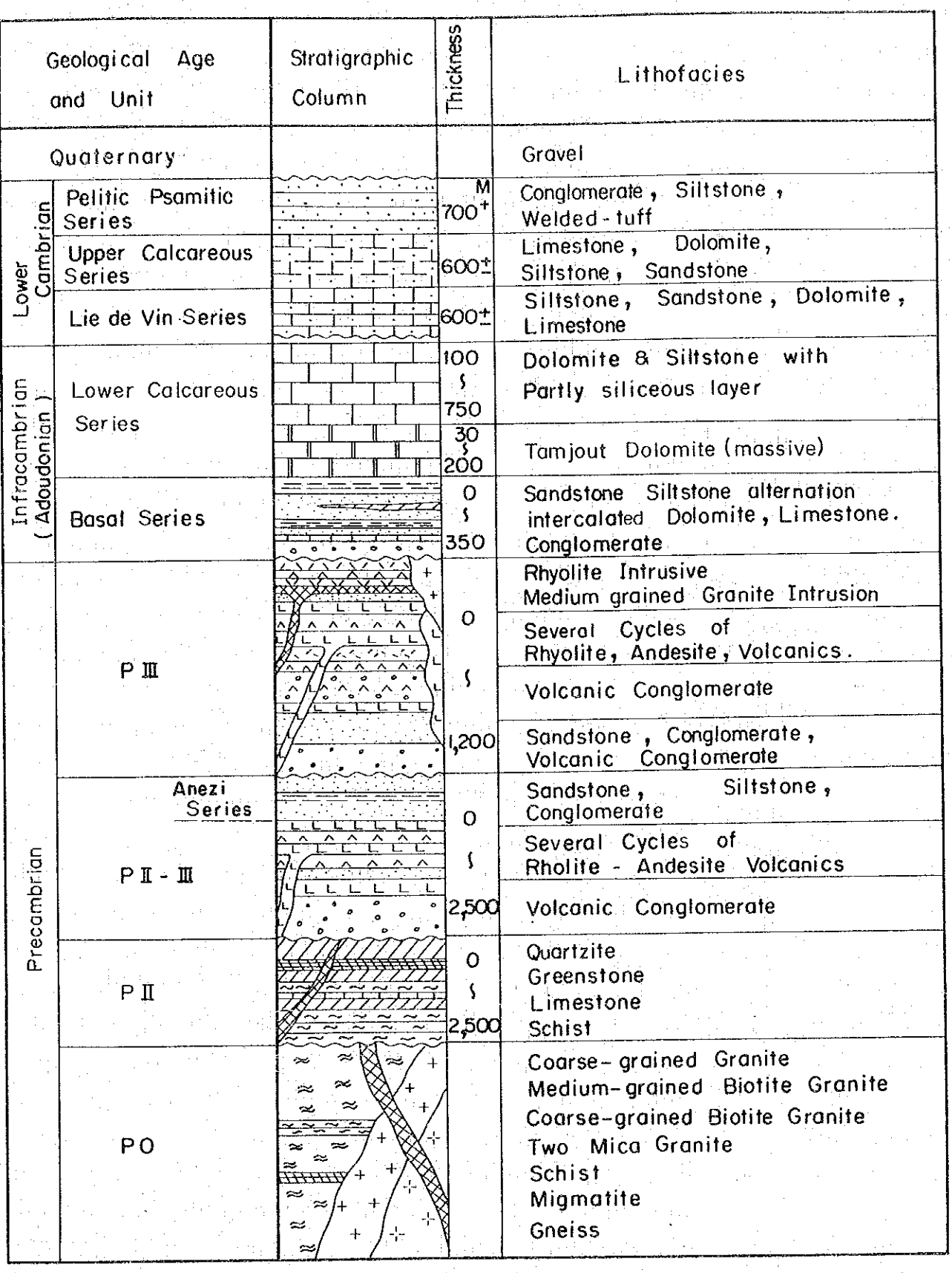
Moreover, such copper components have permeated into fractures to form the mineralized zones mostly with filmy malachite. On the other hand, in the ore deposits of Alous area, concentration can be observed only in the upper parts of fractured zones in the host rocks. Being in the directions of NNE - SSW and E - W

systems, the fractured zones never reach into the overlying Basal Series. Because of unconformable relation between PIII and Basal Series, such concentrations are interpreted to have been formed by permeated copper into the fractured zones before the deposition of Basal Series.

Copper indications by malachite are recognized everywhere in the PIII andesites. Most of these copper indications are found in the fractured zones like those stated above, and they coincide to geochemical anomalies.

On the other hand, the layered sedimentary deposits are used to be found in the vicinities where the mineralized volcanic rocks above mentioned are distributed. This may be considered, therefore, to have been caused by concentration of initially contained useful minerals of the volcanic rocks into Basal Series during its deposition. It is of course, the enriched parts of the deposits have been brought out by reconcentration along the fractures and faults associated with the later faulting movements.

Fig.1-4 Schematic Geological Column of Surveyed Area



Chapter 2 Local Geology

2-1 H Area (Amdouz Area)

2-1-1 Geology

This area is located at the northern extremity among the surveyed fields of present survey, corresponding to the western part of A District in the survey of second year phase. In this area, being located at the southwestern periphery of Azerbalou inlier, the Pre-Cambrian PII-III and PIII formations and Infra-Cambrian Basal Series and Lower Calcareous Series are distributed. As this area is located near the boundary between the Pre-Cambrians and Basal Series, detailed survey about the unconformity between the two was specially emphasized. Each formation is distributed in an eastwesterly trend.

(1) Pre-Cambrian System

Pre-Cambrian system in this area consists of PII-III formation, the oldest formation in Azerbalou inlier, and overlying PIII formation. Facies of the PII-III formation is pale bluish white, rhyolitic tuff breccias. It consists of porous rocks, containing abundant breccias and often intercalating thin layers of shale and sandstone, and is well stratified. Mineralization by disseminated malachite is recognized in some parts of this formation either in the rock itself or along joints.

PIII formation consists mainly of conglomerate layers and is widely distributed in Azerbalou inlier. Intercalating thin layers of rhyolitic tuffs between the conglomerate layers, this formation amounts to more than 2,000 m thick. The conglomerate layers are ill-sorted and consisted of sub-rounded pebbles of of less than 20 cm in diameter, of which rocks are sandstone, granite, quartz rocks, and andesite. The matrix consists of sand and andesitic volcanic ash. Especially in the upper part of this formation, layers of rhyolitic tuffs are intercalated alternatedly with sandstone. The upper, the more it becomes rhyolitic and facies graduates from conglomaratic to sandy rocks upwards.

Its lower part consists mainly of conglomerate layers, locally intercalating thin layers of andesitic tuffs. The conglomeartes consist of pebbles of granite, quartzite, shale, and andesite. Sandstone layers and matrix are chocolate colored and tuffaceous.

(2) Infra-Cambrian System

Infra-Cambrian system is classified into Basal Series and Lower Calcareous Series. Main rock types to constitute the system are dolomite, shale, and sandstone, and layers of conglomerate are intercalated at the basal part. The system is in contact with the Pre-Cambrians of the basement with clino-unconformity.

Basal Series consists of the layers of conglomerate, dolomite, and alternation of sandstone and shale in ascending order. The conglomerate consists mainly of rounded pebbles of quartzite of less than 5 cm diameter and shows well sorted bedding, which can be observed specially distinct in Ait Addi. Mineralization is recognized in the conglomerate near Amdouz. Dolomite is persistent, and the principal dolomite to serve for key bed is stratified at every 30 cm thickness or intercalated as thin layers of about 1 m thick in the alternation of sandstone and shale. The dolomite is generally light gray and forms cliffs. The alternation of sandstone and shale is well developed in the upper part of Basal Series with marked stratification. Crystals of muscovite and pyrite are observed in sandstone and shale, which may suggest the effect of feeble alteration.

Lower Calcareous Series consists of layers of dolomite. The dolomite formation is classified into upper and lower dolomite layers, in which the lower one is called Tamjout dolomite. As Tamjout dolomite is massive, non-stratified, and hard formation with almost constant thickness, it is exposed as continuous cliffs on tops of hills. The upper dolomite layer directly overlies the Tamjout with distinct stratification and is alternated with layers of chert of about 20 cm thick. This formation makes a flat topography when it is distributed widely over hill tops.

From the view point of geological structure, geology of H Area can roughly be divided into Pre-Cambrian and Infra-Cambrian systems. They are in unconformable relation, and the Pre-Cambrians had already been subjected under tectonic movement prior to the deposition of Infra-Cambrians with more complicated structure than the Infra-Cambrians. Its sedimentary environment differs from the Infra-Cambrians, as it is characterized by the repetition of sedimentation mainly of conglomerate and that of pyroclastic rocks by effusion of volcanic rocks. The thick layers of conglomerate of PIII formation suggests the enormous upheaval of the hinterlands. The Infra-Cambrian formations seem to have been deposited generally

under calm condition of sedimentation. There are varieties of rock types, as consisting of the layers of basal conglomerate, alternation of sandstone and shale, and dolomite, but generally speaking, deposition may have been proceeded in order of sandstone, shale, and dolomite in a subsided depression of denudated peneplain.

2-1-2 Geological Structure

Structurally speaking, the Pre-Cambrian formations generally strike in a direction of east - west and dip southwards, forming a monoclinal structure. Within Azerbalou inlier, an eastwesterly anticlinal axis is recognized in its north, and the present survey area corresponds to the south wing of the anticlinal structure.

The Infra-Cambrian system overlies the Pre-Cambrian formations with gentle folding. An anticlinal axis is recognized eastwestward in the west of the present area. Dolomites of Basal Series and Lower Calcareous Series show an anticlinal structure of which axis plunges westward.

2-1-3 Ore Deposits

Mineral indications in H Area are numerous but small scaled. Description about the mineralized zone of Talat-n-Sous will be omitted here, as it has been stated precisely in the paragraph of J Area of detailed survey. The Amdouz mineralized zone is now under prospecting of B.R.P.M. by tunneling. Similarly to that of Talat-n-Sous, this mineralized zone has been formed along the surface of unconformity between PIII formation and Basal Series or in the basal conglomerate of Basal Series, in which copper minerals of malachite and covellite are recognized. As the mineralized zones in this area are developed along the surface of unconformity or in the basal conglomerate, they are considered to be supergene residual deposits. If they were supergene residual deposits, there might be enough time of erosion prior to the deposition of Basal Series. And the field of redeposition of eroded materials might not be but the basal conglomerate of Basal Series. Possibility of ore emplacement, therefore, must be seeked for in the basal conglomerate of Basal Series. Carefull study has to be made from now on about the unconformity surface and basal conglomerate. Aside from the mineral indications above mentioned, there are indications associated with rhyolite and andesite. Malachite mineralization is recognized in the andesitic lavas in Tazert. Similar can be observed in the rhyolite of Azerfnine. Either of them has been prospected by B.R.P.M. by means of boring.