No. 20

KINGDOM OF MOROCCO

REPORT ON GEOLOGICAL SURVEY OF THE HAUT ATLAS OCCIDENTAL AREA

(PHASE II)

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

MMPJ/N
86-64

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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 conduct a geological survey for mineral exploration in the Haute Atlas area of the Kingdom of Morocco, and commissioned its implementation to the Japan International Cooperation Agency.

The Agency, taking into consideration of the importance of technical nature of the survey work, in turn sought the Metal Mining Agency of Japan.

This year's survey was for the second phase survey, and as for this current year, a survey team was formed consisting of five (5) members, and sent to the Kingdom of Morocco. The team stayed there for seventy (70) days from August 5, 1984 to October 13, 1984 as the first period, and for forty-two (42) days from October 21, 1984 to December 1, 1984, as the second period. During the period of its stay, the team, in close collaboration with the Government of the Kingdom of Morocco, especially with Bureau de Recherches et de Participation Miniers, was able to complete survey works on schedule.

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

February, 1985

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

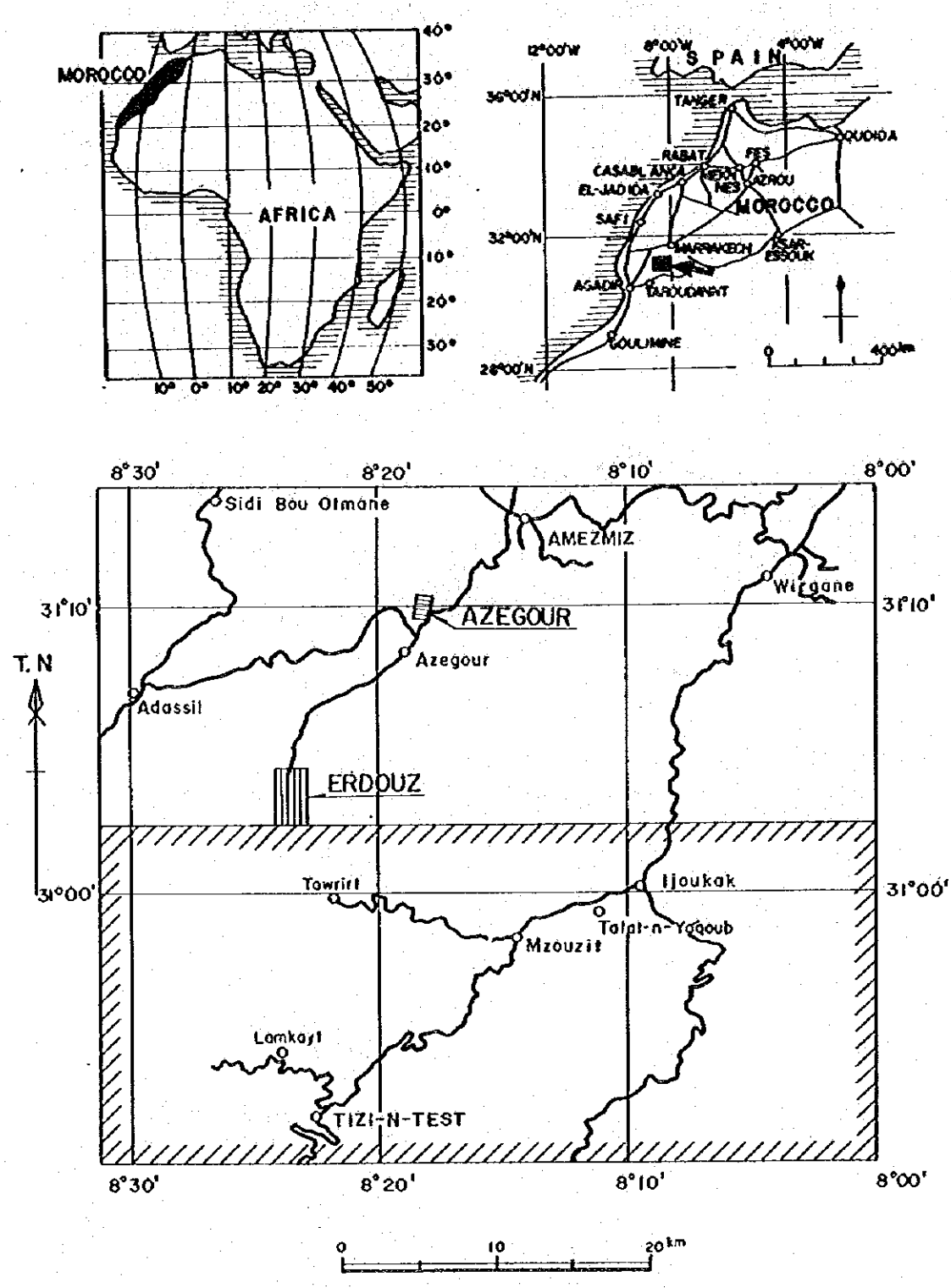

Fig. 1 Location Map of Surveyed Area

GENERAL CONTENTS

SUMMARY

Purpose of the second phase survey of the cooperative investigations for the development of mineral resources in the Haut Atlas Occidental Area of the Kingdom of Morocco was to extract highly favorable area for the emplacement of mineral resources in the southern area, and to elucide the continuity of vein-type lead and zinc deposits in Erdouz sector, and to clarify the continuity of skarn-type molybdenum ore deposit in the lower part underground in Azegour sector.

The contents of survey carried out in each area are as follows,

- o Southern Area: Geological reconnaissance survey; surveyed area 1,100 km^2, surveyed route 367 km. Geochemical survey (Stream Sediment); Number of collected samples = 698, Analysis elements = 5 of Cu, Pb, Zn, Mo, and W.
- o Erdouz Sector: Geochemical survey (Soil); Surveyed area 19.4 km^2, Number of collected samples = 412, Analysis elements = 3 of Cu, Pb, and Zn. Geophysical exploration (CSAMT Method); Surveyed area 5.0 km^2, Number of observation points 27
- o Azegour Sector: Geophysical exploration (SIP Method); 4.6 km (4 Traverse Lines), Number of observation points 144. Drilling operation; 4 Holes, 909.8 m (Carried out by B.R.P.M.)
- o Rock identification by thin section = 22 samples, Ore mineral identification by polished section = 21 samples, X-Ray diffraction = 21 samples, Whole rock chemical analysis = 11 samples, Ore chemical analysis = (Cu, Pb, Zn on 31 samples) (Cu, Pb, Zn, Ag on 39 samples)

Results of Survey

1) Southern Area: This area is overlain by the Pre-Cambrian Group, the Paleozoic Groups, and the Mesozoic Groups and intruded by the granites of Hercynian age. The Pre-Cambrian Group is the basement of this area, and the Paleozoic Groups are widely distributed almost all over the area.

The Paleozoic Group is classified into C I Formation (siltstone, dolomite, andesites; eastern area), C II Formation (pelitic schist, psammitic schist, limestone; central area), C III Formation (limestone, pelitic schist, psammitic schist, green schist; western area), and C IV formation (pelitic schist; northern part of central area) in ascending order. The geological structure of the Paleozoic Groups is characterized by the folded structure with the axis of NE-SW trend formed in the Hercynian orogenic movement, by the intrusion of igneous rocks such as the Tichika Granite, and by the block-faults movement of the trends in E-W and NE-SW. Furthermore, the Groups have a tendency to become stronger on metamorphism, and to develop on the folding in ascending order.

The mineralizations in this area is mainly represented by the vein-type ore deposits of copper, lead, zinc and barite, by the skarn-type ore deposits of copper, tungsten and iron, and by the stockwork disseminated ore deposit of copper. These ore deposits are distributed exclusively in the areas where the Pre-Mesozoic Formations are distributed. Although the skarn-type ore deposits are exclusively observed in the periphery of Tichika granite in the southwestern part of the area and the stockwork disseminated ore deposit in the northeastern part of the area respectively, the vein-type ore deposits are confirmed at 30 odds places all over the

area except in C IV formation.

According to the results of the geochemical survey by the stream sediment, it was revealed that Cu, Pb, and Zn indicated almost similar behaviors, and their strong anomalies are distributed in the area corresponding to the locations of the ore deposits and mineral identifications, in such as the northeastern, the southeastern, the northwestern, and southwestern parts. Anomalies of molybdenum were distributed in the southwestern part and central southern part of the area, and those of tungsten were exclusively distributed in the southwestern part of the area.

In the southern area, as the areas observed the strong mineralization strong mineralizations were observed and promised the favorable area for the emplacements of mineral resources, (1) Agadir Area in the southwestern part of the area (contains the skarn-type ore deposits of copper, tungsten and iron, and vein-type molybdenum ore deposit in granite), (2) Iguidi Area in the northeastern part of this area (dessiminated copper ore deposit), and (3) Taddart Area in the northwestern part of the area (vein type copper ore deposit) have been selected.

2) Erdouz Sector: Geology of this sector is entirely composed of the Paleozoic C III Formation (predominated by limestone), having the folded structure with the axis of NE-SW trend. This sector is characterized by the developments of block-faults of NE-SW and E-W trends. The mineralizations in this sector are the vein-type copper, lead and zinc ore deposits. The north ore deposit at the fold axis of limestone and the south ore deposit at the thightly folded portion of limestone were clarified by the survey carried out in the first phase.

According to the results of the geochemical survey by the soil samples in this phase, it was revealed that Cu, Pb, and Zn indicated almost similar behaviors and the anomalies of above element are concentrated in the north and in the south ore deposits. It has a tendency to indicate the strikes of the veins. However, the anomalies were found to correspond to the fold axis of the limestone in the circumference of the north deposit and to the distributions of limestone which were cut by faults near the south ore deposit, that is, they are coinside with the distribution of the host rock of ore deposits in this sector. Therefore, the long distinct continuity of anomalous values to connect between both of the ore deposits was not recognized.

According to the results of geophysical explorations applying CSAMT method carried out in the northern part, the area was classified into the three unit, the west side of Erdouz Fault of NE-SW trend (4 layers structure, indicated high resistivity), the east side of Erdouz Fault (3 layers structure, indicated moderate resistivity), and the circumference of the north ore deposit (2 layers structure, indicated low resistivity). Such differences of resistivities, especially between the east side and the west side of Erdouz Fault, might indicate difference of nature of constituent rocks caused by block movements of faults in this area. It is considered that characteristic low resistivity structure in the circumference of the north ore deposit should suggest the axis zone of folded structures and complicated folded structure zones of limestone, which is the host rock of the ore deposit, or the fault-aggregated zone rather than directly suggesting the mineralizations and alteration zones. It is not comfirmed that the low resistivity zone in the circumference of the north ore deposit, regarded as the changable layer into the host rock, has the indication of the continuity to the south ore deposit.

As the results of this phase surveys, no positive data indicating that the north ore deposit and the south ore deposit in Erdouz sector were connected each other has been obtained. It is, therefore, strongly possible that both of the deposits were formed by the independent mineralizations respectively. In this connection, it is desirable to carry out subjecting lower part of the both ore deposits in further exploration.

3) Azegour Sector: Geology of this area is composed of schist, interbeded limestone of 80 ∿ 50 meter thick, of the C M Formation and granite. Geological structure of this area is characterized by the monoclinic structure of N-S trend and dips 40° - 70° eastward, by the faults of ENE-WSW trend, the north-south trending dykes of granite. Mineralizations observed in this area are skarn-type copper, molybdenum, and tungsten ore deposits in the Azegour mine and skarn-type molybdenum ore deposit in the north of Azegour mine.

According to the results of geophysical exploration applying SIP Method carried out in the circumference of Tizgui village in the northern part of this area, it was revealed that resistivities on the limestone layers is shown lower than those on other rocks, and that the PFE values and the IP effects on limestone is high. Furthermore, the IP effects tends to shift the higher by the pyrite mineralization. However, no indications directly correspond to the skarn zone and mineralized zone of molybdenum has been recognized in the area.

According to the results of drilling operations carried out in this year, it was revealed that skarnization and mineralization of molybdenum tend to become stronger to the depth at the south side of the east-northeast trending fault. In contrary, skarn zone and mineralization of molybdenum were scarcely observed at the northern side of the fault except silicification and pyritation in limestone. Similar IP effects were obtained at the both sides of the fault.

Although it was impossible to confirm any predominant molybdenum ore deposit in this area by the surveys in this phase, it was tracable the existences of limestone layers and the pyrite mineralization by the SIP survey, especially by the resistivities and the IP effects. It was also clarified that the skarnization and the mineralization of molybdenum might possibly by improved downward at the south side of the east-northeast trending faults. It is, therefore, considered that the downward further exploration should be carried out on such geological conditions in future.

CONTENTS

LIST OF PLATES

PL. II-2-3	Apparent Resistivity Plan (n = 2)	1: 2,000
PL. II-2-4	Apparent Resistivity Plan (n = 3)	1: 2,000
PL. II-2-5	Apparent Resistivity Plan (n = 4)	1: 2,000
PL. II-2-6	Apparent Resistivity Plan (n = 5)	1: 2,000
PL. II-2-7	PFE Plan (n = 1)	1: 2,000
PL. II-2-8	PFE Plan (n = 2)	1: 2,000
PL. II-2-9	PFE Plan (n = 3)	1: 2,000
PL. II-2-10	PFE Plan (n = 4)	1: 2,000
PL. II-2-11	PFE Plan (n = 5)	1: 2,000
PL. II-2-12	Geological Profiles of Azegour Sector	1: 2,000
PL. II-2-13	Apparent Resistivity Pseudo Section and PFE Pseudo Section with Infered Resistivity Structures (Line A)	1: 2,000
PL. II-2-14	Apparent Resistivity Pseudo Section and PFE Pseudo Section with Infered Resistivity Structures (Line B)	1: 2,000
PL. II-2-15	Apparent Resistivity Pseudo Section and PFE Pseudo Section with Infered Resistivity Structures (Line C)	1: 2,000
PL. II-2-16	Apparent Resistivity Pseudo Section and PFE Pseudo Section with Infered Resistivity Structures (Line D)	1: 2,000
PL. II-2-17(1)∿(4)	Geological Drill Log in Azegour Sector ATE-1,2,3,4 (4 Sheets)	1: 200

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

CHAPTER 1 CIRCUMSTANCES AND PURPOSES OF SURVEY

1-1 Circumstances of the Survey

The Kingdom of Morocco is emplaced with rich phosphorous ores to be ranked as the largest scale in the world, and the production of phosphorous ores is ranked to be the third in the world. Furthermore, the country is blessed with other mineral resources, and there is a long history of the development of mineral resources and rich production of them in this country.

Activities for the development of mineral resources in this country have been executed positively by the Bureau de Recherches et de Participation Minieres (B.R.P.M.). Technical cooperation with foreign countries has also been proceeded.

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

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

The present investigation was programmed to be carried out in cooperation with the Bureau de Recherches et de Participation Minieres (B.R.P.M.) of the Kingdom of Morocco, in Haut Atlas Occidental area of 2,200 km^2, during the period of three years starting in 1983. In the first phase of the program, geological survey and geochemical survey were carreied out in an approximate area of 1,100 km^2 of northern part of the subject area. Especially, more accurate geological survey and geochemical survey were carried out in Erdouz Sector and in Azegour Sector which were regarded promissing.

In this year, geological survey and geochemical survey were carried out as the second phase of the program, in the sourthern part of the subject area succeeding the works made in the first phase. More accurate geochemical survey and geophysical exploration were carried out in Erdouz Sector and geophysical exploration and drillings (by B.R.P.M.) were carried out in Azegour Sector where emplacements of promissing mineral resources were expected by the survey made during the first phase.

1-2 Purpose of the Survey

The purpose of this investigation program is to comprehend conditions of emplacements of mineral deposits in Haut Atlas Occidental area of the Kingdom of Morocco by elucidating detailed geological conditions there. In this year, geological survey and geochemical survey were carried out in an approximate area of 1,100 km^2 of the sourthern part of the subject area, the purpose of which was to extract favorable areas for the emplacement of ore deposits, by making synthesized considerations on the relations between geological structure and mineralization as well as the geochemical characteristics in the subject area.

Purpose of the surveys in Erdouz Sector was to elucidate continuation of vein type Lead-Zinc deposits in the surveyed area by making synthesized considerations on the relations between geological structure and mineralization, and to elucidate the continuity of mineralization toward deep parts by clarifying anomalous zones extracted by geophysical exploration (CSAMT Method).

In Azegour Sector, purpose of surveys was to clarify continuity of

mineralization of molybdenum-copper-tungsten skarn type deposits toward deep parts of the surveyed area by making synthesized considerations on the results of existing geological survey, of geochemical survey and of drillings as well as clarifying features of anomalous zones extracted by geophysical exploration (SIP Method).

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 topographically in the western part of the Haut Atlas Range, which runs across the central part of Morocco from east to west. The subject area is in rectangular form of 50 km from east to west and 44 km from north to south, between 30°14'23" and 31°14'14" of the north latitude and between 8°00' and 8°31'23" of the west longtitude. The area is approximately 2,200 km^2. Surveys were mainly carried out in the northern half of the area covering about 1,100 km^2 during the first phase, and they were mainly carried out in the sourthern half of the area covering about 1,100 km^2 during this phase. The subject area is in the County of Amezmiz in the State of Marrakech according to the administrative division (Refer to Fig. 1).

Since railroad and paved road are available from Rabat, the capital of Kingdom of Morocco, to Amezmiz, the principal township in this district, the access is quite easy. Furthermore, a main road (partially unpaved), which is acrossing Houte Atlas Range, is running in about the center of the southern part of the area from Marrakech to Taloudant along Nfis River, and bus service is made available on it. Distance between Rabat to Ijoukak village, which is at the northwestern edge of the southern area, is about 420 km and it takes about 6 hours by automobiles. Possible means of transportation from Ijoukak to each village in the area are walking or horse riding except on the roads running along some of main rivers.

The surveyed area is mainly composed of mountainous land at the altitude of more than 1,000 meters above the sea level. In the central part of the southern area, there is a watershed of Houte Atlas Range at the altitudes of over 3,000 meters above the sea level. These rivers dissected the mountainous land deeply to form deep gorges. Therefore, the land features in this area are quite steep. The highest summit in the southern area is the main summit of Idga Massif of which elevation is 3,616 m above the sea level.

Since Sahara Desert is spread in the south of the subject area, the climate in this area is hot and arid of which temperature reaches 40°C, in summer from July to September. On the contrary, snowfalls are observed in this area during winter season from November to March to indicate wide ambient temperature variations. Therefore, vegetations are recognized only in lowlands along rivers, and uncovered rocks are exposed in most of the highlands.

Inhabitants in this area are mainly of Berber Tribe, and they are living along main rivers forming small villages. They usually speak Berber, therefore, it is sometimes impossible to communicate with them in Arabic which is the official language of the Kingdom of Morocco. Such steep topographical conditions and severe climatic conditions have checked development of industries and they are living on the stock farming of sheeping and goats. They are gentle and diligent in general, and potential working power is abundant. However, many of them are working away from home in big cities in the country or in various European countries.

2-2 Contents and Methods of the Surveys

Contents of the surveys carried out during the present phase are as follows: (1) Geological survey and geochemical survey made in the first half of the phase, (2) Geophysical explorations made in the later half of the phase, and (3) Drillings carried out by B.R.P.M. of the Kingdom of Morocco through the whole phase.

Respective contents and methods of the surveys show Table I.

2-2-1 Geological Survey and Geochemical Survey

Contents of surveys carried out during the present phase are consisted of geological reconnaissance survey in the southern area (1,100 km^2), geochemical survey by collecting samples of stream sediments in the same area and geochemical survey by collecting samples of soil in Erdouz Sector.

Field works were carried out during the term of 70 days from August 5, 1984 to October 13 under the cooperation of B.R.P.M. of the Kingdom of Morocco. Three Japanese engineers organized a crew including a native assistant and labourers, hence three crews were composed. Four wheel drive vehicles or horses were utilized for transporting men and gears from the camp to the surveyed area. Main camp station for the survey and for arranging surveyed results was established in Ijoukak village, which is at the northeastern edge of the southern area, utilizing a lodging house of an old mine. Tentative camps were established according to movements of surveyed area for improving efficiency of surveying work. Locations of tentative camps were Amslouh village at the northwestern part of the area, Souq Sebt Ghbalou village at the southwestern part of the area, and Imi-n-Tisht village at the southeastern part of the area.

Survey routes, sampling points for geochemical survey, and precise surveys were determined as follows according to degrees of necessities in respective areas:

(1) Southern Area: Survey routes were established with approximate interval of 10 km covering whole of the area. Especially in such areas where information on the indication of mineralization had been available, survey routes were set more densely. Geological survey was carried out by mapping along these survey routes. Furthermore, enlarged geological sketches, of which scales varied from 1 to 200 to 1 to 1,000, were prepared for main areas indicating mineralization.

As the fundamental topographical map for the field work, 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 Agriculture of the Kingdom of Morocco. All of the survey data were described in good order in the route map of the scale of 1 to 25,000, and a geological map of the scale of 1 to 50,000 was drawn up basing on these route maps. Geological map for unmapped area was prepared by referring to analysis results of airphotographs of the area.

In parallel to such geological survey, samples of stream sediments were collected at the upstream sides of confluences of rivers for extracting favorable zones of mineralization in the surveyed area. (analysis element are Cu, Pb, Zn, Mo, W).

(2) Erdouz Sector: Developments of tightly folded limestone alternating with schist running from south to north are observed in this area. Copper-lead-zinc vein type or stratform type ore deposits exist in the limestone layers. According to the results of geological surveys and geochemical survey during the first phase, existences of Northern ore deposit (in the range of 100 m x 100 m) in the northern slope and Southern ore deposit (in the range of 150 m x 200 m) in the southern slope were confirmed. It was further considered that possibilities were these two ore deposits should be connected each other and there should be continued below.

Nineteen traverse lines running from east to west were established in the area of 3.6 km from south to north and 1.2 km from east to west including these two ore deposits at the interval of about 200 m. Samples of soil (B Layer) were collected at about 50 m horizontal intervals on each of the traverse line for geochemical survey (analysis element are Cu, Pb, Zn).

Table I Contents of Survey Works

Geological and Geochemical Survey	Field works	Subject Area	Amount of Survey		Number of Geochemical Samples	
			Area (km^2)	Route length (km)	Survey Team	B.R.P.M.
		Southern Area	1,100	367.0	698	
		Erdouz Sector		19.4	412	
	Laboratory works	Items				
		Rock determination by thin section			22	
		Ore mineral identification by polished section			21	
		X-ray diffraction			21	
		Rock chemical analysis			11	
		Ore chemical analysis (Cu, W, Mo)			30	1
		" (Cu, Pb, Zn, Ag)			30	9
		Geochemical samples analysis stream sediment (Cu, Pb, Zn, W, Mo)			660	38
		Geochemical samples analysis Soil (Cu, Pb, Zn)			403	9
Geophysical Survey	Field works	Subject Area	Survey Method	Amount of Survey		
				Area (km^2)	Survey length (km)	Number of Point
		Erdouz Sector	CSAMT	5	–	27
		Azegour Sector	SIP		4.6 (4 line)	144
	Laboratory works	Items			Survey Team	B.R.P.M.
		SIP Test of Rocks			27	
		Resistivity Test of Rocks			26	
Diamond Drilling		Azegour Sector				(ATE 1) 203.30 m (ATE 2) 300.00 m (ATE 3) 170.00 m (ATE 4) 236.50 m

On carrying out survey in this area, a topographical map of the scale of 1 to 2,000 was used, which had been enlarged from the existing topographical map of the scale of 1 to 5,000, and sampling points on each traverse line were decided by the land survey with transit compass and esron tapes.

At the same time, correlations between geological structure and mineralization were studied by elucidating geological conditions by describing details of natures of rocks on each traverse line.

Throughout the surveys in the respective areas, attentions were paid to the following items in geological observations: (1) grain size, texture, natures of component minerals, color and conditions of boundaries with other rocks, etc. on igneous rocks, (2) grain size, natures of main components, color, strike, dip, existence of metamorphic minerals, etc. on sedimentary rocks, and (3) existences of joints, fissures, and faults, shape, scale, etc. on both igneous rocks and sedimentary rocks.

Samples of rocks of representative species and lithofacies as well as rocks indicating unusual lithofacies were collected for investigation with microscope and with X-ray diffraction. Furthermore, samples of mineralized outcrops were taken for mineral determination with polished section and for chemical analyses.

2-2-2 Geophysical Exploration

Contents of geophysical explorations carried out during this phase were: CSAMT Method (Controled Source Audio-Frequency Magnet-Telluric Method) in Erdouz Sector and SIP Method (Spectral Induced Polarization Method) in Azegour Sector.

Field works were made for 42 days covering from October 21, 1984 to December 1 with the cooperation of B.R.P.M. of the Kingdom of Morocco. Base camp for carrying out surveys in both sectors was located in the lodging house of an old mine in Azegour village.

(1) CSAMT survey in Erdouz Sector

CSAMT survey in Erdouz Sector was carried out at 27 stations established in the area of about 5 km^2 (2 km east to west x 2.5 km south to north) at the northern slope of Mt. Erdouz. Eleven frequencies ranging from 2^2 Hz (4 Hz) to 2^{12} Hz (4,098 Hz) were applied for measurements. Electric wire directed toward almost east to west, of which both ends were grounded, was installed as the transmission source at about 5.6 km north of the Erdouz Sector. The distance between both ends of the transmission wire was about 2.8 km. Electric currents passed through the transmission wire were 6A for frequencies less than 1,024 Hz, below 6A for frequencies more than 2,048 Hz, and 2.6A for 4,096 Hz.

(2) SIP survey in Azegour Sector

SIP survey in Azegour Sector was carried out along four traverse lines running from east to west of which lengths were about 1 km respectively. Total length of traverse lines is 4.6 km, and the total number of observation stations are 144. Traverse line were set at the interval of about 200 m. Electrode spacing is 100 m, electrode separation constants (N) are 1 - 5, and transmission and receiver bases were set at the center of each traverse line.

Although transmission currents varied according to resistance of electrode, they were within the range of 2A and 5A. Measurements were made utilizing odd number harmonics from 1 to 11 of each signal by transmitting rectangular wave signal having basic frequencies of 0.125 Hz, 1 Hz, and 8 Hz.

Samples of representative rocks were taken for SIP test and for resistivity test throughout both surveys.

2-3 Member of the Survey Team

Participated member of survey programming, negotiation and field works in this phase is as follows.

2-3-1 Survey programming and Negotiation

(1) Japan side

BABA Yozo	MMAJ
KITA Yoshiyuki	MMAJ
HIDA Kazuhiko	MMAJ

(2) Morroco side

Ahamed LOUARI	B.R.P.M.
Bachir BARODI	B.R.P.M.
Allal TIJANI	B.R.P.M.

2-3-2 Member of Survey Team

(1) Japan Side

WAKABAYASHI	Kensuke	Leader	
SHIBATA	Kiyohisa	(geology)	
NAKAMURA	Akitoshi	(geology)	
OHYA	Takashi	(geophysics)	
OHASHI	Tadashi	(geophysics)	

(2) Morroco Side

Abderrahim	SHBIHI	(geology)	B.R.P.M.
Abderkader	BAKKALI	(geology)	B.R.P.M.
Said	BARRADA	(geophysics)	B.R.P.M.
MATSUTOYA	Shigeru	(geology)	B.R.P.M.

MMAJ : Metal Mining Agency of Japan
B.R.P.M. : Bureau de Recherches et de participation Minieres
MINDECO : Mitsui Mineral Development Engineering Co., Ltd.

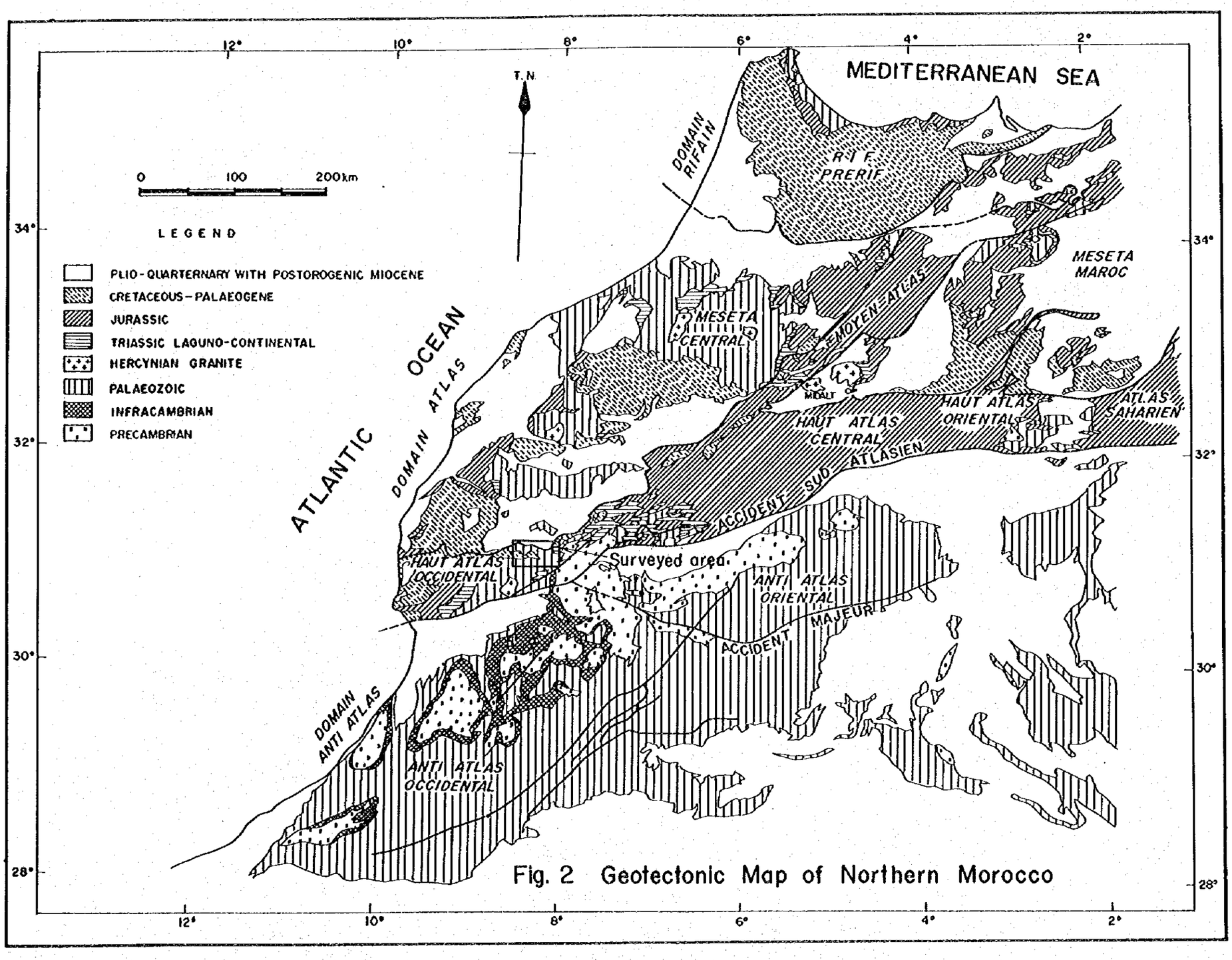

Fig. 2 Geotectonic Map of Northern Morocco

CHAPTER 3 PAST INVESTIGATION AND STUDIES

3-1 Outline of the Regional Geology

Since details of survey results of geological conditions of the survey area were clearly described in the report of the first phase, only outline of the geological conditions are to be described in this report (Refer to Fig. 2).

Houte Atlas region including the surveyed area is located in the northwest of the Pre-Cambrian stable zone that developed Mauritanian craton at the northwestern part of african continent as its neuclear, and it corresponds to geosynclinal zone developed in the Paleozoic age in its circumferencial area. These beds finally formed crystalline schist and metamorphic rocks at the end of paleozoic era by the regional metamorphism accompanied with folding and intrusion of plutonic rocks. After the above movements, peneplanation of basement rocks were proceeded in this area, and superpositions of continental-shallow water-marine sediments were made during the Mesozoic and Tertiary age owing to upheavals and subsidences of the basement rocks repeatedly occured. It is considered that the upheaval of Haut Atlas mountain range to such high altitude as seen today was made during the period of Alpine Orogenic Movement in Miocene age, especially in Pliocene age.

Constituent rocks of the surveyed area are effusive rocks of Pre-Cambrian crystalline schist of Paleozoic, granite intruded in the period of Hercynian Orogenic Movement, sedimentary and effusive rocks of Triassic, Cretaceous, and Tertiary.

Pyroclastic rocks of the Pre-cambrian Groups are distributed in further eastern district from the eastern part of the surveyed area, and minaly consisted of andesitic lava. Thin alternating layers of dolomitic limestone, quartzite, sandstone, conglomerate are intercalated in these pyroclastic rocks.

Crystalline schists of the Paleozoic Groups are widely distributed throughout the western area of Hout Atlas region including the surveyed area. feebly metamorphosed siltstone and andesite, strongly metamorphosed phyllite, various crystalline schists, crystalline limestone, etc. Since texture and structure of original rocks are generally remained in them, existence of complicated folding structure are assumably in this area.

Granites are distributed in the circumferential area of Tichka Highland which is southwest of the surveyed area and in the northern part of Azegour village. These rocks are classified into granite, aplitic granite, and granodiorite, etc.

The Triassic System are distributed in the northeastern part of the surveyed area and in the midstream are of Nfis River. They are made up of alternating layers of reddish purple sandstone, shale, and conglomerate and of basalt lava, and either uncomformably overlies or occurs in fault contact with Paleozoic Groups.

The Cretaceous System occupies comparatively high altitude in various places of the surveyed area. The System mainly consist of red sandstone, and directly overlies Paleozoic Groups in the surveyed area. However, it covers noncormably Jurassic Formation in the western part of the area.

The Cenozoic Groups are composed of the Tertiary Eocene Series and the Quarternary alluvium sediments. The Eocene Series mainly consists of limestone sandstone and conglomerate. On the topographical high area where the Cretacious System is distributed, the Eocene Series is found to lie occuping small area, conformably upon the Cretacious Systems. Alluvial sediments are composed of the gravels of various rocks derived from the hinterland, and is widely distributed in the north plain of the surveyed area.

3-2 Studies on Mineral Ore Deposits in the Surveyed Area

There is no working mineral deposit being mined in large scale in the surveyed area except some barite vein deposits and copper vein deposits being mined in small scale by private companies. On the other hand, it should be noted that Azegour ore deposit (Cu, W, Mo), Erdouz ore deposit (Ag, Pb, Zn) and Assif Al Mal ore deposit (Cu, Pb, Zn) in the northern area were actively mined until 1950s, and Gundafa ore deposit (Cu, Pb, Zn) and i'Ounein ore deposit (Cu) in the southern area were actively mined until 1970s.

Many reports on these ore deposits and on ore mineral indications in the surveyed area are available. However, many of them are of only describing about mineral indications and few of them are of studied from the mining geological view point. References applied on this survey in addition to those of the first phase are listed in the end of this chapter.

Studies on the principal mineral ore deposits are as follows:

J.C. Viland (1972) presented a report (S.E.G.M. No. 931) regarding Gundafa ore deposit. According to this report, this copper-lead-zinc vein deposit, is emplaced in the pyroclastic rocks and in the dolomite of Cambrian System. The length of the outcrop of its main vein is 2,000 m, and it was mined to the depth of 400 m below the surface. Crude ore production during 1928 - 1956 is 32,000 tons, and Pb and Zn contents in the crude ore were reported to be 5 - 10 % and 15 - 20 % respectively. Small scaled exploration is continued there by B.R.P.R. at present.

M.V. Berger (1955) presented a report regarding i'Ounein ore deposit. The deposit, of three copper veins, is emplaced in the phyllite and dolomite of Cambrian System. The veins are 0.2 to 2.0 m thick and 1,000 m to 1,500 m length. Ore minerals consist of bornite, chalcocite, malachite, and azurite. The deposit is being mined under private company at present.

El Omari (1972) and V. Cabla (1973) presented reports describing mineral indications.

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PARTICULARS

I GEOLOGICAL SURVEY, GEOCHEMICAL SURVEY

CHAPTER 1 SOUTHERN AREA

This area is in the southern half of the subject area, and is adjacent to the northern area which the survey were made during the first phase. Geological reconnissance survey and geochemical survey by stream sediments were carried out in the area during this phase. The survey team endeavored to extract favorable areas of emplacement of mineral deposits by studying relations between geological structure and mineralization.

1-1 Geology (Refer to PL. I-1, PL. I-2, Fig. I-1, Fig. I-2)

The southern area is underlain, geologically, by the Pre-Cambrian Group (P_{III}) and the Paleozoic Groups (C_{I}, C_{II}, C_{III}, C_{IV}) which are the basement rocks of this area, Intrusive Rocks intruded during Hercynian Period (Gr), the Triassic System (T), the Cretaceous System (K) of the Mesozoic Groups and ceozoic Formations (Q). The Pre-Cambrian Group is distributed at the eastern part of the area nearly from south to north, and the Paleozoic Groups are distributed almost all over the area. The Triassic System is distributed at the center of the area along Nfis River from northeast to southwest, and the Cretaceous system is slenderly distributed at the southern edge of the center of the area from east to west. Alluvium sediments are distributed along rivers, such as Nfis River, etc., in small scale.

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

1-1-1 Pre-Cambrian Group (P_{III})

The Pre-Cambrian Group in this area consisted of thick andesitic volcanic rocks, lava and pyroclastics.

The andesitic volcanic lavas are dark green or greenish red in color, massive and hard rock. They contain long prismatic crystallines of idiomorphic feldspar and show trachyte structure. Under microscopic observation, these rocks are strongly altered, which plagioclase has been replaced by sericite, calcite, epidote, and pyroxene has been replaced by chlorite, calcite, etc. (Refer to Table A-2-1: SR-37, NR-22, WR-13, WR-16). Each lavas has several hundreds meters thickness in general, and occasionally forms steep cliff.

The pyroclastic rocks consist of andesitic tuff, lapilli-tuff, and tuff breccia of which colors vary from dark green to reddish purple. Lithic fragments in the tuff breccia are rounded or sub-rounded andesite, more than 10 cm in diameter and fine fragments in the lapilli-tuff and tuff are also andesitic. They are strongly altered hydrothermally. Quartz, chlorite, sericite, are seen as alteration product under microscopic observation (Table A-2-1: WR-8, WR-9). The pyroclastic rocks are interbeded between the above andesitic lavas of which thickness ranges from several meters to several tens meters.

Although thin alternative layers of dolomitic limestone, quartzite, sandstone and conglomerate are found in this group in the northern area, no such layers are recognized in the southern area.

The group strikes either from south to north or from northeast to southwest, and dips below 30° toward various directions. Although an anticlinal structure is observed nearby Agarda village, it is considered that the group shows a monoclinic structure inclining westward as a whole. Since the group is block foulted, its accurate thickness is not known. However, it is estimated to be 2,500 m thick at least. The group are corrilated to the upper most formation of Pre-Cambrian Groups (P_{III}).

1-1-2 Paleozoic Groups

The Paleozoic Groups forming thick formations in this area uncomformably covers the Pre-Cambrian Group (P Ⅲ) and it shows the different geological features locally. The groups are, therefore, divided into CI, C Ⅱ, C Ⅲ, and C Ⅳ Formations in ascending order in this survey.

1) C_I Formation

The C_I Formation is widely distributed from south to north in the eastern part of surveyed area, which covering the circumferential area of Iguidi village, northeastern part, and Agdim village, southeastern part of the surveyed area.

The C_I Formation is composed of the alternation beds of andesite, tuff, Calcareous sandstone, siltstone, dolomite, and limestone, and conglomerate bed.

The andesite is blackish green compact and hard rocks, and occasionally intercalated with tuff and tuff breccia which has several to several tens meters thick.

The rocks have undergone thermal alteration, in which the phenocryst of plagioclase replaced by albite and muscovite and the pyroxine changes into chlorite under microscopic observation (Table A-2-1; SR-13).

The tuffaceous or calcareous sandstone and siltstone bed, greyish white, light green, greenish purple in color, is comparatively soft rock and easily weathered to change into soil.

The bed in the middle to lower part of this formation is interbeded with dolomite ranging from several to several tens meters thick. On the contray, the bed in the upper part of this formation is made up mainly thick sandstone and siltstone.

Under microscopic observation, the rock is composed of fine subrounded fragments of plagioclase quartz and orthoclase, and have partially undergone carbonitization (Table A-2-1; WR-6, WR-14).

The dolomite is dark gray or grayish white massive rock and it occasionally forms steep cliffs. Few quartz and clay minerals are seen in this rock under microscopic observation (Table A-2-1; NR-6).

The limestone is reddish purple hard rock. It forms thin layer, several to teens meters in thickness, and accompanied with redish purple tuffs.

The conglomerate, is white in color, contains subangular pebbles of one to ten centimeters in diameters. These pabbles consist of quartzite, sandstone and andesite. This conglomerate bed is about 40 meters in thickness, and it occupies the lowermost portion of the C_I Formation near Assaka village in the southeastern part of the area.

The C_I Formation is the lowest one of the Paleozoic Groups, and rests clino-uncomformably upon the Pre-Cambrian Group. It trends south-north except nearby the fault running from east to west at the south margine of the surveyed area, and it gently dips westward showing 10° - 20° dip.

The C_I Formation has a conformable relationship with the overlying C_{II} Formation, and is estimated to be 4,000 m thick.

2) C Ⅱ Formation

The C Ⅱ Formation is distributed in a northeast-southwest area along Nfis River, from the eastern part nearby Ijoukak village to the southern part nearby Tizi-n-test.

The Formation is composed of psammitic schist, pelitic schist and crystalline limestone. The psammitic schist is a light green, medium to fine-grained hard rock of which consists of chlorite-quartz schist and serisite-quartz schist.

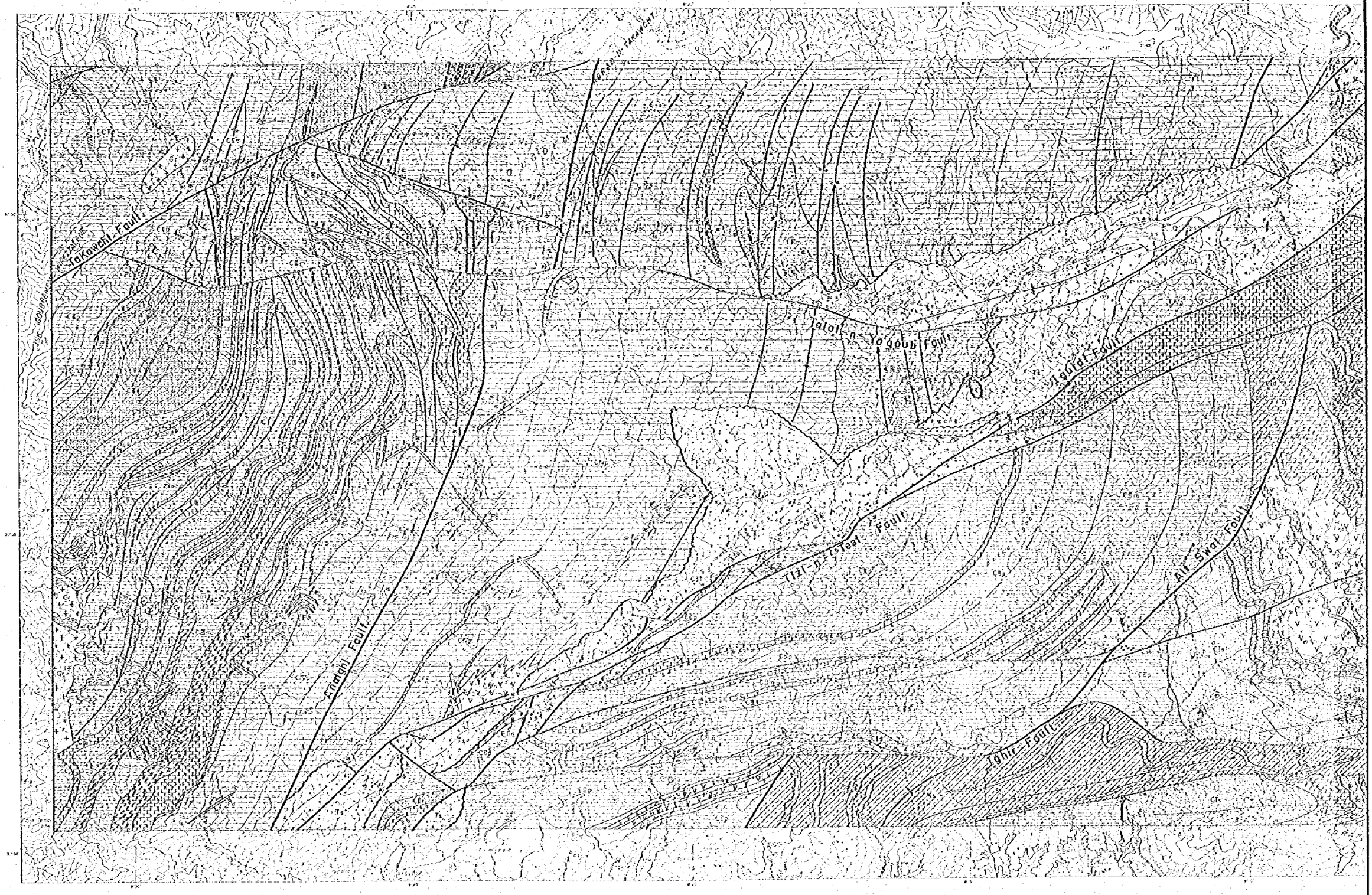
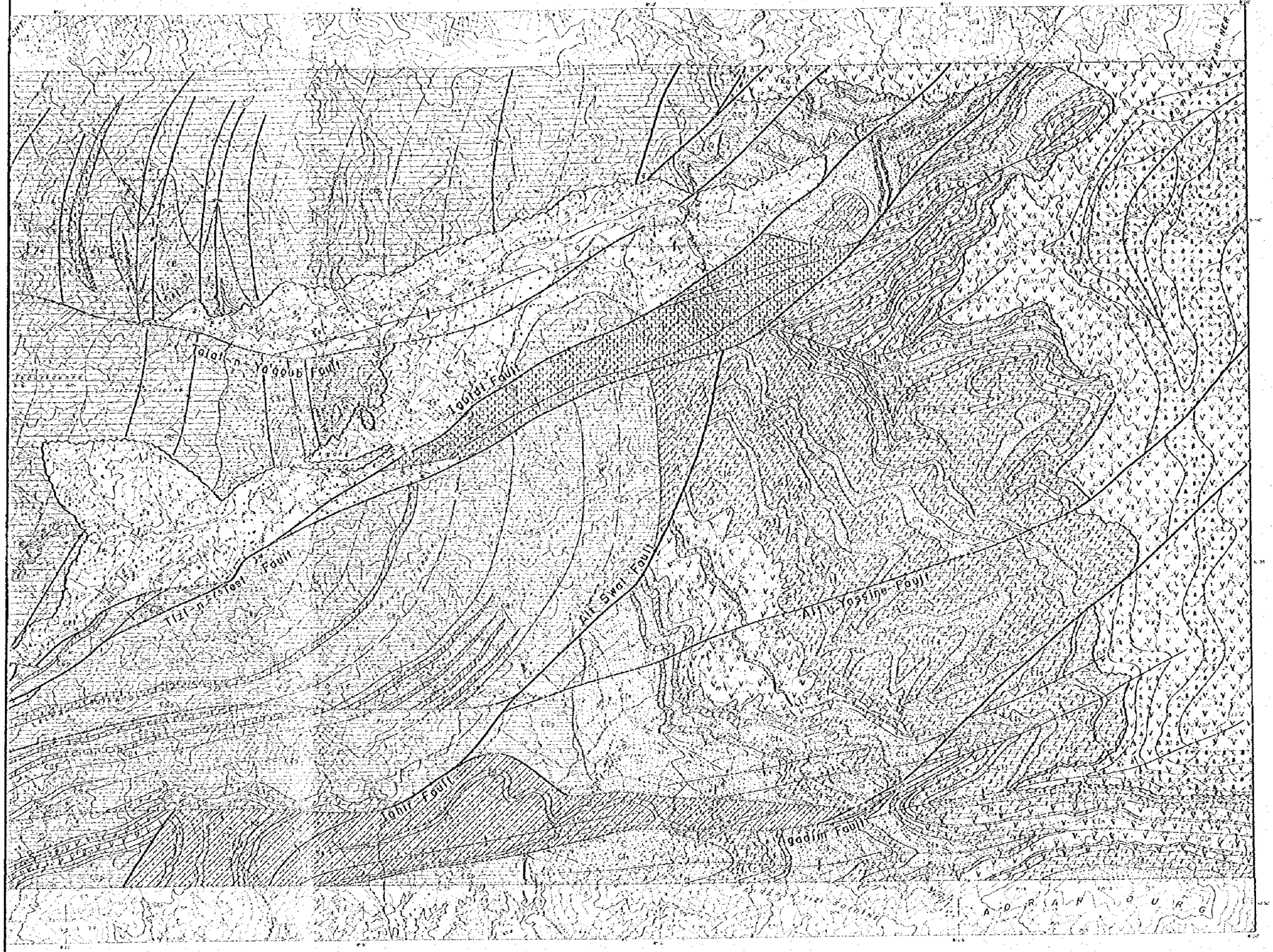


Fig. I-1 Geological Map of Southern Area



LEGEND

- Quaternary — Q gravel, sand, mud
- Cretaceous — Kd dolomite; Ks sandstone, siltstone, conglomerate
- Triassic — Ts sandstone, siltstone, conglomerate
- Ordovician ~ Cambrian
  - CIV Formation — CIVp peritic schist; CIVl limestone; CIVh andesite, tuff, tuff breccia
  - CIII Formation — CIIIn psammitic schist; CIIIp pelitic schist; CIIIl limestone; CIIIa calcareous schist; CIIIt green schist (tuff, tuff breccia)
  - CII Formation — CIIm psammitic schist; CIIp pelitic schist; CIIl limestone; CIIn andesite, tuff, tuff breccia
  - CI Formation — CIs siltstone, sandstone; CIn andesite, tuff, tuff breccia; CIl limestone; CId dolomite; CIc conglomerate
- Pre-Cambrian — Xa andesite; Xt tuff, tapilli tuff, tuff breccia
- Intrusive rock — Gr granite, granodiorite; Po porphyrite, microgranite

- fault
- unconformity
- anticlinal / synclinal axis / overturned fold
- stratigraphic boundary
- bedding plane
- A — A' section line

0 — 5km

Fig. I-1 Geological Map of Southern Area

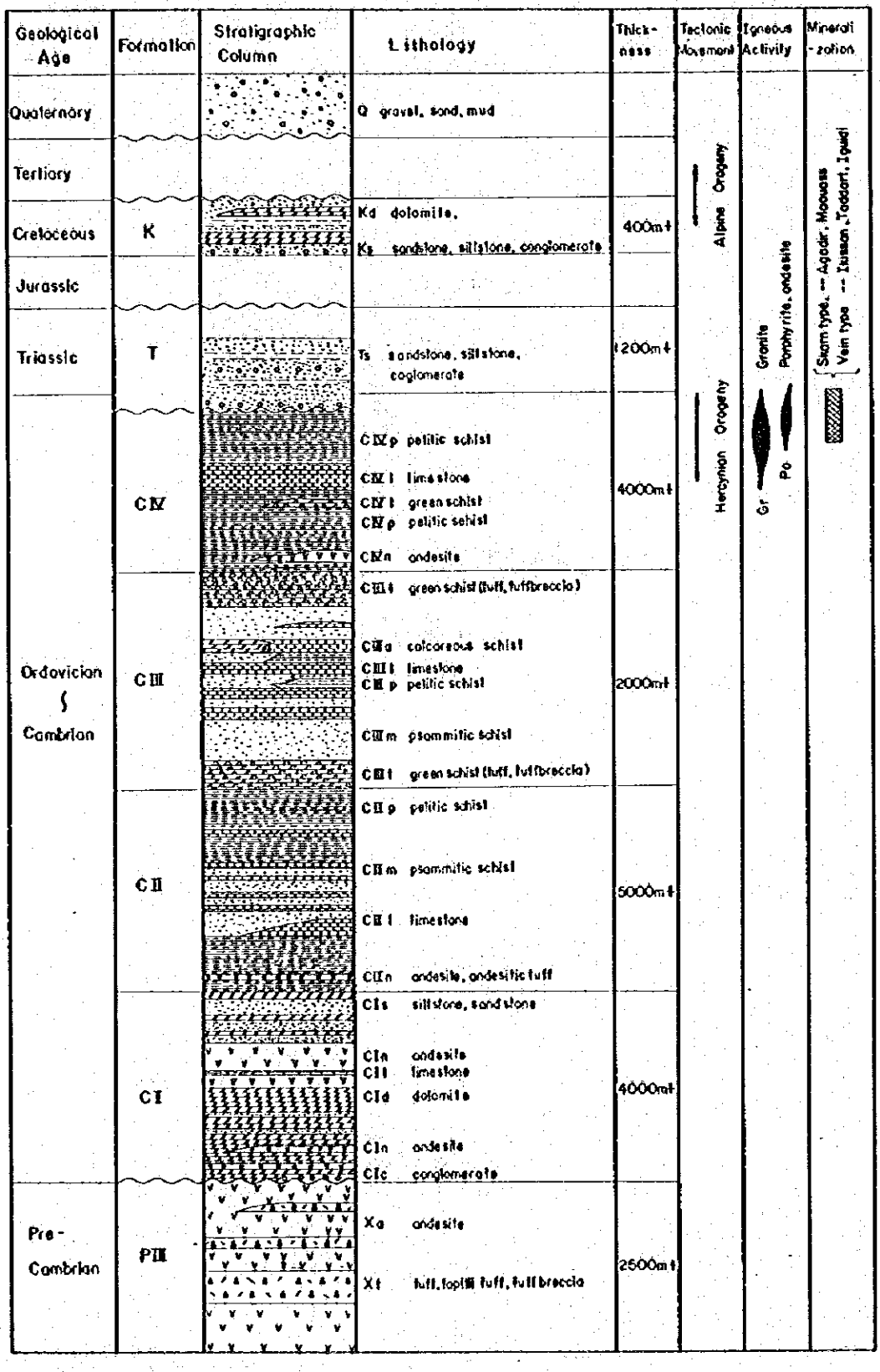


Fig. I-2 Schematic Geological Column of Surveyed Area

Most of the original rocks of these schists are assumed to have been sandstone. Although it generally forms a thick layer by itself, rarelly forms an alternative layer with pelitic schist and limestone.

The pelitic schist is a black or blackish green phyllitic rock of which consists of chlorite-sericite schist and biotite-quartz schist. The original rock is considerably to be mudstone and siltstone.

The crystalline limestone is a white or blackish gray massive rock. The thickness of the limestone ranges from several to several tens meters. Although it forms thin layer or alternative layer with psammitic schist or pelitic schist, occasionally forms thick layer by itself. Since it is developed relatively continuously, it can easily be traced horizontally, and it made up characteristic steep cliffs in various places.

Upper part and lower part of the C$_{II}$ Formation consists of thick pelitic schist and several layers of crystalline limestone, and middle part of it consists of alternative layers of psammitic schist and crystalline limestone.

The Formation has a strike northeast and forms monoclinic structure which dips steeply (about 70°) northwestward. However, folded structures associated with anticline and syncline are also observed partially. The C$_{II}$ Formation has a conformable relationship with the underlying C$_{I}$ Formation. However, relationship with upper layers are still unknown, because the Formation is in fault-contact with the C$_{IV}$ Formation. It is estimated to be more than 5,000 m thick.

3) C III Formation

The C III Formation is slenderly distributed from the area around the Arg village in the northwestern part to the area around the Agadir village in the southwestern part of the surveyed area. Moreover, it is distributed in small area around the Ighil village in the northern central part.

The C III Formation is the limestone predominant formation, corresponds to the similar formation in the Azegour and the Erdouz sectors.

The Formation is composed of green schist, psammitic schist, pelitic schist, crystalline limestone and calcareous schist.

The green schist is light green or dark green rock which has shown from fine and hard to coarse and porous features and it is rarely accompanied by conglomerate beds. The rocks consists of epidote-chlorite schist, quartz-chlorite schist, etc. Beside the rocks frequently remains lapilli and tuff-breccia texture and rarely remains subrounded gravel structure about 10 centimeters in diameter. It is considered that original rocks of them should be andesitic and dacitic volcanic rocks.

The psammitic schist in this Formation is similar to the same rock that found in the C II Formation. It forms alternative layers with the crystalline limestone, and is partially changes to the pelitic schist. The pelitic schist is also similar to that found in the C II Formation, but it is scarce amount in this formation comparatively.

The crystalline limestone is a massive rock with variation in color, such as white, black, yellowish gray, greenish gray. Thickness of the layer ranges from several meters to several tens meters. However, the layer is traceable horizontally because of its continuity is relatively good.

The calcareous schist is a rock consisted of alternative thin layers of psammitic schist or pelitic schist and limestone of which thicknesses are several cm. The rock was nominated as "Calcareous Schist" because it shows characteristically rough and striped appearance owing to portion is leached at the ground surface.

The upper and lower parts of the Formation mainly constists of the green schist, and its middle part consisted of alternative layers of the psammitic schist and the crystalline limestone or calcareous schist. Although, the Formation trends north-northeast, it shows partially east to west. Many anticlines and synclines are observed and, it forms anticlinorium as a whole. The C Ⅲ Formation has a comformable relationship with the overlying C Ⅳ Formation, but the relationship with the lower P Ⅲ Formation is uncertined. The total thickness of the C Ⅲ Formation is considerably more than 2,000 m.

4) C Ⅳ Formation

The C Ⅳ Formation is widely distributed in the central part and in the northeastern part of the surveyed area. The Formation consists mostly of the pelitic schist, but contains some intercalated crystalline limestone and andesitic volcanics.

The pelitic schist is black, or blackish green, or light green in colors. This is a phyllitic rock and consists of chlorite-sericite schist, biotite-quartz schist, etc.

The crystalline limestone is a grayish white massive rock. This is a relatively continuous layer of which thickness is several tens meters, and is intercalated into the pelitic schist.

The andesitic volcanics are distributed around the Tiz-n-Test Ridge, and are composed of the andesitic lava, the andesitic tuff and the tuff-breccia which is dark green or reddish purple in color.

The C Ⅳ Formation strikes south to north in the northern part and northeast to southwest in the southern part of the area. Many anticline and synclinal structures, which the axis trends same direction as above, are observed at the intervals of 0.5 km minimum and 7.5 km maximum. Therefore, it is considered that the thickness of the C Ⅳ Formation is about 4,000 m in spite of its wide distribution. This Formation comformable covers the C Ⅲ Formation.

1-1-3 Mesozoic Groups

1) Triassic System (T)

The Triassic System is distributed along the N'fis River and middle part of its branches.

The Triassic System is composed of the alternation of sandstone, shale and conglomerate.

The alternation of sandstone and shale is reddish purple in color. It is easily weathered to form soft and weak soil. 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 bed is generally several hundred meters thick.

The Triassic System trends east-northeast and dips about 30° southward at the opposite side of the Talat-n-Yaqoub village, but the direction of the trend various from north to east in the upper part of the N'fis River.

The Triassic System set uncomformably upon the Paleozoic Groups along the northwestern boundary of this system and is cut by the faults along the southeastern boundary of it.

The thickness of this system attains a maximum of more than 1200 meter.

2) Cretaceous System (K)

The Cretaceous System in this surveyed area is composed of the alternation of sandstone and siltstone, red in color, and of massive dolomite grayish white in color. Although the System cut by the two east-west faults and contacts the Paleozoic Groups.

The direction of trend of the system shows east to west and dips about 10° southward. However, steep drag foldings due to fault movements are observed at the southern and northern boundary of the system. The thickness of this system attains more than 400 meters.

1-1-4 Cenozoic Groups

The Cenozoic Group in this area is the Alluvium sediments (Q) of Quaternary age.

The Alluvium sediment is distributed in the lowland along the N'fis River near the Tarat-n-Yaqoub village. The sediments consist of stream and talus sediments of the gravels and sands of various rocks drived from the hinterland.

1-1-5 Intrusive Rocks

All of the intrusive rocks occur in the Paleozoic Groups in this area, and the intrusive rocks consist of the stocks of granite and granodiorite and dykes of microgranite and porphyrite.

1) Granite stock (Gr)

The huge granite complex stock, reaching 10 kilometers in diameter, are exposed in the Tichika Massif at the southwest of this area, and it called as "Tichika Granite".

The eastern margine of the Tichika Granite is observed around the Agadir village in the southwestern part of the surveyed area.

The small mass of granite stock occurs near the Tamsoult village in the northwestern parts of the surveyed area. It shows an elipsoid mass elongated northwest to southeast about 0.5 kilometers wide and 2.0 kilometers long.

These granite are characteristically compose of the phenocryst of quartz and kali-feldsper, and show various lithofacies such as a pink coarse-grained holocrystalline granite, diorite to a white fine-grained aplitic granite.

Quartz, plagioclase, orthoclase, biotite and hornblend are commonly recognized as a phenocryst and zircon and apatite are observed as an accessory mineral under microscopic observation (Table A-2-1; Table A-5: WR-1, SR-18).

This rock forms frequently the dykes and sheets in the marginal part of the stock. The surrounding rocks have been subjected to the silicification and to biotitization and change to the gneissous rock. Skarm minerals such as garnet, amphibole, replaced the limestone are found near the Agadir village.

2) Dykes (Po)

The dykes of the intrusive rocks are generally less than 10 meters width. These dykes are mainly observed in the western part of the surveyed area. They are also observed in the area near the Gundaha Mine. The directions of those dykes are shown as NE-SW, NNW-SSE, and E-W, and they are composed of microgranite dykes, aplite dykes, porphyrite dykes. The results of the whole rock chemical analysis and the norm calculation of 10 samples of intrusive rocks and effusive rocks are shown in Table A-5. All of them

has been formed high alkaline rocks ($K_2O + Na_2O$), and the intrusive rocks belong to the category of syenite-alkali granite, and the effusive rocks belong to the category of trachyte-alkali andesite (Fig. 1-3).

1-2 Geological Structure

The characteristics of the geological structure in the southern area are summarized as follows:

1) The Pre-Cambrian Group is the basement rock of this area. It has mainly been formed during active volcanic activities in continental or shallow water environments. The monoclinic structure inclined westward as the whole of the group is assumable by the sedimentation structure.

2) The Paleozoic Groups are regarded as of the Ordovician and Combrian age. It is considered that the lowest Formation (CI) was formed under continental or shallow water environments because the fact that the layer is composed of alternation of dolomite, siltstone and andesite. This Formation shows the weak metamorphosed feature and has a low-angled monoclinic structure westward.

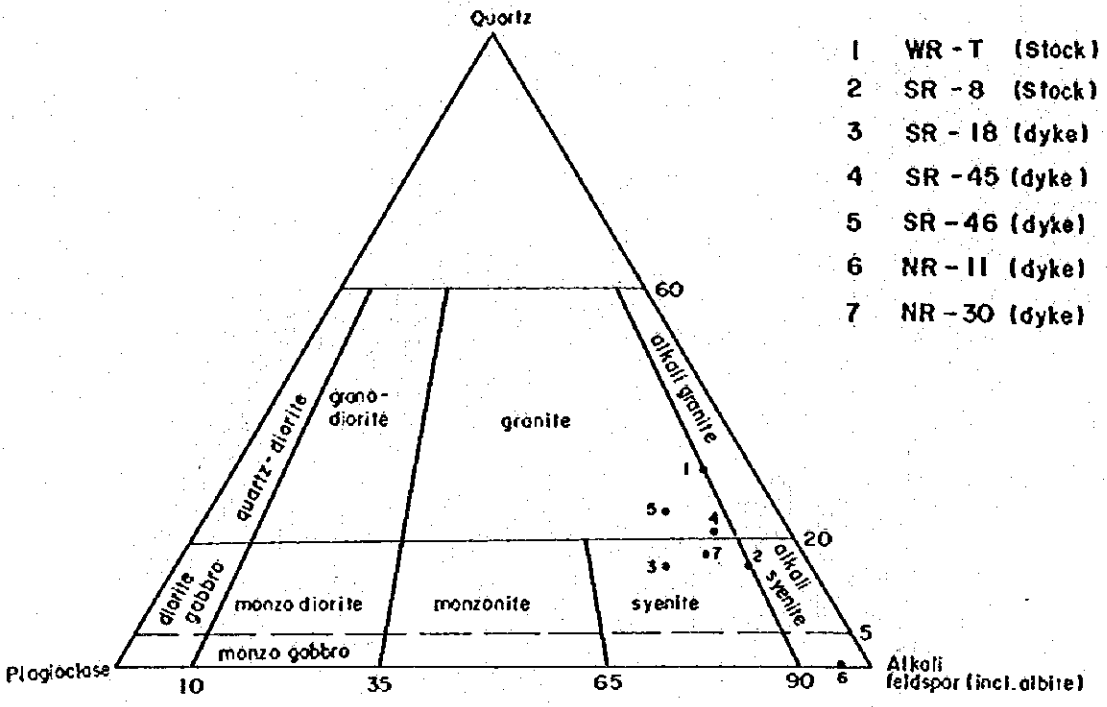
The lower Formation (C II) is composed of psammitic schist, pelitic schist and limestone. It is considered that the sedimentation are progressed gradually under the marine environment. Although folding structures are recognized partially, the C II Formation has a monoclinic structure as a whole, inclining about 40° westward. The middle Formation (C III) is relatively predominated by the limestone which is composed of green schist, psammitic schist, pelitic schist, and crystalline limestone. It is, therefore, considered that the Formation was formed under continental or shallow water sedimentary environments. The folded structure having short piched axis trending south to north is observed. The upper Formation (C IV) is mainly composed of pelitic schist. It is, therefore, considered that the sedimentation of the Formation was accumulated under the marine sedimentary environment.

The folded structure having axis, south to north, is also developed in this Formation. It should be noted that all of these Formation are cut by the faults of system of NE-SW, E-W, NNE-SSW. These facts indicates that the tectonic movement occurs in this area, accompanied with the regional metamorphism, the folding and fault movement, probably during Hercynian age, after the sedimentation of the Paleozoic Groups.

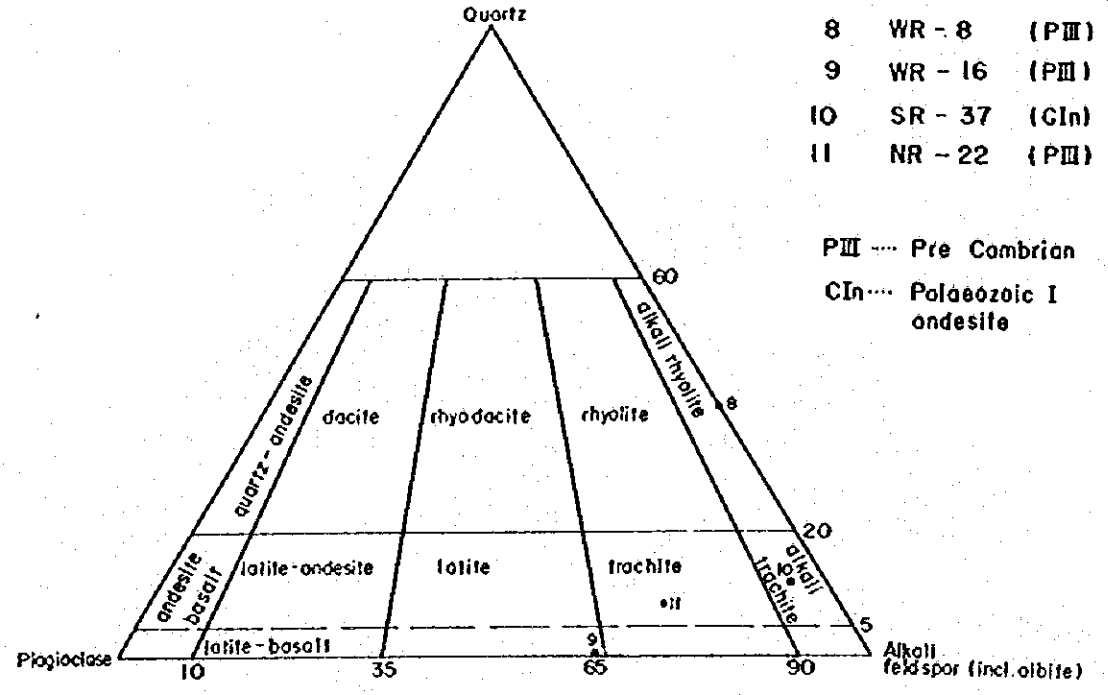
3) After the above geological structure was made up, the intrusion of the plutonic rocks as represented by the Tichka Granite occurred, and the thermal metamorphism affected the surrounding Paleozoic Groups. Some of them formed the stocks, and the rest formed the dykes in the Paleozoic Groups. Furthermore, some of limestone converted to skarn minerals.

4) It has been revealed that the Pre-Cambrian Group, the Paleozoic Groups and the pulutonic rocks are formed the peneplane after the tectonic movement in the first phase survey.

5) Mesozoic Groups, especially the Triassic System in the southern area rests uncomformably upon the Palcozoic Groups. Its unconformity plane along the northern margine of this System inclines nearly 30° southward. Its inclination angle is same degree as the dip of the formation. From this fact, it may be infered that the Paleozoic Groups has been per-



Plutonic Rocks



Volcanic Rocks

Fig.I-3 Classification of Igneous Rocks

(Streckeisen, 1967)