KINGDOM OF MOROCCO REPORT ON GEOLOGICAL SURVEY OF THE HIGH ATLAS OCCIDENTAL AREA

(PHASE II)

FEBRUARY 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

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

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

This year was for the first phase survey, and as for this current year, a survey team was formed consisting of four (4) members headed by Mr. Kensuke Wakabayashi, Mitsui Mineral Development Engineering Co., Ltd., and sent to the Morocco on July 17, 1983. The team stayed there for eighty-seven (87) days from July 18, 1983 to October 12, 1983. During the period of its stay, the team, in close collaboration with the Government of the Kingdom of Morocco and its various authorities, was able to complete survey works on schedule.

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

We wish to take this opportunity to express our heartfelt gratitude to the Government of the Kingdom of Morocco and the other authorities concerned for their kind cooperation and support extended to the Japanese survey team.

January, 1984

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

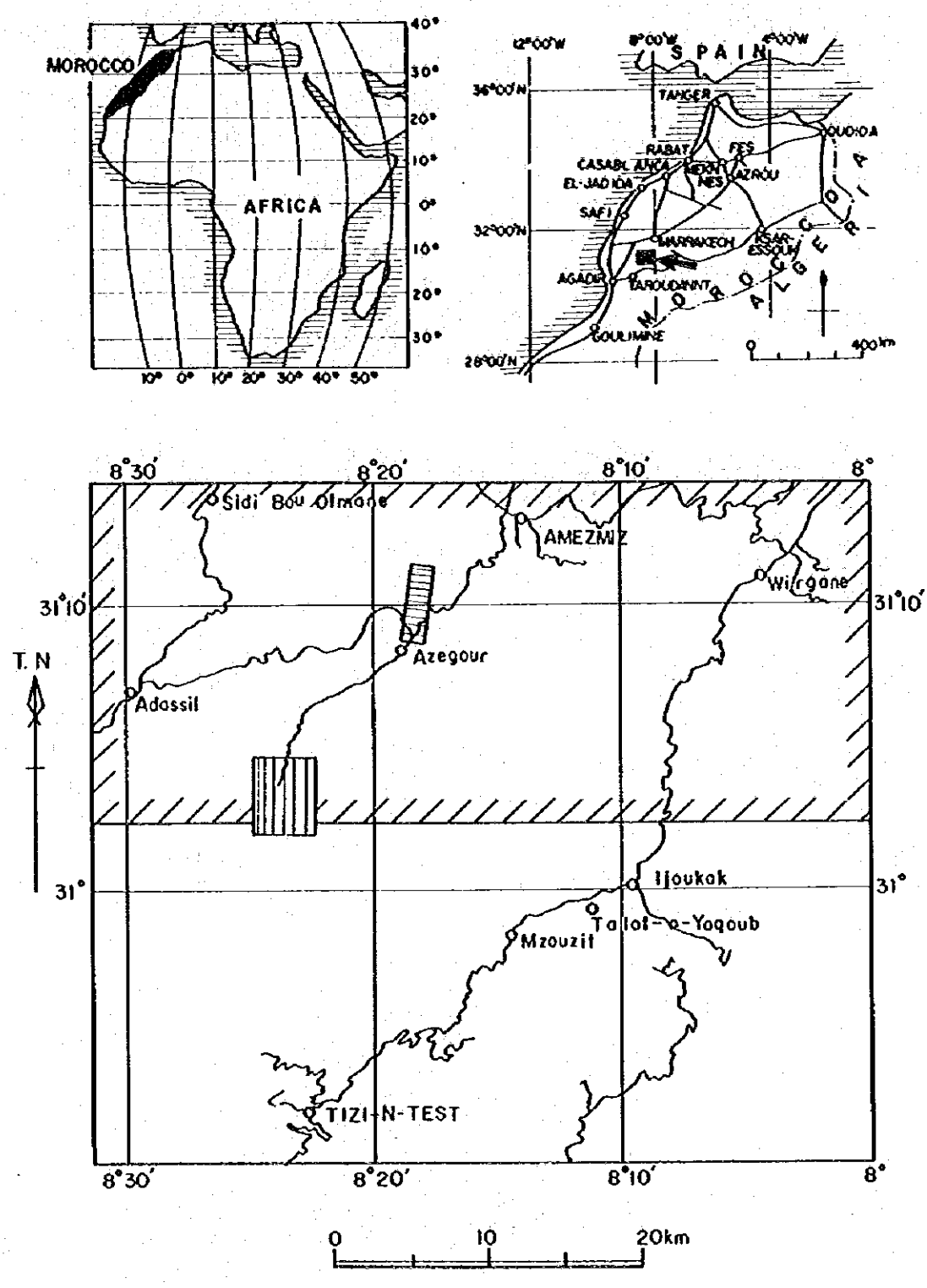

Fig. 1 Location Map of Surveyed Area

GENERAL CONTENTS

SUMMARY

As the cooperative investigations for the development of the mineral resources between the Kingdom of Morocco and Japan, the investigation in the Anti-Atlas area (1975 ∿ 1977) and the investigation in the Haute Moulouya area (1978 ~ 1981) were carried out in the past. Upon request by the Moroccan government, it has been decided to execute another cooperative investigation in the western zone of the Haut Atlas area, beginning in May 1983.

The primary phase investigation was carried out with different purposes in respective areas. In the North Area of the Haut Atlas Occidental area, the purpose of the surveys was to extract highly favorable areas for the emplacement of mineral resources. In the Erdouz Sector, the purpose was to comprehend the relation between the geological structure and the lead-zinc ore deposits, while in the Azegour Sector the purpose was to grasp the relation between the geological structure and the mineralization of the replacement deposits of copper, molybdenum and tungusten ores.

The contents of the surveys carried out in each of the areas are as follows.

* North Area : Geological reconnaissance survey ; area = 1,072.5 km^2 Geochemical survey (stream sediments) ; number of collected samples = 460, elements of analysis = 5 of Cu, Pb, Zn, Mo and W.
* Erdouz Sector : Semi-detailed geological survey ; area = 20

km^2 Geochemical survey (soil) ; number of collected samples = 126, elements of analysis = 3 of Cu, Pb and Zn (in addition to the above, 103 samples were analysed by B.R.P.M.)

* Azegour Sector : Detailed geological survey; area = 7.5 km^2 Geochemical survey (rock); number of collected samples = 206, elements of analysis = 6 of Cu, Pb, Zn, Mo, W and Fe (in addition to the above, 38 samples were analysed by B.R.P.M.)

* Rock identification by thin sections = 23, Ore mineral identification by polished sections = 20, X-ray diffraction = 21, whole rock chemical analysis = 10, Ore chemical analysis (Cu, MoS_2, W = 31), (Cu, Pb, Zn, Ag = 31)

Results of the Surveys

1) North Area: The North Area is underlain geologically by the formations of the period of Pre-Cambrian, Paleozoic, Mesozoic and Cenozoic Eras. The former two are recognized to compose the basement in this area. The Paleozoic formations are widely distributed over whole of the area.

The Paleozoic formations have been metamorphosed by the regional metamorphism, and the metamorphic rocks such as psammitic schist, pelitic schist, green schist and limestone have been formed. The pelitic schist is distributed predominantly in the eastern part of the surveyed area, and the limestone is distributed predominantly in the central part, while both the pelitic schist and the green schist are distributed in the

western part. Concerning the geological structure of the Paleozoic formations, there are remarkable characteristics represented by such factors as the foldings with the axes of NE-SW trend formed in the period of the Hercynian orogenic movement, the intrusion of igneous rocks like Azegour granite, and the blocking by the fault movements of the trends in E-W and NE-SW.

The mineralization in this area is represented by the vein type ore deposits of copper, lead, zinc and barite and by the skarn type ore deposits of copper, molybdenum, tungsten and iron. Both of them are distributed exclusively in the area where the Paleozoic formations are distributed. The distribution of skarn type ore deposits is confined to the area around the Azegour granite, while the vein type ore deposits are found at about 30 localities distributed in whole of the area, but the mineralization of the vein-type is generally weak.

In the geochemical survey of the stream sediments, high correlation is recognized between Cu and Mo and between Pb and Zn. The distribution of these anomalies of well-correlated elements are mostly corresponding one another. The distribution of the anomalies of Pb, Zn and part of Cu are corresponding to the known indications of mineralization. However, there is no new indication of mineralization detected in this survey.

2) Erdouz Sector : This area is underlain geologically by the metamorphic rocks of the Paleozoic Cambrian system. As to the geological structure, it is characteristically represented by the foldings with the axes in the form of the letter of 'S' extending from the northeast to the sourthwest, and the block

movement by the faults trending in E-W and NE-SW direction.

As to the mineralization in this area, the Erdouz North ore deposit (Cu, Pb, Zn) is found on the northern slope while the Erdouz South ore deposit (Cu, Pb, Zn) is recognized on the southern slope. The former is distributed in the limestone showing complicated folding structure along the axis of the anticline. Five ore veins are known in the mineralized area roughly of 100 m x 100 m. The latter is also recognized in the tightly folded limestone of the trend of north and south. The mineralized area is thought to be 150 m x 200 m and the ore deposits of vein type and stratiform type are known.

Both of the Erdouz North and the Erdouz South ore deposits are distributed along the Erdouz fault of the NE-SW trend, accompanying porphyrite dykes.

By the results of the geochemical survey, the intense anomalies of each of the elements of Cu, Pb and Zn are correspondent to the mineralized areas, where the form of the anomalies are suggesting the extension of the ore veins.

As the favorable area for the emplacement of the ore deposits, the depth of the areas around the Erdouz North ore deposits and around the Erdouz South ore deposits are recommended.

3) Azegour Sector : The area is geologically underlain mainly by the metamorphic rocks of the Paleozoic Cambrian system and by the granite and the porphyrite intruding the metamorphic rocks. The geological structure in this area is characterized by the monoclinic structure of N-S trend, dipping 40° ∿ 70° to the east, by the existence of the granite, which forms a massive body in the western area and dykes in the eastern area, by the

lateral dislocation of the strata by the fault trending in ENE-WSW direction and by the intrusion of the porphyrite dykes in the same direction as the above fault.

The mineralization is represented by the skarn type ore deposits of copper, molybdenum and tungsten in the Azegour mine and by the disseminated ore deposits of molybdenum in the skarn zone which is distributed along the limestone bed of the width of 80 meters extending northward from the Azegour mine. The Azegour mine has produced approximately 900,000 tons of ores of the grades of Cu : 1.4 ∿ 2.8 %, MoS_2 : 0.2 ∿ 0.7 % and WO_3 : 0.35 %. The area developed is 150 m x 1,300 m and its depth is approximately 200 meters.

The ore deposit is massive form, the major axis of which is 20 ∿ 50 meters, while the minor axis of it is 5 ∿ 20 meters. The ore deposit is found located in the skarn mass mainly of garnet. It has been recognized that the skarnization is more intense in the deeper part.

The molybdenum ore deposits in the northern area of the Azegour mine are recognized up to near Entifa which is located about 4 km north of the mine. The ore deposits are distributed in the narrow skarn zone of the width of 30 cm ∿ 1 meter extending along the hanging and the foot walls of the limestone as well as along its boundaries with other rocks. The indication of mineralization on the surface is recognized as wide as 10 to 60 cm, extending over 10 meters, with the grade of MoS_2 : 0.13 %. On the level at the depth of 200 meters, the mineralization zone extends 15 ∿ 35 meters with the grade of 0.26 ∿ 0.56 %. It has been confirmed that the mineralization is more intense in the

deeper part, as is the case of the skarnization.

By the results of the geochemical survey, the distribution of high anomalies of Mo is reflecting the mineralization remarkably. The anomalies of Cu are concentrated along the northern side of the fault of ENE-WSW trend. As the favorable area for the emplacement of the ore deposits, the subsurface in the area between Azegour and Entifa is recommended.

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INTRODUCTION

CHAPTER 1 CIRCUMSTANCES AND PURPOSE OF THE SURVEY

1-1 Circumstances of the Survey

The Kingdom of Morocco is rich in mineral resources. Especially the ore reserves of the phosphorous ores are the greatest in the world and the production of the phosphorous ores is ranked to be the third in the world. As for the other mineral resources, they have abundant and various ore deposits. And there is a long history of the development of mineral resources.

The activities of the development of mineral resources in this country have been executed by the Bureau de Recherches et de Participation Minieres (B.R.P.M), which was established in 1928. The activities are quite positively proceeded.

As the cooperative investigations for the development of mineral resources between the Morocco and the Japan, there have been two investigations; the one is the Basic Cooperative Investigation for the Development of the Mineral Resources in the Anti Atlas Area carried out for three years between April, 1975 and April, 1977, and the other is the investigation of the same category in the Haute Moulouya area carried out for three years from September, 1978 to February, 1981.

After these investigations, cooperative surveys in several new projects were requested by the government of the Kingdom of Morocco. Upon the request, the delegation for preliminary investigation and negotiation of the agreement was despatched in May, 1983, and the execution of the surveys in the Haut Atlas Occidental area was agreed.

1-2 Purpose of the Survey

The present investigation is programmed to be carried out with the cooperation of the Bureau de Recherches et de Participation Minieres (B.R.P.M) of the Kingdom of Morocco, in the Haut Atlas Occidental area of 2,200 km^2, in the period of three years starting in 1983. The purpose of the investigation is to comprehend the conditions of the emplacement of mineral deposits by precise elucidation of geology in the subject area through executing various methods of surveys.

In this year, as the first phase of the program, geological survey and geochemical survey were carried out in an approximate area of 1,100 km^2 of the northern part of the subject area, the purpose of which was to extract favorable areas for the emplacement of ore deposits, by the synthesized consideration on the relation between the geological structure and the mineralization as well as the geochemical characteristics in the subject area.

In the Erdouz sector, the purpose of the surveys was to elucidate the relation between the geological structure and the mineralization through clarifying the distribution of the granodiorite and the limestone in which lead-zinc vein type and contact replacement type ore deposits are emplaced. Also, in the Azegour sector, the purpose of the surveys was to give consideration on the regularity of the formation of ore shoots, by clarifying the distribution of the granite and the limestone in which contact replacement type ore deposists of copper, molybdenum and tungsten, as well as by elucidating the relation between the geological structure and the mineralization.

CHAPTER 2 OUTLINE OF THE SURVEYS

2-1 Outline of the Surveyed Area

The subject surveyed area is located in the central western part of the Kingdom of Morocco. It is in the western part of the Haut Atlas range topographically, which runs across the central part of the Morocco in east and west. The subject area is in rectangular form of 50 km in east and west and of 44 km in north and south, between 30°50'26" and 31°14'14" of the north latitude and between 8°00' and 8°31'23" of the west longitude. The area is approximately 2,200 km². It is in the Amezmiz county in the state of Marrakech, by the administrative division (Refer to Fig.1).

As there is a sealed road from Rabat, the capital of the Kingdom of Morocco, to Amezmiz, the principal township in this district, the access is quite easy (the distance is 410 km, taking about 5 hours by vehicle). From Amezmiz to the villages in the surveyed area, there is no other way than on foot or on horsebacks except for some roads along the main rivers which are accessible by vehicles.

The surveyed area is mainly composed of the mountaneous land at the altitudes of more than 1,000 meters above sea level. In the central part of the subject area, there is a watershed of the Haut Atlas range in the direction of east and west at the altitudes of over 3,000 meters above sea level, in the north of which the rivers are flowing northward while, in the south, the rivers are streaming southward. These rivers have dissected the mountaneous land deeply and deep gorges have been formed.

Therefore, the land features are quite steep. The highest summit in this area is the main summit in Erdouz, the elevation of which is 3,579 meters above sea level. As the main rivers, Nfis river is in the eastern part, Amezmiz river is in the center part and Assif Al Mal river is in the western part.

To the south of the subject area, there is Sahara desert, and they have hot arid climate with the temperature of more than 40°C in summer time from July to September. On the contrary, there is snowfall in winter between November and March. The difference of temperature is extreme in this area. Therefore, the vegetation is recognized only in the lowland and along the rivers, and uncovered rocks are exposed in most of the highland.

The inhabitants in this area are mainly of Berber tribe. They speak Berber usually, and it is almost impossible to communicate with them in Arabic, which is the official language in the Kingdom of Morocco.

These inhabitants are residing in small villages scattering along the main rivers due to the steep topographic features and the severe climate, and are living on the stock farming of sheep and goats. They are gentle and diligent generally, and working power is abundant. However, as there are almost no industries in this area, there are many who have gone to other big towns.

2-2 Contents and Methods of the Surveys

The contents of the surveys carried out in the present phase are as follows; The geological reconnaissance survey in the North Area in the northern half of the subject survey area

(of the area of 1,100 km², the Erdour Sector and the Azegour Sector are excluded); The geochemical survey by collecting samples of stream sediments in the same area of the geological reconnaissance survey; The semi-detailed geological surveys in the Erdouz Sector (area is approximately 20 km²); The geochemical survey by soil sampling in the same area; The detailed geological surveys in the Azegour Sector (area is approximately 7.5 km²) and the geochemical survey by rock sampling.

The field surveys were carried out in the term of 90 days from July 17, 1983 to October 14, 1983, with the cooperation of B.R.P.M of the Kingdom of Morocco. Each of four Japanese engineers organized a crew with a native assistant and labourers, hence four crews were composed. Four wheel drive vehicles or horses were utilized for the transportation of men and gears from the camp to the surveyed area. The main camp station for the survey was established at lodging house of an old mine in Azegour village, which is situated in the central part of the North Area. Tentative camps were established according to the change of the actual subject area of the surveys to acceralate the efficiency of the surveys; at the Wirgane village in the eastern part, at the Tawrirt village in the southern part and at the Adassil village in the western part. The survey routes, the precision of the surveys and the sampling points of the geochemical surveys were determined as follows according to the necessities of the respective areas.

(1) The North Area: The survey routes were established with the approximate interval of 5 km in whole of the area. Especially in such areas as having informations that the indications of

mineralization would exist, the survey routes were more densely established. Geological survey was carried out by mapping along these survey routes.

As the fundamental topographical map for the field survey, the topographical map of the scale of 1 to 25,000 was used, which had been enlarged from the map of the scale of 1 to 50,000, published in 1978 by the Ministry of Argiculture of the Kingdom of Morocco. All the survey data were described in good order in the route maps of the scale of 1 to 25,000, and based on these route maps, the geological map of the scale of 1 to 50,000 was drawn up. In the unmapped area, the geological map was prepared by refering to the analysis results of the airphotographs of the area.

In parallel with the geological survey, stream sediments were collected at the upstream sides and at the downstream side of the confluences of rivers, for the geochemical exploration (elements for analysis: Cu, Pb, Zn, Mo and W), to extract possible zones indicated by mineralization in the surveyed area.

(2) Erdouz Sector: In this area, the survey routes were established along the existing roads, along the main rivers and along the ridges so that the interval of the survey routes might have been 300 to 500 meters, and the geological survey was carried out by mapping along these survey routes.

For the field survey, the topographical map of the scale of 1 to 5,000 was prepared by the land survey with transit compasses (Ushikata made) and esron tapes, and using this map as the route maps, geological data and observation results of the mineral indications were described. Upon the basis of these

route maps, the geological map of the scale of 1 to 10,000 was drawn up. In and around the area where the Erdouz North ore deposit and the Erdouz South ore deposit are distributed, which was clarified through the geological survey, survey lines of the interval of 50 to 200 meters were established and precise mapping was completed for the conditions of the emplacement of mineral deposits.

For the consideration on the continuity of the mineralization around the area where mineral indications are distributed, geochemical survey (analysis elements are Cu, Pb and Zn) was carried out by collecting samples of soil at the points of every 25 meters along the above survey lines. Outside of the mineralized area, soil samples were collected at the points approximately every 500 meters along the survey routes.

(3) Azegour Sector: There is a skarn type ore deposit replacing limestone in the southern part of this area. According to the records, more than 900,000 tons of copper, molybdenum and tungsten ores were produced from the deposit.

In this area, in order to clarify the locations of the ore shoots and the continuity of the mineralization in the extension of the limestone bed, survey routes of the intervals of 300 to 500 meters in right angle to the strike of the limestone bed were established in addition to the survey routes along the several skarnized zones including the mineralized portions in the north of the mined out area. Geological survey was carried out along these survey routes.

For the field survey, the topographical maps of the scale of 1 to 1,000 were prepared by the land survey with transit

compasses and esron tapes, and using these maps as the route maps, geological data and observation results were described on them. The survey results were made use of as the base for the geological map of the scale of 1 to 2,000.

In parallel with the geological survey, the geochemical survey (analysis elements are Cu, Pb, Zn, Fe, W, Mo) was carried out by collecting rock chip samples mainly at the points every 25 meters along the strikes of the skarnized zone, where indications of mineralization are included, and the results were employed for the consideration on the relation between the ore shoots and the geological structure.

Throughout the surveys in the respective areas, attention was paid to the following items in the geological observations; as to the igneous rocks, grain size, texture, component minerals, color and boundaries with other rocks are noted; as to the sedimentary rocks, grain size, main components, color, strike, dip, metamorphic minerals are noted; concerning both of the igneous rocks and the sedimentary rocks, existence, forms and sizes of joint, fissure, fault are noted; the significant outcrops of the mineralization were precisely mapped.

As for the rocks of the representative species and lithofacies as well as the particular rocks, samples were collected and were supplied to the examination by microscopic observation and X-ray diffraction. Also, samples were collected at the outcrops of the mineralization to supply to the mineral determination by polished section and to the chemical analysis, for the interpretation of geology and mineralization.

The principal contents and the amount of the surveys are

shown as follows.

[Field works]

Subject area	Amount of survey		Number of samples for Geochemical survey	
	Area(km2)	Route length(km)	Survey Team	B.R.P.M.
North Area	1,072.5	467.7	460	
Erdouz Sector	20.0	63.2	126	103
Azegour Sector	7.5	33.6	206	38
(Total)	(1,100.0)	(564.5)		

[Laboratory works]

Items	Survey Team	B.R.P.M.
Rock determination		
by thin section	23	
Ore mineral identification		
by polished section	20	
X-ray diffraction	21	
Rock chemical analysis	10	
Ore chemical analysis (Cu, W, Mo)	31	3
Ore chemical analysis (Cu, Pb, Zn, Ag)	31	21
Geochemical samples analysed		
rocks (Cu, Pb, Zn, Fe, Mo, W)	206	38
soils (Cu, Pb, Zn)	126	103
stream sediments (Cu, Pb, Zn, Mo, W)	460	

2-3 Member of the Survey Team

Survey programming and Negotiation, Japan side

Suzuki	Haruo	JICA
Sawaya	Shozo	MMAJ
Baba	Yozo	MMAJ
Hida	Kazuhiko	MMAJ
Takedomi	Yoshikazu	MITI

Survey programming and Negotiation, Morocco side

Mohamed	Chahid	B.R.P.M.
Ahmed	Louali	B.R.P.M.
Bachir	Barodi	B.R.P.M.

Member of the Survey Team, Japan side

Esawa	Tadaaki	coordinator	JICA
Baba	Yozo	"	MMAJ
Hida	Kazuhiko	"	MMAJ
Wakabayashi	Kensuke	Leader	MINDECO
Nagumo	Yoshihiro	Member(geology)	MINDECO
Shibata	Kiyohisa	"	MINDECO
Otsubo	Ryohei	"	MINDECO

Member of the Survey Team, Morocco side

Abderrahim	Chbihi	B.R.P.M.
M'hamed	Annich	B.R.P.M.
Abderrahim	Qalbi	B.R.P.M.
Matsutoya	Shigeru	B.R.P.M.

JICA : Japan International Cooperation Agency

MMAJ : Metal Mining Agency of Japan

MITI : Ministry of International Trade and Industry

B.R.P.M. : Bureau de Recherches et de Participation Minieres

MINDECO : Mitsui Mineral Development Engineering Co., Ltd.

CHAPTER 3 PAST INVESTIGATION AND STUDIES

In the surveyed area, there is no mine producing crude ores in large scale, except for the barite ore veins and the marble deposits which are worked in a small scale by private enterprises. However, because such mines as the Azegour mine (Cu, W, Mo), the Erdouz mine (Ag, Pb, Zn) and Assif Al Mal mine (Cu, Pb, Zn) were worked prosperously up to 1950's many records and reports of the investigations concerning these mines are left.

Of these records and reports, those referred to in the present surveys are listed at the end of this chapter. Outline of the principal references is stated hereunder.

(Geological Structure) The whole area of the Kingdom of Morocco is comparatively well surveyed. Especially the studies by G. Choubert and A. Faure-Muret, which were carried out for a long period, are important as the fundamental information by investigation over whole of the country including the present surveyed area. The results of the studies have been published as the geological map of the scale of 1 to 500,000 in 1954. There is another intensive publishment of the past literatures and reports, which is called 'Element de Geologie, Morocaine (A. Michard)', published in 1976.

As for the detailed geology in the Haut Atlas Occidental area, nothing like synthesized articles or literatures have been published yet, although there are some reports to give fragmentary knowledge about it.

By the records and reports above-stated, the rocks which

are composing this area are igneous rocks and sedimentary rocks belonging to the period from the Infra-Cambrian to the Oligocene. It is thought that they have been formed, in the course of the history, through the intense folding movement and the intrusion of plutonic rocks at the end of the Paleozoic Era, followed by the peneplanation and the sedimentation of the younger layers in the Mesozoic to Tertiary periods and by the faulting and the blocking activities during the Alpine orogenic movement.

(Ore deposits) There are many reports and studies, by B.R.P.M. and others, about the ore deposits and the mineral indications in the surveyed area. However, no recent survey reports are available as the most of the principal ore deposits were stopped working in 1950's. On the Erdouz ore deposit, there is a report (B.R.P.M.) by L. Clariond (1954), which states that this deposit is vein-type lead-zinc ore deposit emplaced in the Paleozoic Cambrian limestone and phyllite, and that 2,500 tons of lead and 1,500 tons of zinc were produced between 1927 and 1950. On the Azegour ore deposit, there is a report (Service Geologique du Moroc) by F. Permingeat et al. (1957), which describes the geology and the ore deposits in this area. According to this report, the Azegour ore deposit is massive replacement deposit of copper, molybdenum and tungsten, after Paleozoic Cambrian limestone. In the period between 1930 and 1956, about 900,000 tons of crude ores were produced from this ore deposit, with the grade of MoS_2: 0.2 ∿ 0.7%, Cu: 1.4 ∿ 2.8% and WO_3: 0.35% ±. On the Assif Al Mal mine, there is a report by W. Chazan (1957). The ore deposit is vein-type copper-lead-zinc ore deposit contained in

the Paleozoic Cambrian black phyllite. It seems that exploration and underground mining were carried out for some period after 1948, but no information on the production of ores is available.

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PARTICULARS

(GEOLOGICAL SURVEY, GEOCHEMICAL SURVEY)

CHAPTER 1 OUTLINE OF THE REGIONAL GEOLOGY

1-1 Tectonic Provinces of Morocco and their Characteristics

Most of the African continent has been composed of stable cratons after the Pan African orogenic movement in the period of the late Pre-Cambrian to early Paleozoic Era.(600 ± 200 m.y.). No intense orogenic movement has been recognized since then. However, the zone along the north-western side of the West African craton, including Moroccan area, has been an exception, and has been left as a mobile belt. Geosynclinal activities and orogenic movement occurred in this zone after Paleozoic Era.

The geosynclinal activities and the orogenic movements in Morocco area are recognized to have been developed step by step as a whole, northward from the southern part of the country, which is close to the Pre-Cambrian craton, to the side of the Mediterranean Sea in the north. By the difference of the characteristics of the lithology and the geological structure accompanied by the above activities and movements, the Moroccan terrain has been divided into three zones geologically; the Anti Atlas zone in the south, the Atlas zone in the central part and the Rif zone in the northern part (Refer to Fig.2).

The Anti Atlas zone occupies the area south of the Accident Sud Atlasien, which is confining the southern limit of the Atlas mountain range. This zone has been cratonized since the Hercynian Orogeny in the period of the late Paleozoic to early Mesozoic Era, and is composed mainly of the Paleozoic sediments accumulat-

ed in the shield area which was developed along the northern margin of the stable Pre-Cambrian shield. This Anti Atlas zone is characterized by the comparatively gentle rises of the Pre-Cambrian systems. At present, it is recognized that sedimentary rocks including volcanic products, which are belonging mainly to the lower part of the Paleozoic group such as Infra-Cambrian and Cambrian systems, are widely developed around the core of the Pre-Cambrian systems exposed in the central part of the Pre-Cambrian rise.

The Atlas zone is located in the north of the Anti Atlas zone and occupies the Haut Atlas range, the Moyen Atlas range and the Meseta developed in both sides of the Moyen Atlas. The Atlas zone composes the Mesozoic geosynclinal zone developed on the basis of the thick Paleozoic sedimentary rocks accumulated in and toward the subsided zone in the north of the above-stated Anti Atlas zone. At the period of the Tertiary Alpine orogenic movement this zone was uplifted to form a part of the continent. As for geology and geological structure, there are remarkable differences between the mountain range and the Meseta. In the area of the mountain range, continuous sedimentation is recognized throughout the Mesozoic Era, as this area is supposed to have been correspondent to the central zone of the sedimentary basin in the Mesozoic geosyncline. In the Meseta areas, on the contrary, the sedimentation was intermittent and not dominant, leaving wide range of exposures of the basement rocks. These basement rocks were heavily mobilized at the period of the Hercynian orogenic movement, which is quite different from the case of the Anti Atlas zone. They have been folded,

metamorphosed and intruded by granitic rocks. Also, at the period of the Alpine orogenic movement, the central part of the geosyncline was uplifted to form quite a high mountain range reaching the altitude of more than 3,000 meters above sea level, while merely slight deformation is recognized to have been in the Meseta areas in the outer margin of the geosyncline.

The Rif zone is situated in the northernmost part of the Moroccan terrain, and composes Tertiary miogeosynclinal zone formed on the basis of the Paleozoic and Mesozoic sediments. There are many Nappe structures southward from the northern part, and it is thought that this zone is forming a part of the Alpine orogenic zone found running in the southern Europe. By the repetition of the overthrust movement from the north to the south in the period of the Alpine orogenic movement, this Rif zone would have formed arcuate folding mountain range along the Mediterranean Sea, where a great deal of faults are recognized to have been developed.

1-2 Outline of the Geology in Haut Atlas Area

The Haut Atlas area, where the subject surveyed area lies, occupies a part of the Atlas mountain range, which continues over 2,000 km in the direction of east-north-east along the northern coast of the African continent. The area forms the highest series of the peaks (3,000 ∿ 4,000 m) in the Atlas mountain range. Quite thick sequencies of the Paleozoic formations are distributed in this area. Several stratigraphical gaps are recognized in the formations, reflecting the orogenic movements in the Caledonian period. Also, in the Hercynian orogenic move-

ment, these Paleozoic formations were affected by the mobilization both in the Erzgebirge Phase (325 ∿ 320 Ma) and in the Asturian Phase (295 ∿ 290 Ma) in the Carboniferous period. In the Erzgebirge Phase, the folding of strata, the local metamorphism and the intrusion of granite are recognized to have occurred in the formations, while, in the Asturian Phase, the uppheaval of the basement and the intrusion of granite in the post orogenic period are recognized to have been.

With the peneplanation of the basement rocks in this area after the above movements, non-marine Triassic formations were accumulated, under the continental sedimentary environment, in the subsided zone in a form of graben. In the early Jurasic period, the northewestern part of the African continent was covered by the Tethys Sea, and marine sediments with abundant limestone layers were formed, but by the marine regression of this Tethys Sea, in the period after middle Jurassic, the sediments were formed under the continental or shallow water condition. It is thought that the structural movement which began in the late Jurassic to early Cretaceous period would have culminated in the late Oligocene Epoch, and that complicated structures would have been formed in the Miocene Epoch, by the overturned folds in addition to the overthrust faults. Also, it is thought that the upheaval of the Haut Atlas mountain range to such high altitude as is seen today has been proceeding since the Epoch of Pliocene.

Due to the repetition of the orogenic movement in various periods, the Haut Atlas area is composed of various igneous rocks and sedimentary rocks of the various ages from the Pre-

Cambrian to Tertiary period, and the area is characterized by the development of the intense folding structure and the faulting.

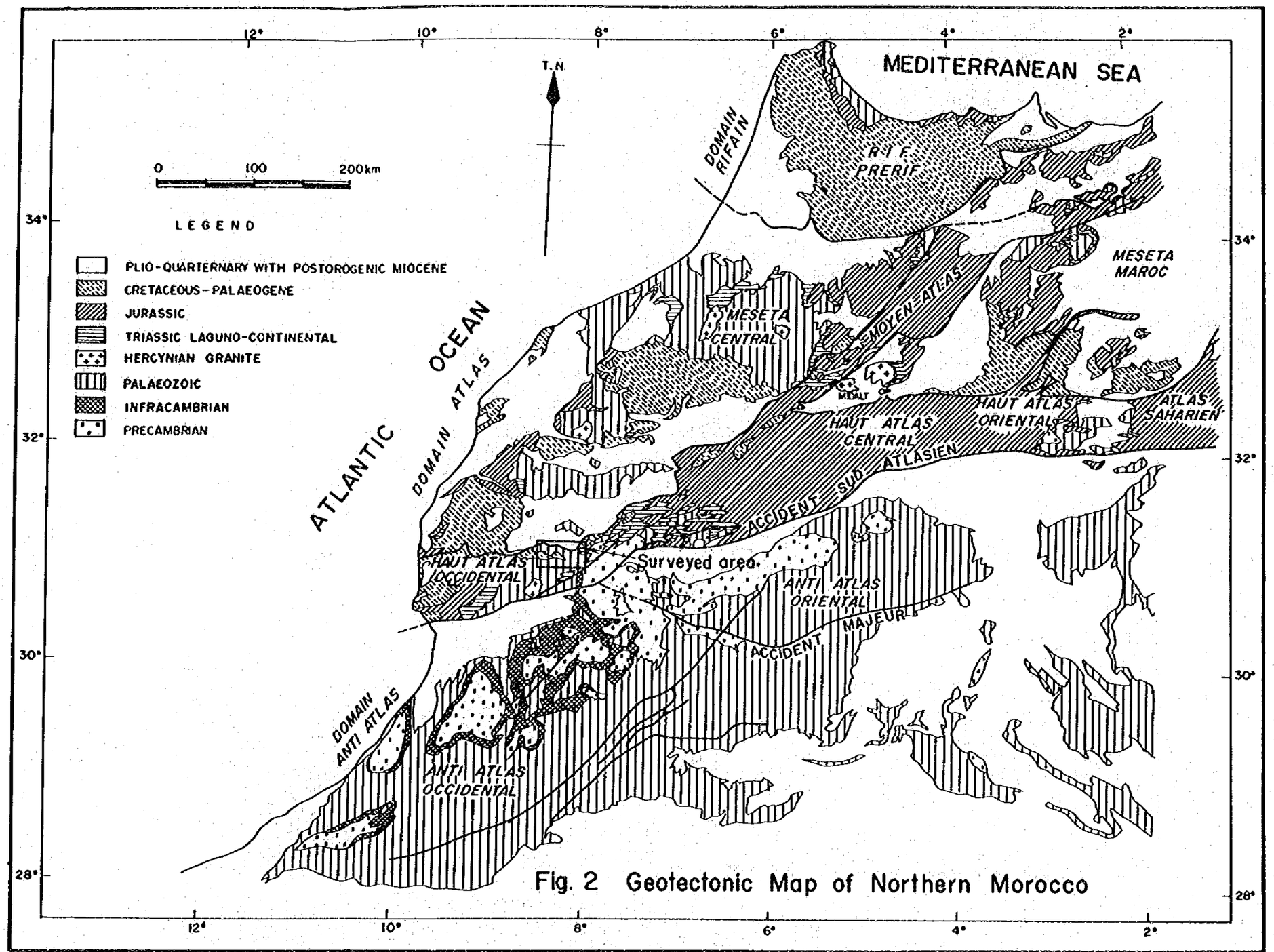

Fig. 2 Geotectonic Map of Northern Morocco

CHAPTER 2 GEOLOGICAL CHARACTERISTICS OF EACH AREA

2-1 North Area

2-1-1 Geology and Geological Structure

(1) Geology (Refer to PL. 1, PL. 2, Fig. 3)

The North Area is underlain, geologically, by the Pre-Cambrian group and the Paleozoic groups as well as by the Mesozoic group and the Cenozoic formations. The Pre-Cambrian group is distributed in the southeastern part of the surveyed area. The Paleozoic groups are thought to belong to the Cambrian to Ordovician systems, which have been metamorphosed to form various schists and are widely distributed occupying the greater part of the surveyed area. The Mesozoic group is composed of the Triassic system, the Jurassic system, and the Cretaceous system. Thye are distributed occupying topographical rises in the western half and in the central part of the surveyed area, and are distributed intermittently in east and west along the mountain foots in the northern margin. They are also found in small areas in the graben zone along the Nfis river in the eastern part of the surveyed area. The Cenozoic formations are composed of Eocene Series and alluvium deposit. They are found in a small scale covering the Mesozoic formations and along the rivers, although they are distributed in the plain in the northern part of the surveyed area and in the north beyond the northern limit of the surveyed area.

The lithology and the characteristics of the rocks in the respective systems are described in the followings.

1) Pre-Cambrian group

The Pre-Cambrian group is composed mainly of andesitic volcanic rocks, lava and pyroclastics, with the inserted layers of dolomitic limestone and thin alternation of quartzite, sandstone, conglomerate and limestone.

The andesitic lavas are dark green or greenish in color, massive and hard rock. Abundant prismatic crystals of the euhedral feldspar are contained in the rock, showing trachitic texture. The pyroclastic rocks are composed of andesitic tuff, lapilli tuff and tuff breccia, forming thick sequences of beds associated with the andesitic lava. The dolomitic limestone is brownish or light grey in color and inserted as thick layers in the above-stated pyroclastic rocks. The thickness of the dolomitic limestone is approximately 100 meters near the Tizgui village. The thin alternation of quartzite, sandstone, conglomerate and limestone is recognized at about 1 km east of the Tizgui village, where the thickness of the respective layers are 5 to 30 cm. They form thick sequence of alternation and are inserted in the above volcanic rocks.

The general trends of the strata are in the direction of NE-SW, dipping to the south. Gentle anticline is recognized around the Tizgui village. Generally, the precise thickness of the strata is not obvious because they are in blocks by the fault movements, but it is thought that the thickness is probably more than 2,000 meters. No fossils have been found in

Geological Age			Stratigraphic Column	Thickness (m)	Description			
Era	Period	Formation			Major Topics	SURVEYED AREA		
						Western	Central	Eastern
Cenozoic	Quaternary	Q			Alpine Orogeny	Unconsolidated terrace and river deposits		
	Tertiary						Alternation of limestone and calcareous sandstone	
		Es						
Mesozoic	Cretaceous	Ks		150		Grey-white ~ slightly pinkish formation limestone, sandstone, siltstone		
		Kd		200		Grey-white formation limestone-dolomite, sandstone, siltstone		
		Kr		200		Reddish formation limestone, sandstone, siltstone ammonite bearing		
	Jurassic	Js		50		Grey-white ~ slightly pinkish limestone, conglomerate, sandstone siltstone, gypsum bed		
	Trias	Tb		200				Dark green basalt flow
		Tr		150 ~ 350				pinkish sandstone, halite bed, conglomerate
Palaeozoic	Ordovician ~ Cambrian			10,000+	mineralization granitic intrusive Hercynian Orogeny	Black shale predominates in the northern part whereas shale, volcanics, and calcareous sediments appear in the southern part.	Calcareous rock predominates with a minor amount of green volcanic rock, black shale and sandstone.	Black shale predominates with intercalation of limestone, green volcanic rock, and sandstone.
Precambrian				2,000+				Volcanic rock and pyroclastics with intercalation of dolomitic limestone, thin layered alternation of chert, sandstone, conglomerate and limestone.

Fig. 3 Schematic Geological Column of Surveyed Area

these beds, but viewing from the lithofacies they are thought to belong to the upper part of the Pre-Cambrian group. As the geological environment for the sedimentation of these beds, the shallow sea is thought to have been with the extensive volcanic activities.

2) Paleozoic group

The Paleozoic group has been metamorphosed by the regional metamorphism after sedimentation and every rock belonging to this group has been changed to metamorphic rock. In the present geological survey, these metamorphic rocks were divided, by the estimation of the original rocks, into psammitic schist, pelitic schist, limestone and green schist. These metamorphic rocks, leaving original textures as they had shown, are distributed zonally. It is thought that they would reflect the thickness, the stratigraphy and the geological structures of the original rocks.

The psammitic schist is thought to have been originated from sandstone. It is medium to fine grained hard rock, with the remain of granular texture, and light green or light yellow in color. The pelitic schist is dark-colored phyllitic rock, with remarkable schistosity. The original rocks are thought to have been shale or siltsone. The limestone is in various color as white, dark or dark grey. It is crystalline limestone, with the thickness of several meters to several ten meters, and well traced stratigraphically. The bedding planes formed at the period of the sedimentation are comparatively well preserved and microfolds are observed. In some cases, the limestone and

the pelitic schist are recognized to form alternation. On the surface, calcareous portions have been eroded out and peculiar rugged features with violent irregularity are seen in this limestone area, where the thickness of the exposed limestones varies from several meters to several ten meters. In the present report, this rock is distinguished and named to be calcareous schist. The green schist is light green to dark green. Sometimes it is hard compact but in other cases it is coarse grained and rough features. Conglomeratic green schist is also found in some case. It is thought that the original rocks of the green shist would have been andesitic or dacitic volcanic rocks.

The Paleozoic formations in the surveyed area are divided into blocks by the several faults of the trends of E-W or NE-SW, and are distributed in the eastern part, in the central western part, in the northwestern part and in the southwestern part of the surveyed area. Differences of the lithofacies of the composing rocks and the geological structures are recognized among the blocks. The characteristics in the respective parts are described in the following.

a) Eastern part: This area occupies the east of the Amezmiz river. Most of this area is underlain by black phyllitic pelitic schist, with several inserted layers of the arenaceous schist. Generally poor in limestone, and no limestone has been recognized except at a point 6 km east of Wirgane. The general trend of the schists is NE-SW and many synclines and anticlines with the axes of the same trend are recognized with the intervals of minimum 0.5 km to maximum 7.5 km. Therefore, the true thickness of the pelitic schist is thought to be approximately

3,000 meters, although the schist is distributed extensively. The upper limit of the schist is not obvious but the lowermost part is thought to be continuous to the formation in which limestone is predominant in the central western part of the surveyed area. The schist is in contact with Pre-Cambrian group bounded by faults in the southeastern part of this area.

b) Central western part: This area occupies the area west of the Amezmiz river, including the Azegour mine and the Erdouz mine. In this area, limestone is predominantly developed in the direction of north and south. By the Mesozoic formations distributed in the central part in the direction of east and west, the geology is divided into two blocks of the northern side and the southern side.

The northern side, where the Azegour mine is distributed, is composed of alternatively distributed limestone, pelitic schist and green schist. Parts of these rocks have been metamorphosed to spotted schist and gneissose rocks by the thermal metamorphism associated with the intrusion of the granites. The limestones are partly replaced and skarnized zones have been formed, in which mineralizations of copper, molybdenum and tungsten are recognized.

The trend of the beds is north and south, with the steep dip to the east or to the west. There are anticlinal and synclinal structures parallelly running in the direction of north and south. The axes of these foldings are plunging to the north with a dip as gentle as about 20°. It is thought that the formation in which the limestones are predominant has its own approximate thickness of 1,800 meters.

The southern side, where the Erdouz mine is distributed, is composed of limestone, calcareous schist, psammitic schist and green schist, which are well stratified. Separated from the northern side by the faults and by the Mesozoic formations, it is difficult to correlate in detail the geology in this side to that in the northern side, but from the viewpoint that the limestones are predominant in both sides and that the rocks composing the southern side are similar to those in the northern side, the formations distributed in the southern side are mostly of the same horizon as those found in the northern side. In the limestone in this area, Archeocyathus (fauna similar to calcareous algae, coral etc.) has been discovered (L. Moler: 1931) and the formations in this area have been regarded to be Cambrian.

The general trend of the beddings is in the direction of NE-SW. Around the Erdouz mine, an anticline in the direction of NE-SW has been recognized. In the area west of this anticline, green schist with the insertions of thin layers of pelitic schist and limestone is widely distributed with the dip to the west, while in the area east of the anticline the green schist and the pelitic schist are found dipping to the east, which is thought to be situated stratigraphically in the upper horizon than the formation in which the limestones are predominant. It is thought that the lower horizon than the formation in which the limestones are predominant is the psammitic schist and the pelitic schist. The total thickness of the formations distributed in this part of the surveyed area is estimated to be approximately 3,000 meters. The lower limit of the formations is

uncertain, but the uppermost part of the formations is thought to be continuous to the thick pelitic schist in the eastern part.

c) Northwestern part: This area is located in the downstream area of the Assif Al Mal river which runs in the western part of the surveyed area. This area is further divided, by the faults, into the northestern block, the northwestern block and the southern block.

In the northeastern block, black pelitic schist is predominant with the inserted layers of psammitic schist in the middle part of the sequence. The general trend of the beddings is in NE-SW direction with the gentle dip to the northeast in the southwestern part (lower horizon side), while in the northeastern part (upper horizon side) the general trend of the beddings varies gradually to the direction of north and south forming synclines and anticlines. This formation is thought to be of the lower horizon continuously underlying the formation in which the limestones are predominant. The thickness is approximately 3,500 meters.

The northwestern block is composed merely of the pelitic schist. The trend of the beddings is in NE-SW direction and synclines and anticlines are repeated. The thickness of this pelitic schist is under 2,500 meters.

The southern block is composed of green schist, psammitic schist and the pelitic schist. The general trend of the beddings is in the direction of north and south. An anticline with the axis in the same direction is recognized in the green schist area in the western part. Most of this block is composed of the

pelitic schist and the psammitic schist which are occupying the eastern wing of the anticline. The thickness of the formation in this part is thought to be approximately 2,500 meters.

d) Southwestern part: This area occupies the upstream area of the Assif Al Mal river in the south of the Adassil village. This part is underlain mainly by the pelitic schist and the green schist with insertions of thin layers of psammitic schist and limestone. The general trend of the beddings is in NE-SW direction with the dip to southeast. Therefore, the upper horizon is found toward the east. By the syncline axis estimated in the green schist in the easternmost part, reversed relation of the bedding is expected and it is thought that the main part of the formations distributed in this area has possibility to compose contemporaneous heterotopic facies of the formations found around the Erdouz mine. The thickness of the formations is more than 3,000 meters.

3) Mesozoic group

The Mesozoic group is composed of the Triassic to Cretaceous formations. The Triassic system is distributed around the Wirgane village in the northeastern part of the surveyed area and around the Imigdal village in the middlestream area of the Nfis river. The Cretaceous system is distributed rather extensively stretching east to west direction from the middlestream area of the Amezmiz river in the central part of the surveyed area to the middlestream area of the Assif Al Mal river. The Cretaceous system is also distributed in small areas on the topographical rises in the eastern area as well as along the mountain

foot along the northern marginal zone. The Jurassic system is distributed in the western area, underlying the Cretaceous system.

a) Triassic system: The triassic system around the Wirgane village is composed of the alternation of sandstone and shale in the lower part and the basaltic lava in the upper part. The alternation of sandstone and shale is reddish purple in color. It is easily weathered to form soft and weak soil, with the insertions of sandstone layers containing halite. The thickness is approximately 150 meters. The basaltic lava is greenish dark-colored, hard and compact rock accumulated in layers. The thickness is approximately 200 meters. This system overlies the Paleozoic formation with unconformity, and is overlain by the Cretaceous system disconformably. The trend of the bedding is in the direction of east and west to N65°E, with the dip of less than 15° to the north.

The Triassic system around the Imigdal village is distributed occupying the triangular graben delineated by the two faults of the NE-SW trend. The system is composed of the alternation of shale, sandstone and conglomerate, reddish brown in color as a whole. Shale beds and sandstone beds are well stratified and have been weathered to form soft rocks. The conglomerate bed is composed of subangular to subrounded pebbles of dolomite, quartzite with less amount of those of the pelitic schist and the psammitic schist. The conglomerate beds are generally as thick as 3 meters. The direction of the trend of the Triassic system in this area varies from N30°E with the dip of about 50° to the northwest to N85°E with the dip of about 70°

to the north. The thickness of this system is thought to be approximately 350 meters.

b) Cretaceous system: The Cretaceous system distributed in the area from the middle-stream of the Amezmiz river to the middle-stream of the Assif Al Mal river is bounded by the peneplain of the Paleozoic basement in the north and by the Medinat fault trending east and west in the south. In this area, the Cretaceous system is divided into the following three zones, upward from the lowermost.

(1) Red alternation of sandstone and shale containing gypsum: the thickness 200 m±.

The red color of this alternation fades out in the upper part. In the limestone, was found Ammonite (Douvelleiceratidae, Paraholiplites, Prochelonicerας or Aconthoplites: determination by Du Dressy; 1983). The alternation is correlated to the lower part of the Cretaceous system.

(2) Greyish white alternation of limestone, sandstone and shale: the thickness 200 m.

(3) Light carmine to greyish white alternation of sandstone and shale: the thickness 150 m.

The general trend of this system is almost in the direction of east and west, dipping as gently as 5° to 10° to the south.

There is a fault called the Amezmiz fault of the trend of east and west at the mountain foot in the northern part of the surveyed area. In the plain extending in north of the fault, the Cretaceous system is distributed intermittently. Strati-

graphical correlation has not been successful in this plain part, as the exposures are limited and the disturbances by the faults are remarkable. Lithologically it is possible to correlate each of them to certain parts of the above-stated Cretaceous system, respectively. It is noted that parts of the Cretaceous system are distributed in small areas occupying the topographical rises in the area where the Paleozoic formations are distributed in the eastern area.

c) Jurassic system: Jurassic system is composed of the greyish white alternation of sandstone and shale containing gypsum, which is underlying the Cretaceous formations in the western area. In the west of the subject area, the thickness of this system is greater gradually, and the system composes one of the significant geological units, but it does not compose important geological unit by any means in this area.

4) Cenozoic group

The Cenozoic group in this area comprises the Tertiary Eocene series and the Quaternary alluvium deposit. The Eocene series is composed mainly of limestone, sandstone and conglomerate. On the topographical high in the area where the Cretaceous system is distributed, the Eocene series is found to lie occupying small areas, conformably on the Cretaceous system. The Eocene series is also found in a narrow zone along the mountain foot in the south of the Amezmiz village.

The alluvium deposits are extensively distributed in the plain part in the northern marginal zone of the surveyed area. They are revealing gentle dip of less than 5° toward the plain

part from the mountaneous land. The alluvium deposits are composed of the gravels of various rocks derived from the hinterland.

5) Igneous rocks

The igneous rocks recognized in the North Area are those intruded in the Paleozoic formations in such forms as stock and dyke. They are overlain by the Mesozoic formations with unconformity. The igneous rocks recognized in this area are granite, dolerite, lamprophyre and so on.

The intrusive rocks in the form of stock are distributed in the following four areas. The characteristics of these rocks are as follows.

a) In the southwest of the Azegour ore deposit: The rocks are granite characteristically pinkish in color, bearing abundant silica and kali-feldspars. This granite is distributed in an area, extended in northwest and southeast, of 7.5 km x 1.0 km. It is called to be Azegour granite. Under microscope, holocrystalling graphic texture is revealed, composed of biotite, kali-feldspar, plagioclase and quartz with small amount of magnetite (Table 7-1, GR-19).

b) About 9 km southwest of the Azegour granite: This is coarse grained holocrystalline quartz diorite. The distribution is in an ovally shaped area, extending in northwest and southeast but limited in the northern side by Medinat fault. It forms a rock body of the area of 3 km x 1.5 km. Under microscope, hornblende, plagioclase, quartz are the main component minerals, but by the hydrothermal alternation, hornblende has

been replaced by the aggregate of actinolite, chlorite, epidote, biotite and sphene, while plagioclase has been saussuritized (Table 7-1, GK-21).

c) In the eastern part, around the fault on the left bank of the Nfis river: The rock is reddish but dark-colored holocrystalline quartz diorite. This rock is distributed in two areas along the fault running in the direction of NNE-SSW, the areas of which are respectively 6 km x 0.5 km and 2.5 km x 2 km. Under microscope, it has hypidiomorphic granular texture. The component minerals are biotite, plagioclase, quartz and fair amount of tourmaline (Table 7-1, GK-105).

d) In the southeastern part, near the Targa village: This rock is medium grained melanocratic dolerite, and is distributed in a half circle area of 1.5 km x 1 km. Along the contact margin with the pelitic rocks, chilled margin is characteristically recognized. Under microscope, although ophitic texture is still left, aggregates of fine minerals such as chlorite, calcite and albite are recognized to have been formed by the intense hydrothermal alteration (Table 7-1, GN-117).

The intrusive rocks in the form of dykes are generally as wide as less than 10 meters and their trends are in the direction of NNE-SSW or NE-SW. In some parts, several dykes are concentrated. The areas where these dykes are remarkably observed are; in the middle-stream to downstream area of the Amezmiz river where dykes of microgranite are found; in the area around the Erdouz mine and the Azegour mine where dykes of microgranite and porphyrite are recognized; around the Areg village where

dykes of microgranite and porphyrite are distributed (GR-60, GR-11, GR-59, GN-61).

The results of the whole rock chemical analysis and the norm calculation of the collected 10 samples of the intrusive igneous rocks are shown in the Table 6. Plotting the results in the Geotimes' triangle for the classification of granitic rocks (Fig.4) have shown that they are rich in alkali (K_2O + Na_2O) and that they are classified to be in the area of syenite-alkaline granite except two basic rocks of GN-117 and GR-45. This is in good harmony with the fact that most of the acidic intrusive rocks have reddish color.

(2) Geological structure

The characteristics of the geological structure in the North Area are summarized as follows.

1. Folding structures developed in the Pre-Cambrian Group and in the Paleozoic formations.
2. Faults dividing the Pre-Cambrian group and the Paleozoic formations into blocks.
3. Intrusion of the igneous rocks into the Paleozoic formations.
4. Formation of the peneplain of the Paleozoic formations, which were the basement for the sedimentation of the Mesozoic formations.
5. The sedimentary structure of the Mesozoic formations which is almost flat, in contrast to the Paleozoic formations remarkably folded.
6. Faults dislocating the flat sedimentary layers of the Mesozoic and the Cenozoid formations.

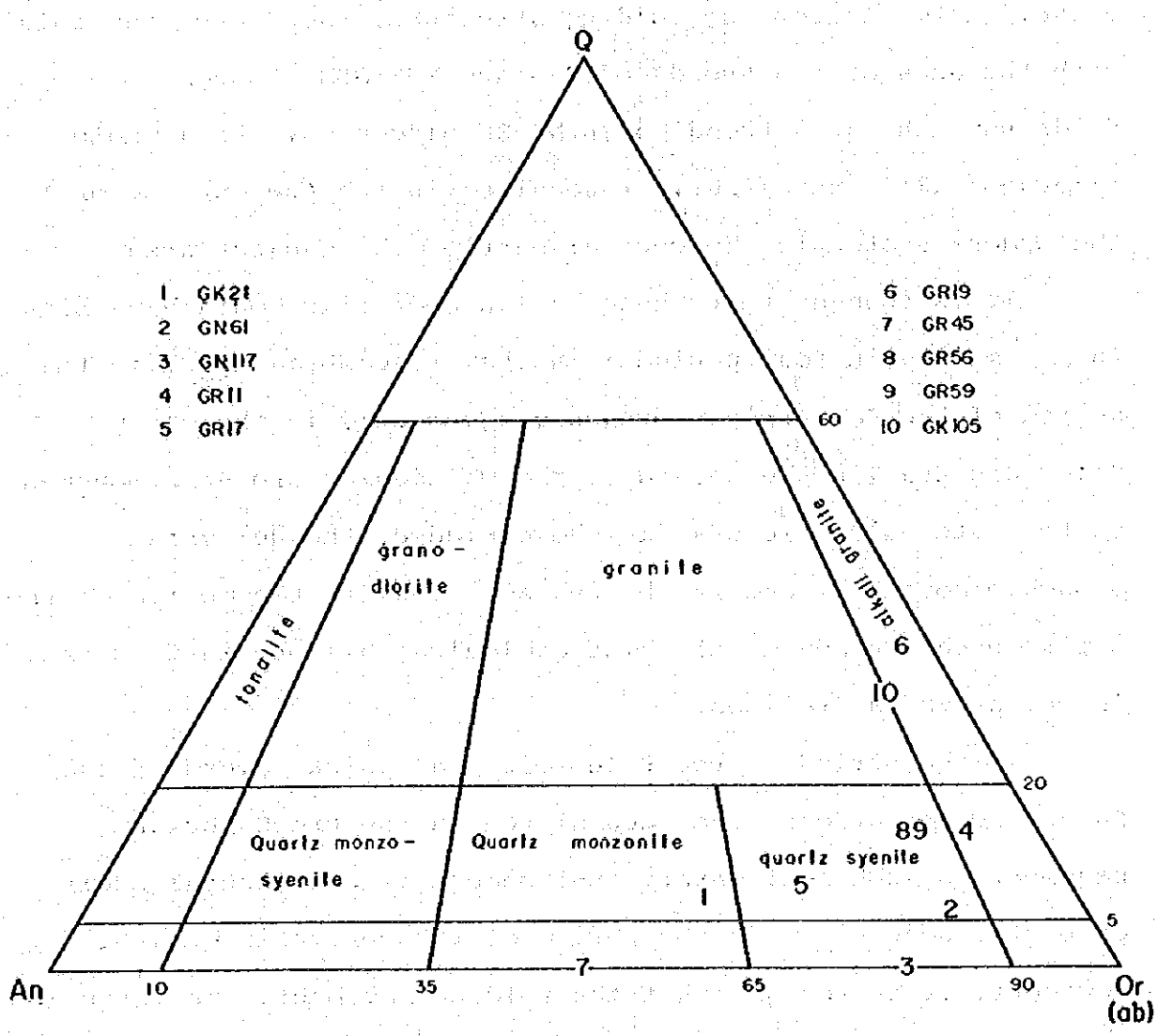

Fig. 4 Classification of Granitic Rocks (Geo Times, Oct. 1973)

The faults observed in this area are of the systems of E-W, NNE-SSW and NW-SE. The former two systems are the most predominant. As for the folding structure, there are many folds with the axes of the trends of N-S and NNE-SSW, though some folds have the axes trending in NW-SE direction. As a whole, a large scaled anticline is recognized in the Azegour sector ∿ the Erdouz sector in the central part of the subject area.

It is thought that these faults and folds would have been formed mainly in four periods; in the Pre-Cambrian age (in the period of the Pan African orogenic movement), in the early Paleozoic Era (in the period of the Caledonian orogenic movement), in the late Paleozoic Era (in the period of the Hercynian orogenic movement) and in the Cenozoic Era (in the period of the Alpine orogenic movement). The geological history in this area is summarized as follows.

In the period of the Paleozoic Era, thick layers of the Paleozoic formations were accumulated on the Pre-Cambrian basement in such sedimentary environment as continental shelf or partly deep sea. In the period of the Hercynian orogenic movement, it is thought that the folding movement, the intrusion of igneous rocks and the block movement by the fault activities would have occurred step by step. Especially, viewing from the fact that no mineralization has been recognized in the Mesozoic formations in this area, the ore deposits are thought to have been formed with the intrusion of the granitic rocks in the period of this Hercynian orogenic movement.

Before the sedimentation of the Mesozoic formations, the subject area had been uplifted to form land and the surface