MINERAL RESOURCES DEVELOPMENT SURVEY OF ANTI ATLAS AREA, KINGDOM OF MOROCCO

SEPTEMBER, 1974

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

The Government of Japan, in response to the request of the Government of the Kingdom of Morocco, decided to make an investigation of the geological structure in Massif du Bas Dra and Ifni areas of the Anti Atlas region, and entrusted the implementation to the Overseas Technical Cooperation Agency. (Which was integrated into the Japan International Cooperation Agency on August, 1974)

OTCA, being fully cognizant of the importance of the said survey in the light of the economic and social status of the region, organized a survey team headed by Mr. Kanji SHIOBARA (Mitsui Kinzoku Engineering Service Co., Ltd.) comprising five members and sent it to the Kingdom of Morocco on November 24th to carry out the geological survey and ore deposit investigation in the above areas.

After returning to Japan on December 31st, 1973, the team analysed the data collected and reached to a conclusion which would be recommended to the Government of the Kingdom of Morocco. I believe that the report will serve to the benefits of the Kingdom of Morocco.

I take this opportunity to express my heart felt gratitude to the Government of the Kingdom of Morocco and people concerned for their kind cooperation and assistance rendered the team.

September 1974

Sinsaku HOGEN
PRESIDENT
JAPAN INTERNATIONAL COOPERATION AGENCY

Letter of Transmittel

To: Mr. Shinsaku Hogen - President
Japan International Cooperation Agency

It is our pleasure to submit herewith a study report on the planning for mineral resources development in the Anti-Atlas area of the Kingdom of Morocco.

This report relates to a geological survey for determining the basic plan of exploration, to clarify the expectations of subterranean mineral resources in the Anti-Atlas region of the Kingdom of Morocco.

This survey constitutes a part of a series of technical studies performed in cooperation with the Kingdom of Morocco. Hence, the report has great significance to all those individuals who participated in the survey.

Following the project selection survey conducted in October 1972 by a team organized by the Overseas Technical Cooperation Agency of Japan (integrated into the Japan International Cooperation Agency on August 1, 1974), and the preliminary study carried out in February 1973 by a team organized by Overseas Mineral Resources Development Co., Ltd., the geological field survey had been performed during period of a 38 days, from November to December, 1973.

As a result of this survey, the geological and ore depositional characteristics in the Anti-Atlas region were confirmed and a promising area was selected. This also enabled the determination of definite plan for the subsequent basic geological survey.

The selected area, situated in the south-western part of the Kingdom of Morocco, consists of formations of the oldest geologic age in the country, with a considerable number of metallic ore deposits, and has great mineral resources potential.

This area contains two types of promising ore deposits, i.e., stratified copper deposits and network dissemination ore deposits of copper; and these deposits should desirably be explored as the object of the basic geological survey.

This area is on a plateau situated at approximately 30°N. Latitude with an elevation of about 1,200 m above sea level, and consists of an arid semidesert terrain, with scarce rainfall. This caused various difficulties to the field survey, but, owing to the cooperation and assistance of the Moroccan officials concerned, the survey was completed without mishape.

This survey was performed by Mitsui Kinzoku Engineering Service Co., Ltd. by order of the Japan International Cooperation Agency.

Extensive cooperation and assistance were extended to the survey team during its field work by officials of the Bureau de Recherches et de Participations Minieres (B.R.P.M.) in various aspects including transportation, accommodations, and labor supply. Further, considerable cooperation and assistance were offered by officials of the Japanese Embassy in Morocco.

Guidance and assistance were rendered by the personnel concerned of the Ministry of Foreign Affairs of Japan, the Ministry of International Trade and Industry of Japan, the Japan International Cooperation Agency, and the Metallic Mining Agency of Japan. In addition, guidance was provided in the mineralogical study by the Power Reactor and Nuclear Fuel Development Agency and the Geological Survey of Japan.

We would like to express our appreciation to all those above-mentioned those cooperation contributed to the successful completion of this survey; and also to Overseas Mineral Resources Development Co., Ltd., Nikko Exploration and Development Co., Ltd., Nittetsu Mining Consultants Co., Ltd., Sumiko Consultants Co., Ltd., Bishimetal Exploration Co., Ltd., and Mitsui Mining and Smelting Co., Ltd.

September, 1974

Orihei Kusano
President
Mitsui Kinzoku Engineering Service Co., Ltd.

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of Anti Atlas Area, Kingdom of Morocco

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CHAPTER 1. INTRODUCTION

1-1 Objective of the Survey

During the visit of the project-finding mission of the Overseas Technical Cooperation Agency of Japan (O.T.C.A.) to Morocco in October 1972, a request was forwarded by the Government of the Kingdom of Morocco and the Bureau de Recherches et de Participations Minieres (B.R.P.M.) to investigate the geologic structure of the Massif du Bas Dra and Ifni areas of the Anti Atlas region.

Upon receipt of the said request, the Japanese Ministry of International Trade and Industry (MITI) awarded subsidy to the Overseas Mineral Resources Development Co., to carry out the survey. Mission was formed (Chief: Hirata of Sumitomo Metal Mining Co. and 4 members), and preliminary survey was carried out in the area during the period of approximately one month from 20 February 1973.

The result of the preliminary survey showed that the southern part of the Anti Atlas region, especially the Kerdous, Ida du Zeddout, Ait Abdallah, and Tabia areas were promising enough to warrant further mineral investigations.

A strong request was forwarded from the Japanese Ambassador in Morocco to MITI in August 1973 to follow-up the preliminary survey.

MITI commissioned OTCA to send a survey team to study the feasibility of mineral resources development in the Anti Atlas region of Morocco. The survey team left Japan on 24 November 1973.

The major objectives of the survey were as follows.

To clarify the geology and ore deposits of the central-southern Part of the Anti Atlas region by geological reconnaissance of the area comprising 14,000 km^2 and detailed survey of the larger ore deposits. The area was selected as being the most promising from the results of the preliminary survey.

To study the genesis of the ore deposits and the factors controlling the enrichment of the ore deposits. The purpose of this work will be to obtain basic information for planning future exploration. The basis of this work will be the results of the above surveys.

To evaluate the economic prospects of the area by paragenesis of the mineral potential on the basis of the above work.

To draft an operational plan for the mineral resources development survey of the area to be carried out in the future.

1-2 Members of the Survey Team

Leader	Kanji Shiobara (Mitsui Kinzoku Engineering Service Co., Ltd.)
Members	Noboru Arakawa (Mitsui Kinzoku Engineering Service Co., Ltd.)
	Tadao Aoyama (Nittetsu Mining Consultants Co., Ltd.)
	Kaneo Kakegawa (Nikko Exploration & Development Co., Ltd.
	Hirofumi Taniguchi (Bishimetal Exploration Co., Ltd.)
	Akitsura Shibuya (Sumiko Consultants Co., Ltd.)
Advisors	Mitsuo Ohori (Mining Division MITI)
	Tsuneaki Mizuno (Metal Mining Agency of Japan)

1-3 Itinerary of the Survey Team

Month	Day	Movement	Quarters	Transportion	Activities
Nov.	24 Sat.	Tokyo→Paris	Paris	Aircraft	Departure
	25 Sun.	Paris→Rabat	Rabat	"	Eintered Kingdam of Morocco.
	26 Mon.		"		Courtesy call to BRPM, Japanese Embassy. Reception at Japanese Embassy.
	27 Tues.		"		Discuss survey Plan at BRPM. Luncheon party by BRPM. Reception by Directeur General of BRPM.
	28 Wed.		"		Preparation for field work
	29 Th.	Rabat→Agadir	Agadir	Motor Car	Move to Agadir
	30 Fri.	Agadir→Tamaloukt	Tamaloukt	"	Proceed to Tamaloukt
Dec.	1 Sat.		"	"	Tamaloukt, Amadouz, Talate N'Souss project
	2 Sun.		"	"	"
	3 Mon.		"	"	"
	4 Tues.		"	"	"
	5 Wed.		"	"	"
	6 Th.	Tamaloukt→Aoulouz	Aoulouz	"	"
	7 Fri.		"	"	Tirzzit project
	8 Sat.	Aoulouz→Taroudannt	Taroudannt	"	Team member Ohori leave Morocco Tirzzit project. Move to Taroudannt. Discussion with Mr. Matsutoya
	9 Sun.	Taroudannt→Tizert	Tizert	"	Alouss project
	10 Mon.		"	"	"
	11 Tues.		"	"	Visit Iminirfi mine, Talate Nouamane mine
	12 Wed.		"	"	Tizert project

Month	Day	Movement	Quarters	Transportation	Activities
Dec.	13 Th.		Tizert	Motor Car	Tizert project
	14 Fri.		"	"	Tiferki project
	15 Sat.	Tizert→Taroudannt	Taroudannt	"	Amane Tazert project Idint project move to Taroudannt
	16 Sun.		"	"	Study of collected samples and data
	17 Mon.		"	"	Ambassador Hirahara, Directeur Guessous, chef Bouchta inspect Alouss, Tizert, Amane Tazert Project. Conference.
	18 Tues.	Taroudannt→Tafraout	Tafraout	Motor car	Move to Tafraout Ambassador Hirahara return via Taroudannt-Tafraout-Agadir
	19 Wed.		"	"	Tasserirt project, Agoujgal project
	20 Th.	Tafraout→Agadir	Agadir	"	Geological survey of Precambrian formations near Tafraout, Move to Agadir
	21 Fri.		"		Survey of Agadir harbour
	22 Sat.	Agadir→Marrakech	Marrakech	"	Argana project Youssoufia mine Kettara mine Move to Marrakech
	23 Sun.	Marrakech→Rabat	Rabat	"	Move to Rabat
	24 Mon.		"	"	Study of field data
	25 Tue.		"	"	Study of drill cores, collected samples, discussion with Mr. Matsutoya et al.
	26 Wed.		"		Study of drill cores and samples

Month	Day	Movement	Quarters	Transportation	Activities
Dec.	27 Th.		Rabat		Report and discuss the result of field work to BRPM. Dinner party by BRPM.
	28 Fri.				Courtesy call to Director Submit interim report. Dinner party with BRPM staff by Japanese Embassy
	29 Sat.	Rabat→Paris	Paris	Aircraft	Leave Morocco
	30 Sun.	Paris			
	31 Mon.	Tokyo			Arrive Tokyo

1-4 Acknowledgements

The members of the survey team wish to record their deep gratitude to the authorities of the Government of the Kingdom of Morocco for the kindness and courtesy extended to them through the staff of B.R.P.M.

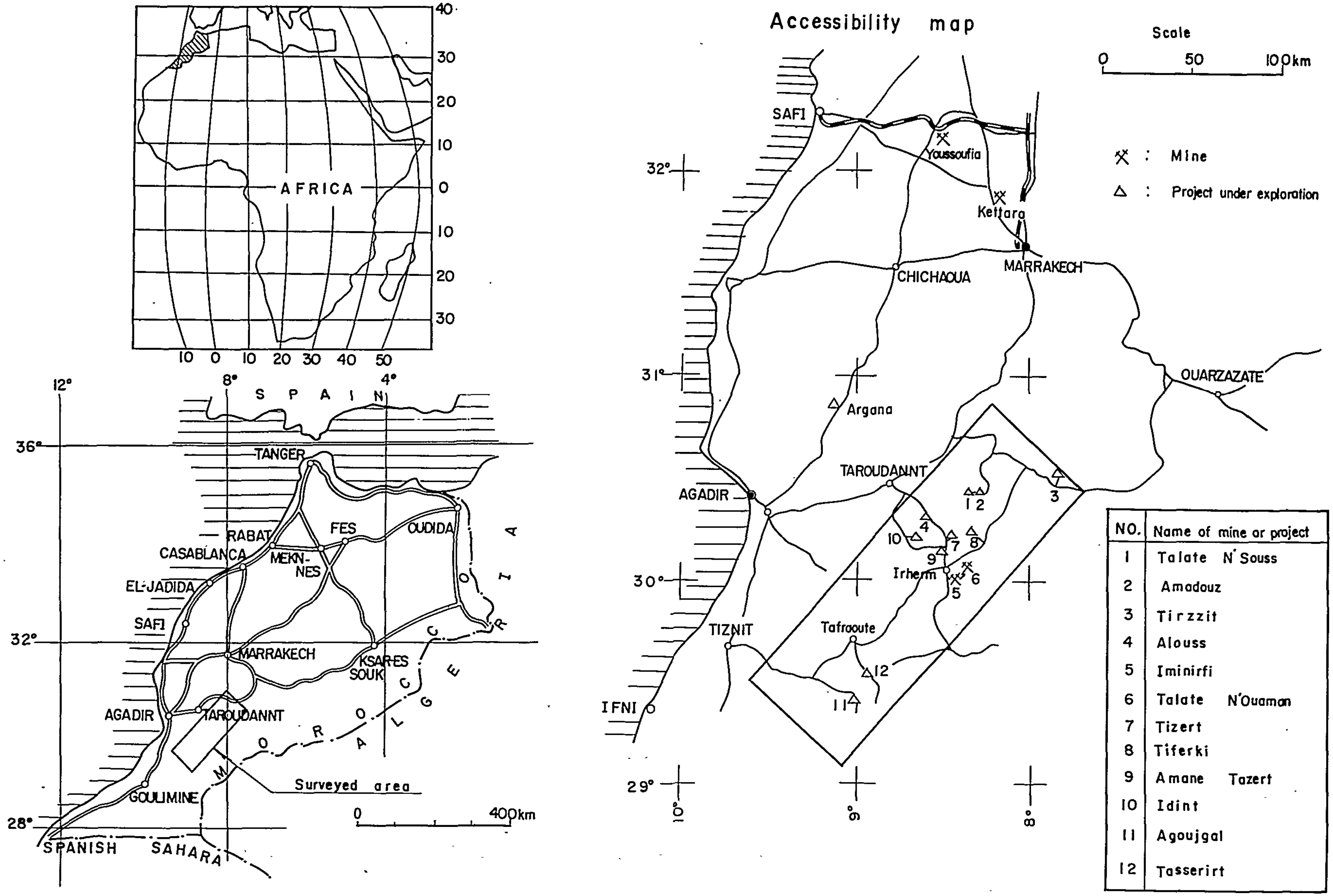
The Directeur General, Officers, and staff of the B.R.P.M. assisted the team in many ways, provided the team with valuable information and data, and offered facilities during the survey. Two to three staff members of B.R.P.M. were always with the team during the field work and cooperated with the survey, arranged lodgings, hired field workers, procured transportation, and various other facilities. Without these assistance the work would have been impossible and the members of the team wish to express their deep appreciation to the following personnel.

Bureau de Recherches et de Participations Minieres

Directeur Général	A. Benjelloun
Secrétaire Général	M. Diouri
Directeur Technique	A. Guessous
Chef du Department de la Géologie Miniere	R. Bouchta
Géologue	S. Matsutoya
Géologue	J. Skacel
Géologue	M. Clavel
Géologue	M. Popescu
Géologue	M. Salem
Géologue	M. Taïb

The members of the team express their deep appreciation for the kindness and encouragement given by Ambassador Hirahara, First Secretary Komachi and the staff of the Japanese Embassy to Morocco.

Fig.1. Location map of the surveyed area



NO.	Name of mine or project
1	Talate N'Souss
2	Amadouz
3	Tirzzit
4	Alouss
5	Iminirfi
6	Talate N'Ouaman
7	Tizert
8	Tiferki
9	Amane Tazert
10	Idint
11	Agoujgal
12	Tasserirt

CHAPTER 2 CONCLUSION

Although the time was limited, the Survey Team investigated twelve (12) mines of the Anti Atlas region and efforts were made to clarify the geology and ore deposits of the said area. Also the genesis of the deposits and factors which control the enrichment of ores were studied in some detail. On the basis of these investigations, plans for future prospecting were drafted, and various conditions for exploitation of these minerals and also the economic feasibility were discussed.

The following is the summary of the conclusions of the above work.

1. The Anti Atlas region is located in the southwestern part of Morocco, and geology of the area consists of oldest formations of the country, and the potential for mineral resources is very large. The stratigraphy consists mainly of Infracambrian and early Cambrian formations. These overlie Precambrian Strata which are exposed sporadically as inliers at the northwestern margin of the northwest African craton. There are evidences of many episodes of igneous activity during the Precambrian period. Many copper deposits were formed associated with the igneous activity during the Precambrian II and III. Also sedimentary copper deposits were formed associated with the depositional process of lower Infracambrian formations. These deposits were later effected by the Paleozoic Hercynian orogenic movement and were more or less remobilized and enriched. This is believed to be the process by which the original orebodies of the present ore deposits were formed.

These deposits are distributed widely in this area, and in Morocco this is an especially rich area for mineral resources.

2. There are two important types of ore deposits in the Anti Atlas region. One is the bedded copper deposits which occur in the lowermost basal series of the Infracambrian system. This system is considered to constitute either the uppermost part of the Precambrian strata or the lowermost part of the Cambrian formations. The other type is the network to disseminated deposits which occur in rhyolite. The volcanic rock is

associated with the acidic volcanic activity of Pre-Cambrian III.

It was shown by the present work that some of the bedded deposits contain uranium, and that uranium should be investigated in future exploratory works.

3. The genesis of the bedded copper deposits is considered to be as follows. Copper was precipitated and deposited in association with the deposition of the siltstone which occurs at the upper part of the basal series of the Infracambrian system. These deposits were remobilized and recrystallized by the effect of the Hercynian orogeny and were partly concentrated, these most probably are the original form of the present bedded copper deposits of this area.

Therefore, emphasis should be laid in future exploration to the analyses of the geologic structure, especially folds, faults, fissures, and mechanism of igneous intrusion.

Also as there are evidences of the formation of the primary sedimentary deposits being controlled by the paleogeography of the Precambrian system which constitute the geological basement of the area, paleogeographical studies of the area will also be important for mineral exploration.

4. Network and disseminated copper deposits occur in rhyolites which are associated with igneous activity, especially the acidic volcanic activity of Precambrian III. It is believed that the primary deposits were formed primarily by hydrothermal activity and then they were remobilized at the time of Hercynian orogeny.

Therefore, in future prospecting, first the distribution and the structure of rhyolite bodies in Precambrian III must be clarified, and then the concentration of the base metals within the rhyolite bodies must be located through structural studies, especially of the fault and fissure systems.

5. The Anti-Atlas region is, in general, at the early stage of mineral

exploration and the past work has been more or less in the nature of search for outcrops and tracing of these mineral showings. Thus for individual mineralized areas, detailed structural geological investigation followed by further wider scale detailed survey based on the results of these investigations will be necessary.

Also at the same time, it is most important to clarify the general geologic structure by basic regional survey and to delineate the promising areas on the basis of the regional survey. Then the promising areas should be explored in detail. This systematic survey will clarify the mineral potential of the area efficiently and will lead to effective development of the mineral resources. Thus this method is considered by the experts of the field to be the best way of assessing the mineral resources of large areas.

6. The following is a mineral exploration plan based on the scheme explained above. The plan calls for three years of regional survey and detailed survey. These two phases are followed by a detailed prospecting phase.

During the first year, photogeological maps and structural maps of the area comprising approximately 12,000 km^2 will be prepared on the basis of data obtained from airborne surveys including magnetometry and radiometry.

During the second year, areas considered to be important for mineral exploration which will total approximately 4,000 km^2 will be delineated from the results of the work of the first year. Geological survey will be carried out in these areas. Also areas will be selected whose subsurface structure cannot be clarified because of the Infracambrian sedimentary cover and gravimetry will be carried out. The major objective of this operation will be the subsurface structure, especially the burried Precambrian domes and rises together with faults and lineations. These areas will total approximately 2,000 km^2.

During the third year, detailed geological survey and structural drilling will be carried out in order to clarify the geological structure of the most promising areas delineated by the work of the second year. The total area for this investigation will be about 30 km^2.

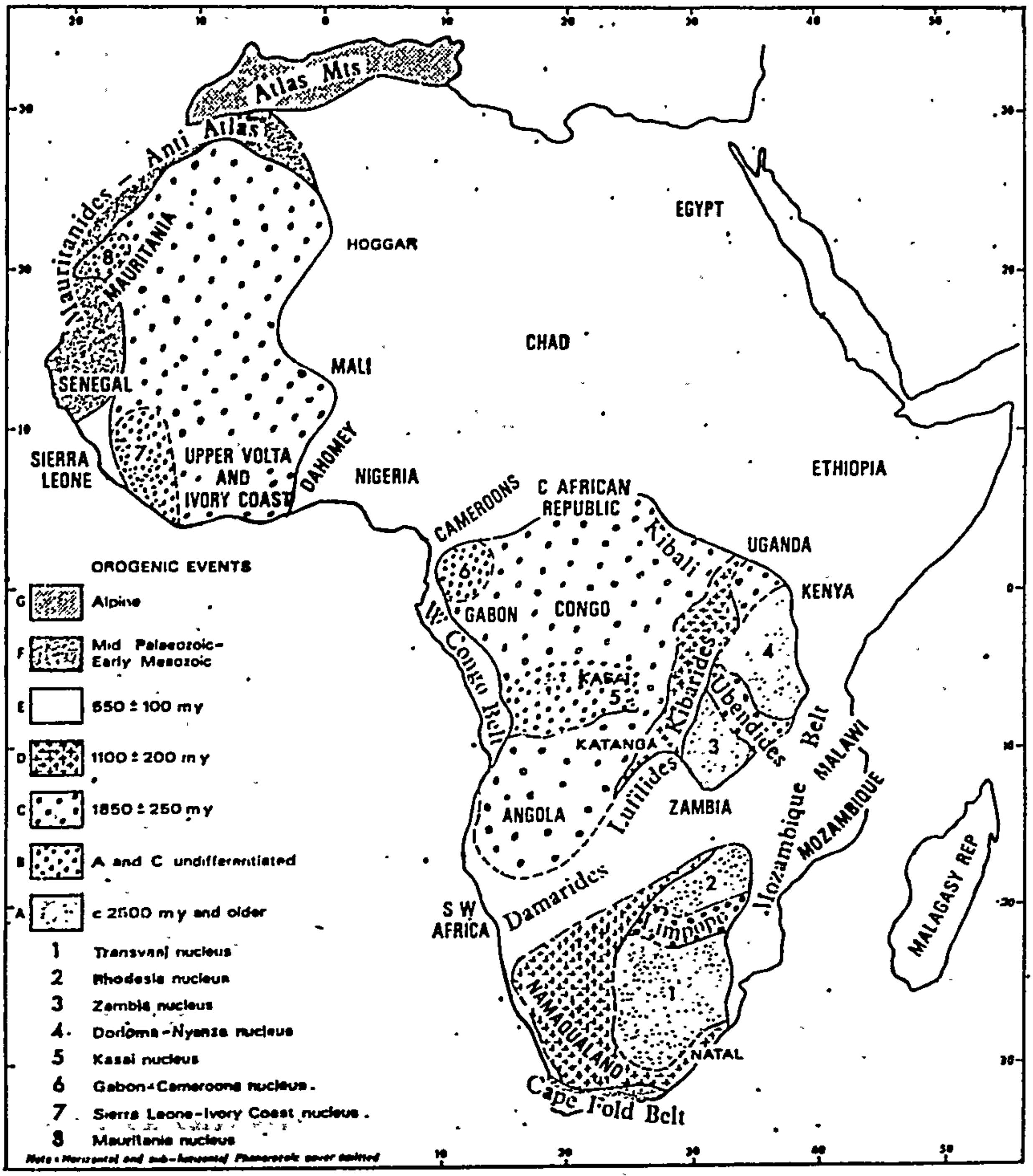
After the fourth year, the regional survey explained above will be followed up by detailed prospecting.

7. Although the Anti Atlas region is yet in the very early stages of mineral exploration as mentioned previously, its mineral potential is very high, especially for copper and other metals including uranium has not yet been investigated. It is the conclusion of this team that properly planned systematic exploration such as the one laid out in the previous section will block out large returns in terms of mineral reserves for not only known deposits but also for those which will most probably be newly discovered by the project.

Also conditions in this region relating to the development of mines are favorable and thus development of many mines can be expected.

The production of minerals from this region with copper as the major commodity will result not only in the increase of exportable commodities, but it will contribute greatly to the development of the Anti Atlas region, and also will provide employment for the population at the same time.

Fig. 2 Generalised map of the major orogenic structural units of Africa
by: T.N. Clifford 1972, (Note & M. Serv. geol. Maroc n° 236)



CHAPTER 3. GENERAL GEOLOGY

Before going into the geology of Morocco, the outline of the geology of the African continent and the characteristic features of the geology in Morocco which is located at the northwestern edge of the continent is presented.

The African continent occupies a vast area which is approximately 20 per cent of the total land area of the earth. The geological age of the continent is very old and Precambrian formations which were formed at the oldest geologic time are widely distributed.

These Precambrian rocks distributed in the African continent consisted of eight isolated cratons during the oldest (over 2,500 million years ago) times. These formations suffered four episodes of orogeny (mountain-building movement) during The Precambrian period and the area increased with each movement. And they finally developed into three cores of South, Central, and Northwest Africas. (Fig. 2)

The fifth large scale orogeny occurred from the end of Precambrian to early Paleozoic era and as a result approximately half of the continent became land area.

In the northwest part of the continent including Morocco, However, large scale marine transgression and regression occurred during Paleozoic, Mesozoic (Trias, Lias of middle Jurassic, middle Cretaceous), and Cenozoic (late Miocene) eras. Thus in this part, Paleozoic (Anti Atlas, part of Haut Atlas, and part of Meseta) formations are developed in the south and Mesozoic (Haut Atlas, Moyen Atlas, Meseta, Rif), and Tertiary (a part of Meseta, Rif) formations to the north.

Most of the African continent had transformed into a stable zone after the early Paleozoic orogeny, but the northwestern part had undergone Variscan (Hercynian) Orogeny later during Paleozoic era. And the area north of the Haut Atlas underwent Alpine Orogeny after the Jurassic period.

Precambrain stable zone which developed from the core of Mauritania craton is widely developed to the south and the southern Anti Atlas region of south Morocco formes a Hercynian orogenic zone surrounding this stable zone in an arc from northwest to north.

Alpine orogenic zone is widely developed to the north of this Hercynian orogenic zone with the Haut Atlas Range forming the southern border. This Alpine orogenic zone constitutes the major part of Morocco.

The above is the brief outline of the geology of Morocco, and it will be mentioned in some detail in the following paragraphs. (Fig. 3)

The Haut Atlas Range extends in east-northeast direction somewhat south of the central part of Morocco. The highest peak is more than 4,000 m above sea-level. Atlas Moyen (medium Atlas) branches northeastward from the central part of the Haut Atlas (high Atlas) Range.

To the south of the Haut Atlas Range, the Anti Atlas mountains extend more or less parallel in northeast direction. The altitude of the latter range is from 1,500 to 2,500 m above sea-level.

At the northern end of Morocco, Rif Range extends eastward along the Mediterranean coast in concave arc and the highest peak is 2,450 m above sea-level.

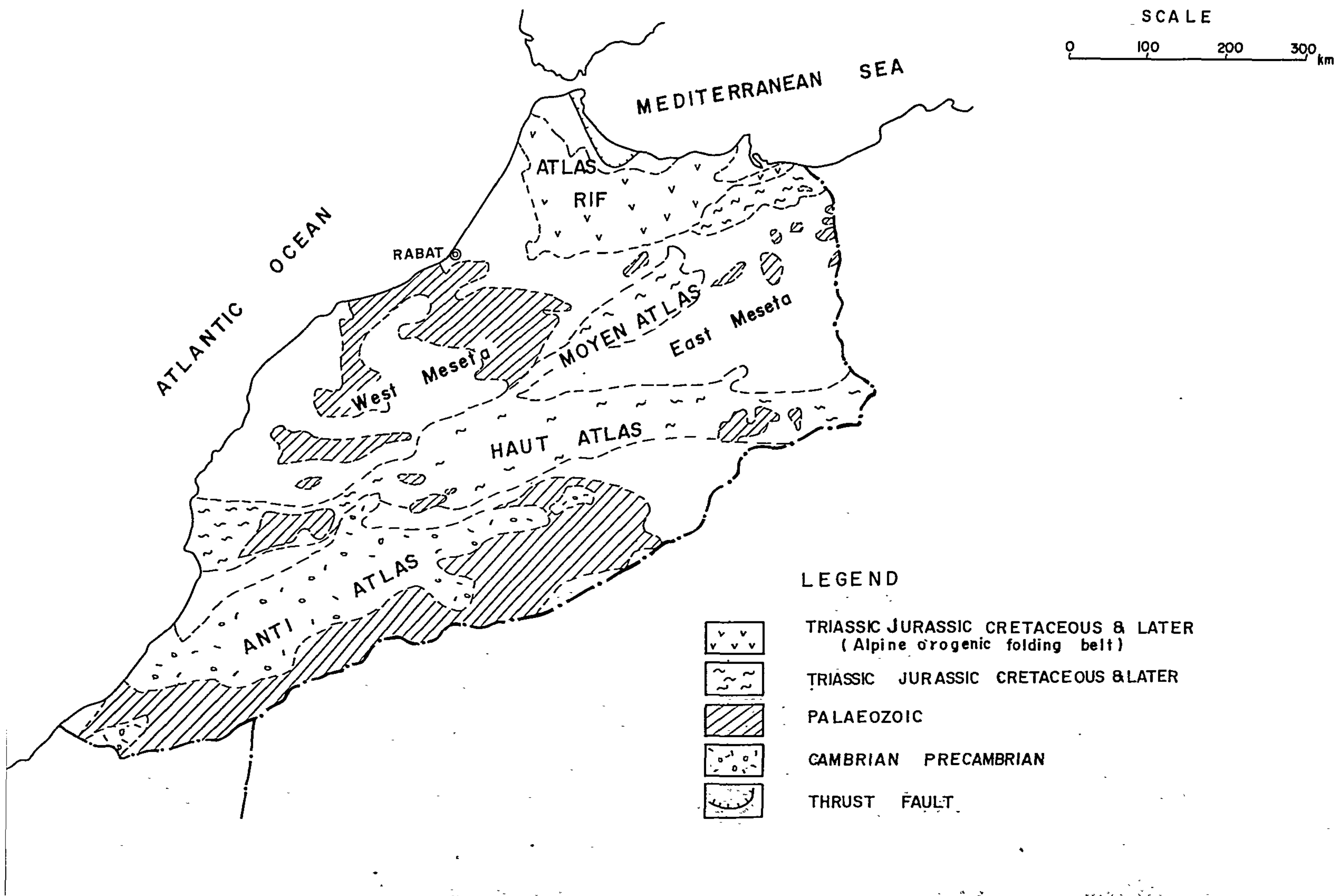
The plain or highland areas between these mountain ranges each represent individual geological units.

The following is a brief description of the geological units of Morocco.

The southernmost unit is the Anti Atlas zone whose main component is the Anti Atlas Range. This zone consists of Precambrain Basement. And the overlying Infracambrian (Adoudounian) and lower Cambrian formations are widely distributed. These are the oldest geological units of Morocco.

The Precambrian basement is exposed fairly continuously from the central to the northeastern part of the Anti Atlas zone, while it is exposed intermittently in isolated islands and distributed as inlier of

FIG 3 TECTONIC MAP OF MOROCCO



various scale in the southwestern part.

Adoudounian and lower Cambrian formations are widely distributed surrounding these inliers. Middle Cambrian, Ordovician, Silurian and other Paleozoic formations are developed in succession at the peripheral parts of the Infracambrian and lower Cambrian strata. These Paleozoic formations have been affected by strong Hercynian orogeny.

In other words, the Anti Atlas zone is a Hercynian orogenic zone consisting of lower and middle Paleozoic formations which were developed around Precambrian centers.

Haut Atlas zone lies to the north of the Anti Atlas zone. Geologic basement consisting of Cambrian - Devonian formations are observed in parts of the western and eastern Haut Atlas zone. And outcrops of Precambrian formation which extends from the Anti Atlas zone can be observed in the western part of the central Haut Atlas.

These outcrops of the basement rocks, however, are very sporadically observed and Triassic, Jurassic, Cretaceous and other middle and upper Mesozoic formations are the dominant geological units of the Haut Atlas zone. These Mesozoic formations underwent Alpine orogeny.

Similar geologic conditions are observed in Moyen Atlas zone and thus Hault Atlas and Moyen Atlas can be geologically grouped in the same unit. They belong to the Alpine Orogenic zone with Mesozoic strata being their major geological component.

Area to the east of the Moyen Atlas is called eastern Meseta. This and the central Morocco region (western Meseta) to the west of Moyen Atlas both have somewhat complex geology.

The geologic basement of these two regions consists of older Paleozoic (Cambrian-Devonian) and Carboniferous formations (Vissen-Namurian). These older rocks are exposed widely especially in the western Meseta as Paleozoic inliers in irregular and massive manner. These basement rocks have been affected by Hercynian Orogeny.

Around these inliers of basement rocks, large scale marine transgression occured at least twice, once in Lias and the other during middle Cretaceous period. The former sea covered eastern Meseta and most of northeastern Morocco including Haut Atlas, Moyen Atlas. It extended to the Mediterranean Sea and a part of the area west of the Haut Atlas. The latter sea covered a wide area to the south of the central plateau including Moyen Atlas and Haut Atlas and most of the western Meseta.

Thus Lias to Miocene strata are widely distributed in eastern Meseta and Cretaceous to Eocene formations are dominant in western Meseta.

These areas consist of relatively stable sedimentary basin and have not been much affected by Alpine Orogeny.

The Rif zone of northernmost Morocco has partly been affected by marine transgression during Trias and thus basement Trais formation is exposed partly. But the dominant geologic unit are Tertiary ranging from Eocene-Oligocene to Miocene which were affected strongly by Alpine Orogeny. Complex folding and faulting including thrust faults are frequently observed.

The above is a brief description of the general geology of Morocco and the following is a brief outline of the igneous activities of the region.

The major episodes of igneous activities of Morocco occurred during Precambrian period and Hercynian orogeny.

The Precambrian period of this region is divided into five periods of PO, PI, PII, PII-III, and PIII. And these correspond to Archean, old Precambrian, middle Precambrian, young Precambrian and the uppermost Precambrian formations.

Each of these formations has been affected by characteristic orogenic movement, and thus active igneous activities are observed in all of these formations.

The major igneous activity of PO is represented by granitic rocks.

Basic igneous activities such as gabbro, diorite, and others as well as granite and syenite are observed in PI.

In PII, ultra basic igneous activity such as serpentine is characteristic and also intermediate to basic rocks such as gabbro-diorite are abundant. Evidences of some acidic activities such as granite and quartz diorite are also observed. Volcanic rocks are found in some parts.

Volcanic activity was strong in PII-III and rhyolite, andesite and other volcanic rocks occur widely. Granitic and dioritic intrusion are observed in some parts.

PIII was the period of most intense volcanic activity and andesite, rhyolite and other intermediate to acidic volcanic rocks are abundant. Granite occurs in some parts.

It is thus seen that granitic and dioritic intrusion occured throughout the Precambrian period, and the characteristic igneous activity of the earlier and middle period is basic intrusion while that of the later period is volcanic activities.

Igneous activity was also intense during the Hercynian Orogeny. Intensive granitic intrusion is observed, and these rocks are widely distributed in central Morocco and Meseta, and also in western Haut Atlas. These bodies are accompanied by many ore deposits.

Basic igneous activities such as gabbro and diorite were also very strong and these rocks are distributed widely in central Haut Atlas and Tafilalt in southeast Morocco. Saxonite and serpentine crop out in parts of the northeastern part of Rif.

Plutonic activity is not observed after Mesozoic, but volcanic rocks of this period are exposed widely.

Basaltic activity occurred during the three periods of Permo-Trias, Cretaceous, and Quaternary. Permo-Trias basalt occurs widely in Haut Atlas, southern Moyen Atlas, central Morocco, southwestern and northeastern parts of eastern Meseta. Cretaceous basalt is distributed widely in

Stratigraphic Section from Pre-Cambrian to Lower Cambrian, Anti Atlas, Morocco

After Dr.G.Choubert

	Stage	Lithostrati-graphic subdivision	Sedimentary cycle	Fossil zone or isotopic age		
Lower Cambrian	Ourmast horizone	Micmacca horizone	Sedimentation cycle of middle Cambrian (Regression)	VIII	Paleolenus, Kingaspis etc	Lower Cambrian
	Asrir	terminal sandstone & volcanic tuff	Sedimentation cycle of lower Cambrian	VII	Gentilaspis, Protolenidae	
	Issafene	complex schist series		VI	Longianda, Callavia Gigantopygus	
				V	Neltneria, Bondonella	
				IV	Hebediscus, Pareops	
	Amouslek	calcareous schist series		III	Daguinaspis, Marcaisia	
				II	Choubertella	
				I	Fallotaspis fazemmourtensis	
		basal limestone	(Regression)		Premiers Archaeocyafha	
Adoudounian (Infra Cambrian)	Upper	upper calcareous series	Sedimentation cycle of upper Adoudounian	900 ~ 500 M.Y.	Collenia	Terminal Pre Cambrian ~ Early Cambrian
		"Lie-de-Vin" series	(Regression)			
	Lower	lower calcareous series	Sedimentation cycle of lower Adoudounian		Collenia	
		Basal Series	(Discordance)			
Pre-Cambrian	P III	Ouarzazate series	volcanic of continental series (Discordance)		Stromatlites Collenia	
	P II-III		(Discordance)		1,300 ~ 950 M.Y.	P.C late
	P II		(Discordance)		1,650 ~ 1,400 1,300 M.Y.	P.C middle
	P I		(Discordance)		2,100 ~ 1,700 M.Y.	P.C early
	P O				2,270 ~ 2,200 M.Y.	Archean

central Haut Atlas. The Quaternary basalt occurs in eastern part of central Morocco and northeastern margin of Rif.

As mentioned earlier, acidic igneous activity was intensive during Precambrian II-III and III. These rocks occur in parts of the central Haut Atlas Range as well as widely in Precambrian inliers of the Anti Atlas Range. Dacite of the Carboniferous Viseen series is found in the northeastern margin of Morocco. Intermediate to acidic rocks occur in Miocene epoch and dacite and andesite occur in parts of northeastern margin of Rif and at the northeastern extension of Moyen Atlas Range.

CHAPTER 4. GEOLOGY OF THE ANTI ATLAS REGION

As mentioned previously, the geology of the Anti Atlas region consists mainly of Infracambrian (Adoudounian), and lower and middle Cambrian sedimentary formations which are distributed around cores of Precambrian inliers. These Paleozoic units overlie Precambrian basement which crops out as inliers. These inliers are distributed as islands of various scale size.

Later Paleozoic and Mesozoic sedimentary units are found in the northern and western parts of the Anti Atlas Range. And lower Paleozoic (Ordovician and Silurian) strata are widely developed together with the Cambrian formations in the southeastern parts of the Range.

These geological units are strongly affected by Hercynian Orogeny.

The Precambrian inliers are called "Boutonnier" and consist of Precambrian massifs and the major ones are from south to north, Bas Dra, Ifni, Kerdous, Tagragra d'Akka, Irherm, Azrar, Izerbi, Zenaga, Siroua, El Graara, Tiffernine, Serhro, and Dugnat.

These inliers are of various sizes and have irregular shape, but their distribution is generally aligned parallel to the major direction of the Anti Atlas Range-northeast. The inliers are larger and more abundant in the central and northeastern parts of the Anti Atlas Range. They extend northward to the central part of the Haut Atlas from central Anti Atlas. In the northeastern part, Tifernine and Sehro, and other inliers form large masses elongated northeastward. The El Graara inlier is exposed in the central Anti Atlas as though branching out to the southeast. Infracambrian sedimentary formations are widely found immediately above the these inliers.

The central part of the subsidence which formed the Infracambrian sedimentary basin is the arc-like part extending from the western margin of the Siroura inlier (central Anti Atlas) through Azzar and Tagragra d'Akka inliers to the southern margin of the Ifni inlier. The northern part of Kerdous inlier is located approximately at the central part. (Fig. 4)

The Infracambrian formation overlies the Precambrian units unconformably, but it is in turn overlain conformably by lower Cambrian formations. Thick Paleozoic formations deposited by repeated transgressions and regressions in middle Cambrian, Ordovician, Silurian, Devonian, and Carboniferous periods. These formations are affected by Hercynian Orogeny and many folds and faults are observed. Also large scale intrusions of basic rocks associated with the orogeny are found.

The Anti Atlas region became geologically stable after the Hercynian Orogeny. Some Cretaceous and Eocene sedimentary rocks and also Post-Tertiray terruginous sediments and small scale Quaternary volcanic formations are found in the northern and western parts of the Anti Atlas Range, but these are of minor importance in the region.

The following is a description of the Precambrian, Infracambrian, and Cambrian formations which constitute the major part of the geology of the Anti Atlas Range.

4-1 Precambrian Formations

The Precambrian formations of this region have been studied stratigraphically and they are divided into PO, PI, PII, and PIII. Recently physical age determination has been carried out on these rocks and the stratigraphy is now becoming clear.

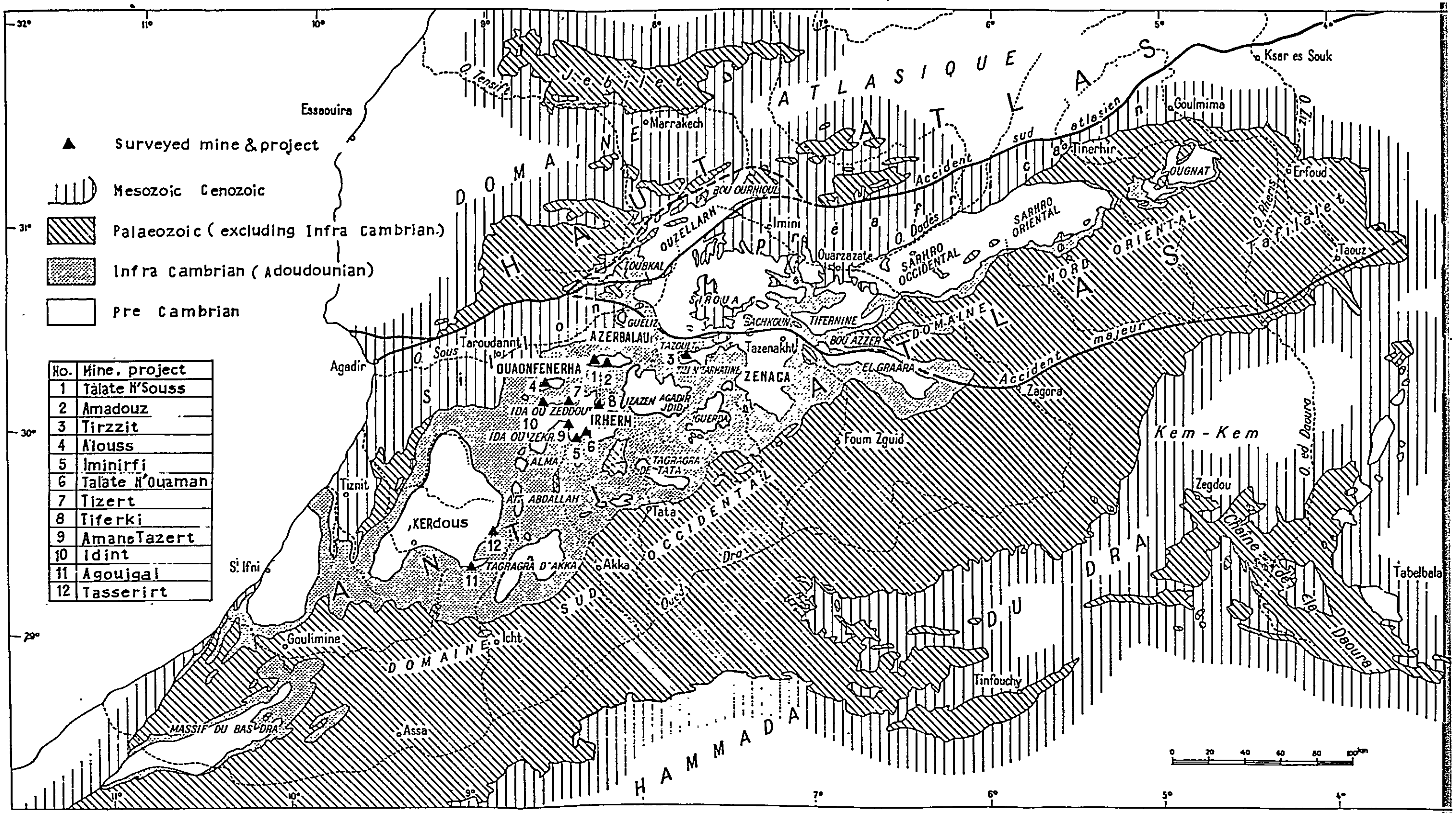
They are as follows in ascending order.

PO is the oldest Precambrian unit and is believed to be correlated to Archean. It is well developed in Kerdous inlier. The lithology consists of granite, schist, mica schist, and migmatite. The age is believed to be older than 2,200 million years. This is unconformably overlain by PI.

PI is the older Precambrian (Proterozoic) formation and the major lithology consists of igneous and metamorphic rocks. They are, granite, syenite, gabbro, diorite, migmatite, amphibolite, chlorite schist and others. The age is inferred to be 1,700 - 2,100 million years.

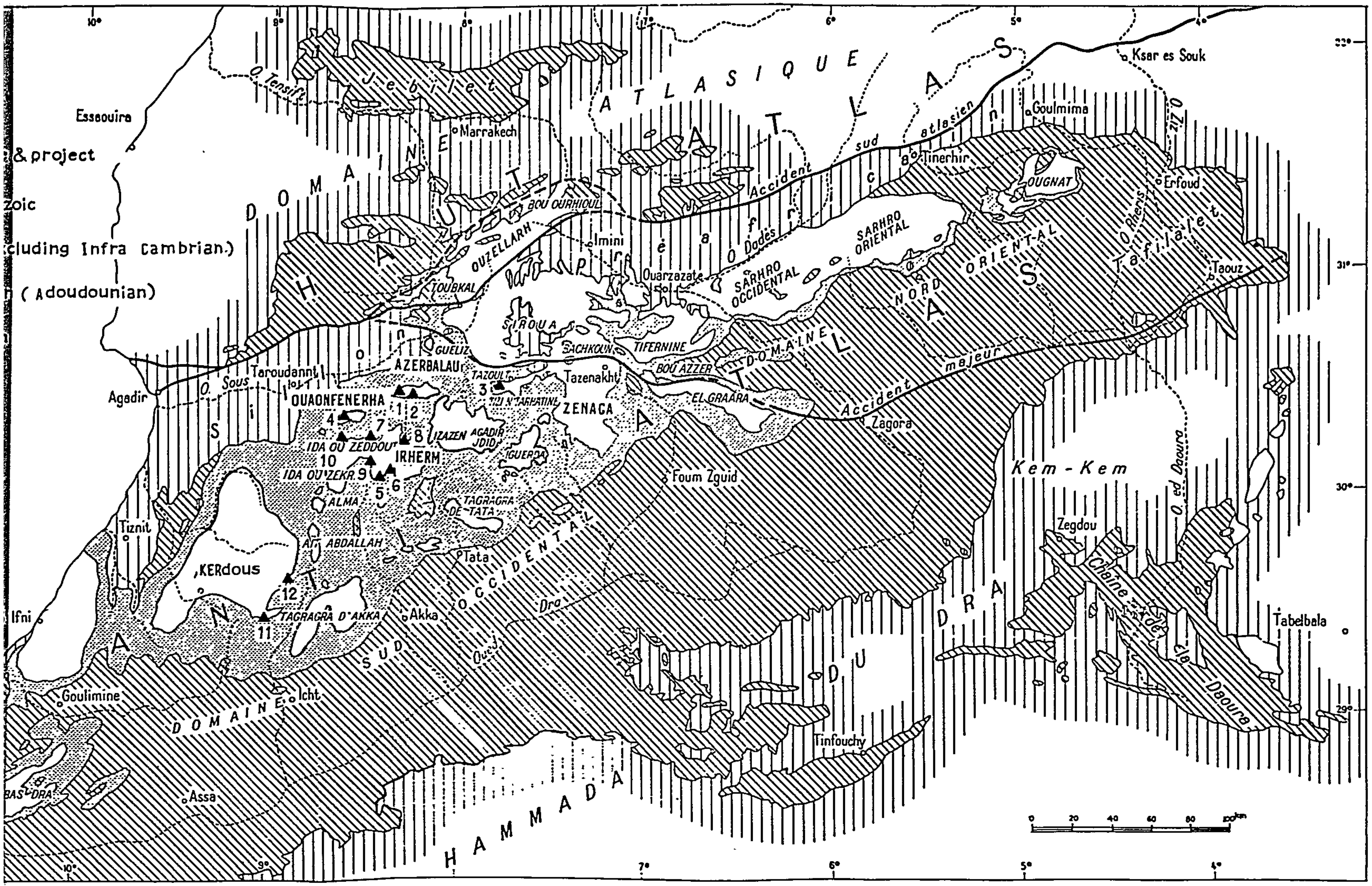
Fig. 4 Schematic geological map of Anti-Atlas area

Quoted from : G. Choubert 1963, Histoirgéologique du Précambrien de L'Anti-Atlas (Hote & M. Serv. géol. Maroc, n° 162)



Schematic geological map of Anti-Atlas area

Quoted from : G. Choubert 1963, Histoirgéologique du Précambrien de L'Anti-Atlas (Hote & M. Serv.géol.Maroc, n°162)



PII overlies PI unconformably and is middle Precambrian (Proterozoic) formation. It contains flysch sediments and characteristically contains schist quartzite and basal limestone. Also gabbro, diorite and granitic intrusive bodies are found. Volcanic sediments also occur in some parts. The age is inferred to be 1,300/1,400 - 1,500 million years.

PII-III is younger Precambrian (Proterozoic) formation and contains schist, graywacke, and flysch sediments as well as conglomerate and lenticular limestone. Rhylolite, ignimbrite, tuff, andesite and other volcanic rocks occur in large amounts. Granite and diorite intrusions are observed in some parts.

PIII is the uppermost Precambrian formation and contains very large amounts of volcanic rocks especially acidic rocks. The uppermost part is conglomerate, but rhyolite, andesite, ignimbrite, tuff, tuff breccia constitute the major part of the formation with limited occurrences of granitic intrusive bodies. The age including the Infracambrian (Adoudounian) formation is inferred to be 500 to 900 million years.

4-2 Infracambrian (Adoudounian) Formations

Infracambrian (Adoudounian) formations unconformably overlies PIII. It is divided into lower and upper strata and regression is observed between the two units. Each have its own sedimentary cycle.

The lower unit comprises the basal series at the bottom and the overlying lower calcareous (dolomitic) strata. The lithology of the basal series is conglomerate, sandstone, slate, and limetstone. It is generally 100m thick and in some parts 400m. Limestone is intercalated as one or more layers.

Thick dolomitic rocks form the major part of the lower calcareous formation and many conglomerate, slate, and sandstone are often intercalated. The thickness exceeds 2,000m is some places.

The upper Adoudounian is further divided into upper and lower units. The lower strata contain characteristically reddish purple shale called

"Lie-de-Vin" series. The upper unit consists of upper limestone formation.

Largest transgression of lower Adoudounian occurred and the "Lie-de-Vin" series deposited after the regression which followed this large scale transgression. This series consists of conglomerate, sandstone and shale. Limestone and dolomite intercalations are found in this series and thus it is seen that repeated transgression and regression occurred during the deposition of this series. The thickness of this series is 400 - 600m in the western part, but it decreases to the east.

The upper limestone formation is thick at the western part and attains maximum of 500m and is 200 - 300m at the central Anti Atlas and becomes thinner to the east.

Lower Cambrian formations overlie the Infracambrian units and evidences of unconformity are not observed between these two units and only that of regression is found. Trilobite and other fossile are found in the lower Cambrian formations and thus the age is accurately determined.

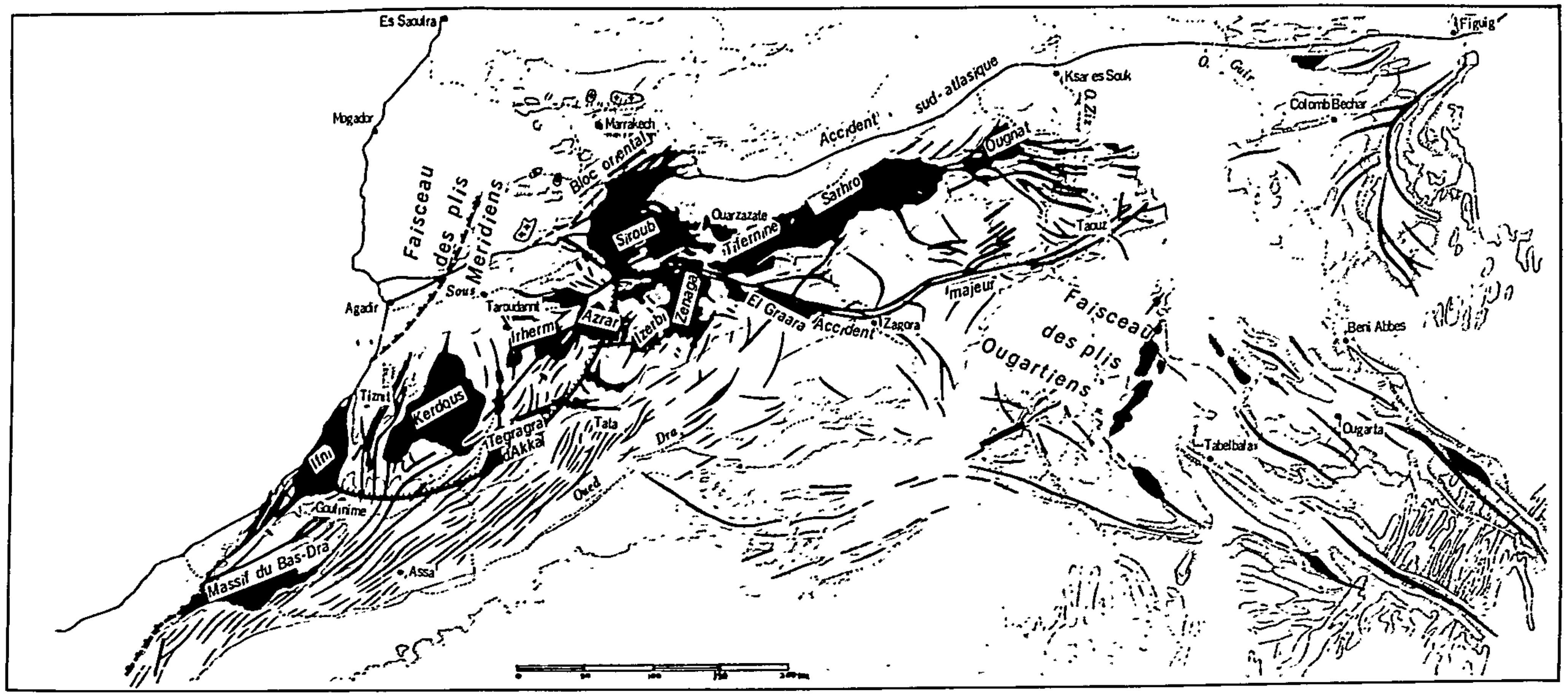
On the other hand collenia is the only fossil identified from the Infracambrian formations. Also Collenia Beistromatolite fossils are found from the quartzite series of the lower Precambrian III formations.

Thus, stratigraphically the Adoudounian (Infracambrian) formations grade into lower Cambrian at the top and to uppermost Precambrian at the bottom, but its relation to the lower PIII formation is unconformable. Paleontologically, however, Adoudounian formations do not contain Cambrian fossils and the occurrence of only Collenia makes it closer to PIII.

Recently A.A. Prashnovsky and K. Sdyuy and others have carried out electron microscopy and biochemical studies of bacteria and algae from Adoudounian and Cambrian formations. The final results are not yet published, but they have shown that there are distinct differences in flora of both bacteria and algae from the two geological units. The samples from the Cambrian units have distinctly higher amino acid content and also they contain glucosamine.

FIG. 5 Schematic tectonics of the hercynian folding

Quoted from : G. Choubert 1963, Histoir géologique du Précambrien de L'Anti-Atlas (Note 8 M.Serv.géol.Maroc, n°162)



Legend

- Folding of precambrian basement
- Folding of hercynian overlying rock
- Fault — important big fracture
- Granite of hercynian
- Limit of main Adoudounian subsidence

The present knowledge shows, therefore, that Adoudounian is the transitional phase between the uppermost Proterozoic and the lowermost Cambrian unit.

4-3 Cambrian Formations

The lowermost base of the Cambrian unit in this area consists of black oolitic limestone whose thickness is 20 to 30m. It contains Archaeocyathide fossils.

Above this limestone, the lower Cambrian unit can be divided into eight zones by fossils.

Zones I to III consists of schist-limestone and the thickness is 300 - 450m. The lithology of zones IV to VI is schist complex and the thickness is 100 - 400m. Zone VII consists of sandstone and volcanic tuff and is 150 - 175m thick.

Zone VIII consists of schist with thickness of 60m and evidences of marine regression is found between zones VII and VIII. A different sedimentary cycle is observed from zone VIII to middle Cambrian formations above.

Middle Cambrian formations overlie zone VIII. These consist of schist containing paradoxites and sandstone containing Lingules. The thickness is approximately 1,000m.

The above is the brief outline of the Precambrian, Infracambrian, and Cambrian formations which constitute the major part of the Anti Atlas Range. The details of the Ordovician, Silurian, Deveonian, and Carboniferous units will not be mentioned here.

4-4 The Outline of Geological Structure

The most important structural lineation of the Anti Atlas region extends approximately in east-west direction through the central part of the Range. It is called the "accident majeur". The geology is separated by this tectonic line and it differs to the north and south of this line. (Fig. 5).

There are three major Precambrian tectonic lines. The oldest extends in the direction of the PO (Archean) orthogneiss and is called the direction of "Zagorides" movement NW - SE to WNW - ESE. The second is in the direction which formed mica schist and migmatite. It is called "Berberides" direction N - S. The third is the youngest of the Precambrian and is in the direction of the formation of PII and PII-III. This forms the backbone of the Anti Atlas Range and is called the direction of eastern and western Anti Atlas movement, E - W. These Precambrian tectonic lines naturally control the structure of the Precambrian units.

There are three major directions in the Hercynian structure. The first is N - S direction and this is important in the western Anti Atlas, Haut Atlas in the north, and Meseta. The second is the WSW - ENE to E - W direction, and this direction generally control the disposition of the Anti Atlas Range and is parallel to the Haut Atlas Range. The third is the NW - SE to WNW - ESE direction, it is characteristic in Ougarta and Daura, and also played important role in eastern and central Anti Atlas areas.

It is seen that the three major Precambrian tectonic directions coincide with those of the Hercynian period. They, however, combine to form complex patterns in each area and the distribution is not simple.

CHAPTER 5. ORE DEPOSITS

It was shown in chapter 3 that the geology of Morocco consisted of the following large geological units. They are, from south northward, Anti Atlas zone, Haut Atlas and Moyen Atlas zone, east Meseta zone of eastern Morocco, west Meseta zone of central Morocco, and RIF zone of northern Morocco.

The ore deposits of each zone naturally have distinct features and they form metallogenic provinces.

These ore deposits will be reported below from the southernmost Anti Atlas zone northward.

5-1 Anti Atlas Zone

High temperature veins and pegmatite veins are known in the Precambrian granites from central to western Anti Atlas Range. Tungsten molybdenum quartz vein deposits are known at five localities. Also berylium tin bearing pegmatite veins are known at one locality, but these are generally of small scale.

There are manganese deposits in central Anti Atlas, they are braunite-calcite veins in Precambrian II rhyolite and andesite, four mines of this type are known. Also two volcano sedimentary braunite-hollandite deposits are known at two localities. These manganese deposits are again small.

In the central Anti Atlas area, PII basic rocks (serpentine) are widely distributed, and asbestos deposits associated with these rocks are known at four localities, but these are also small.

The serpentine is distributed along the south of "accident majeur" major tectonic line. Two or three cobalt and nickel deposits related to this ultramafic body are known. These are veins and massive deposits. The deposit at Bou Azzer is the most important of these deposits.

The Bou Azzer deposit occurs near the contact of serpentine and quartz-diorite and is closely related to the SW trending fissure. The mine is medium sized operation of 1,500 - 1,700 tons of metal production per year. The ore reserve is approximately 4 million tons of with Co grade of 1.0 per cent.

In the eastern Anti Atlas area, copper veins occur in Precambrian granite and the Bou-Skour mine is the most important mine. The operation started in 1958, and produced about 60,000 tons of crude (Cu 2.8 - 3.0 per cent) ore per year. The production in 1965 was 3,497 tons of concentrates (Cu 32 per cent) and it was one half of the total copper production of Morocco at that time.

Other copper deposits are known in eastern Anti Atlas area, but they are generally small.

Network and disseminated copper deposits occur in Precambrian III rhyolite in central and southern Anti Atlas area. Alouss mine and Talate N'Souss deposit are the two important deposits of this type. Considerable amount of drilling and tunnelling were carried out at the Alouss mine and reserves of approximately 6 million tons (Cu 0.8 per cent) have been calculated, but it has not yet been developed. Talate N'Souss is now being prospected.

Bedded cupriferous pyrite deposits occur in green schist consisting of volcanic sedimentary rocks of Precambrian II. The most important of these deposits is the El Bleida deposit in the central eastern part of the Anti Atlas area. Prospecting has been completed and 2.7 million tons of Cu 2.7 per cent ore have been confirmed and development is being planned.

Bedded disseminated copper deposits are known to occur widely in the lowermost Infracambrian sedimentary formations in the central to southern parts of the Anti Atlas region. The country rocks are shale, sandstone, dolomite, and conglomerate of the lowermost Infracambrian. Many outcrops have been found and they are being actively prospected by BRPM.

Iminirfi mine was the earliest to be developed and recently it mined out the reserves amounting to 250 thousand tons of Cu 1.8 per cent. The nearby Talate N'Ouamane mine is now being developed. The reserves of this mine is 1.2 million tons of Cu 2.0 per cent and the crude ore is being milled at the ore dressing plant of the Iminirfi mine. The scale of operation is 200 tons of crude ore per day.

It can be seen from the description above that as the Anti Atlas zone consists of complex Precambrian geology, various types of ore deposits occur and this constitutes one of the very important mineral provinces of Morocco. The deposits of special significance can be summarized as follows.

(1) Disseminated bedded copper deposits at the lowermost part of the Infracambrain sedimentary formations.

(2) Network dissemination copper deposits in PIII rhyolite.

(3) Bedded cupriferous pyrite deposits associated with PII green schist.

(4) Vein and massive nickeliferous cobalt deposits associated with PII serpentine.

(5) Copper deposits in Precambrian granites.

5-2 Haut Atlas and Moyen Atlas Zone

One of the important mineral concentration in this zone is manganese deposits. The deposit at Bou-Arfa in the eastern part of Haut Atlas is the most important bedded manganese deposit which occur in limestone. Also the Imini deposit at central Haut Atlas occurs in Cretaceous formations and is very important.

As for lead zinc deposits, Ksar Moghal, Ibourhalene, and others are lead and zinc veins in limestones in the eastern part of Haut Atlas region.

There are bedded lead zinc deposits in Lias limestone at the north-eastern margin of Moyen Atlas and the most important one is that at Bou Beker-Toussit.

A niobium bearing carbonatite deposit occurs associated with post-Hercynian alkali rocks in Haut Atlas Range, but it is small.

Bedded copper deposit is known in the Trias sedimentary rocks near western Argana of the Haut Atlas zone.

Also some pyrometasomatic deposits are known to occur in the area. They are magnetite pyrite deposits at Tassennt of central Haut Atlas, scheelite and copper deposits at Azgour of western Haut Atlas, and others. They are all of small scale.

Thus, the major mineral deposits of this zone are bedded manganese deposits, bedded lead zinc deposits, and vein deposits.

5-3 Eastern Morocco (Eastern Meseta) and Central Morocco (Western Meseta) Zone

Bedded lead deposit at Milbaden and lead vein deposit at Aouli are the important deposits of the eastern Meseta zone. They both occur in Mesozoic formations. Several deposits of this type are known in this area.

Tin tungsten veins and lead zinc copper veins which are associated with granites which are related to the Hercynian orogeny are known in the eastern Meseta. But these are all small deposits.

Many stibnite-quartz-pyrite veins related to Hercynian microgranites are known in the central to eastern part of central Morocco as well as lead zinc copper veins. These are again of small scale.

One of the most important mineral deposits in western Meseta is the Kettara mine of Jebilet area. The deposit is a bedded cupriferous pyrrhotite deposit in Carboniferous green schist. Many deposits of this type are known in this area. The reserves of the Kettara mine are approximately 10 million tons and the production is 1,500 tons (S 28 per cent, Cu 0.6 per cent) per day.

There is a barite deposit which was formed in the fractures of limestone in Jbel Ighoud. This is an important barite mine.

One of the important mineral commodity in this area is phosphates. Phosphate deposits occur in late Mesozoic to Tertiary sedimentary basins which developed in the periphery of Paleozoic massifs. These massifs are raised and exposed in western Meseta. The Khouribga and Youssoufia are well known and developed deposits. Five other undeveloped sedimentary basins are known.

Petroleum and natural gas are also found in the sedimentary basins of this area and Haricha, Sidi, Fili which is northeast of Rabat and Sidi Rhalem, Jeer, Kechoula located east of Sssauira are presently producing areas.

5-4 RIF Zone

This is a relatively poor area concerning mineral occurrences.

Many small and dissemination lead zinc deposits, those formed in fractures of limestones, bedded deposits in limestones are known, but they do not seem to be economical.

On the other hand, there are many clay kaoline, bentonite, and other non-metallic deposits. Rock salt and gypsum deposits are also known.

CHAPTER 6. OUTLINE OF THE PRESENT SURVEY

The itinerary of the survey team was laid out in chapter 1. For several days after the arrival in Morocco, the team made efforts to gather information and data on the geology and mineral resources of the area, and mines to be surveyed, and also obtained valuable information from the staff of the BRPM. Plans and general preparations for the field work were made. The field survey was carried out during the 25 days between 29 November and 23 December. Upon return from the field, the results were discussed with the staff of BRPM, preliminary report was prepared and submitted, the drill cores from the mines were logged and collected samples were studied during a period of several days before the team's return to Japan.

Major efforts of the field work was directed to the study of 12 representative deposits in the central-southern part of the Anti Atlas region. The occurrences of the deposits, the genesis, the scale and reserves were studied with the objective of obtaining information for planning future exploration of the area.

At the same time, geological reconnaissance traverse was made to the maximum possible extent for collecting basic information for planning future regional surveys of the area.

Also the team visited the Youssoufia phosphate mine and Kettara iron sulphide mine and made efforts to understand the geological outline and the mining operations of the area.

Twelve mines were surveyed, two of which were copper dissemination deposits in Precambrian III rhyolite and the remainder were bedded deposits whose major part consisted of copper dissemination in lower Infracambrian (Adoudounian). In one of the latter deposits, significant uranium concentration was found together with copper. The team was strongly impressed that it should be borne in mind during future exploration that uranium is concentrated together with copper when certain geological conditions are met.

Of the mines surveyed, one mine is presently operating at 200 tons per day, one had been mined out recently, and another ceased operation some time ago. The remaining 9 mines are either presently being prospected or has been prospected to various degrees. One deposit is totaly unexplored with the outcrope being the only available source of information.

These deposits all occur within or at the periphery of the Zenaga. Azerbalau (Tangerfa), Irherm, Kerdous, and Ouaonfenerha (Tabia) massifs of the Precambrian inliers.

It is often observed that copper showings and bedded copper deposits occur in the lower sedimentary formations of the Infracambrian sedimentary formations in the vicinity of the network and dissemination deposits in rhyolitic bodies.

The outline of the features of these deposits are shown in Table. The results of the surveys of these deposits will be mentioned in detailed in the following chapters.

During the course of the present survey, radioactivity of all rocks including the mineralized zones was measured systematically in order to determine the distribution of radioactivity. This was carried out with two purposes in mind, one was of course the survey for radioactive mineral concentration, but also the other important objective was to obtain data to determine the feasibility of using radiometry in regional geological survey. The members of the team are of the opinion that as certain rocks were shown to have high radioactivity, the method would be a very useful tool for regional geological survey.

Also it was noted that in the bedded copper deposits, uranium occurred together with copper as one of the important minerals and it was necessary to consider uranium prospecting together with copper in future work. Also the fact that Precambrian rhyolites have conspicuously high radioactivity indicate that for future prospecting for network and disseminated copper deposits in these rock bodies, radiometry should also be carried out simultaneously. The findings of radiometric survey will be reported in detail later.

Table of Surveyed Projects

Mineral Resources Development Survey in Anti Atlas Area, Kingdom of Morocco

Type of Mineralization	Project	Inlier	Ore Horizon or Host Rocks	Ore Minerals	Ore Deposits
Stratiform type	Tirzzit	Zenaga	Infra Cambrian Basal Series Eastern part--siltstone, sandstone underlying Tamjout limestone Western part--siltstone overlying limestone siltstone, sandstone, underlying Intermediate limestone.	oxide minerals > sulfide minerals malachite>>>azurite--as lamina, spot, film a few bornite---fine grain spoted	high grade zone : maximum thickness 2.0m, Cu 1.98%, thin beds, low grade not continuous. extension : strike elongation 1200m, dipside elongation 400m, average thickness 0.8m. ore reserve : 800,000t, Cu 1.8% (by B.R.P.M.)
	Amadouz	Azerbalau (Tangerfa)	Infra Cambrian Basal Series conglomerate, sandstone underlying "Petit Calcaire" limestone	Oxide minerals>>>sulfide minerals malachite, azurite---as spot, film chalcocite bornite Chalcopyrite, pyrite ------as spot, patch, dendrite	high grade zone : maximum thickness 4.5m, Cu 2.37%, distinct change of thickness, grade. extension : strike elongation 1500m, dipside elongation over 600m, average thickness 1.77m. ore reserve : 2,066,000t, Cu 1.22%, Ag 10g/t (after B.R.P.M.)
	Tiferki	Irherm	Infra Cambrian Basal Series (conglomerate, sandstone, siltstone) Pre Cambrian III Series (conglomerate)	Oxide minerals > sulfide minerals malachite----as spot, film, lamina chalcopyrite, chalcocite---spoted in conglomerate	high grade zone : maximum thickness 5.0m, Cu 1.41%, generally low grade, not continuous. extension : strike elongation 1000m, dipside elongation 500m, average thickness 1.75m. ore reserve : 375,000t, Cu 1.17%, (after B.R.P.M.)
	Tizert	Irherm	Infra Cambrian Tamjout limestone Basal Series (conglomerate, sandstone, siltstone, limestone) Pre Cambrian III Series (conglomerate)	malachite, azurite---as spot, lamina, film chalcocite, chalcopyrite, bornite--fine grained spoted. galena, sphalerite---acompanied with quartz veinlet.	extension : block / strike elongation / dipside elongation / thickness grade northern 700m 400m 4.85m 1.35% central 600m 300m 6-8m 1.30-1.37% southern 700% 800m 1-5m 1.0-2.0% ore reserve : 1,556,000t, Cu 1.62% (after B.R.P.M.)
	Talate N'Ouaman	Irherm	Infra Cambrian Basal Series (siltstone, sandstone)	sulfide minerals: oxide minerals = 7:3 malachite, covelline---as spot, lamina, film and bandded structure in high grade zone. bornite, chalcocite, chalcopyrite, pyrite--as veinlet, spot.	extension : block / strike elongation / dipside elongation / thickness east 550m 100m 0.6-1.0m west 1000m 750m 0.8m ore reserve : 1,200,000t, Cu 2.01% (after Mine Company)
	Iminirfi	Irherm	Infra Cambrian Basal Series (siltstone, sandstone)	oxide minerals>>>sulfide minerals malachite---as film, lamina. chalcocite, chalcopyrite----spot.	high grade zone : maximum thickness 3.5m, Cu 1.8-2.0% extension : strike elongation 200m, dipside elongation 400m, average thickness 1.00m. ore reserve : mined out. total mined ore 250,000t Cu 1.8%.
	Amane Tazert	Irherm	Infra Cambrian Tamjout limestone (limestone) Basal Series (sandstone, siltstone)	malachite, azurite, covelline----as spot, film acompanied with calcite, quartz veinlets. chalcocite, chalcopyrite, bornite---as spot, with acompanied with calcite, quartz veinlets.	high grade zone : thickness in Basal Series 2.0m, Cu 0.8-1.0%, thickness in Tamjout Limestone 3-4m, Cu 2.5%. extension : 2.5km NS x 1.2km EW ore reserve : 200,000t Cu 2.0% (by B.R.P.M.)
	Idint	Irherm	Infra Cambrian Basal Series (siltstone) Pre Cambrian III Series (conglomerate)	oxide minerals>> sulfide minerals malachite---as patch, film, spot in conglomerate, and as band, lamina in siltstone. bornite as spot.	high grade zone : unexploration extension : outcrop 300 x 100m
	Tasserirt	Kerdous	Infra Cambrian Basal Series (limestone, siltstone, conglomerate)	oxide minerals>>>sulfide minerals malachite---as lamina, lenticle, film in siltstone, and chalcopyrite, chalcocite---as spot in limestone.	high grade zone : bedded parts are low grade, and secondary enrichment in limestone along fault. extension : 400m NS x 170m EW ore reserve : secondary enrichment part mined out.
	Agoujgal	Kerdous	Infra Cambrian Tamjout limestone (limestone) Basal Series (sandstone, siltstone)	malachite, azurite---as lamina, spot chalcopyrite, chalcocite, bornite, pyrite, a few galena, sphalerite---as spot, acompanied with quartz, calcite veinlets. meta-zeunerite (U-mineral)	high grade zone : thickness in limestone 1.15m. Cu 1.7-2.0m, poor continuity. extension : mineralized area 500m EW x 200m NS ore reserve : 36,000t U_3O_8 0.1% (by B.R.P.M.)
Network and dissemination type	Talate N'Souss	Azerbalau	Infra Cambrian Basal Series (siltstone, sandstone, limestone) Pre Cambrian III Series (dacite, andesite)	chalcocite, chalcopyrite, pyrite--disseminate with quartz veinlet. malachite, azurite--disseminate, as film along fissure, joints.	high grade zone : disseminated type in dacite, andesite, and bedded ore in Basal Series. extension : 60m EW 30m NS thickness 10m. ore reserve : 38,000t Cu 3.0% (after B.R.P.M.)
	Alouss	Ouaonfenerha (Tabla)	Infra Cambrian Basal Series (siltstone, sandstone, conglometrate) Pre Cambrian III Series (rhyolite)	chalcocite>> bornite, chalcopyrite, pyrite---disseminate, as veinlets malachite, azurite--as film in veinlets, disseminate.	high grade zone : disseminated type in rhyolite, and weakly mineralized indication in Basal Series. extension : A orebody 400 x 150 m Cu 0.9% B orebody 550 x 200 m Cu 0.8% C orebody 130 x 130 m, 230 x 40 m Cu 0.7-0.8% ore reserve : 6,000,000t Cu 0.8% (after B.R.P.M.)

CHAPTER 7. SURVEY OF ORE DEPOSITS

7-1 Talate N'Souss Project

7-1-1 Area

Aoulouz Area, Taroudannt District, Agadir Province.

Topographic map (1/100,000 scale): Taliouine 1-2

7-1-2 Location and Access

Latitude 30°26' N, Longitude 8°20' W, Elevation 1,400m above the sea level. From Agadir to Aoulouz via Taroudannt, it is 164km by high way. After going down 37km to south from Aoulouz through rough road, there is Tamaloukt village (1,080m above the sea level). From the village, the road connects to the prospecting road of 12km to this projected area on the plateau of 1,400m above the sea level. Four wheel driving car would be suitable for the road from Aoulouz to the project site.

At 1.8km north-east of the main area, another weakly mineralized area of the Northern east Area is located.

7-1-3 Type of Deposit

Dissemination and stratiform types.

7-1-4 Geology

(1) Geological Location

Northern rim of Azerbalau inlier.

(2) Geology

It is composed of the volcanic sequence of the Precambrian III group and unconformably overlying Infracambrian Basal Series.

1) Volcanic sequence of the Precambrian III in this area is

composed of andesitic and dacitic volcanics.

Andesitic volcanics

It is characterized by the colour of dark reddish brown to purplish brown, and is composed of massive or flow-banded lava, amygdaloidal andesite, lapilli-tuff, tuff, tuffaceous sandstone etc.. The volcanics show generally well bedded sequence, but in some places, it occurs as intrusives.

Under the microscope, reddish brown andesite (sample A2504) has phenocrysts of plagioclase showing albite and carlsbad twinning, and of amphibole like mineral which is replaced by hematite and epidote, and the matrix showing pilotaxitic texture made of lath-shaped plagioclase, plagioclase microlite replaced by hematite, and of small amount of devitrified glass.

Dacitic volcanics

The unit shows the colour of white, pale gray, pale greenish gray and pale pinkish gray, and is composed of lava, lapilli-tuff, tuff and welded tuff. The unit is stratified as a whole and has some intrusives.

Under microscope, mineralized acidic rocks taken from trenches are observed as dacitic tuff which has fragmental phenocrysts of corroded quartz, plagioclase, and biotite etc. with fine-grained andesite lapilli in the matrix with devitrified glass shards.

General trend of volcanic sequences of the Precambrian III system shows the strike in the NE-SW direction and the dip 10° - 30° to the north.

2) The Infracambrian Basal Series is composed of clastic sediments such as conglomerate, sandstone and limestone, that is correlated to "Petit Calcaire", and shows ENE-WSW strike and 10° - 15° dip to the north.

Conglomerate is greenish gray in colour, and is mainly composed of subrounded pebbles of 5 cm in maximum diameter of quartzite and reddish brown andesite. Conglomerate occurs as lenticular from with maximum thickness of 4 meters. Sandstone is mainly purplish brown in color and occurs as thin lenses around the ore deposit. "Petit Calcaire" limestone is pale gray in color in the area, recrystallized, and widely distributed from the northern east mineralized area toward the west. But it had mostly been eroded out around the main mineralized area.

3) Geologic structure

The volcanic sequences of the Precambrian III which is the host rock of the copper deposit, are generally monoclinic to the north, though showing dome structure of small scale around the main mineralized area.

Several faults of E-W system (N 80° W) in the Precambrian III group and those of N 30° W system in the Basal Series are observed in the area.

7-1-5 Ore Deposit

(1) Host rock

The host rocks of the disseminated mineralization in Talate N'Souss are mainly dacitic volcanic rocks, but weak mineralization is also observed in the amygdaloidal andesite which is filled by secondary quartz distributed in the central part of trench No. 2 and in the andesite in trench No. 3, 4 and 5. Dacitic rocks in the main mineralized area are microscopically tuffaceous though they look like dacite porphyry megascopically.

(2) Alteration

Hydrothermal alteration in the area is not very intensive, but local and weak. In the main mineralized area, some dacitic volcanics show pinkish and compact feature due to silicification. The rocks, in which original tuffaceous texture remains around the silicified zone, are characterized by chloritization of biotite, and partial sericitization of plagioclase, and large amount of sericite network in the matrix.

In northern east mineralized area, alteration of andesitic rocks is observed in relatively large area.

(3) Ore minerals

Chalcocite, chalcopyrite (in limestone as the stratified deposit) malachite, azulite.

(4) Occurrence of ore minerals

The copper mineral, that is believed as primary in the deposit, is only chalcocite, and occurs as dissemination or minor veinlet mainly in the dacitic volcanic rocks.

The major copper oxide is malachite, and is observed as film along the joints and fissures in the host rocks and as dissemination altered from the above mentioned chalcocite in some cases. In some places, even if copper oxide is mostly leached out by weathering.

(5) Dimensions of ore deposits

Relatively intense mineralization of copper dissemination in rhyolite volcanics has been being confirmed in the main mineralized area at present (see Fig. VII-1-A). The assay data of copper in the main mineralized area obtained by B.R.P.M. are listed below.

	Copper percent	Sampling length
Trench No. 1	2.38%	48 m
Trench No. 2	5.4	16
Pit No. 1	3.18	6.3
Pit No. 2	1.08	1.1 (stratified mineralization in limestone)

Because of no significant mineralization in other trenches, pits and drill cores, dimensions of the ore body is inferred that the plane dimensions are presented as 60 m of EW and 30 m of NS, and ore grade is about 3 percent copper. The thickness of the ore body is not known yet but it could be assumed as about 10 m, because the thickness of dacitic volcanic sequence which yields intense copper dissemination is assumed to be of about 10 m by drilling No. 3.

(6) Stratiform deposit

In the prospecting pits for the disseminated deposits, and in the outcrop around the main mineralized area, weak copper mineralization of stratiform type is also observed in basal conglomerate, sandstone and limestone of Infra Cambrian Basal Series. It occurs as dissemination of chalcopyrite, chalcocite and malachite in the bedded rocks, and makes stratiform as a whole.

7-1-6 Ore Reserves

As it is inferred that the mineralized area would be a elipse of 60 m x 30 m, and thickness of the ore body is 10 m and density is 2.7 g/cm^3, the ore reserves would be calculated as 60 x 30 x 0.78 x 10 x 2.7 = 38,000 (tons). The grade of ore would be about 3 percent copper.

7-1-7 Past Prospecting and Present Situation

Since 1972 this area has been prospected by B.R.P.M. as follows, and trenching is now continued.

	Number	Length or depth	Total amount
Trenching	6	20 to 40 m	215 m
Pitting	6	5 m in average	30 m
Drilling	8	70 m in average	560 m

7-1-8 Recommendation for the Further Exploration

As Most of host rocks are dacitic pyroclastic rocks and the mechanism of igneous activity which is directly related to the mineralization is not clear yet, in order to obtain the controlling factor for mineralization the further investigations for volcanological occurrence of acidic volcanics and their structure would be necessary. Further exploration would be recommended as follows.

A. Reexamination of the geology around the main mineralized area.

B. A vertical drilling at the center of the ore deposit.

C. Regional geological survey for the distribution and behavior of acidic volcanic rocks.

7-2 Amadouz Project

7-2-1 Area

Tamaloukt Area, Taroudannt District, Agadier Province.

7-2-2 Location and Access

This project is located 125 kilometers (direct distance) east of Agadir City (5 kilometers east of Talate N'Souss Project) at 30°26' of north latitude and 8°17' west longitude, having an average elevation of 1,400 meters A.S.L.

One may reach Tamaloukt Village by jeep along an unpaved road of 37 kilometers from Aoulouz Village on the national road running from Agadir City, and from there to the neighbourhood of the outcrop line by a steep mountain path of 7 kilometers.

7-2-3 Type of Ore Deposit

The ore deposit is of stratiform type, mainly of copper.

7-2-4 Geology

(1) General geology

The ore deposit is, according to the classification of Precambrian group inlier, situated in the south-west marginal area of north-west branch of Arae Inlier, and the geology consists of Precambrian group III system (PIII) as seen predominantly in the marginal area of the Inlier, covered unconformably by Basal Series of Infra cambrian system and the Lower Limestone series (Tamjout Series). (See Figs. VII-2-A and VII-2-B.)

1) Pre-cambrian group III system (P III)

This system is composed of sandstone formation, conglomerate formation and andesite formation in ascending order from the lower horizon.

a) Sandstone formation

This formation consists of medium-grained sandstone having clear bedding planes and showing a characteristic purplish-brown colour, and at times contains pebbles presenting sorted texture in such portions.

Sandstone is observed to have been transformed to andesitic tuff gradually toward the western region. The formation shows the strike of N40°W, the dip of 30°SW and the thickness of more than 20 meters on the whole.

b) Conglomerate formation

This formation, presenting a characteristic purplish-brown colour, consists generally of conglomerate of pebbles of 2 to 5 centimeters in size and, occasionally, of 15 centimeters. They are mostly quartzite, andesite and rarely granitic rock. There are frequently found intercalations of sandstone, which sometimes forms an alternation with the aforesaid rocks, but in the west region, sandstone predominates as conglomerate facies reduce.

This formation is, as in the lower sandstone formation, observed to have the general strike and dip of N40°W and 30°SW respectively and the thickness of more or less 80 meters.

c) Andesite formation

This formation, looking purplish-brown coloured like the aforesaid sandstone and conglomerate formations, develops mainly in the west area of the mineralized zone generally in the form of pyroclastics such as andesitic lava, tuff-breccia, tuff, etc. while forming small dikes on the west-out side. It shows the general strike and dip of N40°W and 30°SW with the thickness of about 50 meters in the tuffaceous part.

2) Basal series

This series is composed of formations, from the lower horizon, of conglomerate, limestone (Petit Calcaire equivalent), alternated sand-siltstone, intermediate limestone and alternated shale-sandstone.

a) *Conglomerate* formation

This formation, generally brown coloured, particularly well develops in the east part of the area, having the maximum thickness of 43 meters and including blocks of about 1 meter in diameter, but generally the thickness is less than 10 meters.

This formation pinches out toward the west, at the same time becoming fine-grained and transformed to sandstone or siltstone.

Pebbles are mostly quartzite, accompanied by subordinate andesite. There are observed interbeded siltstone in the westerly mineralized area and interbeded sandstone in the easterly area. The general strike and dip are N60°W or EW and 10° to 20°SW respectively.

The conglomerate is generally looks brown in color as previously stated, and in most cases turns to greenish grey on the hanging wall side of the westerly mineralized area, presumably suggesting some relations to mineralization. The formation is covered with limestone, becoming remarkably calcareous near the top.

b) Limestone formation (Equivalent formation to Petit Calcaire)

This formation consists of grey to greyish-white recrystalized limestone, having a comparatively constant thickness of 9 meters on an average, overlaying the aforesaid conglomerate and sandstone formations conformably. Frequently, though from part to part, there are observed conglomerate thin beds consisting of quartzite pebbles. The strike and dip of the formation are N80°W to N80°E and 15° to 25°S respectively with some variations and gradually becoming steep toward the west.

c) Alternated sandstone-shale formation

This formation is an alternation of greenish shale and dark grey medium grained sandstone, having the confirmed thickness of about 60 meters in the eastern portion and the general strike and dip of N80° to 85°W and 10° to 15°S respectively.

Sandstone is relatively predominant in the east, and in the west there is observed mica schist in place of shale.

d) Intermediate limestone formation

This formation is about 28 meters in average thickness and of rock nature similar to the underlying limestone, and includes in various portions conglomerate thin beds containing quartzite pebbles.

The strike and dip are N80°E and 10°S. It forms in many cases small and topographically continuing cliffs.

e) Alternated shale-sandstone formation

This formation is a thin alternation predominant in shale, having the thickness of 130 meters and the colour tone varying from dark brown to green and further to brown as it shifts from lower to upper portions. The strike and dip are N70°E and 10° to 15°S.

3) Lower limestone series (Equivalent formation to Tamjout)

This series, consisting of limestone, is the top horizon as confirmed in this Amadouz area. It is confirmed to be more than 97 meters thick and forms characteristic steep cliffs which are topographically continuing. It is greyish-white coloured and compact dolomitic by rock nature, including in the upper portion thinbedded conglomerate (mostly quartzite pebbles) or lenticular thin beds of quartz.

The series has an average strike and dip of N60°E and 60°SE. Further, in this area, P III series shows a strike and dip of N40° to 60°W and 5° to 10°S indicated in the case of the Basal Series of the upper horizon, which clearly suggests a relation of angular unconformity.

(2) Geological structure

1) Folding structure

Both P III series and Basal Series indicate a monoclinal structure respectively in terms of the macroscopic interpretation, and no remarkable folding structure can be observed except for minor variations.

2) Paleo-topography of basement

Of Basal Series, Petit Calcaire limestone formation is generally stable in thickness by contrast with the underlying conglomerate formation of which thickness varies quite remarkably, getting swollen toward the east and pinching out toward the west portion. This presumably indicate that the area would be the correspondent to the background of Paleo-topography. (See Fig. VII-2-C.)

7-2-5 Ore Deposit

(1) Scale and occurrence of ore deposit

The ore deposit is a stratiform deposit having as host rock conglomerate formation of Basal Series (transformed to sandstone facies in west part) occurring mainly on the upper part of conglomerate formation (directly below Petit Calcaire limestone formation) and particularly well developed in a place where the thickness is less than 10 meters, but not in such portions as conglomerate formation swells or pinches out.

As regards the scale of the ore deposit, the strike has so far been confirmed to extend 1,500 meters (EW) by outcrops and pitting, and the dip side more than 600 meters by diamond drilling although the extension toward the dip side has not been made clear yet entirely.

(2) Ore minerals

The minerals are observed to include such sulfide minerals as chalcocite, bornite and rarely in the drilling cores chalcopyrite and pyrite while in the outcrops and pits, predominant are oxide copper minerals such as malachite, azurite, etc. accessory mineral is quartz although found in part.

Oxide copper minerals are observed to exist either in a film form of secondary precipitation in the cracks of conglomerate or in a dotted state remaining in the matrix. The former sometimes extends up to Petit Calcaire limestone formation immediately above.

On the other hand, sulfide copper minerals remain scattered in small quantities in the matrix in a microcrystalline form, and, in the drilling cores are occasionally found in dendritic forms accompanied by networks of quartz veinlet.

(3) Deposit conditions and bonanza

Seeing from the results of diamond core drilling, outcrops and pits, the mineralization is not uniform over the aforesaid area with variations both in thickness and copper grade, forming lenticular bonanza in parts (of comparatively high grade). According to data from B.R.P.M., the conditions of typical bonanzas, all observed in fine-grained conglomerate, are as follows:

Pit No. 25	4.5 meters thick	2.37% Cu grade
DDH No. 16	2.7 meters thick	2.09% Cu grade

The present surveys failed to go so far as will be able to refer to the cause of bonanza formation.

(4) Alternation of host rock

Generally speaking, the deposit is observed to be confined within such area of conglomerate as looking greenish-grey coloured, probably due to the existence of chlorite, but the direct relationship to the mineralization is not clear.

7-2-6 Ore Reserve

By B.R.P.M. data

Possible Ore Reserve	2,400,000 tons
Copper Grade (1.30 meter thick)	1.13%

Roughly Estimated by Survey Party

Possible Ore Reserve	2,066,000 tons
Copper Grade (1.77 meter thick)	1.22% (meter % cut off)

7-2-7 Past Exploration and Present Status

The following exploration works have been conducted by B.R.P.M.

up to 1972, but as at this time the project is left unworked.

43 pits (average depth of 3 meters)

22 drilling holes (30 - 150 meters deep)

Besides, there is an indication that some selective mining had been made on certain high grade parts of the outcrops prior to the exploration works by B.R.P.M.

7-2-8 Points of Problems

(1) Environment of mineralization

The present surveys reveal the possibility that the ore deposit would have occurred in a limited area presumed to be the paleotopographical background of the basement (P III) in conglomerate formation of Basal Series, but it needs further reviewing on whether such thinking may also be allowed to apply when viewed more extensively.

(2) On formation of bonanza

The conditions of bonanzas so far confirmed are as stated above, but they are found in limited parts and rather less concentrated or continued. Relations with paleo-topography may be well conceivable in respect of the geological positions of deposit, but the relations with bonanzas are not clear, and further, from the finding that neither the development of folding nor that of fissure is remarkable in this area and, as a result, making the formations simpler, it may be reasonable to presume that the deposit lacks in factors for enrichment of a stratiform deposit.

(3) Recommendation for future exploration

Thinking from the ore reserve and the grade currently confirmed, apart from reviewing the economic grade of ore, necessity is indicated that the extensions of mineralization be pursued toward the dip side of the deposit for the immediate purpose of possible space for exploration. In addition, according to B.R.P.M., there being reported an indication of a similar type of stratiform deposit about 500 meters west of this area, it is desired that an extensive survey be conducted for the two areas combined together and also for clarification of the cause for bonanza formation.

7-3 Tirzzit Project

7-3-1 Area

Aulouz Area, Taroudannt District, Agadir Province.

Topographic map (1/100,000 scale): Taliouine 3-4

7-3-2 Location and Access

Located 70 km east of Agadir. Lat. 30°32' N., long. 7°49' W.

Proceed 46 km eastward from Aoulouz along the paved road connecting Taroudannt and Quarzazate, then 10 km northward on an unpaved road to the mine office.

7-3-3 Type of Deposit

Bedded depost

7-3-4 Geology

(1) Geological location

Northwestern periphery of the Zenaga inlier.

(2) Geology

The geology of the area consists of Precambrian III system, and Infracambrian system which unconformably overlies the Precambrian formations. The Precambrian system consists of andesite in the lower part and alternation of quartzite, conglomerate, and shale in the upper part. The Adoudounian system consists of Basal Series in the lower part which is composed of alternations of conglomerate, sandstone, and silt stone and lower limestone series which is composed mainly of limestone and also alternations of sandstone and siltstone.

Precambrian III (PIII) andesite is dark reddish brown to reddish brown, compact, hard, and cryptocrystalline with plagioclase phenocrysts. It occurs as lava with thickness of more than 34 m, striking N 35° W and dipping NE 15°. It is partly rhyolitic.

Conglomerate is reddish brown to purplish gray, the pebble size ranges from fine to 2 cm, and they are predominantly rhyolitic pebbles with subangular shape.

Quartzite is reddish brown and hard. Banded structure is developed and the bedding plane is clear. The general strike is N 40° - 50° W, dip NE 40°, and the thickness is 100 m.

Sandstone is reddish brown to gray, siliceous and fine-grained. It alternates with fine-grained conglomerate.

Irregular quartz veinlets run through both andesite and alternation of conglomerate and sandstone.

The Basal Series of the Infracambrian system is composed of conglomerate-limestone alternation, conglomerate, conglomerate-sandstone alternation, sandstone and siltstone in ascending order, and the strike is E-W and dips N 20° - 30° with thickness of 30 - 40 m.

The limestone of the conglomerate-limestone alternation zone is pink, recrystallized, sandy and thin. The conglomerate is mainly made of rounded quartzite pebbles of about 4 cm in diameter.

The sandstone of the conglomerate-sandstone alternation zone is reddish brown and medium-grained. The sandstone and siltstone which overlie these formations are the mother rocks of the deposits. The sandstone is grayish green, siliceous, hard, and fine-grained in the lower parts, and is gray, calcareous, and fine-grained and weathered in the upper parts. The siltstone is pale green and foliated, and the upper part is pale greenish gray, siliceous, and hard fine sandstone. In the western part of the mine area, sandstone and siltstone form alternations and thin reddish brown limestone beds are intercalated.

The lowermost horizon of the lower limestone series consists of thin Tamjout limestone. This is dark gray, and massive dolomitic rock and is 1.0 - 2.0 m thick. The upper sandstone-siltstone-limestone alternation is about 90 m thick. The sandstone and siltstone are purplish brown, and the limestone is sandy and gray to grayish white.

(3) Geologic structure

Folds: The Precambrian III system generally has simple geologic structure with general strike of N 35° - 50° W and dip of NE 15° - 40°, the Adoudounian system, on the other hand, has a general E-W strike and N 20° - 30° dip. The relation between the two systems is clearly that of angular unconformity.

The Adoudounian system is extensively folded, and intraformational folding is strong in the western part of the deposit, especially in the ore-bearing horizon. The folding is stronger in the upper horizons.

Faults: A fault with N 30° W strike was observed in the eastern part of the deposit. The formations in this area are generally not faulted.

Alteration: The siltstone and sandstone of the ore-bearing horizon is generally strongly chloritized, and sericitization is also observed. Fair amount of sericite was observed between the hanging wall and the orebody in the adit.

Paleotopography: The thickness of the Basal Series is constant throughout the area at 35 - 40 m, and evidences of the effect of paleotopography were not found in the mineralized area.

7-3-5 Ore Deposits

The deposit of this mine is of bedded type occuring in the host rock of sandstone and siltstone of the Basal Series. In the eastern part, the siltstone immediately under the Tamjout limestone is mineralized, while in the west, siltstone immediately below the reddish limestone bed is mineralized as well as the one below Tamjout.

The major ore mineral is malachite and azurite is found in small amount in the western part. Bornite was found in the drill cores. Malachite occurs as thin films or thin beds along the foliation planes of siltstones and intercalated sandstones. The mineral also occurs scattered in fine grains, and in banded structures in the high grade parts of some sandstones.

The drilling data of BRPM shows that the grade is Cu 1.98 per cent for a thickness of 2 meters in drill No. TT7 and, Cu 2.03 per cent for 1.40 m in drill No. TT17 in the eastern part, and Cu 1.38 per cent for 0.7 m in drill No. TT2 in the western part. These are high grade ores, but they are not continuous and the grade is generally low. The extent of the deposit confirmed from the exposures and drilling is 1,200 m in strike direction and 400 m in dip direction and the average thickness is 0.8 m.

7-3-6 Reserves

BRPM data show that reserves of 800,000t of ore with average grade of 1.80 per cent were confirmed from the results of drilling in the central and western areas. Also it is expected that future exploration will prove additional 3 x 10^6 tons in these areas and further 2 x 10^6 tons from the eastern part which is yet unexplored.

7-3-7 Future Prospecting

(1) It is necessary to clarify the genesis of the ore deposits, especially the enrichment process of the ore deposits.

(2) The effect of paleotopography to the formation of the ore deposit has not been clarified for the whole area and investigations in this field will be of great importance to future prospecting.

(3) The fold structure must be clarified in the regional scale, especially the relationship between the folding of Tamjout limestone and of the Basal Series must be clarified.

(4) It has been said that there is no special relationship between ore enrichment and alteration, but from the present study it seems that this hypothesis can be reconsidered.

7-4 Alouss Project

7-4-1 Area

Taroudannt area, Taroudannt District, Agadir province.

Topographic map: 1/100,000 Taroudannt 3-4

7-4-2 Location and Access

Latitude 30°20' N, Longitude 8°35' W.

The mine site is reached by 3 km of narrow gravel road from the junction about 58 km south-east from Taroudannt through the highway to Irherm.

7-4-3 Type of Mineralization

Both dissemination and stratiform types.

7-4-4 Geology

(1) Geological province

Northern rim of Ouaonfenerha (Tabia) inlier.

(2) Geology

It consists of andesitic and rhyolitic rocks of the Precambrian III group and unconformably overlying Infracambrian Basal Series (see Fig. VII-4-4).

The Precambrian III group in the area is composed of dark reddish brown coloured tuff and siltstone, reddish brown coloured sandstone and conglomerate, dark green coloured andesite lava, and the rhyolitic volcanic rocks from lower to upper; and in the latest rhyolitic rocks the ore deposits of dissemination type have been found.

The rhyolitic volcanics occur as the thin tuff breccia at the bottom, which contains the andesites fragments, and as lava flow or lava dome with volcanic necks as a whole. Because of errosion, the rhyolitic rocks are extended in only a small area of 800 m x 800 m at present. As the distribution is distinctly controlled by the faults, it is suggested that the rhyolite bodies had been errupted along the faults (see Fig. VII-4-A).

The rhyolite is pinkish to dark gray in colour under naked eyes, and has the various features such that some are rich in the phenocrysts of quartz and feldspar, the other are siliceous with minor amount of phenocrysts, and some of them have the bands or networks of chlorite.

Under the microscope, the rhyolite has the phenocrysts of quartz, potash feldspar, small amount of plagioclase and chloritized mafic minerals and often contains fragmental matter. The matrix shows variety of texture from granophyric to glassy.

The Basal Series, which overly the Precambrian III group, is distributed in the southwestern area of the ore deposit. They are composed of conglomerate, sandstone, siltstone and the limestone correlated to "Petit Calcaire", and generally trends to East-West and dips about 20° to the south. In these series, weak stratiformed copper mineralization has also been found.

(3) Geological structure

The geological structure in the area is characterized by the fault of NNE-SSW system and the conjugated fault of ENE-WSW system. They develope in the andesitic volcanics of the Precambrian III group and rhyolite volcanic necks occur along the faults, while the rhyolite bodies are cut by these faults. However, the Basal Series are not affected by these faults. Therefore, it is believed that those fault systems had been active since before the rhyolitic igneous activity through the Precambrian III period.

7-4-5 Ore Deposits

(1) Host rock

Copper occurs in the rhyolite, and rhyolitic pyroclastic rock, as dissemination and veinlet.

(2) Alteration

In rhyolite, silicification, chloritization and epidotization are recognized. Silicification is often observed as the secondary quartz as pseudomorphs after phenocrysts and as replacement product in the matrix, and also as quartz veinlet.

Chlorite occurs as bands and networks in the rhyolite, and tends to be generally more abundant near the ore bodies except for A-ore body. But locally negative correlation is observed between the amount of chlorite and the degree of mineralization in B-ore body as shown in Fig. VII-4-B-(2). Under microscope, chlorite occurs as veinlet, network and alteration relic of mafic minerals.

Epidote occurs mainly as granular clinozoicite, coexisting with quartz, chlorite and ore minerals.

Andesitic rocks surrounding the rhyolite body are widely and strongly suffered by epidotization, although the relation to mineralization is not certain.

(3) Ore minerals

Sulfide minerals: Chalcocite, bornite, chalcopyrite, pyrite.

Oxide minerals: Malachite, azulite.

(4) Occurrence of ore minerals

Sulfide minerals are mainly composed of the chalcocite in which bornite occurs as a core in some cases. Chalcopyrite and pyrite are found limitedly in tuffaceous part of rhyolitic rock in the northern part of A-ore body. Sulfide minerals occur mainly as dissemination, veinlets or network with quartz and/or calcite and sometimes patches along the joint and crack planes.

The oxide copper minerals mainly composed of malachite occur near the ground surface as film along the craks of various directions and also as secondary alteration product after disseminated copper sulphide minerals.

(5) Dimensions of ore deposits

There are found three ore bodies of A, B and C in rhyolitic volcanic rocks.

A-ore body is situated in the rhyolite which erupted in the west side of the fault of NNE-SSW direction, and has the spindle-like form with the dimensions of 400 m in N-S direction and 150 m in E-W direction.

B-ore body is located north east of A-ore body and shows the spindle-like form with the dimensions of 550 m in NS direction and 200 m in EW direction in the rhyolite body which erupted in the east side of the faults of NNE-SSW direction.

C-ore body is located at the south-end of the rhyolite body which is the same unit as the host rock of B-ore body, is composed of the two ore bodies of 130 m x 130 m and 230 m x 40 m along ENE-WSW fault.

Ore grade of each ore body ranges from 0.6 to 1.0 per cent of copper, and is around 0.8 per cent of copper in average.

The ore bodies mentioned above are distributed along the conjugated faults of NNE-SSW and ENE-WSW direction. The direction of the veinlet in the ore bodies is consistent with the direction of the faults. These suggest that the mineralization would strongly be controlled by geological structure.

7-4-6 Ore Reserves

According to the data from B.R.P.M., estimation of the ore reserves is presented as follows.

Ore body	Probable reserves error ±10 - 30%	Possible reserves error ±50%	Inferred reserves
A	3,940,000t Cu 0.91% Ag 14.5 g/t	600,000t Cu 0.82% Ag 6.4 g/t	
B		1,150,000t Cu 0.74% Ag 8.0 g/t	300,000t
C		83,000t Cu 0.74%	50,000t
Total	3,940,000t	1,833,000t	350,000t
	5,773,000t		
	6,123,000t, Cu 0.8%		

7-4-7 Past Prospecting and Present Situation

In this project, relatively large amount of exploration works such as trenching, drifting (8 drifts, total 234 m), pitting (4 pits, 10 m in average depth) and drilling (total 1,600 m) had been carried out by B.R.P.M. and others until 1969 and since then no active exploration has not been undertaken.

7-4-8 Consideration and Recommendation

It is thought that the dimensions of this ore deposit are almost confirmed by past exploration work. Exploitation of this deposit which has the ore reserves of 6,000,000 tons and the ore grade of 0.8 per cent of copper, seems to be not very much atractive unless additional ore reserves in the vicinity were found.

For the further exploration, the regional geological survey to clarify the distribution of rhyolitic igneous activity in the area would fundamentally be recommended, in order to find additional ore reserves.

7-5 Iminirfi Mine

7-5-1 Area

Irherm Area, Agadir Province

Topographic map (1/100,000 scale): Taliouine 5.6.

7-5-2 Location and Access

Located 7 km southeast of Irherm. Lat. 30°02' N., long. 8°25' E., altitude 1,600 m above sea-level.

Proceed 12 km from Irherm on an unpaved road to the mine. Irherm is located 177 km on the highway from Agadir harbour via Taroudannt.

7-5-3 Type of Deposit

Bedded deposit

7-5-4 Geology

(1) Geological location

Southern periphery of the Irherm inlier.

(2) Geology

The geology in the vicinity of the ore deposits consists of the Infracambrian Basal Series and overlying lower limestone. The Basal Series consists of conglomerate, sandstone, and siltstone (called schist at the mine) in ascending order, sandstone and siltstone often form alternation. The lower limestone series is composed of massive dolomitic rock and is believed to be correlated to the so-called "Dolomies de Tamjout". Gabbroic dykes are found in the southern and eastern parts of the deposit, these intrusive bodies cut the ore bodies and thus is of later activity.

(3) Geologic structure

There are two NW-SE trending parallel anticlinal structures near the ore deposits, and the ore mineralization is developed westward from the western limb of the eastern anticline. Significant faults were not observed.

7-5-5 Ore Deposits

The deposits occur in the uppermost (immediately below the upper limestone bed) horizon of the Basal Series. The host rocks are pale green sandstone-siltstone alternation and the deposits are developed westward from the western limb of the anticline. There are upper and lower mineralized beds within 7 m of thickness. The upper layer has been the major target of mining. The general trend of the deposits is N 40° W strike and 30° - 40° SW dip.

(1) Constituent minerals

Small amounts of chalcocite, chalcopyrite, and bornite are the sulfide minerals. But the major ore mineral is malachite. The sulfide content is very small even at the bottom of the deepest adit.

(2) Occurrence

Both sulfides and oxidized minerals occur as fine-grained dissemination, but in the high grade parts, malachite is concentrated along the foliation of the host rock and shows banded structure.

(3) Size and grade of the deposits

The extent of the mineralized zone is 200 m in strike direction, 400 m in dip direction, thickness is 3.5 m maximum, 0.8 m minimum and 1.0 m in average. The grade is 1.8 - 2.0 per cent Cu.

7-5-6 Ore Reserves

Approximately 250,000 tons of ore with grade of Cu 1.8 per cent were mined until ceasing operation at the end of the first half of 1973.

7-5-7 Past Prospecting

1963 Open cast mining was started by BRPM.

1965 Ore dressing plant with capacity of 200 t/day completed with Czechoslovakian aid.

1968 Start underground mining.

1973 Conclude mining operations.

7-5-8 Future Prospecting

One characteristic feature of this mine is that there are two parallel anticlinal axis on the eastern and western sides of the deposit, and that it is highly probable that these structures contributed to the enrichment of the ores.

The staff of the mine has postulated the hypothesis that the copper ores of the lower horizons moved upward as oxidized ores along the fractured zones which were formed at the time of folding and that this was the major mechanism of the enrichment of the ores. The mechanism of enrichment of ores will be one of the most significant problems which must be clarified by future work.

7-6 Talate N'Ouaman Mine

7-6-1 Area

Irherm area, Agadir Province.

Topographic map: (1/100,000 scale): Taliouine 5.6.

7-6-2 Location and Access

Located 7 km northeast of Iminirfi mine (7-5). Lat. 30°03'N., long. 8°24'W. Altitude 1,700 m above sea-level.

Proceed 9 km on an unpaved road from the Iminirfi mine.

7-6-3 Type of Deposit

Bedded deposit

7-6-4 Geology

(1) Geological location

Southern periphery of Irherm inlier.

(2) Geology

The lithology of the geologic units of the area in the vicinity of this mine is identical to that of the Iminirfi mine mentioned previously.

7-6-5 Geologic Structure

Folds in the scale of those at the Iminirfi mine cannot be observed in this mine, and the general trend of the geology is a monoclinic structure with N70° E strike and 20° S dip. Locally, however, there are many small folds whose axies trend generally in the direction of the dip of the formation. Also intraformational folds are developed in the siltstones or alternation of siltstone and sandstone which constitute the host rock of the ore deposit.

Significant faults are not observed but many fractures are observed in strongly folded zones.

7-6-6 Ore Deposits

The deposits of this mine are similar to those of the Iminirfi mine. The bedded orebodies occur in siltstone or silt-sandstone alternation directly underlying dolomitic limestone. The upper bed was the major target of mining at Iminirfi mine while the lower bed is being mined in this mine.

(1) Ore minerals

The major ore minerals of the upper bed are oxidized copper minerals while those in the lower bed are sulfide minerals. The sulfide minerals are bornite, chalcocite, covelline, chalcopyrite, and pyrite. The oxidized minerals are malachite and very minor amount of azurite. The important minerals are bornite, chalcocite, and malachite. The ratio of sulfide to the oxidized minerals of the lower bed is approximately 7 : 3. Also the silver content of the crude ores of this mine is relatively high (Ag 60g/t). The silver mineral is not known, but according to the mine staff, it is higher in the lower part (3 times that of the upper horizon) of the deposits.

(2) Occurrences

Most of the sulfide occurs in fine disseminations in the host rock or associated with calcite veinlets, several of these vienlets from banded structure. Oxidized minerals occur more in the upper bed and they occur along the foliations and fractures. Also there is tendency that malachite, covelline, chalcocite, and bornite is more abundant at the anticlinal parts while chalcopyrite and pyrite are more abundant in the synclinal parts.

(3) The size and grade of the deposits

The confirmed extent of the mineralized zone is 1,400 m in strike direction, 1,000 m in dip direction. But the high grade portion of this mineralized zone is 100 m in strike and 550 m in dip directions in the eastern side and 750 m in strike and 1,000 m in dip directions in the western side. These high grade parts are connected along the anticlinal axes of small folds. The above extent of the high grade portions are the case of the lower bed and those of the upper bed are much more limited. The thickness of the upper bed is 0.6 - 1.0 m and varies considerably while that of the lower bed is relatively constant at about 0.8 m.

(4) Enrichment

The fold structure of the host rock plays an important role in the enrichment of the ore deposit. The concentration of ore minerals in the anticlinal parts indicate the close relationship between the grade and the fold structure. The mechanism for this is not clarified, but remobilization of ore minerals could be a possibility. The abundance of oxidized minerals in the upper bed can also be explained by this process.

7-6-7 Ore Reserves

The data of the mine shows reserves of 550,000 tons of ores with 2.05 per cent proven, and 650,000 tons of Cu 1.95 per cent ores estimated; bringing the total to 1.2 million tons of ores of Cu 2.01 per cent.

7-6-8 Exploration-Past and Present

The deposit was prospected together with the Iminirfi deposit and development was started in 1973. At present the mine is operated by a Morocco 50 per cent and Rumania 50 per cent joint venture.

The production is 200t/day of crude ore with the grade of Cu 1.75 per cent and Ag 60g/t. The crude one is sent to Iminirfi mine by truck for milling and the concentrate is sent to Agadir harbor by truck. Sixty tons of the crude ores come from the upper bed and the remaining 140 tons from the lower ore bed, thus the mineral ratio is 40 per cent oxidized and 60 per cent sulfide minerals. Mixture of oxidized and sulfide ore minerals is treated by flotation (sulfide coated), the recovery is 84 per cent, and the copper concentrate is Cu 31 per cent. The number of mine personnel is mining 165 (140 underground, 25 surface), milling 35, and others 65 with a total of 265. The work schedule is three eight hour shifts.

Drift is carried out for prospecting and drilling is being done for the peripheral parts. Mining is done by room and pillar method.

7-6-9 Future Prospecting

One of the major problems to be solved for prospecting purposes at this mine is the mechanism of enrichment. The ore shoots are formed along the anticlinal axes and are closely related to folding as mentioned in the preceding sections. One of the possible processes is remobilization. This is yet to be proven, and this problem, the team feels, is of major importance for future exploratory work of this mine.

7-7 Tizert Project

7-7-1 Area

Irherm Area, Taroudannt District, Agadir Province.

7-7-2 Location and Access

Located approximately 11 km north of Irherm. Lat. 30°13' N., long 8°27' W.

Proceed 55 km from Taroudannt toward Irherm on highway, turn eastward and proceed 11 km on an unpaved road to the deposit. Topography is that of a peneplane of 1,400 m above sea-level. The peneplane is dissected by the Tizert River and outcrops of the deposit are seen continuously along the cliffs formed by this river.

7-7-3 Type of Deposit

Bedded deposit.

7-7-4 Geology

(1) Geological location

Northern periphery of the Irherm inlier or Ida-ou-Zeddout inlier.

(2) General geology

The geological basement of this area is Precambrian III conglomerate. Rhyolitic dykes have intruded though this basement which is overlain unconformably by lower Infrabambrian Basal Series.

The Basal Series consists of lens-shaped basal conglomerate, alternation of coarse to fine grained sandstone-siltstone-shale, and micro conglomerate in the upper part. In some parts, lenses of limestone (Petit Calcaire) are intercalated in the upper part of conglomerate. The thickness of the series varies between 10 to 80 m.

The Basal Series is overlain by 0 - 120 m of dolomitized limestone (the Tamjout limestone or the lower limestone) and quartz beds are intercalated in this formation.

(3) Lithology

1) Precambrian III basement conglomerate

Subangular to rounded pebbles (20 - 50 cm) of quartzite, andesite, rhyolite, and granite are the main constituents of this rock. It is chloritized and green near the ore deposit, but it becomes reddish brown away from the orebodies.

2) Precambrian III rhyolitic dykes

The outcrops of the rhyolitic dykes observed in the western part of this area consist of pale green porphyritic rhyolitic dykes associated with pyroclastics such as rhyolitic welded tuff or tuffs.

Very minor amounts of malachite and chalcocite are found in the sheared zones of these dykes.

3) Basal conglomerate lenses of the basal series

The basal conglomerate of this area occurs intermittently and in some localities it directly overlies PIII conglomerate. In such areas, it is difficult to establish the boundary between the two formations. The PIII conglomerate, however, is polygentic while this bed is monogenetic with subrounded 1 - 3 cm pebbles of quartzite. The matrix is sandy to siliceous.

4) Sandstone-siltstone-shale alternation of the basal series

siltstone ..... Pale green, often mixed with argillaceous and arenaceous materials.

Sandstone ..... Pale green, calcareous, often alternation of fine and coarse-grained parts. Bedding well developed in some localities.

Shale .... Reddish brown, phyllitic in some localities.

As mentioned before, pale green sandy limestone lenses are intercalated in this bed.

5) Microconglomerates of the basal series

A part of this conglomerate occurs as intraformational conglomerate, but generally it occurs at the uppermost part of a series of beds, in other words as the top conglomerate. The majority of pebbles are quartzite with minor content of rounded sandstone and limestone pebbles. The matrix is very calcareous. The size of the pebbles ranges from 2.5 to 0.5 cm and the color is generally pale green.

6) Dolomitic limestone (Lower limestone formation)

This is correlated to the Tamjout limestone, and contains intercalations of this quartzite and is dolomitic. These features are characteristic of Tamjout limestone. The lower part of this bed is grayish white but the upper part is discolored to violet.

(4) Geologic structure

The general strike and dip of the Basal Series of this area are N20°-40° E and 15°-30° NW. This formation is gently folded.

7-7-5 Ore Deposits

(1) Mineralized horizon

There are the following four mineralized horizone in this area.

(A) The PIII conglomerate and the basal conglomerate of the Basal Series.

(B) The middle part of the Basal Series.

(C) The boundary of the uppermost part (mainly micro-conglomerate) of the Basal Series and the overlying lower limestone (Tamjout dolomitic limestone).

(D) Lower limestone (Tamjout limestone).

(2) The extent of mineralization

Three mineralized zones, namely the northern, central, and western zones have been confirmed along a distance of 3,000 m in strike direction (NNE) and 800 m in dip direction (SSE).

1) Northern zone

The extent of mineralization of this zone is 700 m in strike and 400 m in dip directions. The mineralization occurred mainly in (B) and (C) of the preceding section. The results of the drilling by BRPM showed that metal concentration in (C) microconglomerate is relatively stronger (for example, in drill hole S-52, the thickness of mineralization is 4.85 m with average grade of Cu 1.35 per cent including the high-grade portion of 2.90 m with grade of Cu 1.90 per cent). Mineralization of 1.30 m thick with Cu 1.06 per cent is observed in some parts of the lower limestone formation but these are very intermittent.

2) Central zone

The drilling results have shown that there is a mineralized zone in this part with dimensions of 600 m in strike and 300 m in dip directions. The mineralization in this zone occurred mainly in (C) the coarse sandstone or microconglomerates of the uppermost horizon of the basal series. The results of prospecting indicates that the general thickness of the ore deposit is 6 - 8 m and the copper grade is 1.3 - 1.7 per cent. Also it was shown there are lenses of high-grade portions with thickness of 1 - 2 m and grade of Cu 3-4 per cent in some parts of this zone.

3) Western zone

It was confirmed by trenching, drilling, and tunnelling that there are five orebodies in a zone of 700 m in strike and 800 m in dip directions. These deposits occur in all of the (A), (B), (C), and (D) horizons. But the enrichment is especially strong along the boundary between the microconglomerates and the lower limestone (Tamjout limestone) horizon (C). The tunnelling showed that metal concentration occurred in the small conglomerate lenses of the middle and lower parts of the Basal Series. Drilling at 150 m intervals, however, showed that these orebodies are not continuous and that the size and grade varies considerably. It is recorded in the BRPM data that the largest orbodies in (a) the PIII conglomerates are 3 m in thickness and Cu 1.0 per cent, (b) the basal series 1 - 4 m thick and Cu 1.0 - 1.7 per cent, and (c) the contact between the uppermost part of the basal series and the lowermost part of the lower limestone (Tamjout limestone) are 1 - 5 m thick and 1.5 - 2.0 per cent Cu.

Also copper mineralization is observed in the thin layers of the lower limestone which is widely distributed in this area. Outcrops of lead and zinc quartz network-venis are also confirmed in this area.

(3) Ore minerals

1) Bedded deposits

a) Sulfide ores: Chalcopyrite, bornite, chalcocite, and other minerals occur in sandstone, micro-conglomerate, or limestone formations.

b) Oxidized ores: Malachite is the main component. The ore occurs as either irregularly precipitated material or in thin films filling the fractures of the host rocks. Banded structure of the ore in alternations of sandstone and conglomerate is observed in the western zone.

2) Veins

Quartz veins: Coarse-grained sphalerite and galena occur in the network-veins in limestones. These veins are considered to have been formed by remobilization of the lead and zinc minerals which were originally formed in the copper deposits in the Basal Series.

7-7-6 Ore Reserves

The following reserves were tabulated for these deposits from the BRPM data and the results of the present survey.

Orebody	Proven (t)	Estimated (t)	Probable (t)
Central Zone (RUN A-1)	756,300 (Cu 1.69%)	-	-
(RUN B)	-	-	130,000 (Cu 1.80%)
(RUN D-1)	-	-	27,000 (Cu 2.46%)
Western Zone	177,700 (Cu 1.94%) (Ag 29g/t)	394,800 (Cu 1.01%) (Ag 17g/t)	70,000 (Cu 3.85%) (Ag 46g/t)
Sub-total	934,000 (Cu 1.73%)	394,800 (Cu 1.01%)	227,000 (Cu 2.51%)
Grand Total	1,555,800 (Cu 1.62%)		

7-7-7 Prospecting Past and Present

The outcrops of these deposits were discovered circa 1969, and trenching was carried out. Since then the following work has been carried out until 1973.

Drilling:	80 holes, total length of 10,390 m
Vertical shaft:	One, 36 m
Declining drift:	One, 305 m
Level:	Two, 925.5 m
Trench:	Twelve, 241.7 m

These operations were completed in 1973 and at present no further work is being done.

7-7-8 Future Prospecting

Although the nature of enrichment of this deposit has not been clarified sufficiently, the concentration of the metals in the uppermost sandstone and microconglomerate of the Basal Series directly underlying the lower limestone is an important factor in considering the mechanism of mineralization. And also makes this a typical deposit for the consideration of the genesis of this type of ore deposits.

Significant folding was not found during the course of the present study, but it seems highly probable that a detailed analysis of the geologic structure of the Basal Series will yield significant results for discovering further new orebodies. Thus regional surveys of the area around this deposit is highly recommended.

7-8 Tiferki Project

7-8-1 Area

Irherm Area, Taroudannt District, Agadir Province

7-8-2 Location and Access

This project is located at 30°14' of north latitude and 8°14' west longitude, 22 kilometers (direct distance) north-east of Irherm, the nearest village, from where it can be reached by an unpaved mountain road of 37 kilometers. The average elevation is 1,600 meters A.S.L.

7-8-3 Type of Ore Deposit

The ore deposit is a stratiform type containing copper as a major constituent.

7-8-4 Geology

(1) General geology

The ore deposit is situated in the north-east periphery of

Irherm Inlier according to the classification of Pre-cambrian group Inlier, and the geology consists of Basal Series of Infra cambrian system underlaid unconformably by Pre-cambrian III system (P III) which forms the basement and overlying Lower limestone series (Tamjout). The rocks are as mentioned below in ascending order from the lower horizon. (See Figs. VII-8-A and VII-8-B.)

1) Pre-cambrian group III system (P III)

P III system conglomerate well develops as a whole, but in the northern part, massive bodies of quartzite called P II system are so arranged toward the north-eastern direction as seemingly to be abutting on P III conglomerate series, and andesite-rhyolite dikes are distributed in the quartzite. (Many are still unclear about the horizon of P II quartzite body.)

a) Conglomerate series

The series is purplish-brown coloured and the pebbles are composed mainly of quartzite of 5 to 25 centimeters and additionally of granite, rhyolite, andesite, etc., the matrix being andesitic.

The thickness of conglomerate series is confirmed to be more than 20 meters by diamond drilling, and possibly more as expected from the state of surface distribution.

2) Basal Series

The Series consists of conglomerate formation in the lower part and fine-grained sandstone and siltstone formation in the upper part.

a) Conglomerate formation

The formation is reddish-brown in the lower part and greyish-green in the upper, having partial inclusion on thin beds of silt-sandstone. It contains generally of quartzite pebbles, and their sizes are getting bigger toward the footwall side to the maximum diameter of 20 to 25 centimeters, making it difficult to tell them from P III while becoming gradually fine-grained until they get to 1 to 5 centimeters in diameter on the hanging wall side.

The conglomerate formation has, within a range so far as it is swollen, intercalations of lower limestone beds (Petit Calcaire) on the footwall side (according to data furnished by B.R.P.M.). The thickness of conglomerate formation is 0 to 50 meters.

b) Siltstone and sandstone formation

The trenched surface area of the formation is mostly soft and fine-grained while the diamond drilling cores show thin alternation of greyish-green siltstone and sandstone of the same colour and is calcareous on the whole.

The thickness of the formation is 1.5 to 5 meters.

3) Lower limestone series (Equivalent to Tamjout series)

The series is generally grey to greyish-black coloured, and has on the footwall side many intercalations of thin beds of clear grey coloured siltstone while on the hangingwall side the rocks are of dolomitic nature, containing as well many lenticular thin quartz beds (80 centimeters thick maximum), breccias and veinlets.

The series has the thickness of more than 70 meters as confirmed by diamond core drilling. Although the conglomerate formation of P III shows comparatively unclear bedding planes, sandstone formation included partially therein has the strike of NNE and dip of more or less 60°E as compared with the general strike and dip of NNW and 25°E in the upper horizons including Basal series overlying P III formation. This clearly indicates the relations of clino unconformity.

(2) Geological structure

1) Folding structure

Basal Series and lower limestone series of this area generally show a monoclinic structure, and in the outer portions, when viewed from extensive standpoint, such variations of strike as likely to indicate the folding structure although without remarkable folding or fault.

2) On paleo-topography of basement

Basal Series are found to develop extensively and continuously, and the main mineralization zone therein is presumed to be within a range in which the thickness of Basal Series comparatively reduces.

7-8-5 Ore Deposit

(1) Ore horizon

Of the mineralization which is observed over an entire area ranging from the top horizon of P III conglomerate series to that of Basal Series, the main body of this deposit is found to be a stratiform ore deposit particularly concentrated in the top horizon of P III conglomerate series, conglomerate formation of Basal Series and alternated silt-sandstone formation.

Further, according to data from B.R.P.M., there are observed partially thin secondary malachite sendimentation along irregular cracks in the P II quartzite massive body, and, additionally, small quantities of chalcopyrite in andesite-rhyolite dike intruding the said quartzite massive body.

(2) Scale and occurrence of ore deposit

The deposit extends over an area of about 1 kilometer in longitude of strike side as traced along the outcrop line and 500 meters on the dip side (confirmed by diamond core drilling), but is occurring on and off, and found after partially pursuing the bonanza outcrops (parts of comparatively high grade) that each bonanza unit is a thin lenticular body in the order of 200 meters maximum of strike side. The results of diamond core drilling spanned at 100 to 150 meters also show the discontinuity of bonanzas.

(3) Ore minerals

As for ore minerals, malachite is generally predominant and occurs in the conglomerate in forms of spot or microcrystalline dissemination in the matrix and secondary sedimentation film in cracks while in the sand-siltstones they are of bedded dissemination along thin bedding planes.

Also in the drilling cores is slightly observed microcrystalline of chalcocite and bornite in the matrix of P III conglomerate.

(4) Extension and grade of ore deposit

This deposit is of low grade ore as a whole, and although there are swollen portions in part, they are presumed to be mostly discontinuous or in a state of small lens. An example is given below (B.R.P.M. data).

Location:	Entire portion: Thickness:	Entire portion: Cu grade:	Extracted portion: Thickness:	Extracted portion: Cu grade
	Meter	%	Meter	%
Trench No. 1	5.00	1.41	2.00	1.75
Trench No. 3	3.00	1.49	2.00	2.14
Drilling TF6	1.20	2.07		

The table below shows the average taken from B.R.P.M. data on the estimated extensions of each bonanza unit by following the outcrop line.

Bonanza unit:	Extension:	Average thickness:	Cu grade:	Ore horizon:
	Meter	Meter	%	
N 1	230	1.43	1.57	Alternated portion of sand-siltstones
2	150	1.75	1.15	- do -
3	210	1.75	1.28	Hanging wall of P III conglomerate
4	200	2.33	1.01	Conglomerate portion of Basal Series.

(5) Alternation of host rock

The mineralized sand-siltstones on the surface outcrops are bleached and altered due to the weathering, and the mineralized host rocks throughout P III Basal Series show grey to greyish-green colour by contrast with the non-mineralized host rocks being purplish-brown coloured.

7-8-6 Ore Reserve

Of the records of drilling and trenching (B.R.P.M.), 3 blocks trenched and 4 blocks drilled ore a total of 7 blocks have been taken for calculation of possible ore reserves to show the following.

	Block:	Thickness: Meter	Cu grade: %	Ore reserve: Ton
Trenching:	2	1.75	1.15	33,750
	3	1.75	1.23	68,750
	4	2.33	1.01	91,500
Drilling:	D-3	1.96	1.31	55,250
	D-5	1.44	0.94	40,750
	D-6	0.96	1.66	27,000
	D-9	2.08	1.14	58,750
Total		1.75	1.17	375,750

7-8-7 Past Exploration and Present Status

The exploration works are in progress continuously by B.R.P.M. on this deposit although the date of commencement is not known, namely:

1) 30 trenches (each 10 to 20 meters long) completed.

2) 20 holes of drilling planned, of which 12 completed and others still being worked (each about 40 meters to 100 meters deep).

7-8-8 Further Exploration

(1) Scale of deposit and bonanza

The exploration results known to date disclose different ore horizons of each bonanza and excessive variations of thickness and copper grade, irrespective of the types of host rocks, and no remarkably high grade portions observed. All this forces us to think that the deposit consists of thin, low grade formations of small scale, with poor possibility of enrichment.

(2) Recommendation for future exploration

Apart from reviewing the economic grade of ore, it is desired that an extensive survey would be conducted covering the surrounding area in order to discover a similar type of deposits, concurrently to clarify the interrelations with the mineralization of chalcopyrite observed in the andesite and rhyolite intruding P II quartzite body, and further extension of the ore blocks toward the east can be expected by the continued drilling exploration by B.R.P.M.

7-9 Amane Tazert Project

7-9-1 Area

Irherm Area, Agadir Province

Topographic map (1/100,000 scale); Taliouine 5.6

7-9-2 Location and Access

Located 6 km north of Irherm. Lat. 30°08' N., long. 8°30' W., altitude 1,600 m above sea level.

Proceed 8 km west from Irherm on the highway between Taroudannt and Irherm, then turn south and proceed 1 km on an unpaved road to the center of the deposit.

7-9-3 Type of Deposit

Bedded deposit

7-9-4 Geology

(1) Geological location

This deposit is located at the southern periphery of the Irherm inlier.

(2) General geology

The geology of the area in the vicinity of this deposit consists of Precambrian P III conglomerate, Infracambrian Basal Series which unconformably overlies the P III conglomerate and the lower limestone series.

P III occurs in somewhat low are a to the north of the deposit, and the major unit is reddish conglomerate which contains quartzite boulders. This does not crop out near the deposit.

Basal Series consists of reddish to grayish green sandstone-siltstone-shale alternation and limestone lenses (Petit Calcaire) which is less than 5 m thick. The total thickness of the series near the deposit is 90 - 100 m.

The lower limestone series is divided into lower, middle, and upper beds by their lithology. The lower bed is dark gray to grayish black dolomite and is brecciated at the bottom. It is associated with small lenses or bands of quartz. The middle bed is dolomitic limestone associated with large quartz lenses, it is generally called G.L.S. (grandes lentilles de silica). The upper bed is massive grayish white dolomitic limestone and does not contain quartz lenses. The lower and middle beds probably can be correlated to the so-called "dolomies de Tamjout". The thickness of the lower limestone series near the deposit is more than 60 m.

(3) Geologic structure

Folding is the outstanding structural feature of this deposit. The central part of the deposit is structurally an anticline which trend NNW-SSE, and there is a small fold which crosses the former obliquely. Thus the structure in the vicinity of the deposit is complex and the dip of the formations varies from 20° to 80°.

There are no significant faults, but small faults and fractures are developed where the dip of the formations is steep.

7-9-5 Ore Deposits

The deposits are bedded deposits which occur in the Basal Series and lower limestone series. The extent of mineralization is wide ranging from the sandstone and siltstone directly under the limestone lenses of the Basal Series to the G.L.S. of the lower limestone series. The important mineral concentration, however, is the lower bed of the lower limestone series.

(1) Ore minerals

Chalcocite, chalcopyrite, bornite, covelline are the major sulfide ore minerals and oxidized minerals include malachite, azurite, and hematite.

(2) Occurrences

The sulfide minerals occur either finely scattered graind or as veinlets associated with calcite or in some cases quartz in the lower limestone bed. Small amount of bornite is observed in G.L.S., and sulfides are almost non-existent in the Basal Series.

Oxidized minerals generally occur throughout the mineralized zone, but they are abundant in the Basal Series where they occur as finely scattered grains or as films along faults and fractures. They show the same occurrence as the sulfides in the lower limestone series.

(3) Grade

The mineralization in the Basal Series is malachite and weak, the orebody is about 2 m thick and the grade is 0.8 - 1.0 per cent Cu. The major part of the orebody is in the lower bed of the limestone series, the ore minerals are sulfide and the thickness and grade confirmed by trenching are 3 - 4 m and Cu 2.5 per cent. The ore minerals in the G.L.S. are mainly malachite, and smaller amount of chalcopyrite and covelline occur in quartz lenses or veins. The grade of the ores in G.L.S. may be somewhat higher than that in the Basal Series.

The average grades are lower bed ≫ G.L.S. > Basal Series.

(4) Size of the deposits

The mineralized zone extends for 1.2 km in east-west, 2.5 km in north-south directions. At present, prospecting is carried out (pits and trenches) in an area of about 1 km of outcrops. The zone of high mineral concentration, such as Cu 2.5 per cent, however, is very limited.

(5) Factors controlling metal concentration

The following factors are considered to have influenced the enrichment process of these deposits.

1) The continuity of the brecciated zone at the bottom of the lower limestone, is the most strongly mineralized horizon.

2) It is seen that the steeply dipping parts of the strongly folded formations have the highest grade and thus it is believed that mineralization is closely related to folding.

3) Significant faults have not been found, but small faults and fractures are developed in the strongly folded zones, and calcite, quartz veins and malachite films occur in these fractures. Therefore, these fractures played important roles in mineralization.

4) The effect of paleotopography to mineralization is not clear at this moment because the existence of PIII is confirmed only by drill cores.

7-9-6 Ore Reserves

The reserves calculated by BRPM are 200,000 tons of Cu 2.0 per cent ores. Sufficient data could not be collected during the present work to calculate the reserves.

7-9-7 Exploration Past and Present

Prospecting was started by BRPM in spring of 1973 and 13 trenches (each 7 - 13 m long) were dug and five holes were drilled by the time of the present survey. A 20 m shaft was being lowered into the central part of the deposit and is was 17 m deep at the time of the survey.

7-9-8 Future Prospecting

The geologic structure, especially the folding is not yet clearly understood in the vicinity of this deposit, and this will be one of the main problems to be solved for future exploration. As for the ore deposit itself, the genesis and the factors controling the enrichment must be clarified.

The fold structure is known for a very limited area near the deposit, but as it is one of the important factors which affect the enrichment of the ores, it must be investigated on a larger scale.

The basic question regarding the ore genesis of these deposits is the fundamental problem of syngenetic or epigenetic origin. The is brought to the attention here because of the existence of the calcite and quartz veins. These were probably formed by remobilization of the metal concentrated syngenetically with the host rock, but this must be studied to be certain.

Three factors were presented in 7-9-5-(5) as influencing the concentration of the metal, but these were inferred on the basis of the observation of a small area and may not be applicable to the whole mineralized zone. Study of the concentration of the sulfide minerals will be of prime importance in relation with the genesis of the ore deposit.

The deposit is located very favorably, for example it is close to the highway, and not far from the Agadir Harbor compared to the presently operating Talate N'Ouaman mine. Therefore, if reserves could be increased by future exploration, the deposits are indeed exploitable. As the prospecting work was started only recently, there are rooms left for future work. Regional geological survey with tracing the lower bed of the lower limestone series and structural investigation with the major effort directed to the clarification of the fold structure will be most effective.

7-10 Idint Project

7-10-1 Area

Irherm Area, Taroudannt District, Agadir Province.

Topographic map: 1/1,000,000 TAROUDANNT 5-6

7-10-2 Location and Access

Latitude 30°13'N, Longitude 8°39'W, Elevation 1,100 m sea level.

The mineral deposit is located 36 km southern west of Taroudannt. We can drive to the project through the paved road of 11 km from Taroudannt and the following gravel road of 45 km.

7-10-3 Type of Mineralization

Stratiform copper deposit.

7-10-4 Geology

(1) Geological province

Northern west rim of Irherm inlier..

(2) Geology

It consists of the conglomerate and andesite lava, which overlie unconformably the quartzite of the Precambrian II in the adjacent area, and the siltstone and limestone of the Infracambrian Basal Series which distribute in the north of the mineralized area. The conglomerate has been correlated to the lower horizon of the Precambrian III group from rock facies, and is composed mainly of subrounded quartzite pebbles of

30 - 40 mm in diameter with minor amount of pebbles of siltstone, schist, andesite and granite. The conglomerate bed contains thin sandstone layers. The matrix of conglomerate is siliceous and compact with gray to grayish green colour.

Andesite of the Precambrian III is characteristic in its reddish brown colour, while siltstone of the Basal Series is pale green in colour and has well developed lamination texture.

(3) Geologic structure

General strikes of the Precambrian III and unconformably overlying Basal Series are NNE-SSW and E-W respectively. The ore bearing Precambrian III group forms presumably, the top of dome structure.

7-10-5 Ore Deposit

(1) Horizon of mineralization

The mineralization of stratiform type occurs mainly in the conglomerate of the Precambrian III and poor mineralization has also been found in the overlying siltstone of the Basal Series.

(2) Ore minerals

Malachite and subordinate bornite.

(3) Occurrence of mineralization

The mineralization in the conglomerate of the Precambrian III is observed as dissemination and film of malachite in the matrix. The ore grade reaches to 3 - 4 per cent copper in higher grade parts, although it is distinctly variable. In the siltstone of the Basal Series, stratified mineralization is observed mainly as the dissemination of malachite, however, it is generally very poor.

(4) Extension of ore deposit

The mineralized conglomerate is located on the top of the gentle hill, and has extended 300 m long along strike (NE-SW) and 100 m wide along dip (NW-SE) with various ore grades. As the exploration has not been carried out, the thickness of the ore deposit is not found yet.

7-10-6 Ore Reserves

Because of no prospecting works, the ore reserves are not blocked out. However, supposing the thickness of the ore body were 2 meters, the inferred ore reserves would be calculated as 300 m x 100 m x 2 m x 2.5 = 150,000 tons with uncalculated ore grade.

7-10-7 Past Exploration and Present Situation

Since the mineralization was found by B.R.P.M., any exploration has not been carried out up to the present day.

7-10-8 Recommendation

The mineralized conglomerate has been correlated to the lower horizon of the Precambrian III group, because it contains quite many quartzite pebbles derived from the Precambrian II group. However, the mineralization is more reasonably considered to be closely related to the formation of the stratiform deposit in the overlying Basal Series and it could be formed during the sedimentation of the Basal Series or after sedimentation of the Basal Series by remobilization from the primary precipitation in the Basal Series rather than by the mineralization during earlier stage of the Precambrian III period.

If the mineralization had occurred in Precambrian Conglomerate by remobilization from the primary precipitated source in the upper Basal Series, the thickness of the deposit would possibly be rather limited.

First thing for the further exploration, in order to clarify the thickness of the ore deposit, it would be recommendable to put down the test pits at least ten different places.

7-11 Agoujgal Project

7-11-1 Area

Aoukerda Area, Tafraout District, Agadir Province.

7-11-2 Location and Access

Located 35 km southwest of Tafraoute, 125 km south-southeast of Agadir Harbor. Lat. 29°24'N., long. 9°00'W.

Road transportation to Tafraoute is good, but the road to the mine from Tafraoute is negotiable only by four-wheel-drive vehicles.

The altitude of the deposits is about 1,400 m and they are in a hilly region which is well dissected with well developed streams.

7-11-3 Type of Deposit

Bedded deposit.

7-11-4 Geology

(1) Geological location

Located at the southern periphery of the Kerdous inlier.

(2) General geology

The major geological units of this area are Precambrian PII granite, dolerite and Infracambrian formations which unconformably overlie the former rocks.

Granite: This belongs to PII and forms a batholith. It is found in the central part of the deposits. It is phanerocrystalline and is weathered near the surface.

Dolerite: This is a greenish gabbroic rock relatively abundant in feldspars and is distributed in the peripheral parts at some distances from the deposits. This rock occurs near the deposit in dyke from.

Infracambrian system: This unit is composed of three series, i.e., Basal Series, lower limestone series, and upper limestone series.

1) Basal Series

This series consists of basal conglomerate (0 - 6 m thick), thin limestone layer (Petit Calcaire, 7 - 8 m thick), and siltstone-fine sandstone-alternation in ascending order. The basal conglomerate is absent and coarse sandstone directly overlies PII granite unconformably near the deposit. Also thin limestone layers are missing near the deposit.

2) Lower limestone

This is correlated to the Tamjout limestone and is dolomitic. It contains thin quartz layers which are characteristic of the Tamjout rock. Sandstone pebbles occur in the upper part of this series. (20 - 30 m thick).

Overlying this series is a dolomitic limestone intercalating calcareous siltstone. This is thick and is distributed in the topographically higher localities.

3) Upper limestone

This is a dolomitic limestone widely distributed in areas to the south of the deposit.

These Infracambrian formations generally have monoclinic structure dipping southward with inclination of 10° - 20° and striking in E-W direction.

(3) Geological structure

Thereare E-W trending small faults near the deposits, but large faults are not observed.

Since the Precambrian rocks are igneous, folds are not observed. The Infracambrian system has gently dipping monoclinic structure and complex folds are not found. The upper limestone seems to have gentle undulating structure.

7-11-5 Ore Deposits Bedded

Copper deposits occur in Infracambrian Basal Series and lower limestone. Uranium deposits occur in the Basal Series.

(1) Copper deposits

1) Host rocks

Two mineralizations are observed. One occurs in siltstone and coarse sandstone of the basal series and the other in dolomitic limestone (Tamjout limestone) of the lower limestone series. The former mineralization is somewhat stronger than the latter.

2) Ore minerals and occurrences

The sulfide minerals are chalcopyrite, chalcocite, bornite, and pyrite with rare occurrence of sphalerite and galena.

The oxydized minerals are malachite and azurite.

Larger part of the sulfide minerals occur in quartz and calcite veinlets. And some occur as scattered grains in the host rock. The oxydized minerals occur either as films along the bedding planes of the host rock or scattered in siltstone and sandstone.

3) Grade

The BRPM data show that mineralization in the basal series is generally weak with the average grade of Cu less than 1.0 per cent and maximum content of 1.5 per cent. There is a large old adit in the central part of the deposit.

The Tamjout limestone is mineralized along a thickness of 15 m and the high-grade part is 1.15 m thick and contains 1.7 - 2.0 per cent copper. The major ore minerals of this part are chalcopyrite and bornite. This mineralized zone, however, is not continuous and the copper grade seems to be less than 1 per cent for the whole orebody.

4) Size of the deposit

The extent of the mineralization itself is observed in a wide area, but the orebodies occur intermittently and the thickness and grade both vary rapidly. The extent of the ores probably would be 500 m in east-west and 200 m in north-south directions.

(2) Uranium deposits

Strong radioactivity was confirmed in the Basal Series and the immediately overlying siltstone-sandstone alternation. BRPM carried out active radiometry. This is near the copper concentration.

During the present survey, scintillation counter was used to record the radioactivity. The measured results are:

1) PII granite: 0.015 - 0.017 mR/h (0.025 mR/h in joints and cracks).

2) Coarse sandstone of Basal Series: 0.025 - 0.6 mR/h (locally very strong).

3) Siltstone-sandstone alternation of upper part of the Basal Series (host rock of the copper deposit): 0.01 mR/h (unoxydized and unargillized parts).

4) Lower limestone (Corresponds to Tamjount limestone): 0.003 - 0.007 mR/h.

It is seen that the radioactivity of the coarse sandstone is noteworthy. Also detailed study of the anomalous zones showed that yellowish brown clay near the border of coarse sandstone and the overlying sandstone-siltstone alternation was highly radioactive. For example:

a) Yellowish brown powdery clay in coarse sandstone: 0.4 - 0.6 mR/h.

b) Yellowish spots in conglomeratic sandstone overlying the coarse sandstone: 0.16 mR/h.

c) Grayish white clay in coarse sandstone: 0.125 mR/h.

d) Yellowish brown bands or lenses in coarse sandstone: 0.3 - 1.2 mR/h.

These measurements are 50 to 200 times stronger that the background 0.007 mR/h at the Agadir Harbor. These anomalies, however, are limited to the yellow to yellowish brown lenses or spots. These are oxydized zones where laterization is advanced and malachite is the copper mineral. The source of the radioactivity is assumed to be uranium oxides, and the collected samples are being studied in the laboratory. The extent of uranium mineralization is probably in the order of 200 m east-west and 100 - 150 m in north-south directions.

7-11-6 Ore Reserves

(1) Copper deppsits

The copper deposits are irregular in shape and low in grade and does not warrant calculation of the reserves.

(2) Uranium deposits

The BRPM data indicate 36,000 tons of ore containing 0.1 per cent U_3O_8.

7-11-7 Prospecting Past and Present

1955: BRPM and the French company Smith jointly carried out the following: 2 trenches (40 and 60 m), 6 pits (average depth 40 m total of 240 m), 51 holes by wagon drill (total depth 1,230 m),

1956: Prospecting tunnel 160 m in length.

1959: 3 holes were drilled in the southern part, but ceased work due to low grade. Old adits where the high grade parts were mined can be seen, but they cannot be studied because of collapse.

7-11-8 Future Prospecting

(1) Copper deposits

1) The shape of the deposits is not yet clear and the

enrichment process is also unknown.

2) The mine has been prospected considerably in the past, but the basis for the work is not clear and efforts should be concentrated toward a clearer objective with sound basis.

For example it is doubtful whether the wagon drilling has reached the basal series or not.

3) The relationship between the structure of the host rock and the ore deposit is not clear.

Therefore, it will be necessary in future work to clarify the geologic structure of the general area and also the structure of the host rock with relation to the orebody by geological survey.

Also the shape of the basement granite (paleotopography) must have some relation to the orebodies and thus geophysical methods should be employed for the analysis of the basement structure.

Drilling should be based on the results of these work. Also drilling deep enough to reach the basement should be made in order to obtain information of the geologic structure.

(2) Uranium deposits

The source of uranium is most probably the Precambrian granite. In this case, the minor constituent minerals probably concentrated and deposited. But there is also the possibility that uraniferous veins may occur in the granite bodies.

Again the structure and chemistry of the granite basement will yield interesting facts concerning the origin and the process of uranium deposit fromation.

7-12 Tasserirt Project

7-12-1 Area

Situated near Taghaou Village, Tafraout District, Agadir Province.

7-12-2 Location and Access

This project is located at 29°35' of north latitude and 8°56' west longitude, and can be reached by paved road from Tafraout City to Taghaou Village of 37 kilometers and about 4 kilometers on foot from there to the mine sits. The elevation is approximately 800 meters above sea level.

7-12-3 Type of Ore Deposit

The ore deposit is of stratiform type with copper as main constituent, accompanied by secondary bonanzas occurring in a form of characteristic vein or small lens considered to be derived from the former.

7-12-4 Geology

The deposit is situated in the east marginal area of Kerdous inlier according to the classification of Pre-cambrian group inlier, and the geology consists, from the lower horizon, of Pre-cambrian group 0 system (PO), Basal Series of Infra cambrian system which is unconformably underlaid by the former, and lower limestone series (Tamjout series). (See Figs. VII-12-A and VII-12-B).

(1) Pre-cambrian group 0 system (PO)

While muscovite-biotite gneiss, quartz, basalt, etc. are observed well-developed over the entire area, the mine area is mostly composed of granitic gneiss. The system has the general orientation of gneissosity of N70°E and 50°NW, and is partially intruded by irregular pegmatite dikes.

(2) Basal Series

This series consists, in ascending order from lower horizon, of conglomerate formation, siltstone formation, sandstone formation and alternated formation of such.

1) Conglomerate formation

This formation is a thin bed 1 to 2 meters thick and contacts directly with the underlying PQ gneiss series by unconformity with the contact plane striking 10° - 40°E and dipping 13° - 15°SE.

The matrix of the comglomerate is arkose sandstone in the state of crystalline assemblage of quartz and mica, and the pebbles are fine-grained.

2) Siltstone, sandstone and alternation series

The series is divided into three groups from the nature of rocks, namely in the lower part greyish-green, compact and calcareous siltstone, in the middle part reddish-brown calcareous sandstone and in the upper part the alternation of both.

Generally, the series has clear bedding planes and intercalates with thin beded limestone (Petit Calcaire ? or the equivalent ?), partially accompanied by small lenticular masses of fine-grained conglomerate.

(3) Lower limestone series (Tamjout series)

This series is considered to be equivalent to Tamjout limestone series and is the top horizon seen in this area, more than 6 meters thick, grey coloured and dolomitic, but has very few quartz lenticular thin beds that are typical to Tamjout limestone series. The general strike and dip of the series through Basal Series are NS-N20°E and 12° - 15°E respectively.

7-12-5 Ore Deposit

(1) Scale and occurrence of ore deposit

Mineralization is observed within a range of about 400 meters in the south-north direction and about 170 meters in the east-west direction centering about the top of a gradually sloping hill in this area. Although weathering and oxidization are remarkable and the original structure is unclear, it is considered to be a stratiform ore deposit occurring in the conglomerate or sand-siltstone beds, accompanied by characteristic secondary bonanzas of irregular veins in faults and along cracks in the alternated sand-siltstones or by small lenticular ore bodies occurring closer to bedding planes.

(2) Ore minerals

Ores are mainly malachite with chalcocite residues partially, and the dissemination of microcrystalline chalcopyrite is also observed in the conglomerate or thin bedded limestone.

Malachite usually comes in a film state along cracks and is also observed spotted frequently in the gossan of the leached-out zones. (See Fig. VII-12-C.)

(3) Precipitation conditions and concentration

Primary stratiform mineralization occur mainly in sandstone and siltstone, but are almost leached out leaving predominantly limonite and gossan.

Sulfide copper minerals contained in the conglomerate formation or limestone thin beds are extremely low in grade.

It is typical that in the central part of the deposit several small bonanzas of oxide copper of irregular veins or lenticular types are formed on the hanging wall side of horizons of the stratiform deposit (in the silt-sandstone up to Tamjout limestone series) by remobilization and enrichment of copper along the well-developed faults that vertically intersect the bedding planes. However, selective mining was conducted in the past apparently on these bonanzas which now leave nothing but traces.

(4) Others

The deposit is extremely oxide-iron stained due to the effect of underground water and weathering, and fragile on the whole, and in the drifts, folding in small scale developes in the sand-siltstone portion, and it is in leached zone of perimary copper deposition.

7-12-6 Ore Reserve

As stated above, primary copper deposits is too low in grade to estimate ore reserves and mineable ore is secondary enrichment ore.

However the small groups of secondary enrichment ore are almost mined out.

7-12-7 Past Exploration and Present Status

Mining was undertaken actively in the past along the faults by sinking from the surface aiming at small secondary bonanzas. B.R.P.M. conducted exploration on horizons of primary mineralization by drifting 250 meters and sinking 2 or 3 winzes (timing not clear) and ended up with unsatisfactory results. At present, the deposit is left unworked.

7-12-8 Further Exploration

The fact that the principal parts for a stratiform ore deposit are almost completely leached out and, in addition, the secondary bonanzas of small scale completely mined out may not warrant future exploration or mining. However, it will provide an example worthy of note for its remarkable secondary enrichment in case where an extensive regional survey is conducted in the future for stratiform deposit potentialities in this area.

Finally, it may be reasonable to consider the deposit to be of a syngenetic stratiform deposit common to this area rather than of epigenitic origin related with granite as once thought so by B.R.P.M.

CHAPTER 8. THE MINES VISITED

During the course of the survey, the team had the opportunity to visit three mines in the Anti Atlas region. The report of the visit is presented in this chapter.

8-1 Argana Copper Deposits

8-1-1 Location and Access

Located approximately 60 km northeast of Agadir Harbor at the southwestern edge of the Haut Atlas Range, altitude 1,000 - 1,300 m above sea-level. Lat. 30°46'N, Long. 9°18'W.

The deposits occur along the new road which links Agadir - Chichaoua - Marrakech at 92 - 110 km from Agadir.

8-1-2 Geology

Permian to Jurassic sedimentary formations are widely distributed in the vicinity of these deposits. The stratigraphy of these formation can be summarized as follows.

Jurassic	Sandstone, conglomerate, limestone, dolomite.
Triassic	Basalt lava, siltstone-calcareous sandstone alternation.
Permian	Sandstone-siltstone alternation, calcareous sandstone and conglomerate.
Precambrian	

These formations are continuous in approximately north-south direction with a very gentle dip. But the Triassic system is fairly strongly folded.

8-1-3 Ore Deposits

The deposits are of bedded type occurring in the sandstone-siltstone alternation and the scheme of the beds are as follows.

1)	Ait Ktab	Thin, Cu 1.5%, cut by small faults.
2)	Argana (II)	Thickness 0.7 m, Cu 0.65%
3)	Argana (I)	" 0.5 m, Cu 0.60%
4)	Bigoudine (II)	Low grade
5)	Bigoudine (I)	"

These beds are not continuous.

Malachite is the major ore mineral and chalcocite is rarely seen in the drill cores and pits.

These ores occur in thin layers or scattered along the bedding plane of the siltstone. These layers are distributed in north-south direction for 30 km.

The formations are generally flat in this area, but small folds are developed in the Triassic strata and the ore minerals are concentrated in these locally disturbed zones. Although there are no large faults, small faults are abundant especially in Ait Ktab.

The reserves of this mine amount to 40 million tons of ore with average grade of 0.9 per cent Cu according to the report of the BRPM staff. From the results of the present survey, however, the team is of the opinion that the deposits are of very low grade and there are doubts as to the continuity of the orebodies.

8-1-4 Prospecting and Operation

The deposits were prospected circa 1964 by the staff of BRPM and trenching and drilling (17 holes average of 100 m depth) were made in areas of relatively good ore showings. The results showed low grades and the project was canceled. At the same time, work was done by USSR and

Japanese geologists; but these again did not produce promising results. The Russian work was done over a six months period and studied the genesis of the deposits and theoretically analysed the depositional cycles of the ore beds.

8-2 Youssoufia Phosphate Mine

8-2-1 Location and Access

This mine is situated on a gentle hilly region of 350 - 400 m above sea-level. It is connected by main highway to Safi Harbor on the west coast, El - Jadida harbor and Casa Blanca Harbor on the north coast and is most conveniently located. It is 90 km to Safi Harbor and about 104 km to Marrakech.

Location is lat. 32°17' N., long. 8°31' W.

8-2-2 Geology

The major geological units of this area are phosphoritic shale, calcareous shale, calcareous sandstone, dolomite, and limestone. These formations are widely distributed and they are correlated to the Eocene epoch. They are divided into the upper, middle, and lower beds with limestone separating them. Bi-valve fossil groups occur in these beds.

8-2-3 Ore Deposits

The ore deposits are of marine sedimentary origin and are one of the major mineral resources of the Kingdom of Morocco.

There are two to four ore beds. It is recorded that; from the surface to the depth of 12 m, the ore bed is 2.0 m thick and the grade $Ca(PO_4)_2$ 60 per cent; 4.0 m thick and the grade 68 per cent to the depth of 25 m; 10.0 m thick and 62 per cent to the depth of 50 m. It is confirmed that the ore is developed in lower Eocene formations.

It is said that the ore reserves of the four ore beds in the

Youssoufia area alone amount to 1,800 million tons (1,500^{3}m , 1.20 t/m^3) and the average grade is approximately 69 per cent $Ca(PO_4)_2$ (approximately 35% P_2O_5).

8-2-4 Mining Operations

The annual production of phosphorites in the Youssoufia area is about 6 million tons with the grade of 69-71 per cent $Ca_3(PO_4)_2$ (about 36-39 per cent P_2O_5). The production of 1972 was 4 million tons.

There are one open cast pit and two underground operations. The crude ore is washed by water to remove clay and other impurities and most of them are exported.

8-2-5 Management

The mine is presently operated by O.C.P. (Office Cherifien des Phosphate). The number of employees is about 2,700 of which 27 are engineers.

8-3 Kettara Cupriferous Iron Sulfide Mine

8-3-1 Location and Access

Located 32 km northwest of Marrakech, in a hilly area and the altitude is about 500 m above sea-level. Lat. 31°52'N., long. 8°30'W.

The mine is reached by proceeding 35 km from Marrakech on the highway linking Marrakech and Safi.

8-3-2 Geology

The major geological unit of the area near the mine is Carboniferous green schist (Visean series of lower Carboniferous and Namurian series of the upper Carboniferous).

A large fault with N60°W trend cuts through the deposit and there are a number of N20° - 30°W trending faults which probably branched from the major fracture. The deposit is relatively developed where these faults are notable.

Silicification and chloritization are strong near the deposit.

8-3-3 Ore Deposit

The deposit is a bedded cupriferous iron sulfide deposit which occurs concordantly in green schist. The general strike of the deposit is N30°E and the dip 70°NW.

Extension of 1,500 m in strike and 600 m in dip directions have been confirmed and the thickness varies between 7 and 40 m with the average of about 11 m.

At the mine, the deposit is classified by the degree of oxidation into oxydation zone, and principal zone from the surface. The oxidation zone is about 30 m deep from the surface.

A large variety of minerals occur in the ores. The major ore minerals are pyrrhotite, and pyrite, and the accessory contents include chalcopyrite, marcasite, magnetite, siderite, galena, sphalerite, covelline, native bismuth, bismuthinite, cassiterite, native silver, and rarely selenium.

Pyrite and chalcopyrite are the major ore minerals of the cementation zone while pyrrhotite is the major component of the principal zone. Chalcopyrite occurs along the bedding plane of the green schist as spotty inclusions in the pyrrhotite grains.

The gangue minerals are chlorite, quartz, micas, calcite, dolomite and others. Chlorite and quartz are by far the most abundant gangue.

The grade is Cu 3-10 per cent in the cementation zone and Cu 0.6, S 36, and Se 0.08 per cent in the principal zone.

The ore reserves are announced to be about 10 million tons.

8-3-4 Prospecting and Mining Operations

The deposit was discovered in 1929. BRPM began prospecting in 1960 and mining was started in 1965.

The present annual production is 400 thousand tons of crude ores and the future plan calls for 600 thousand annual production in 1974. The target grade of crude is Cu 0.6 and S 28 per cent.

Sublevel stoping is used in mining and the intervals between the main adits are 50 m. The height of the sublevel is 15 m with 3 steps and the width of pillar is 10 m. Mining recovery is about 65 per cent.

Flotation was once used for ore dressing, but now only mineral zigs are used. The concentrate grade is S 34 per cent.

The concentrate is shipped 122 km to Safi Harbor on the west coast by trucks and rail. It is used for sulfuric acid production.

8-3-5 Management

Societe D'exploiatation de Pyrrhotine de Kettara is operating the mine. The stocks are held by the following organizations.

BRPM	55.5%
OCP (Office Cherifiende Phosphate)	21.0%
BEPI (Bureau d'Etudes et de Participations Industrielles)	21.0%
CCM (Compagnie Miniere et Metallurgique)	2.5%

The total employees of the Kettara mine is 340. Underground workers number 120 and surface workers 220.

CHAPTER 9. GENESIS AND ENRICHMENT PROCESS OF THE DEPOSITS

The deposits investigated during this mission can be classified into two types. One is the bedded copper dissemination deposits which occur in the lower formation of the Infracambrian (Adoudounian) series which overlie the Precambrian system. The other is the copper network dissemination deposits which occurs in Precambrian III rhyolite.

The genetical history of the former type is interpreted as follows. The deposit was primarily formed in a specific horizon by precipitation of copper during the deposition of the host rocks. Then it was remobilized and concentrated by later geologic forces and took its present form. Thus, these deposits can be classified in the chemical precipitation deposits.

The latter type is different. They occur in the Precambrian III volcanic rocks and are believed to have been formed by hydrothermal activity following the Precambrian volcanism of the host rock.

Therefore, the genesis and the factors which contributed to the enrichment of these two types of deposits differ.

9-1 Bedded Copper Deposits

It is clear from various studies of bedded deposits that the most important factors concerning the genesis and enrichment of the deposits of this type are the stratigraphy and lithology of the ore-bearing horizon.

Several ore-bearing horizons were found in the deposits surveyed, but the most widely occuring and predominant was the uppermost horizon of the Infracambrian Basal Series. The lithology is alternation of sandstone and siltstone. The ores are especially rich where the platy bedding is well developed. This is immediately overlain by the Tamjout dolomite which is correlated to the Infracambrian lower calcareous series.

The basal conglomerate which is the lowermost horizon of the Infracambrian series, is the next important horizon concerning copper mineralization of the area. It was noted during the present survey, however, that metal concentration occurred only where the thickness of the conglomerate was less than 10 m, and that the orebodies in this horizon occurred rather intermittently and very irregularly. Dolomitic limestone of the Petit Calcaire occurs immediately overlying the mineralized basal conglomerate at the Amadouz mine.

The third strong mineralization is found in the Tamjout dolomite, this is observed at the Tizert, Amane Tazert, and a part of the Agoujgal deposits.

Precambrian III comglomerate is also mineralized in some cases, but this mineralization is always limited to the parts immediately underlying the Infracambrian sedimentary rocks. The examples of this type are seen at the Tiferki, Tizert, and Idint deposits.

Also mineralization is observed in the conglomerate and limestone beds intercalated in the Basal Series, but these ores are all discontinuous and weak.

In other words, the bedded copper deposits occur mostly in the three horizons, namely the lowermost, uppermost parts of the Basal Series and the immediately overlying Tamjout limestone. Of these three, the most important is the central one, the siltstone/sandstone alternation of the uppermost horizon of the Basal Series. Minor mineralization is seen in the intercalated limestone and conglomerate in the Basal Series and the Precambrian III conglomerate is the lowest mineralized zone. Thus, it is seen that metal is distributed in a wide range vertically.

The rocks on both lower and upper sides of the predominant sandstone/siltstone alternation generally become porous when metal is concentrated within them.

Copper sulfide minerals such as chalcopyrite are common in all ore-bearing horizons although they are in minute amount.

With the above facts in mind, the genetical history of the deposits is inferred as follows.

1) The copper content of the sea water or brine was relatively high at the time of the deposition of the Infracambrian Basal Series, especially the siltstone/sandstone alternation. This probably was caused by the relatively high copper content in the Precambrian III volcanic rocks which were the major source of the sedimentary rocks, and also the post-volcanic activity continued to the time of the deposition of the Basal Series. The copper-bearing hydrothermal solutions were supplied during the deposition.

2) The copper which was dissolved in the sea water or brine probably precipitated under low-oxygen, high-hydrogen sulfide, reducing environment at the time of the deposition of the uppermost siltstone of the Basal Series. Bacteria most probably played important roles during the presipitation.

3) Regression occurred later, and by the time the Tamjout dolomite was deposited, copper did not precipitate due to the change of the chemical environment.

4) The copper which precipitated in the siltstone was later dissolved and circulated, by the activity of the warm hypersaline brine which probably originated from connate or fossil water. And it recrystallized to form the present orebodies.

The cause of the remobilization of the copper after the formation of the deposit is not clear, but two possibilities can be considered; one is the diagenesis associated with the solidification of the Basal Series and the other is the forces associated with the Hercynian Orogeny. Both of these factors may have been responsible for the process.

The enrichment of the deposits, however, seems to be closely related to folds all of which are believed to be the product of Hercynian Orogeny and thus it is most likely that remobilization of the deposit occurred by the circulating hypersaline water which originated from the warm connate water at the time of the Hercynian Orogeny. Then most of the copper which originally precipitated in the siltstone recrystallized and remained in the rock while some of the metal was dissolved and moved into the permeable rocks immediately above and under the siltstone.

It is, naturally not difficult to imagine that there were repeated cycles of secondary oxydation, dissolution, reprecipitation by meteoric waters during the period from Hercynian to the present. These processes, however, probably did not change the shape of the deposits very much with the exception of sheared zones. This is because the original form of the deposits were relatively thin and platy, and the geological units of the different horizons consisted of piles of units which differing permeabilities.

During the course of the present survey, it was noted that strong mineralization generally occurred in zones where fold structures were developed. Also it was seen that zones of complex fold structures showed high concentration of copper.

The Basal Series which is the major ore-bearing horizon is generally folded, and even in cases where this series is not folded mineralization was strong when the overlying Adoudounian series was strongly folded and especially in cases where there were intraformational folds.

Such examples are observed at Iminirfi, Talate N'Ouaman, Tirzzit, Amane Tazert and other deposits. The structure of the Amane Tazert deposit is very complex consisting of a main fold and intersecting small folds. The ore shoot occurs at the intersection of these folds.

Since the mineralization is closely associated with fold structures, it will be necessary in future prospecting to clarify the regional fold structure and locate the strongly mineralized zones. Also the study of the structure of the individual deposits will undoubtedly be an important guide for finding the ore-shoots of the deposits.

As mentioned above, the remobilization of the metal during the formation of the deposits was strongly affected by folding which represent orogenic movement. Therefore, the clarification of the fold structure will form the basic foundation of future exploration projects of the bedded copper deposits.

The relation between metal concentration and the topography of the surface of the Precambrian basement (paleotopography) is also of significance.

Very close relation between the paleotopography and the metal concentration was noted in one or two of the surveyed deposits. In the Amadouz deposit, the thickness varies considerably and the ore occurs in the basal conglomerate, but it occurs only where the thickness of the conglomerate is less than 10 m.

This seems to suggest that there was a tendency for the metal to be concentrated on the slopes of the paleotopography than at the depressed zones. The reason for this tendency is not clear, but either the primary precipitation of copper occurred under chemical conditions formed in such sedimentary environment or the metal was concentrated by reprecipitation under such sedimentary conditions after remobilization. Whichever the case, this is one example of the relation between the paleotopography and ore genesis.

The Agoujgal deposit is a peculiar deposit which contains uranium. This deposit is developed in the small depressions of the basement PII granite. Uranium is especially strongly concentrated in such zones. This uranium most probably was supplied from the basement granite and precipitated in the lowermost sandstone of the Basal Series and perhaps is closely related to the copper, but the mechanism of the precipitation of the two elements is not strictly the same. These processes, however, are strongly influenced by paleotopography.

As is shown above, close relationship between the deposits and paleotopography is confirmed for these deposits. And it is believed that study of these relationships will provide important clues to the search of ore deposits.

Secondary oxydation and enrichment are observed in some of these deposits, but these are of limited scale and they are generally not of great significance.

Amane Tazert, Tasserirt, and Talate N'Ouaman are examples of deposits affected by secondary enrichment through fracture systems. But the effect is very small in relation to the entire mineralization.

To summarize the above, it can be said that the major factors influencing the genesis and enrichment of these ore deposits are first the ore-bearing horizon and lithology, second the folding, and third the paleotopography of the basement.

9-2 Network-Dissemination Copper Deposits in Rhyolites

The Talate N'Souss and Alouss mines are the two mines with deposits of this type which were surveyed during the present investigation.

These deposits all occur in Precambrian III rhyolite bodies. These rocks are associated with many volcanic and pyroclastic rocks and indicate the intense volcanic activity of PIII.

The deposits consist of network of fine veinlets or dissemination of copper minerals, and the overall shape is irregular and massive. The ore shoots as mentioned in the description of the deposits, are very closely controlled by the fissure system.

The primary formation of these deposits were most probably due to the hydrothermal solutions which followed the PIII acidic volcanic activities. These primary orebodies, however, could not have survived the Hercynian Orogeny without being metamorphosed to some degree. Evidences of secondary alteration such as leaching and enrichment are also observed near the outcrops.

The primary deposits are considered to have been similar to the hydrothermal network and disseminated deposits in rhyolite/dacites which are rather common in the Tertiary volcanic regions such as the Kuroko Zone of Northeast Japan. It is inferred that the major ore minerals were pyrite and chalcopyrite.

Precambrian volcanic rocks including rhyolites were most probably metamorphosed during the Hercynian Orogeny. Porphyroblastic textures, banding, and gneissose textures are observed markedly in some of the rhyolite bodies.

This metamorphism was probably of low temperature and low pressure nature. But it was intensive enough to remobilize and recrystallize the primary pyrite/chalcopyrite assemblage to the present chalcocite/bornite assemblage.

The movement of the metal during the remobilization could not have been very strong and the deposits are believed to have retained their original shape.

To summarize the above; in order to explore this region for copper deposits of this type, first the distribution and shape of the rhyolite which hosts these deposts must be clarified and for which regional geological and structural survey must be carried out. Second the shape of the deposit and the distribution of the ore shoots within these rhyolite bodies must be clarified by the study of the fracture system within the rock.

CHAPTER 10 RADIOMETRY

As the occurrence of radioactive minerals was expected from the Anti Atlas region, systematic radiometry was carried out for each horizon and rock type including the copper deposits. Portable scintillation counter was used.

The objective of this radiometry was to gather basic data for using this method in geological surveys of this region utilizing the differences of radioactivity of the component rocks as well as to search for radioactive minerals.

The bedded copper deposits generally do not have radioactive anomaly, but uranium concentration was found in the sandstone of the Infracambrian series in close association with the copper orebodies at the Agoujgal deposit. Here, relatively radioactive PII granite occurs immediately below this sandstone and it is believed that this granite was the source of the uranium. In this mine, uranium is concentrated in the depressium of the basement granite.

Thus it seems most likely that in areas where the basement is made of radioactive granite, uranium will be concentrated together with bedded copper deposits in zones of the granitic depression.

These facts suggest that there are possibilities of the uranium concentration in conglomerates and sandstones derived from radioactive granites regardless of the existence of copper deposits. This should be borne in mind during future exploratory work.

The PIII rhyolite which is the host rock of the Alouss mine is relatively radioactive. The source of this radioactivity will probably be clarified by mineralogical work, and although this rhyolite will not be economically exploitable for radioactive minerals, this will be useful for indirect method of copper prospecting. Especially as the redioactivity is strong where the copper concentration is high, this method will be useful for copper prospecting as well in this mine.

The radioactivity of different rock types will be mentioned later in detail. But generally, acidic igneous rocks such as granite and rhyolite have the highest radioactivity. Within these acidic rocks, there are relatively high and low radioactive types and they each have their characteristics.

Quartzite generally have the lowest radioactivity and this is the characteristic feature of this rock.

Conglomerates are generally not very radioactive, but they can be highly radioactive in some places, and this shows that it is dependent on the source rock and the sedimentary environment.

Andesite and basalt have intermediate radioactivity and these rocks have no significant characteristics of this nature.

The radioactivity of the sandstones and siltstones vary greatly and this shows that the radioactivity is greatly affected by the sedimentary environment and the source rock. Thus, it will be useful in future exploration for uranium to determine the radioactivities of conglomerate, sandstone and siltstone.

It is seen from the above results that there are possibilities of the occurrence of uranium deposits in this area and this should be considered in future exploratory work. Also it was shown that radiometry will be a useful tool in determining the distribution of various rock facies in this region.

10-1 Method of Survey

The variations of radioactivity of the copper-bearing horizon and the neibouring strata was measured.

TSC-121 γ-ray scintillation survey meter (Nihon Musen Irigaku Kenkyujo) was used. The probe was held within 10 cm of the exposure and the average count of 5 - 10 seconds was read.

10-2 Radioactivity of Various Rocks

The radioactivity of various rocks are as follows.

1) Conglomerates: PII .... 0.0075 mR/h; PII-III .... 0.014 - 0.016 mR/h; PIII .... 0.003 - 0.012 mR/h; Basal Series .... 0.005 - 0.01 mR/h.

One of the causes of the relatively high radioactivity of PII-III conglomerates may be the wide occurrence of granite and gneiss which are the sources rocks.

2) Sandstone, Siltstone: PII, PIII .... 0.007 - 0.009 mR/h; Basal Series .... 0.006 - 0.0175 mR/h.

The variation of the radioactivity is very large especially with siltstone. Near the uranium orebody of the Agoujgal mine, the arkose sandstone of the basal series have an average of 0.016 mR/h, and in the fine-grained part it is as high as 0.125 - 0.60 mR/h. This abnormally high radioactivity indicates the occurrence of the uranium deposit.

The siltstone of the Basal Series at Tiferiki mine has a relatively high radioactivity of 0.0175 mR/h. This may be the effect of the PIII rhylite dykes which intruded into this siltstone.

3) Limestone: With the exception of the limestone of the Agoujgal mine, the radioactivity of the limestone and dolomite in the basal series and the Infracambrian lower series is all within the range of 0.003 - 0.007 mR/h. This is the lowest value of all the rock types which occur in this region. The radioactivity of the Tamjout limestone of the Agoujgal mine is 0.0065 - 0.01 mR/h and is higher than those of the other limestones.

4) Rhyolites: The rhyolites of this region can be divided into two groups from their radioactivity, the higher and the lower groups. The former group has radioactivity of 0.03 - 0.042 mR/h while the latter 0.010 - 0.014 mR/h. The radioactivity of the rhyolite of the Alouss mine is relatively high and the source is not yet known.

The radioactivity of the rhyolitic dyke rocks is in the range of 0.0125 - 0.015 mR/h and is the same as that of the lower group. Even the low radioactive rhyolites generally show high values in the sheared zones; in the order of 0.023 mR/h.

5) Andesites: The andesite lavas can be grouped into two as in the case of rhyolite lavas, but they are generally weakly radioactive. The values are 0.012 - 0.013 mR/h, 0.005 - 0.008 mR/h and in the sheared zones 0.017 mR/h.

6) Dolerites: The radioactivity of dolerite dykes is 0.01 mR/h and is equivalent to the median value of the andesites.

7) Granites: PO......0.009 - 0.0145 m/Rh; PII......0.016 - 0.020 mR/h; There are two types of PII-III granites; one with 0.024 - 0.030 mR/h and the other with 0.014 mR/h radioactivity. The former PII-III granite has the highest radioactivity.

8) Schists, Migmatites: The PO and PII schists and migmatites have the same radioactivity as the PO granites, i.e., 0.0075 - 0.013 mR/h.

9) Gneiss: The radioactivity of the PO gneiss is in the range of 0.016 - 0.018 mR/h and is somewhat higher than that of the PO granites, migmatites, and schists.

10) Quartzite: The radioactivity of the PII quartzite is about the same as the limestones at 0.005 mR/h.

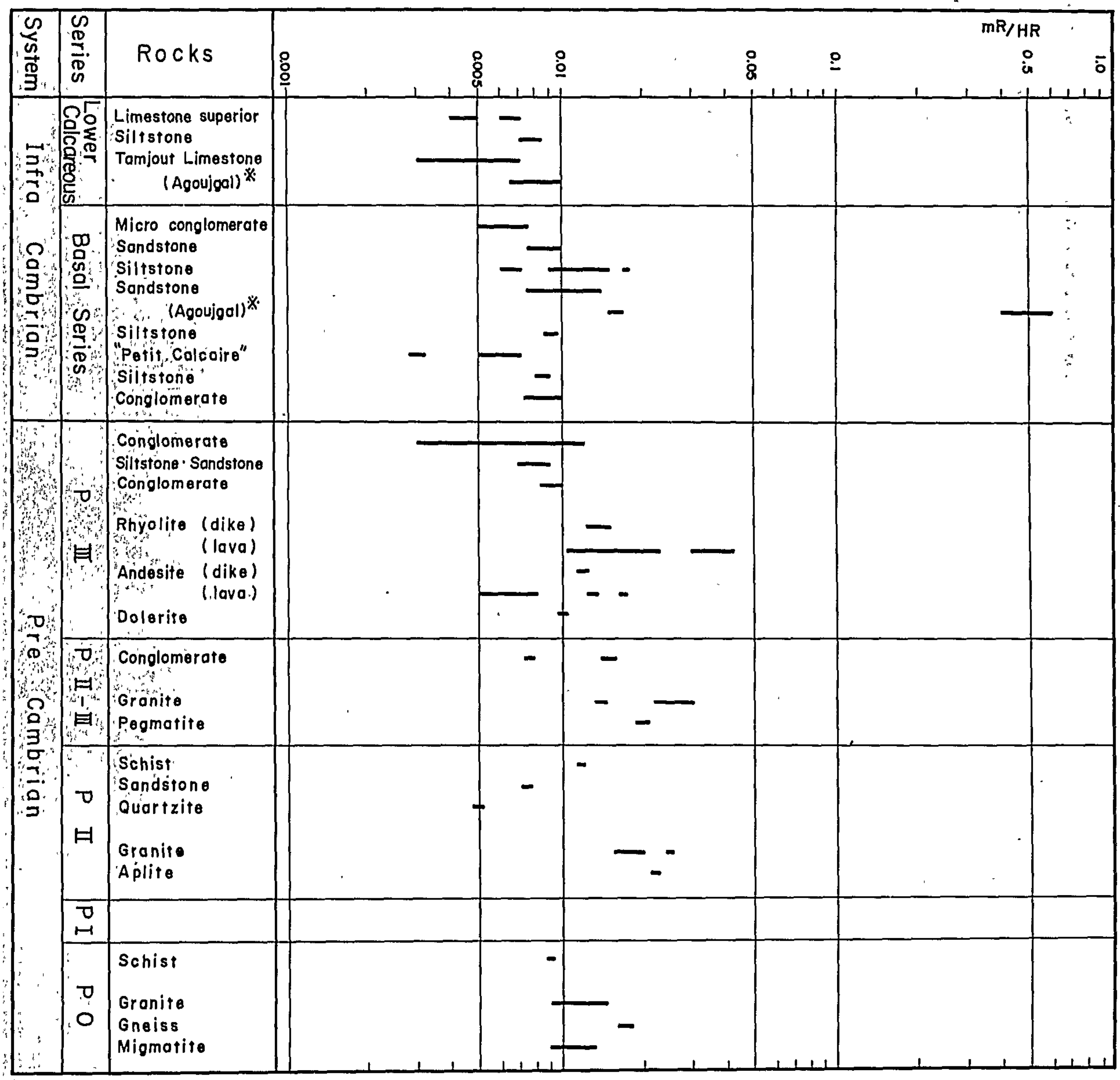
10-3 Application of Radiometry to Copper Exploration

1) Bedded deposits

Radioactivity was measured systematically at the Tizert, Amadouze, and Tirzzit mines. Measurements were made on the geologic units from PIII below the ore-bearing horizon to the Tamjout limestone and higher units above the ores. Significant increase of radioactivity was not observed in the copper ore-bearing horizon. (Fig. VII-3-C, VII-7-C-(1)(2)).

The radioactivity of the Tamjout limestone and higher units, however, are always lower than that of the Basal Series and the lower strata. Therefore radiometry can be used to determine the boundary between

Radiometric Evaluation of the Rocks in Anti Atlas, Morocco



※ : Agoujgal Project under exploration

the Basal Series and the Tamjout limestone.

2) Disseminated deposits

The Alouss deposit occurs in the PIII rhyolite which is highly radioactive and the dimensions of the deposit are fairly large at 800 m x 800 m. Rhyolite occurs at relatively high horizon of PIII and thus the rock is expected crop out on the surface. Therefore, radiometry is effective for prospecting for Alouss type copper deposits.

10-4 Radioactive Minerals from Agoujgal and Alouss Mines

Samples of the arkose sandstone of the Agoujgal mine in which uranium is concentrated and of the rhyolite of the Alouss mine which showed high radioactive anomaly were studied in the laboratory with the results shown in the appendices. The uranium bearing mineral from the Agoujgal mine has been determined as meta-zeunerite, a hydrous arsenide of uranium and copper.

CHAPTER 11. FUTURE EXPLORATION PROGRAM

At present, exploration of the Anti Atlas region is generally in the initial stage. There are many exploration projects underway, but these projects are all based on outcrops and the major operations are the tracing of these exposures by trenches and pits. Tunnelling and shallow drilling are carried out only in very limited cases. There are, however, two or three deposits whose prospectings have progressed to further stages, but the work in this region is yet generally in the initial stage.

The present exploration based on outcrops has not yet produced large deposits with the exception of two or three mineable ones.

One of the most important mineral resources of this region is the bedded copper deposits. In the case of these deposits, they crop out only at the peripheries of the Precambrian inliers and the major part of the ore-bearing horizon is burried subsurface. And at the peripheries of these inliers, exploration has been carried out only where outcrops were found and systematic work on the basis of geologic structure of the area has not yet been made.

Another type of mineral deposit of prime importance in this area is the network dissemination copper deposits in Precambrian rhyolite. Exploration for this type again has been made on those with significant outcrops. Regional survey of the Precambrian system, especially systematic exploration based on the geologic structure and the rhyolite distribution of the area has not been made.

The past work, however, has borne fruits and information concerning ore genesis, enrichment and other factors related to the formation of the deposits are being accumulated and large mineral potential is coming to light.

Thus, as for the projects in progress, it will be necessary to clarify the details of the geologic structure and then carry out exploration of larger areas utilizing the results of the structural studies.

Of special importance in the future work of this area, however, is the large scale regional survey with the purpose of understanding the general pattern of the geologic structure, and the relation of these structural patterns to the metal concentration. Then it will be possible to delineate areas for further systematic prospecting. It is needless to point out that the results of the previous surveys should be fully incorporated in this regional work.

The systematic exploration starting from the regional survey with emphasis on geologic structure and proceeding to the more detailed survey of selected areas will not only enable the evaluation of the mineral potentials of the total region, but also the degree of importance and urgency of the exploratory projects within the region. And thus it will enable more efficient prospecting and development of the mineral resources.

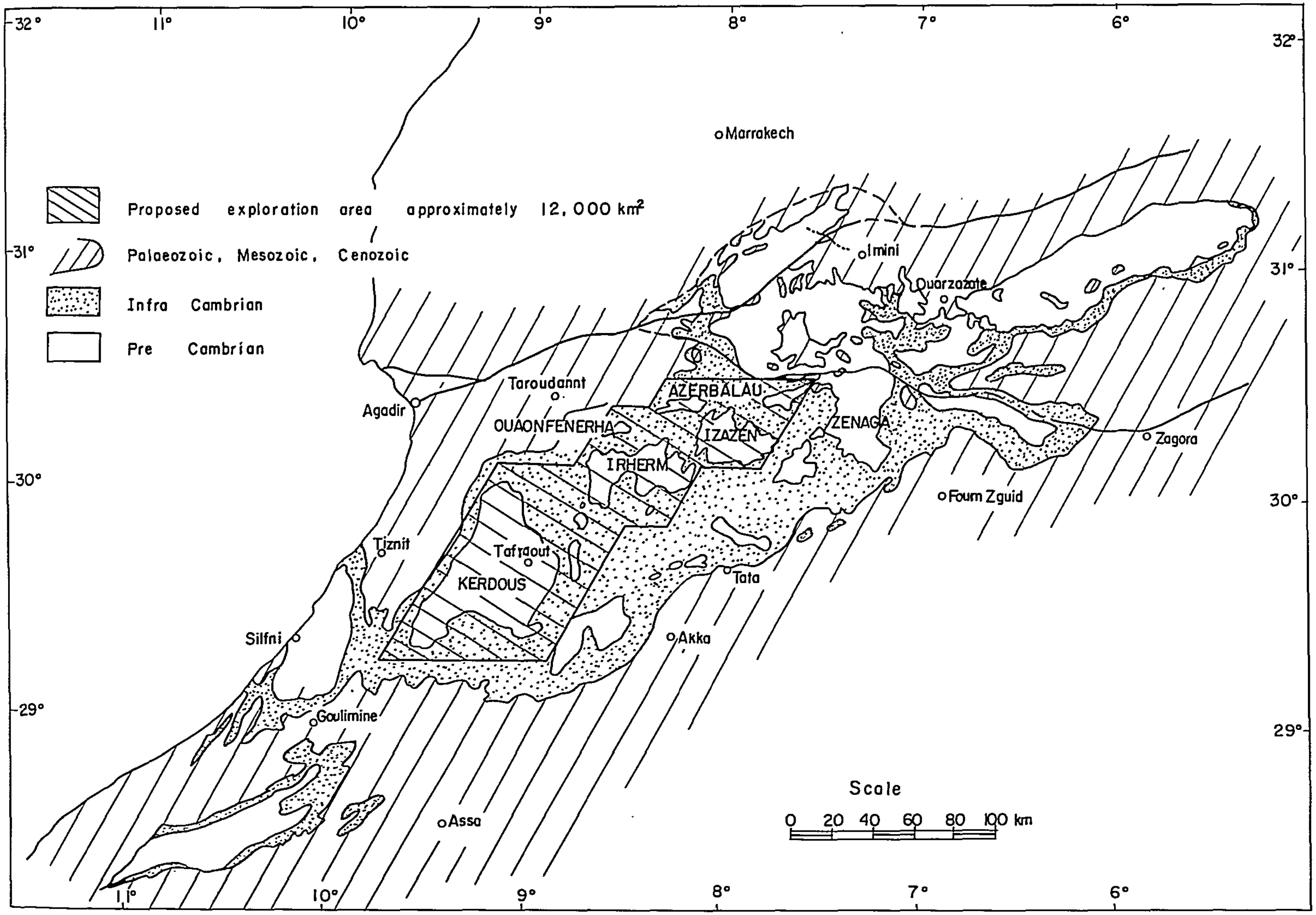
A plan of regional gelogical survey which the team considered important for the region was drafted as follows. The plan calls for three years of regional survey in three phases, and from the fourth year on detailed prospecting will be undertaken based on the results of the regional project.

11-1 First Year

Prepare geological and structural geological maps of approximately 12,000 km^2 of the region by phtogeological methods including airborn magnetometry and radiometry.

The major objective of this survey is the clarification of the geologic structure of the areas, the accurate distribution and the shapes of the Precambrian inliers, the structural characteristics of the inliers, folding, faults and other structures of the Paleozoic strata including the Infracambrian units. Also the prediction of the location of the Precambrian crypto dome of the basement under the younger sediments is of primary importance. At the same time, information concerning the inner structure of the Precambrian inliers, especially the pattern of the igneous activities would perhaps be available from these works.

Fig 6 Proposed Area for the First Year Exploration



Airborne radiometry will provide data on the distribution of rocks as well as for the search of uranium minerals.

The airborne surveys are planned with the traverse interval of 1 km and the direction of the traverses at N 30° E., tie lines normal to the main traverses at 10 km intervals would bring the total length of photometry, magnetometry, and radiometry to approximately 13,300 km.

After the analyses and interpretation of all measured data, they will be compiled and the photogeological data correlated with ground-checked data. And finally photogeological and structural maps of the region will be completed.

The expenses necessary for the first year are estimated as follows.

(a) Airborne survey (12,000 km^2, 13,300 line-km).

Color aerial photography, photogeology	¥31,716,000
Airborne magnetometry, radiometry, and interpretation	¥39,287,000
Check and discussion	¥4,089,000
Sub-total	¥75,092,000

(b) Ground geological check (crew of four, field work 45 days).

	¥28,403,000
Sub-total of (a) and (b)	¥103,495,000

(c) Contingencies	¥10,350,000
Grand Total	¥113,845,000

11-2 Second Year

Areas with high possibility of finding mineral deposits will be delineated. This work will be based on the geologic structure which would have been clarified from the results of the work of the preceding year. The total area of these promising parts of the region will probably be in the vicinity of 4,000 km^2. Ground geological survey will be carried out for these areas and the detailed geological structure will be clarified.

And also for areas of prime importance, detailed geological survey will be carried out. This will be approximately 8 km^2.

Parallel with this geological work, gravimetric work will be done for an area of about 2,000 km^2. These areas will be important zones selected from those parts where the Infracambrian and younger sedimentary cover obscures the subsurface structure. The major objectives of this work will be the understanding of the Precambrian dome structures, folds, and faults.

The expenses necessary for the work to be carried out during the second year are estimated as follows.

(a)	Geological survey (crew of nine, 70 days of field work).	
	Recconnaissance 4,000 km^2	
	Detailed survey 8 km^2	¥74,893,000
(b)	Gravimetric survey	
	2,000 km^2	¥65,307,000
	Sub-total of (a) and (b)	¥140,200,000
(c)	Contingencies	¥14,020,000
	Grand Total	¥154,220,000

11-3 Third Year

Areas totaling about 30 km^2 will be selected. These areas will be considered to be of special importance to the mineral resources of the region. And detailed geological survey will be carried out on these areas.

Also drilling to a depth in the order of 200 m will be made. A total of 11 holes which will amount to 2,200 m will enable accurate inferrence of the subsurface structure.

The expenses necessary to carry out the work outlined for the third year are estimated as follows.

(a)	Geological survey (crew of six, 30 km^2 50 days of field work)	
		¥56,519,000
(b)	Structural drilling (wire-line method)	
	11 (holes) x 200 m = 2,200 m	¥83,733,000
	Sub-total of (a) and (b)	¥140,252,000
(c)	Contingencies	¥14,025,000
	Grand Total	¥154,277,000

11-4 After the Fourth Year

Effective detailed prospecting will be carried out for areas and deposits which were selected on the basis of the importance and urgency from the results of the regional survey of the preceding three years. The purpose of these prospecting projects will be to find new deposits and ore reserves. The newly discovered reserves and grade will be blocked out and the economic feasibility of the mineral development of the region will be studied. The economically feasible mines will be developed successively.

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APPENDICES

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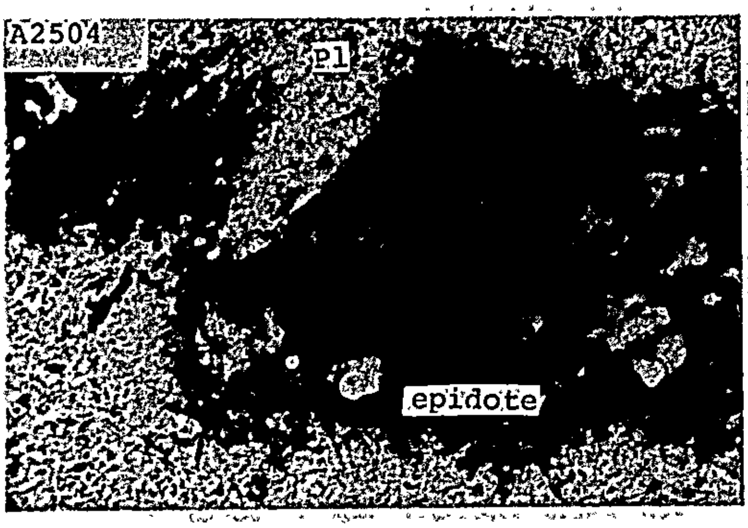
Microscopic Observation

A 2504



------------------- 1 mm -------------------

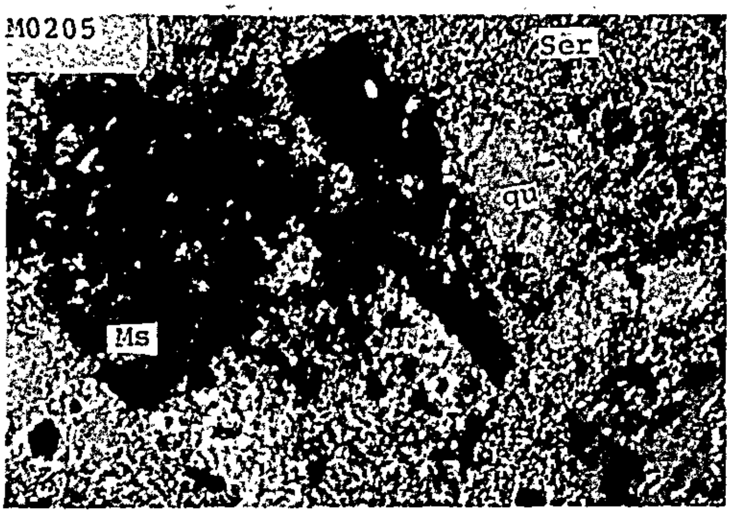
open nicol

pl: plagioclase

Rock Name: Andesite
Locality : Talata N'Souss Project

Plagioclase (albite rich composition) and quartz are observed as phenocryst and mafic minerals are altered to epidote and hematite. Groundmass is composed of plagioclase (Ab_{85} An_{15} from the data of extinction angle and twice V), hematite and slightly altered glass. The rock is slightly chloritized and sericitized.

M 0205



------------------- 1 mm -------------------

crossed nicols

Ser: sericite

Ms : muscovite

qu : quartz

Rock Name: Dacitic (?) tuff

Locality : Talate N'Souss Project

Fragments are quartz, plagioclase, opaque minerals (magnetite and hematite) and andesitic rock having plagioclase lath. Matrix is composed of plagioclase, quartz, hematite and altered glass. Chlorite and sericite occur commonly as the altered minerals.

M 0204

------------------- 1 mm -------------------

crossed' nicols

Chl: chlorite
Pl : plagioclase
Ser: sericite

Rock Name: andesite
Locality : Talate N'Souss Project

The rock is fresh but is partly altered to sericite. Phenocrysts of plagioclase (probably albite, up to 3 mm in size) and anhedral quartz are observed. The groundmass is composed of plagioclase, quart, hematite and weakly altered glass. Epidote and apatite occur as accessory minerals. Mafic minerals are entirely altered to chlorite and hematite is found especially around the quartz grains.

M 2503

------------------- 1 mm -------------------

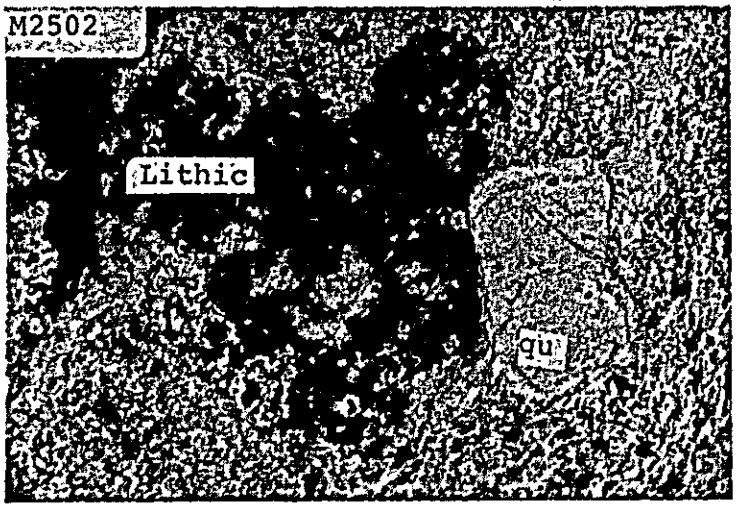
crossed nicol

qu: quartz
Ms: pebble of mudstone

Rock Name: Pebble Conglomerate
Locality : Amadouz Project

Chert, sandstone, argillized siltstone and andesite? Origin pebble are found as lithic fragments. Quartz and hematite grains are also observed as crystal fragments. The rock is ill-sorted. Matrix is composed of quartz, carbonate, hematite and clay minerals. Alteration minerals are large amounts of carbonate and sericite, and small amounts of chlorite and epidote. It is not determined whether hematite is primary mineral or secondary one.

M 2502



------------------- 1 mm -------------------

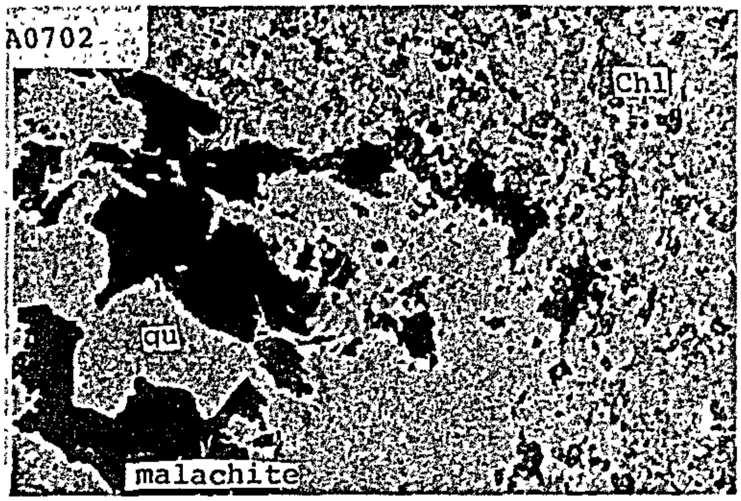
open nicol

qu: quartz

Rock Name: Mylonitized pebble conglomerate
Locality : Amadouz Project

The rock is ill-sorted and pebbles are poorly rounded. Fragments are composed of rhyolite, sandstone, quartz grains and hematite grains. The quartz grains show the wavy extinction. On the other hand, the matrix is composed of quartz, carbonate (mainly calcite), sericite, epidote, chlorite and actinolite. Chlorite is often found surrounding the quartz fragment.

A 0702



------------------- 1 mm -------------------

open nicol
Chl: chlorite
qu : quartz

Rock Name: Cupriferous and calciferous siltstone
Locality : Tirzzit Project

Quartz grain and its aggregates occur as fragments. The diameter of the fragment is about 1 to 2 mm. Matrix is composed of quartz, carbonate (calcite and Cu-carbonates), muscovite, hematite, montmorillonite and actinolite. The rock is comparatively suffered from strong alteration than the rocks mentioned before.

A 0804

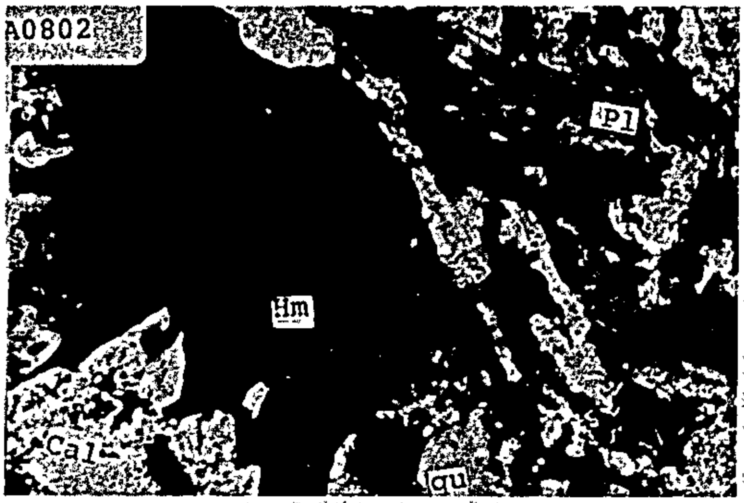
-------------------- 1 mm --------------------

open nicol

Rock Name: Coarse-grained sandstone
Locality : Tirzzit Project

Cherty rock and sericitized siltstone are observed as lithic fragments, and quartz as crystal fragment. The fragments are subangular to rounded in shape, sorting is not good. Only one crystal of biotite is also observed. Matrix is composed of fine-grained quartz, hematite and clayey minerals. Alteration minerals are sericite and small amounts of chlorite.

A 0802



------------------- 1 mm --------------------

crossed nicols

Hm: hematite

qu: quartz

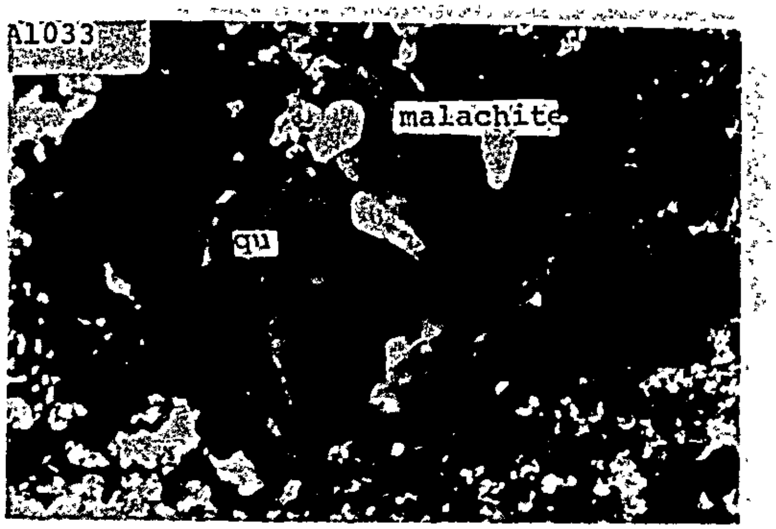
pl: plagioclase

Rock Name: Andesite

Locality : Tirzzit Project

The rock has the lineation characterized by the arrangement of plagioclase phenocrysts (0.2 to 0.5 mm in diameter). The minerals of groundmass are mainly plagioclase and hematite. Plagioclase is not suffered from the alteration. Hematite, quartz and calcite occur as amygdaloidal minerals. The amygdale is 0.2 to 5.0 cm in size.

A 1033



-------------------- 1 mm --------------------

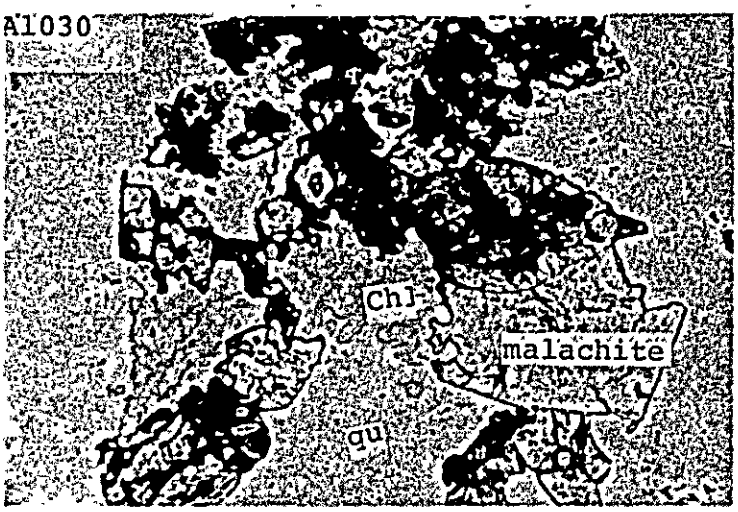
crossed nicols

qu: quartz

Rock Name: Rhyolite
Locality : Alouss Project

Phenocrysts of quartz, potash feldspar and plagioclase and magnetite are observed in the matrix of fine-grained quartz and altered glass. Chlorite and malachite is comparatively abundant than the rock of A 1030.
But, in this rock, malachite is not closely associated with chlorite.
Malachite is pale green to brownish green in color, and is fibrous and radial aggregates.

A 1030



------------------- 1 mm -------------------

open nicol

Chl: chlorite
qu : quartz

Rock Name: Rhyolite
Locality : Alouss Project

Phenocrysts of quartz, partly chloritized potash feldspar and plagioclase (less abundant than potash feldspar) are observed in the groundmass of quartz, potash feldspar, hematite and glass. Alteration minerals are the large amounts of chlorite. Malachite is commonly associated with quartz and chlorite.

A 1022

-------------------- 1 mm --------------------

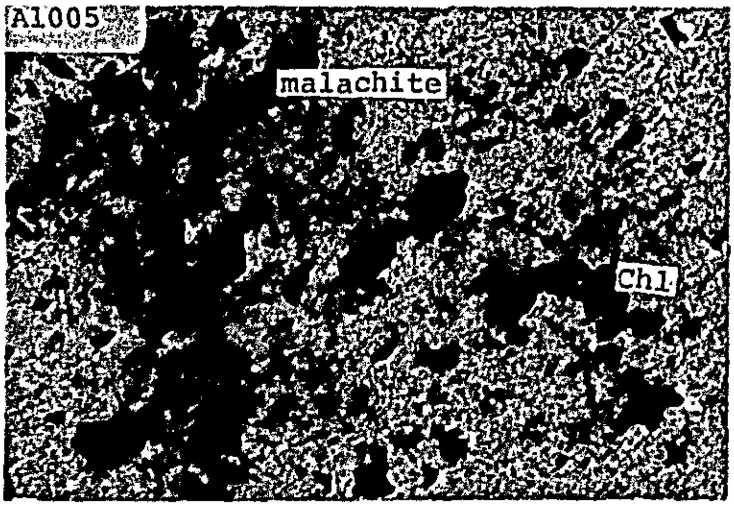
open nicol

Chl: chlorite
qu : quartz

Rock Name: Rhyolite
Locality : Alouss Project

Phenocrysts of quartz, potash feldspar and partly altered plagioclase (chloritized) are observed in the groundmass of quartz, hematite and altered glass. Epidote and large amounts of chlorite are found as alteration minerals. Malachite (2V = -60°) is also closely associated with chlorite, and is especially rich in seggregation veins of quartz.

A 1005



-------------------- 1 mm --------------------

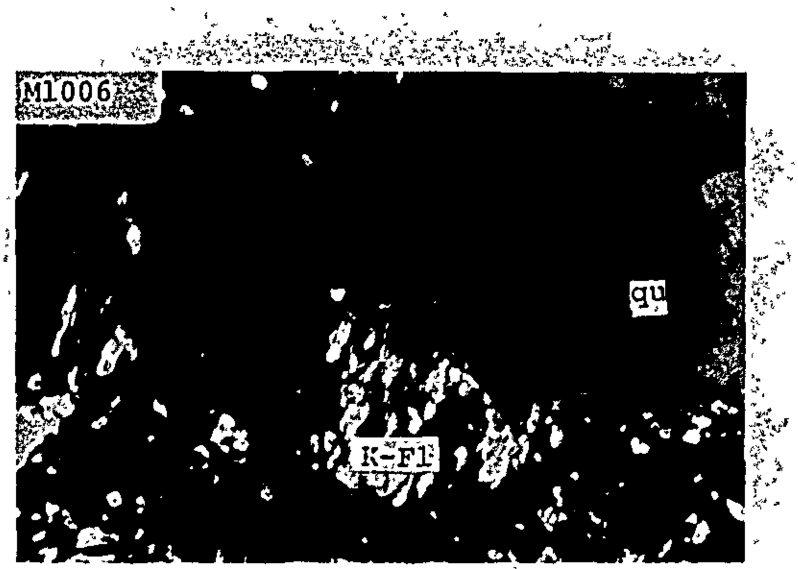
open nicol

Chl: chlorite

Rock Name: Rhyolite
Locality : Alouss Project

Phenocrysts are composed of quartz and potash feldspar (microcline twinned, and partly altered to epidote). Groundmass is composed of quartz, potash feldspar and slightly altered glass. Chlorite is observed as the alteration mineral. Malachite (twice V is about -60°, greenish in color) is closely associated with chlorite.

M 1006



------------------- 1 mm -------------------

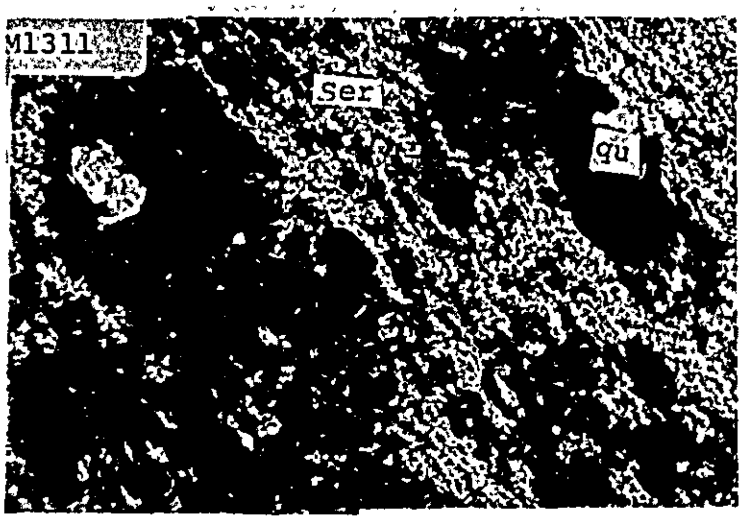
crossed nicols

K-Fl: potash feldspar
qu : quartz

Rock Name: Rhyolite
Locality : Alouss Project

Phenocrysts are composed of quartz (0.5 to 2.0 mm in size and showing the wavy extinction), potash feldspar (microcline twinned) and small amounts of plagioclase (albite rich composition). Groundmass is composed of quartz, potash feldspar, hematite, apatite and glass. The rock is comparatively fresh than the other rhyolites but is suffered from slight chloritization and sericitization. The rock has the weak lineation.

M 1311



------------------- 1 mm -------------------

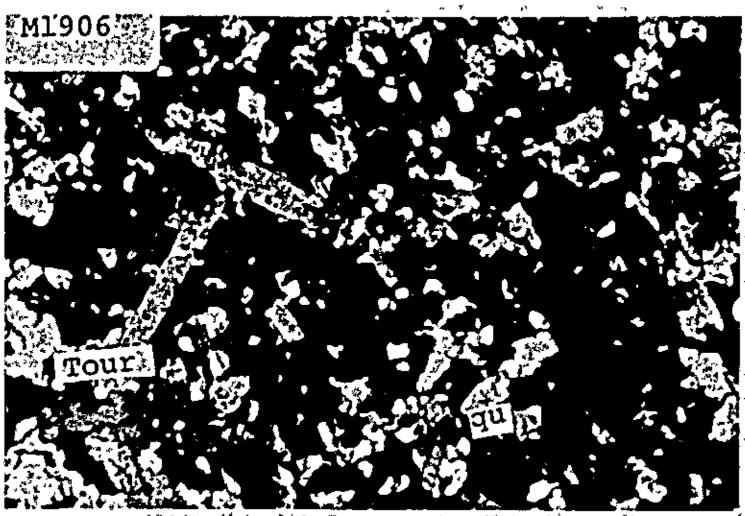
crossed nicols

qu : quartz
Ser: sericite

Rock Name: Cupriferous fine-grained sandstone
Locality : Tizert Project

Fragments are composed of quartz grain and carbonaceous rock (volcanic origin?) and calcite aggregates after plagioclase (?). Matrix is mainly composed of quartz and altered minerals. Alteration minerals are mainly sericite and carbonate, and small amounts of chlorite and hematite. Sericite is arranged along the bedding plane. Malachite is commonly disseminated, and is fibrous and is pale greenish blue in color.

M 1906



-------------------- 1 mm --------------------

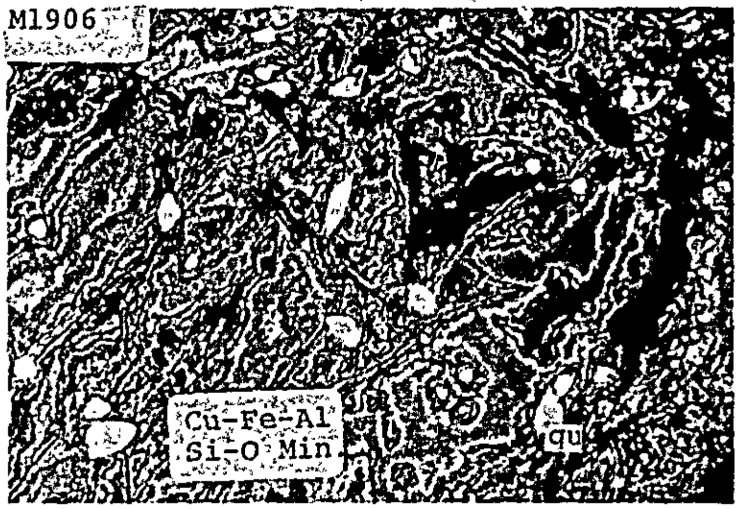
crossed nicols

Tour: tourmaline
qu : quartz

Rock Name: Cupriferous sandstone
Locality : Agoujgal Project

Two layers are observed in the thin section. One layer is composed of equigranular quartz, tourmaline and small amounts of epidote. Tourmaline is colorless to pale green under the open nicol and is biaxial negative. They do not elongated along the bedding plane or the lineation. It is also checked by the diffraction pattern. The other layer is composed of unidentified mineral and small amounts of chlorite and calcite. The unidentified mineral is yellowish green in color and is checked by the diffractometry and by the electron probe microanalyzer qualitatively. The components are mainly Al and Si, and it contains small amounts of Cu, Fe and Ca. The mineral of this composition has not been reported yet. It is probably the hydrous silicate.

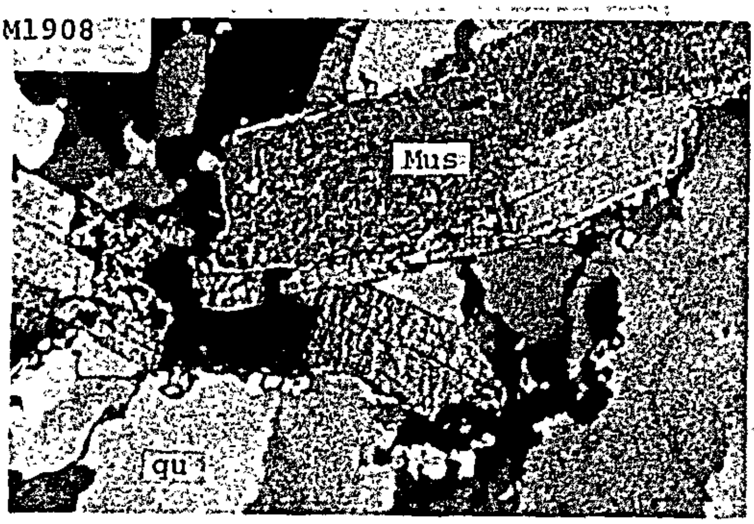
M 1906



------------------- 1 mm -------------------

According to the result of investigation for radioactive minerals (see M1907), the unidentified mineral mentioned earlier may be meta-zeunerite or olivenite.

A 1908



------------------- 1 mm -------------------

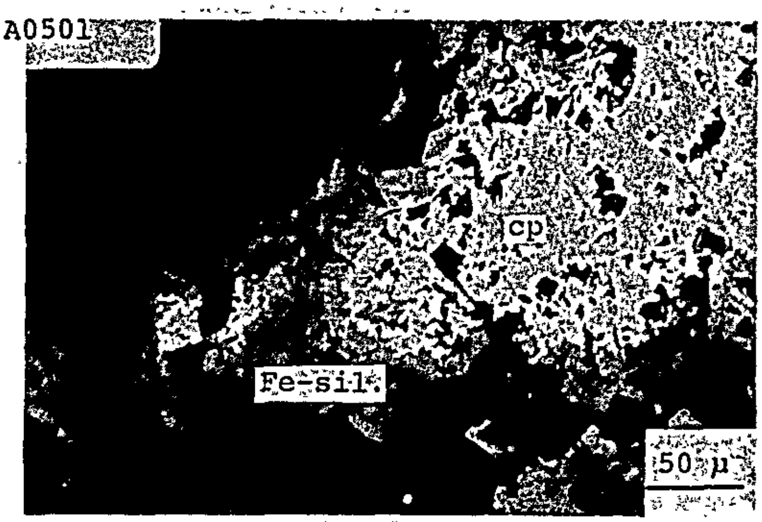
crossed nicols

Mus: muscovite
qu : quartz

Rock Name: Muscovite gneiss
Locality : Tasserirt Project

Quartz, plagioclase and muscovite are the main consituent minerals, and epidote, opaque minerals, apatite and zircon occur as the accessory minerals. The rock is holocrystalline, but the major constituent minerals are not equigranular. Quartz is elongated along the gneissocity plane. Plagioclase (having albite and/or polythynthetic twins) are selectively altered to serictite and partly to chlorite. Finer grains of sericite are slightly argillized.

A 0501



cp chalcopyrite
Fe-sil: iron-silicate

Rock Name: conglomerate
Locality : Amadouz Project

Chalcopyrite grains are always replaced by greyish mineral which has colloform bands in cases. The latter mineral contains iron and silicon based on qualitative analysis by EPMA. Iron content of it shows remarkable zoning in most cases. It may be hydrous(?) iron silicate. Chalcopyrite surrounded by the mineral occurs as constituent grains in conglomerate. Octahedral exsolution lamella of anatase (determined by ore-microscopy and EPMA) are commonly observed. Matrix of the exsolved anatase is a iron-silicate. This iron silicate contain less iron than the former iron-silicate. More detailed microscopic study is necessary on the two minerals. (See enclosed EPMA chert.)

M 2502

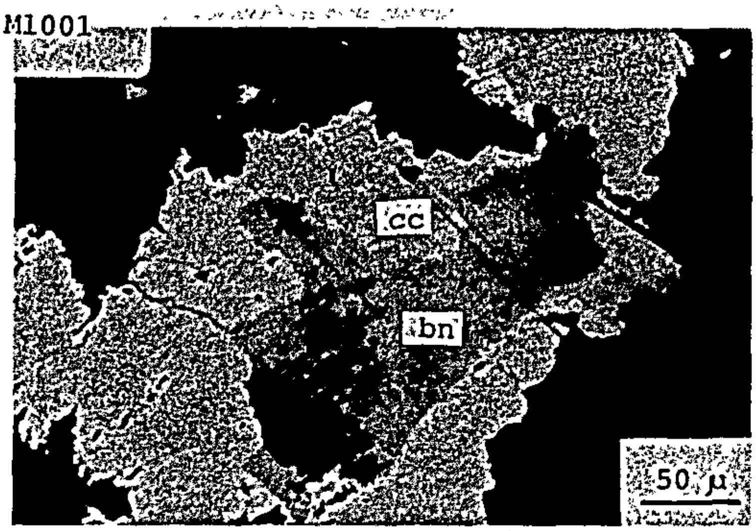
Rock Name: Conglomerate

Locality : Amadouz Project

Chalcopyrite is most common opaque mineral in this specimen. It occurs as disseminated grain or small veinlets. Sphalerite and pyrite associate with chalcopyrite in lesser amount.

Calcite coexists with these sulfide minerals in most cases. Anatase and iron-silicate are observed in some constituent sand grains.

M 1001



cc: chalcocite

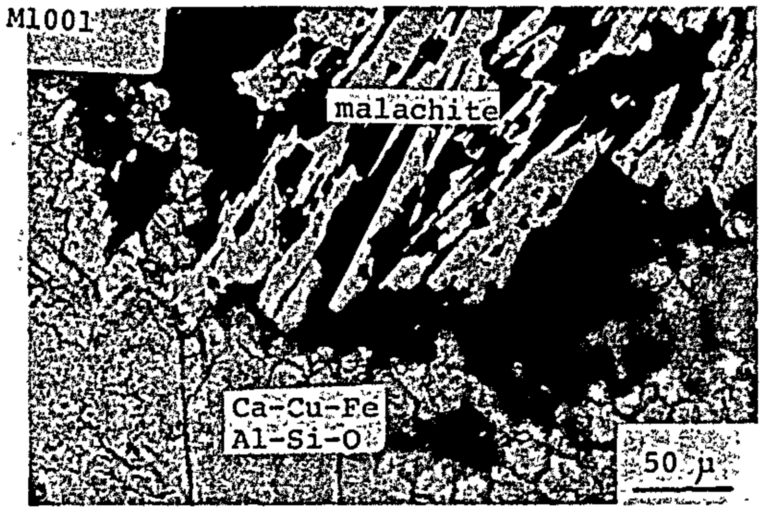
bn: bornite

Rock Name: Rhyolite

Locality : Alouss Project

Chalcocite is common sulfide mineral in this specimen. Bornite is always replaced by chalcocite. As mentioned in the description on A1501, chalcocite is not bluish under the microscope. Bornite is easily stained in one or two days. Fibrous grey mineral with strong anisotropism and greenish internal reflection is malachite ($CuCO_3 \cdot Cu(OH)_2$). It is determined by etching, X-ray diffraction analysis, and EPMA. EPMA analysis shows that the malachite contains appreciable iron. Soft greenish mineral which surrounds malachite cannot be determined (See A1501 and M0203). EPMA analysis shows that the mineral is consist of Cu-Fe-Ca-Al-Si. So it may be a kind of hydrous Cu-Ca-Fe-Al silicate.

M 1001



A 1202

qu: quartz

cp: chalcopyrite

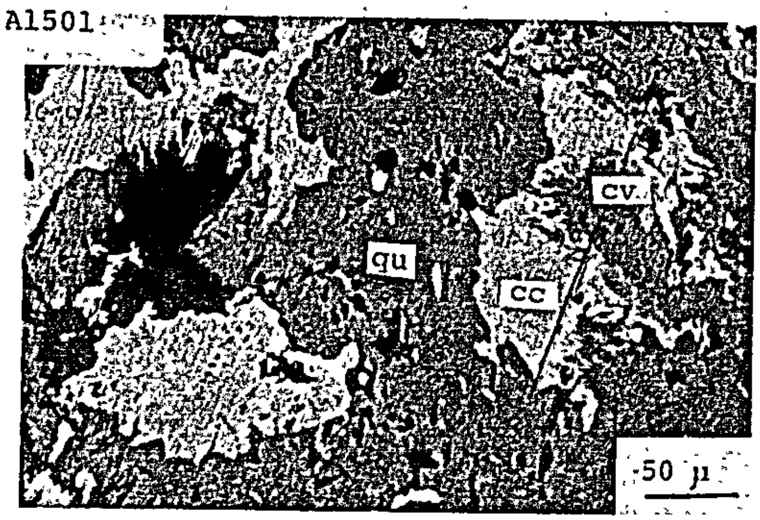
sp: sphalerite

Rock Name: Siltstone

Locality : Talate N'Ouaman Mine

A laminae rich in chalcopyrite, calcite and sphalerite is observed. Neither chalcopyrite-dot in sphalerite nor sphalerite-star in chalcopyrite are observed. Calcite associates intimately with these sulfide minerals in the laminae. Grains of chalcopyrite of n μ - 10 μ in diameter are scattered in the other part of the siltstone.

A 1501



qu: quartz

cc: chalcocite

cv: covelline

Rock Name: limestone

Locality : Amane Tazert Project

Chalcocite occurs with covelline contacting each others. These two minerals replace cracks of host limestone. Complicated crystal boundaries are commonly observed in a grain of chalcocite. It is peculiar that the chalcocite is grey to slight blueish grey in color. EPMA analysis shows, however, that the chalcocite contain nearly same amount of Cu and S with it from the Kosaka mine, Japan.

Judging from the experimental study on binary system of Cu-S, chalcocite does not coexist with covelline. There are three minerals between covelline and chalcocite on the join. They are djurleite ($Cu_{1.96}S$), A 1501 continued.

anilite ($Cu_{1.79}S$) and blaubleibender-covelline (CuS_{1-x}). It is hard to distinguish chalcocite from djurleite by EPMA or ore-microscopy. Weak anisotropism between crossed nicols tells us that the Cu-S mineral is not digenite (anilite). Therefore, the mineral is designated as chalcocite in this case. On the other hand, covelline could be distinguished from blaubleibender-covelline by use of ore-microscope.

Greenish transparent mineral often associates with chalcocite. It might be a secondary mineral of chalcocite. It contains Cu, Fe, Ca, Al, and Si by EPMA. (See M1001).

X-ray Chart

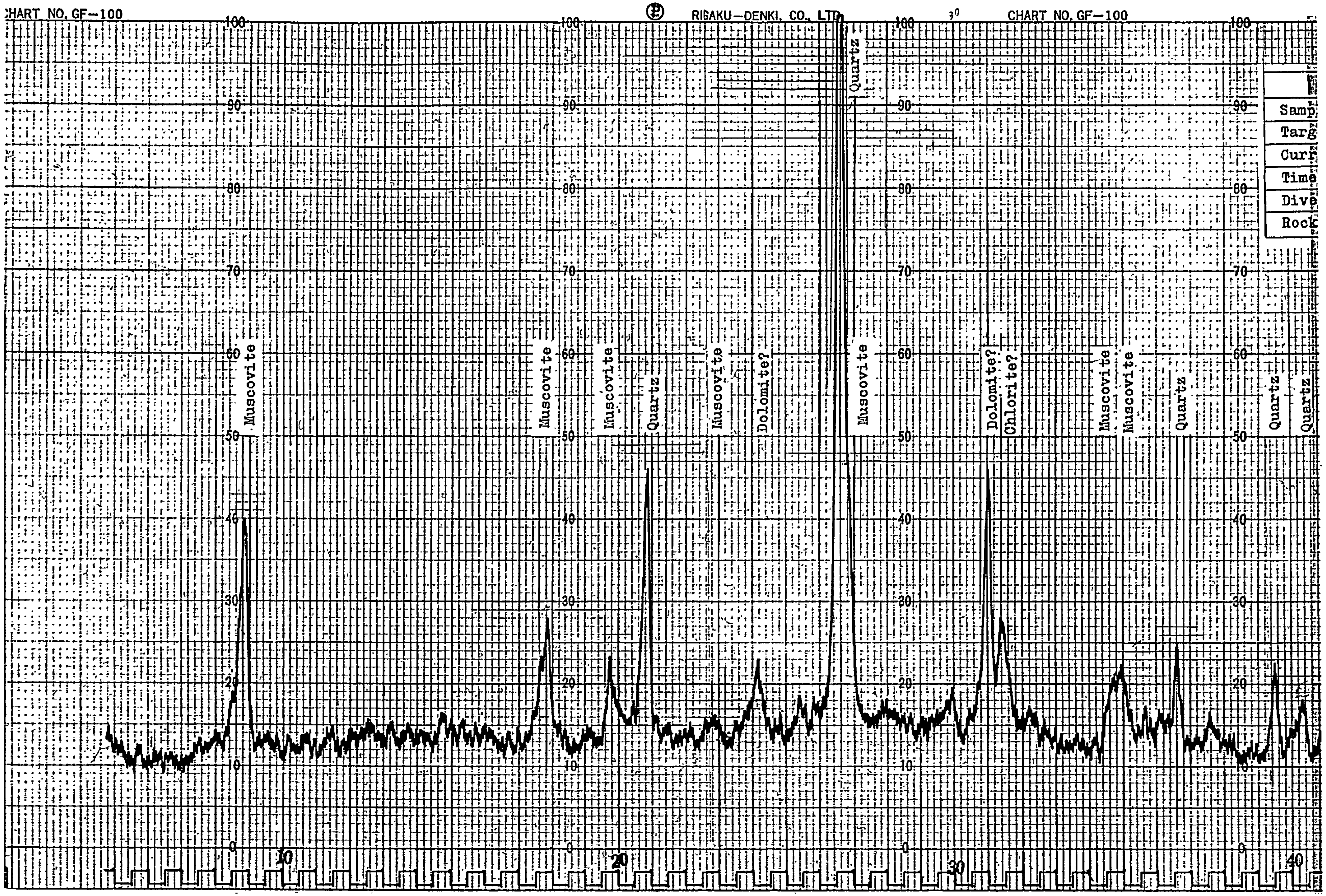


CHART NO. GF-100
RIGAKU-DENKI, CO., LTD.
CHART NO. GF-100
Muscovite
Muscovite
Muscovite
Quartz
Muscovite
Dolomite?
Quartz
Muscovite
Dolomite?
Chlorite?
Muscovite
Muscovite
Quartz
Quartz
Quartz
Samp
Targ
Curr
Time
Dive
Rock
10
20
30
40

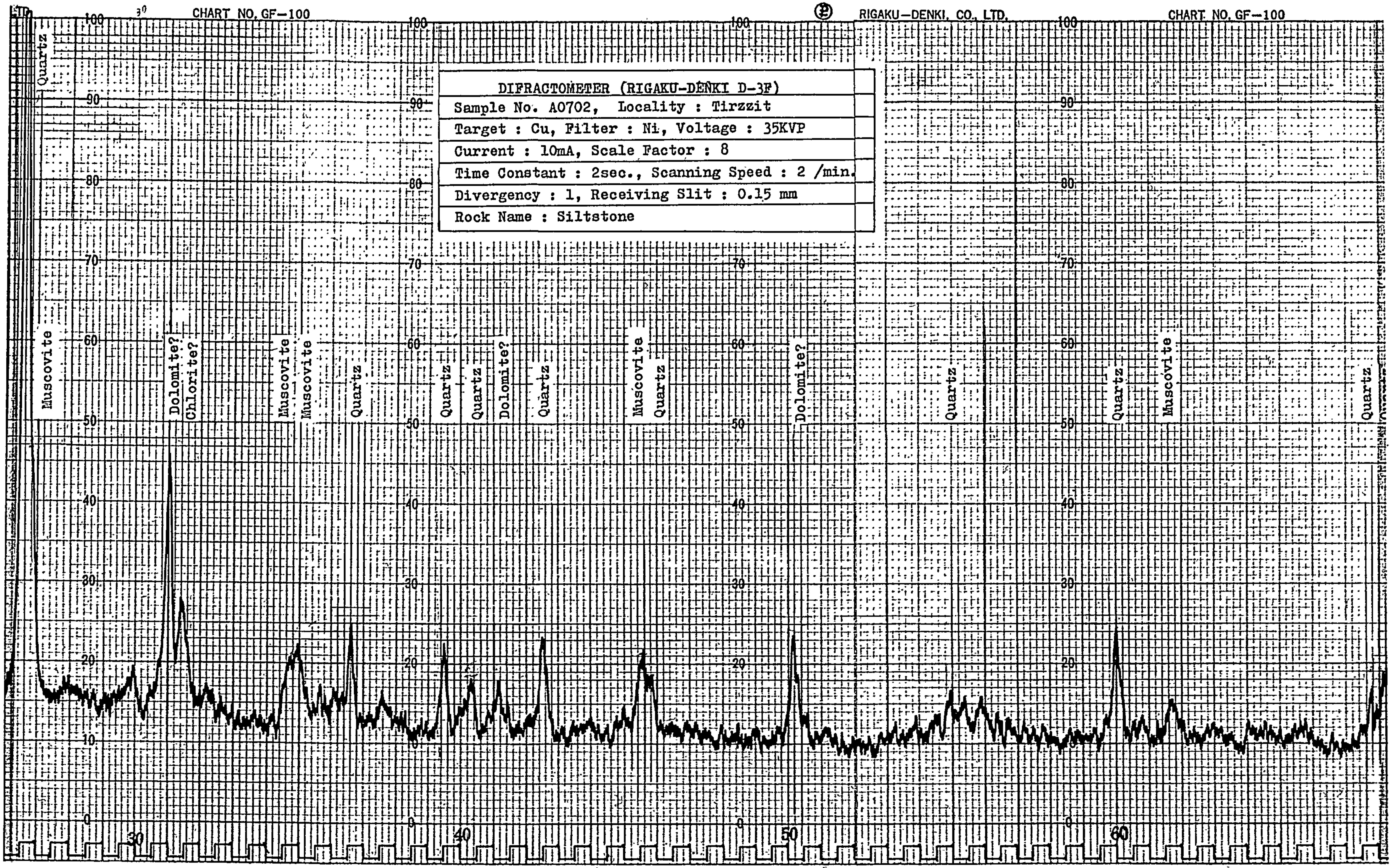
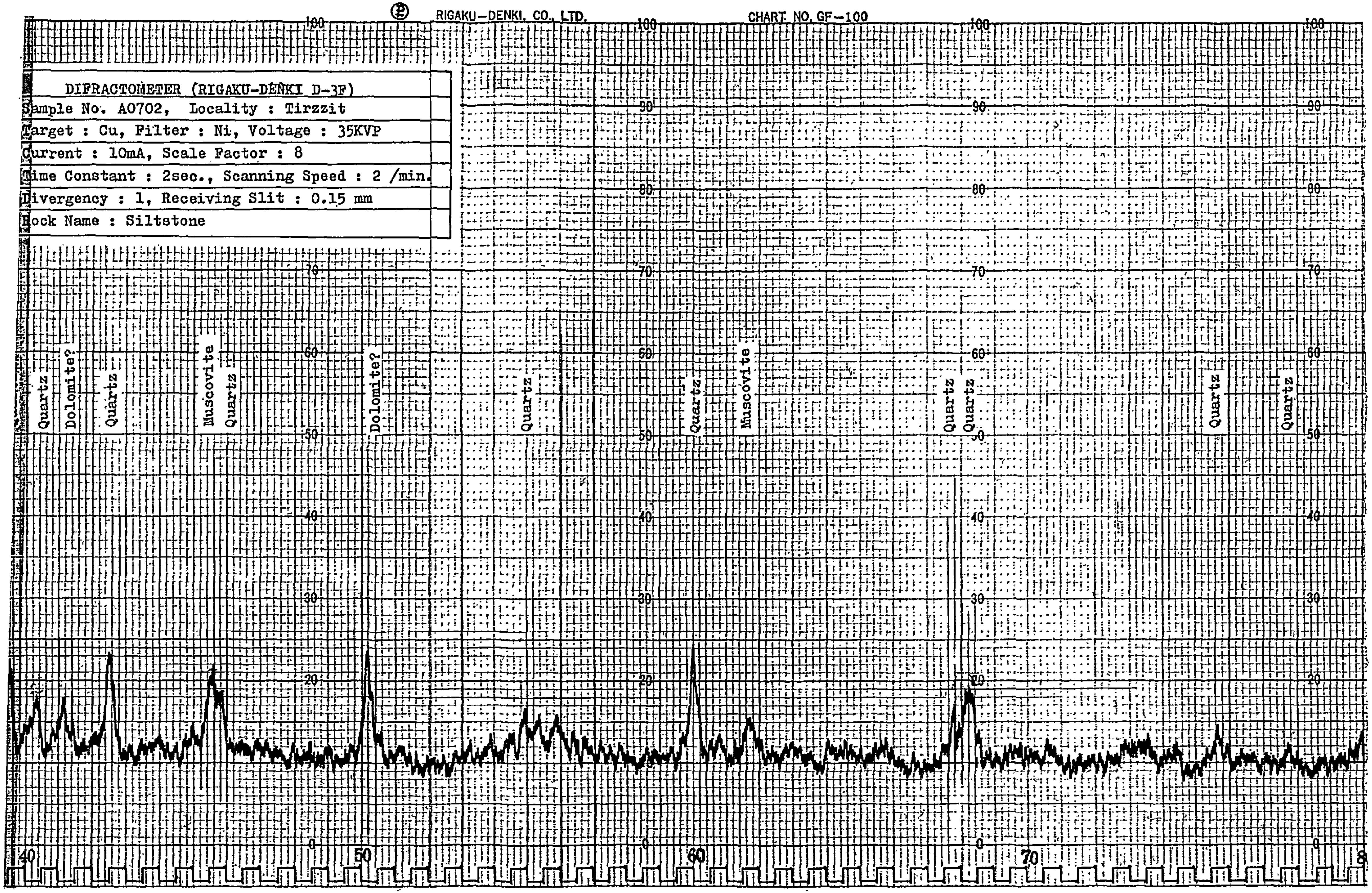


CHART NO. GF-100
RIGAKU-DENKI CO. LTD.
CHART NO. GF-100
DIFRACTOMETER (RIGAKU-DENKI D-3F)
Sample No. A0702, Locality : Tirzzit
Target : Cu, Filter : Ni, Voltage : 35KVP
Current : 10mA, Scale Factor : 8
Time Constant : 2sec., Scanning Speed : 2 /min.
Divergency : 1, Receiving Slit : 0.15 mm
Rock Name : Siltstone
Quartz
Muscovite
Dolomite?
Chlorite?
Muscovite
Muscovite
Quartz
Quartz
Quartz
Dolomite?
Quartz
Muscovite
Quartz
Dolomite?
Quartz
Quartz
Muscovite
Quartz
30
40
50
60


RIGAKU-DENKI. CO., LTD.
CHART NO. GF-100
DIFRACTOMETER (RIGAKU-DENKI D-3F)
Sample No. A0702, Locality : Tirzzit
Target : Cu, Filter : Ni, Voltage : 35KVP
Current : 10mA, Scale Factor : 8
Time Constant : 2sec., Scanning Speed : 2 /min.
Divergency : 1, Receiving Slit : 0.15 mm
Rock Name : Siltstone
Quartz
Dolomite?
Quartz
Muscovite
Quartz
Dolomite?
Quartz
Quartz
Muscovite
Quartz
Quartz
Quartz
Quartz
40
50
60
70
80

Chemical Analysis

CHEMICAL ANALYSIS OF SEDIMENTARY ROCKS

Sample No.	LOCATION	FORMATION, ROCK NAME	CaO	MgO	SiO_2	Al_2O_3	MnO	Total Fe
	Project Name		%	%	%	%	%	%
M0801	Tirzzit	Infra Cambrian Siltstone	15.17	7.96	35.58	8.36	0.41	1.58
A1321	Tizert	Infra Cambrian Tamjout Limestone	28.15	17.50	8.08	2.41	0.50	0.75
A1319	Tizert	Infra Cambrian Tamjout Limestone	29.30	19.61	5.58	0.76	0.41	2.38
M1308	Tizert	Infra Cambrian Basal Series Siltstone	0.49	3.73	62.14	17.01	0.03	3.53
M1306	Tizert	Infra Cambrian Basal Series Sandstone	8.89	10.38	44.86	16.06	0.10	2.90

Sample No.	Locality	Formation, Rock Name	Cu	Pb	Zn	Mo	Co	Bi	Ni	Mn	As	S	Au	Ag
			%	%	%	%	%	%	%	%	%	%	g/t	t/g
M0801	TIRZZIT	Infra-Cambrian Siltstone	5.40	0.004	0.017	0.003	0.008	0.012	0.008	0.26	0.001	0.04	<0.1	34
A0502	AMADOUZ	Infra-Cambrian Conglomerate	0.85	<0.003	0.018	0.004	0.008	0.014	0.008	0.11	0.001	0.29	<0.1	14
A1401	TIFERKI	"	2.49	0.006	0.021	0.004	0.010	0.014	0.010	0.02	0.001	0.06	0.1	5
A1306	TIZERT	Pre-Cambrian III Conglomerate	0.83	0.003	0.014	0.005	0.009	0.016	0.011	0.26	0.001	0.06	<0.1	13
A1315	TIZERT	Infra-Cambrian Micro-Conglomerate	0.48	0.003	0.015	0.004	0.008	0.013	0.008	0.16	<0.0005	0.40	<0.1	1
A1320	TIZERT	Infra-Cambrian Tamjout Limestone	0.33	0.016	0.024	0.004	0.005	0.010	0.004	0.19	<0.0005	0.06	<0.1	1
A1201	TALATE N'OUAMAN	Infra-Cambrian Siltstone	2.02	<0.003	0.020	0.004	0.010	0.016	0.008	0.11	0.001	0.12	0.1	24
A1502	AMANE TAZERT	" Limestone	2.70	0.004	0.011	0.003	0.006	0.012	0.003	0.07	0.001	0.17	0.3	12
A1503	IDINT	Pre-Cambrian III Conglomerate	1.41	0.008	0.012	0.004	0.008	0.012	0.008	0.02	0.001	0.05	<0.1	18
A1904	TASSERIRT	Infra-Cambrian Limestone	0.07	0.003	0.006	0.004	0.005	0.011	0.004	0.27	<0.0005	0.05	<0.1	< 1
M0202	TALATE N'SOUSS	Pre-Cambrian III Rhyolite	18.3	0.005	0.007	0.004	0.007	0.010	0.005	0.004	0.009	0.02	0.3	634
M1007	ALOUSS	"	0.73	<0.003	0.009	0.003	0.005	0.008	0.004	0.03	<0.0005	0.12	<0.1	13

Chemical Analysis of Radiometric Rock Samples

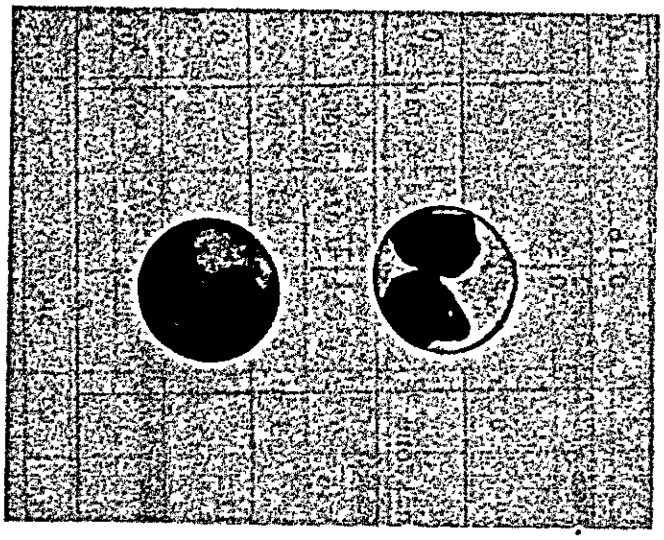
Project Name	Sample No.	Formation, Host Rock	Reading Value by Scintillation Counter mR/HR	Grade		Minerals
				U_3O_8%	ThO_2%	
Agoujgal	M1901	Infra-Cambrian Basal Series Sandstone	0.125	0.018		
"	M1902	"	0.16	0.011		
"	M1905	"	0.56			Identified Arseniosiderite Quartz, Kaolinite & Fayalite Not recognized U-minerals.
"	M1906	Infra-Cambrian Cupriferous Sandstone	1.20	0.31		
"	M1907	"	1.27	0.32		Identified Meta-zeunerite as U-mineral and Olivenite in the green vein-like part.
Alouss	M1011	Pre Cambrian III Rhyolite		0.002	0.003	
"	M1012	"		0.002	0.004	

Radioluxograph

M 1907

ASA: 3000

Exposure: 135 minutes

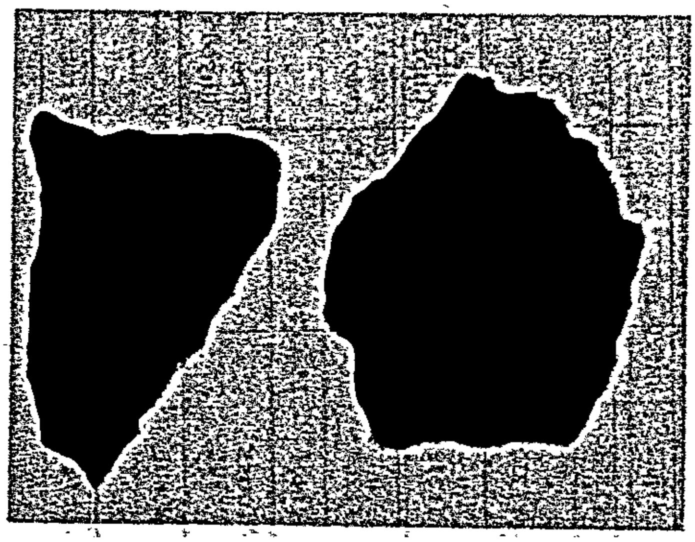


M 1905

ASA: 3000

Exposure: 40 hours

M1010 M1009



ASA: 3000

Exposure: 48 hours