KINGDOM OF MOROCCO

REPORT ON GEOLOGICAL SURVEY OF THE HAUTE MOULOUYA AREA

PHASE II

(VOL. I)

FEBRUARY 1981

METAL MINING AGENCY
JAPAN INTERNATIONAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

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PREFACE

The Government of Japan, in response to the request of the Government of the Kingdom of Morocco, decided to conduct a geological survey for mineral exploration in the Haute Moulouya 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 ten (10) members, and sent to the Kingdom of Morocco. The team stayed there for seventy-one (71) days from May 8, 1979 to July 18, 1979 as the first period, and for thirty-eight (38) days from September 26, 1979 to December 2, 1979, as the second period. 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 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, 1980

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

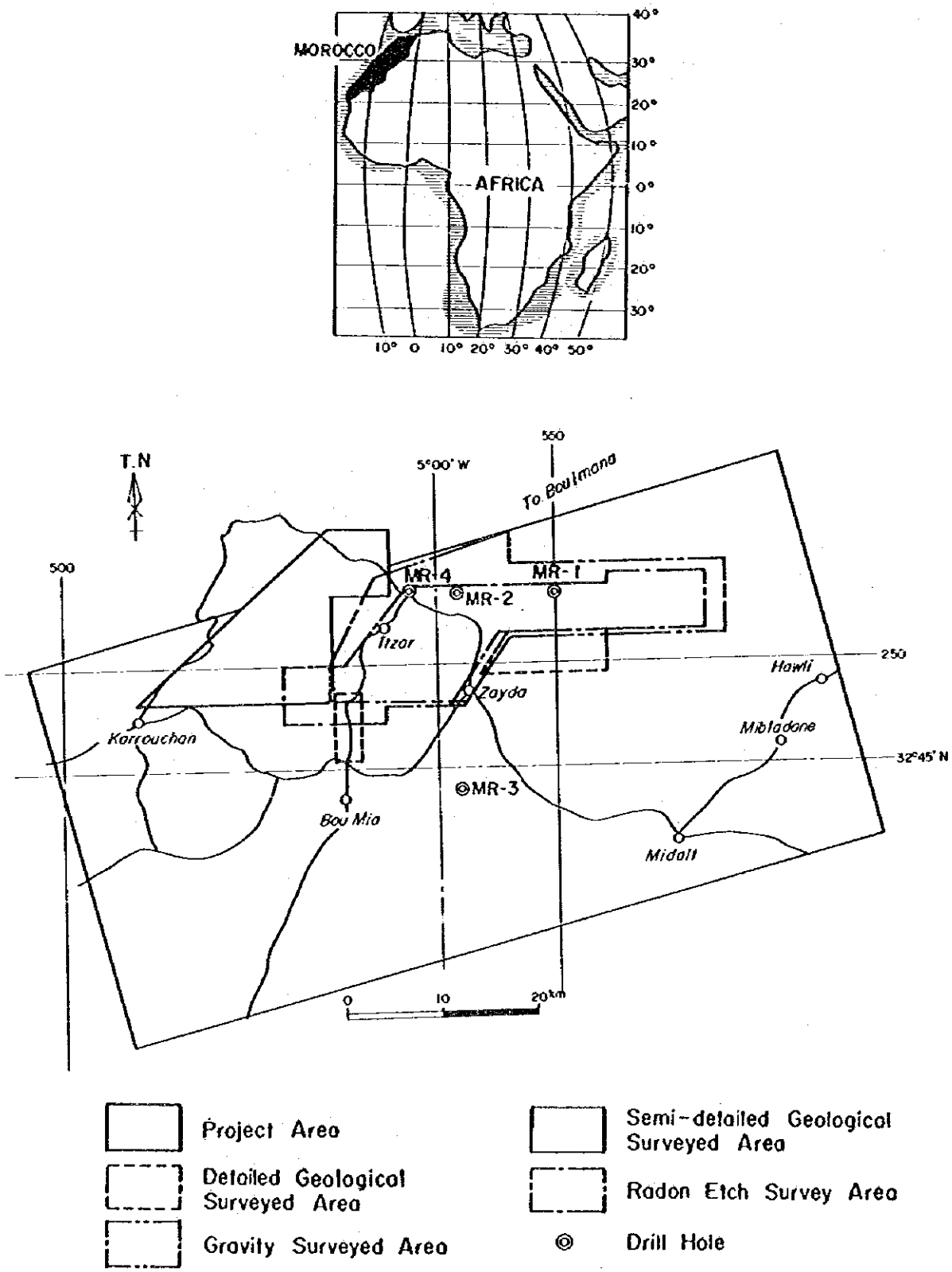

Fig. 1 Location Map of the Surveyed Area

INTEGRATED CONTENTS

SUMMARY

(1) Purpose: As the second phase survey program in Haute Moulouya area in the Kingdom of Morocco, a geological survey (including radon-etch survey), and geophysical prospecting and drilling were carried out for the areas which were selected in the first phase survey as possessing a high possibility of embedding mineral resources. The purpose of this survey was to establish the prospecting guideline for further phases and then to select promising areas for mineral resources through a detailed study of geological structures and understanding of geological environments and mineralization.

(2) Geological structures: The geology composing this area was roughly summarized in the first phase report. The basements are of crystalline schists of Pre-Cambrian or Palaeozoic system and of granites intruded in the Hercynian orogeny. And above them, sedimentary rocks and effusive rocks of Permo-Triassic, Jurassic, Cretaceous and Cenozoic systems are accumulated. In this phase survey, the basements structure and deposition environments of sedimentary rocks have been more precisely studied.

The basements structure was made clear by gravity prospecting and drilling work that the greater part of the surveyed area consists of granites, and there is a saddle-like structure between Zayda granite body and Bou Mia granite body that the north side of this structure gently slopes northward and the south side dips southward. And in the basements, it has been infered that northeast of north-northeast trending fault-like structures and ridge-like structures, two basin structures to the east of Itzar and the south of Bou Mia and a large graben structure to the northwest of Karrouchan area were existed.

In addition, on the basements, there exist several linear valley-like structures extending comparatively in parallel to the direction of NNE-SSW and shorter secondary valley-like structures in the directions of NW and N-S. The rear slope of this valley-like structure is considered to have acted as a dam against the principal sedimentary direction, and exerted and influence on deposition. Roughly speaking, sedimentary rocks covering the basements have been accumulated in the basin between the Moyen Atlas mountain block in the northwestern part and the Haut Atlas mountain district in the south. But fair differences in geological structure and thickness of strata are observed between the north and south sides of the Bou Mia - Zayda granite bodies in the center of the surveyed area and Karrouchan area, and it is presumed that sedimentary condition was diversified each periods.

The sedimentary environment in Permo-Triassic periods was controled greatly by the basements structure and the Palaeotopography. On the north side of the Bou Mia - Zayda granite bodies, the basements structure closely resembles that of the present and its depth is considered to have been deepened toward the Karrouchan graben. The P-T Red Sandstone Formation indicates a tendency to increase in thickness in the same direction. And the arkose sandstone originated from granites generally exists at the bottom of that. But in the Karrouchan area, the arkose sandstone is deposited thickly in spite of the basements is crystalline schist. This fact shows that the Permo-Triassic sediments was supplied from the southeast side to the northwest side. On the other hand, the present basements structure shows a southward slope on the south side of the Bou Mia-Zayda granite bodies. In this area, the stratum directly covering the basements, is made up of

mudstone except arkose sandstone. This fact indicates that materials was transfered from the crystalline schist in the Atlas mountains lying to the south or southeast, and the basements in this area is considered to have been situated rather higher than the north side, and it was assumed that this region was subjected to later diastrophism resulting in the present deepening state southward. Sediments were generally carried down from the southeast side into the northwest side correspond to the overall levels of the terrain in the early period of the P-T Red Sandstone deposition. However, since valley-like structures of the principal direction NNE-SSW existed on the basements, locally deposition was progressed along the valley-like structure and there is a tendency to accumulate thick within valleys, basins and damed up places. In the Jurassic period, almost the whole area except its north area was in neritic sedimentary environment. But in the Dogger period, the Haut Atlas area was under the abbysal sedimentary environment because of the development of a NNE-SWW trough. In the Cretaceous period, the whole area including the central part have submerged below sea level but it is presumed that the environment was repeated dry condition. From the Permo-Triassic period to this Cretaceous period, sedimentation progressed under a stable condition rather than great tilting as a whole though some troughs partially formed.
In the Tertiary period, however, upheaval of the Moyen Atlas and Haut Atlas occurred, and the sedimentation progressed in the inland basin formed by the upheaval, with supply of materials from surrounding rocks. In this period, faulting and folding were also active, and of the areas under survey, the Karrouchan area suffered the severest influence.

(3) Mineralization: In this surveyed areas, mineralization of lead and uranium was observed in the following places.

As lead ore deposits, there are low-grade ore deposits in the arkose sandstone deposited in a depression in the granites to the north of Bou Mia and the stratified sandstone type ore deposit in arkose sandstone around the Zayda granite body. Both ore deposits were distributed along the valley-like structure when arkose sandstone was sedimented and as the structural control of ore deposition, the existence of arkose sandstone and palaeochannels on the basements are assumed to have played most important role.

As uranium mineralization, vein-like uranium mineralization in the granite body in the area northeast of Zayda, carapace type and vein-like type uranium mineralizations in the area on the north of Bou Mia were observed. And in addition, a rather high measured value (150 c/sec) of radioactivity was detected in the arkose sandstone in P-T Red Sandstone Formation in the Karrouchan area. Each of them is low in grade, small in scale and can not be evaluated as suitable for mining, but because of vein-like type uranium mineralizations in the granite was comparatively dense distributed and primary uranium minerals such as pitchblende and uraninite were confirmed, it is considered to have a role as a supply source of the stratified uranium ore deposit in the sedimentary rock. Furthermore, the results of the radon-etch survey performed this year, it have been revealed that anomalous values concentrated zone which shows 10 times the background value to the northeast of the Zayda granite body, a nearly concentrated zone of anomalous values which is 2.5 to 3.5 times to the north of the Bou Mia granite body, and a few sub-anomalous value zones of more than 1.25 times to the northwest of Zayda village were distributed.

- A zone concentrated the anomalous values to the northeast of the Zayda granite body is corresponded to the area of P-T Red Sandstone Formation, and to the area where valley-like structures on the basements has been concentrated. Furthermore, it has a vein-like uranium mineralization area in the Zayda granite body in the hinterland and also it is located on the strikewise extension of these veins.

  The anomalous value zone on to the north of the Bou Mia granite body has been detected in the area where the Cretaceous formations are accumulated, and so the detected anomalous values are considered as indicating an information from deeper underground. This area has the Bou Mia granite body in its hinterland and indicates a graben structure geologically.

  The anomalous values zone to the northwest of Zayda village lies on the area where the P-T Red Sandstone Formation and the Cretaceous formations occur and the depth of the basements is considered to be around 200 m, the limit of radon-etch detection. This anomalous values zone presents a few scattered distributions, and the distributed positions were observed to have a tendency to correspond with valley-like structures and depressions in the basements found in gravity prospecting.

(4) Survey Methods: This phase survey was correspond to the geology carried out combining all or some of following methods, the surface geological survey, surface radioactivity survey, radon-etch survey, gravity prospecting, drilling work etc. And further for areas in which mineralization was found, surveys by detailed sketching, microscopic investigation for minerals, and XMA analysis, were performed.

Consequently, these methods proved extremely useful to make clear the geological structure and mineralization of this area. Particularly, the radon-etch survey carried out on the north of the Bou Mia - Zayda granite bodies was a very effective method to obtain an information of uranium deposits. The gravity prospecting and drilling work simultaneouly carried out in this area, on the other hand, were useful to clarify the depth and geological structure of the basements and sedimentary environment. It was ascertained that this area is very promising as a favarable site of uranium ore deposits from a viewpoint of the geological structure and sedimentary environment.

Therefore, in the future uranium prospecting in this area, simultaneous performance of a radon-etch survey, gravity prospecting and drilling work shall be considered as effective methods.

(5) Conclusion:

1) Lead deposits: The lead ore deposits in this area are sandstone-type ore deposits which are limited in the arkose sandstone of the P-T Red Sandstone Formation. These deposits were formed in the arkose sandstone on palaeochannel, that is, valley-like structures of the basements. Accordingly, further prospecting should take account of this fact. By the drilling, it has been ascertained that no arkose sandstone exists in the south side of the Bou Mia - Zayda granite bodies, therefore, as the subject area of prospection, whole area except the southern parts is recommended. Particularly, the area developed several valley-like structures toward the Itzar basin (which was presumed by gravity prospecting) is hopeful.

2) Uranium ore deposits: All uranium mineralization observed in this area are on a small scale, but as a result of this survey, the following

points were made clear and the possibility of the existence of uranium ore deposits is expected.

a) Many vein-like uranium mineralizations exist in the granite body. It is presumable that these observed mineralizations are residues having been oxidized and erroded out, so there is a possibility of a high-grade vein-like uranium deposit in the area covered still by the P-T Red Sandstone Formation.

b) The vein-like uranium mineralization zone in the granites is able to regard as the source of supply of the sedimentary uranium deposits.

c) As the formation of sedimentary uranium ore deposits, the P-T Red Sandstone Formation, especially the arkose sandstone is considered the most favorable because it presents high measured values of radioactivity. And decolored zones and sulphide minerals have been observed in this formation, it is considered that these facts also shows the existence of a reduction environment. In some drillings, anomalous values of uranium were detected in well loggings.

d) A tendency of structural control for the deposition of arkose sandstone to follow the valley-like structure of the basements, thus these basements structures is considarable to the important control factor of concentrations of uranium.

e) As the result of the radon-etch survey, a few anomalous value zones were detected and these are overlapped with the zones of favorable conditions in geological structure, therefore, the possibility of uranium ore deposits underlying this anomalous value zone is very high.

From the above results, the following areas are considered to have high possibility of underlying uranium ore deposit.

1) North of the Zayda granite body: Vein-like uranium ore deposits or sedimentary uranium ore deposits.

2) North of the Bou Mia granite body : Sedimentary uranium ore deposits.

3) North of Zayda : Sedimentary uranium ore deposits.

4) Karrouchan area : Sedimentary uranium ore deposits.

(6) View to future programme

As the guiding principle for uranium ore deposit prospecting is as follows:

1) North of the Zayda granite body: In the radon-etch survey made this year, measuring points were located at spacings of 500 m and more, accordingly form of distribution and continuity of anomalous zone could not be obtained so clear. On the basis of this reason, further radon-etch survey should be carried out at spacing of 100 m to 200 m or at closer spacings if the occasion arises. And to make the characteristics of anomalous values clear, core drilling should be perform, and geological study, radioactivity well logging analysis of uranium content in the drilling core etc., made to clarify the substantiality of uranium concentration.

2) North of the Bou Mia granite body: Gravity prospecting was not made this year for this area, therefore the estimate of the basement depth is approximate. And spacings of the radon-etch survey were 500 m to 1,000 m. Consequently, regarding this area, gravity prospecting should be carried out for an area of about 100 km^2, and drillings to a depth of about 250 to 400 m, and a detailed radon-etch survey should be performed at the same time.

3) North of the Zayda and Karrouchan areas, the depth of the stratum contains uranium is assumed to be deep, therefore an investigation is desirable, after the results of prospecting in the above two areas have been obtained.

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Chapter 1 Circumstance and Purpose of the Survey

The Kingdom of Morocco has long history and abundant experiences as to the development of mines. Especially, as seen in the fact that the production of the phosphorous ore in the Kingdom is eminent for the world standard, the Kingdom of Morocco is one of the important nations to produce underground resources. In this country, exploration and development of various mineral resources have been positively carried out by the Bureau de Recherches et de Participacion Minieres (BRPM in short), established in 1928, and works of joint ventures participated by foreign capitals are also active.

Cooperative survey between Morocco and Japan for the development of mineral resources commenced in April 1975 in the Anti Atlas regions as basic cooperative geological survey for the development of mineral resouces. This survey was carried out for three years untill April 1977. Subsequently, a request was made by the Moroccan government for a cooperative survey of several new areas, and in discussions between the preliminary reserch mission and the Moroccan government, it was decided to select the Haute Moulouya area as the area to be investigated. Based on the agreed program, in the first phase survey, a geological survey, gravity prospecting and mineral research were carried out taking 100 days, from 11 September to 18 December of that year.

As a result of above survey, the geological structure of the surveyed area was made clear generally and new informations for lead and uranium ore deposits in the area have been obtained, that is, lead ore deposits exist as sedimentary deposits accompanying the arkose sandstone in the area of the granite basement; stratified dissemination lead ore deposits are closely related to the Jurassic calcareous formation and faults, and

lead vein ore deposits where the mineral composition changes in the vertical are found controlled by the fault structure. Small scale but numerous uranium mineralization are observed, which may be as good sources of supply of uranium. Furthermore, the peripheries of the granites form a palaeotopographical basin which is a possible site of uranium accumulation. Based upon these results of the first phase survey, areas possessing a high possibility of uranium embedding were selected and further surveys were recommended.

The survey to be reported here was performed in accordance with the above recommendations as the second phase cooperative survey mineral resources development in the Haute Moulouya area of the Kingdom of Morocco. The purpose of this phase survey was to obtain detailed informations on geological structure in the areas which were considered to have a high possibility of containing lead and uranium ore deposits, and to establish useful guiding principles for survey activities by clarifying the geological environment and mineralization areas where the existence of lead and uranium ore deposits are to be expected.

Chapter 2 Members of the Survey Team

Members of the survey team in the field survey are as follows:

Leader (and Field Representative)	Junnosuke Oikawa	MESCO, Inc.
Deputy-leader	Kensuke Wakabayashi	MESCO, Inc.
General affairs liaison	Mitsuru Suemori	JICA
"	Kazumori Kano	MMAJ
Survey Member	Fukio Kayukawa	MESCO, Inc.
"	Terumi Ishikawa	MESCO, Inc.
"	Hirotaka Nishimoto	MESCO, Inc.
"	Kazuyasu Sugawara	MESCO, Inc.
"	Kazuhiko Kinoshita	MESCO, Inc.
"	Tomio Tanaka	MESCO, Inc.
"	Shigeji Asaoka	MESCO, Inc.
"	Hiroyuki Ohga	MESCO, Inc.

From the Moroccan side, a geologist Mr. M. Annich participated in the field survey throughout the period, who was engaged chiefly in the collection and compilation of the bulletins, the reports and drilling data, and also participated in the actual works of the geological survey and joined the discussions with Japanese engineers as appropriate. In addition, Mr. S. Barrakad, the Chief in charge of uranium exploration of BRPM, and also Mr. Shigeru Matsutoya, a specialist dispatched from Japan to BRPM, participated the survey as appropriate and performed liaison and support activities.

Furthermore, prospectors from BRPM participated in each field survey team.

Chapter 3 Contents of Survey Operations

The survey were performed for the areas which were selected as expecting area of ore deposits. The area covers totally about 3,200 Km^2, centered around the Haute Moulouya area in the central region of the Kingdom of Morocco. The survey included a geological survey, a radon-etch survey, geophysical prospecting (gravity) and drilling work (Fig. 1).

The field survey was performed in two stages: the first half and the second half. The first half survey was done for 72 days, from May 8 to July 18, 1979, and was endeavored to clarifying the geological structures and environments and to affirming the mineralization in the above mentioned area. The second half survey was spent 38 days, from September 16 to November 2, which supplementary survey to the first half survey were performed, and problems revealed in laboratory studies were checked. And, at the time of second half survey, the inquiry for the results of the first half survey, and discussions on further programme were made with BRPM engineers. A survey base was set up at Itzar village in the central part of the surveyed area, and four-sheel-drive vehicles were used for travel to and from the base to the survey sites.

3-1 Geological Survey

The Geological survey consisted of a semi-detailed geological survey and detailed geological survey. Surveys were carried out by 5 teams. Each of the five Japanese geologists made up a team accompanied by a Moroccan assistant and laborers. Contents of the survey district are as follows:

Areas	Semi-detailed geological survey	Detailed geological survey
Karrouchan northeastern sector	222 Km^2	-
Bou Mia northern sector	21 Km^2	0.3 Km^2
Zayda northern sector	48 Km^2	2.5 Km^2
Total	291 Km^2	2.8 Km^2

For the semi-detailed geological survey, topographic maps of scale 1 : 50,000 published by the Ministry of Agriculture of the Kingdom of Morocco were enlarged to scales of 1 : 25,000 and 1 : 10,000. The root-map were made using these maps and the geological maps were built up on the same scale.

In the detailed geological survey, detailed geological maps of scale 1 : 2,000 were accomplished using pocket compasses, measuring tapes, hand levels and altimeters.

In geological surveying, grain sizes, textures, constituent minerals, colors, boundary structure with other rocks, etc. were observed for granites. For sedimentary rocks, an attention was paid to sedimentary structures such as grain sizes, principal constituents, colors, strikes, inclinations, lithological changes, cross beddings, sole marks etc.; and for continental sediments, the existence of carboniferous substances was noted. For limestone, the existence and species of fossils, and for all rocks, the forms and scales of faults were observed, and if in the case of it accompanied by mineralization, the existing and continueing condition of minerals was surveyed, and detailed sketch made partially. During the survey, each survey team carried with a radioactivity measuring instrument (Scintillometer; model SPP-NP2), and measured radioactivity values of

each rocks.

After surveying, microscopic observations of rock specimens, XMA analysis and chemical analysis (Pb, Ba, U, Th) in the laboratory were performed, and the existence of minerals and condition of mineral assemblages were investigated.

3-2 Radon-Etch Survey

Radon-etch survey was carried out over about 300 km², north of Zayda. For the survey, 3 Japanese engineers (one engineer concurrently as a geological surveyor) organized 3 teams, each comprising a Moroccan assistant and laborers. Measuring points in the eastern area were decided by using pocket compasses and measuring tapes after arranging a base line, and in the western area points were decided by using the topographic maps (scale 1 : 25,000 which were prepared by enlarging the maps of scale 1 : 50,000), measuring tapes and clinometers.

The radon gas detection cups were procured from U.S. Terradex Co. The cups were emplaced in holes dug with shovels and pickaxes and recovered being left for about 20 days. The recovered cups were returned to Terradex Co. The company undertook etching analysis, track counting, primary analysis and issued reports on the results of measurement to the survey team. The number of detection cups emplaced was 749, but some could not be recovered or were buried improperly. The effective number of cups recovered was 673.

3-3 Geophysical Prospecting

The area of geophysical prospecting is north of Zayda village. The area covers about 400 Km², extending 40 km east and west, 17 km north and south and roughly coincides with the area covered by the radon-etch survey.

The survey included gravity observation, levelling on the observation station, and analysis in Japan. The filed survey was performed by 3 Japanese engineers, each accompanied by a Moroccan assitant and laborers.

Gravity observation : There were 878 gravity observation stations throughout the area of 400 km² at which gravity observation was performed. For gravity observation, two gravimeters, made by La Coste & Romberg INC of the U.S.A., were used. The spacing between observation stations was standardized at about 400 m, and the stations were preferentially sited on the principal roads and branch roads. In places other than rear roads, stations were sited by measurement using compass. And to make closed observations, a base station was provided in front of the stuff quarters in Itzar village and observations made once a day.

Levelling : Levelling with the auto-level was carried out for all gravity observation stations but the distance measurement for some stations were carried out by stadia measurement.

Analysis : The field data were carried out topographical and other corrections using a computer and the Bouguer anomaly maps were prepared in Japan. And based on a Bouguer anomaly map by reduction densitly ρ = 2.5, filter analysis and quantitative analysis by modeling calculations were performed, and the underground structure of this area were estimated.

3-4 Drilling

Drilling work was initially scheduled for 3 sites (MR-1, MR-2, MR-3), but one more was added during the work. The locations and drilled depths in meters are as follows:

Name of drill-hole	Site	Drilled depth (m)
MR-1	Tanfi Micha area, notheast of Zayda	148.30
MR-2	Itzar basin area	265.95
MR-3	Geophysical prospecting area	138.00
MR-4	Itzar basin area	100.10

For MR-4 hole, additional drilling was done by BRPM and the length of the hole reached 375.70 m.

Drilling machine, a Crealius D-100 was used with the wire line method, supplying bentonite mud water. After the inspection of recovered drill core was done by geologists, mineralized or alternated portions were conducted under microscopic observation, XMA analysis and chemical analysis. Radioactivity well logging was also performed for each drilled hole.

Chapter 4 Outline of the Survey

4-1 Geography of the Surveyed Area

The project area is located in almost the central part of the Kingdom of Morocco. It lies between N 32°30' to 33°03' and W 4°30' to 5°07'. It falls in the administrative district of Midalt in Ksar es Souk, Meknes.

This area is linked to the Capital, Rabat, by paved road via Meknes. The journey time by a car is about 5 hours (nearly 300 km). Between Rabat and Meknes and between Meknes and Midalt, regular bus services are operated several times a day.

Itzar where the survey base is sited and the surrounding towns and villages, Zayda, Midalt, Mibladane, Bou Mia are connected by paved roads. With the recent popularization of tractors, farm roads have developed which can be passed to jeep so traffic conditions are good, and from Itzar, each survey area can be reached by car. But in winter, the mountainous routes are often blocked by snow. The local inhabitants use horses, asses, and camels, in addition to the bus service.

This surveyed area consists of peneplane or plateaus of 1,200 to 1,700 m above sea level and surrounding mountainous zones of 2,000 m and more above sea level. In the plateau zone, a terrace topography is developed which has poor vegetation, but the mountainous zone is rich in acicular trees such as cedars, pines, etc. And among the plateau zones slightly high and roughly round hilly areas are formed around Bou Mia and Zayda where basement granites are distributed. The Moulouya river is the principal river. It nearly in the central area, flows from west to east, and it forms a steep valley at places.

4-2 Outline of the Geology

Details of geology of the survey area are described in the first phase report, only the outline will be described in this report (Figs. 2 and 3).

The Haut Atlas area which is included in this survey area is located in the northwest and north of the Precambrian stable zone that developed Mauritania craton in the northwestern part of the continent of Africa as its nucleous, and lies in the geosynclinal belt zone developed in the paleozoic age in the marginal area of it.

The rocks composing this area consist of crystalline schist of the Precambrian or Palaeozoic, granite bodies that were intruded in the both of which form the basements. Hercynian orogenic period, the P-T Red Sandstone Formation and β_{P-T} Basalt Formation of the Permo - Triassic, sedimentary rocks of the Jurassic and Cretaceous, and sedimentary rocks and effusive rocks of the Cenozoic.

Crystalline schists are principally found in the eastern part of this surveyed area, and are exposed in a small scale in the western part. These rocks consist of chlorite-sericite schist, amphibole schist, quartz-sericite schist etc. and contain amphibole. Crystalline schists occur in the eastern Hawli area for about 20 x 10 km, in dome-shaped folded structure. Granites occur east of Zayda village and northwest of Bou Mia village. These rocks are classified into granite, porphyritic granite, aplitic granite, glanodiorite and migmatic granite. Among them the aplitic has slightly higher measured values of radioactivity than other granites, and forms gentle sloped sheets or veins.

The P-T Red Sandstone Formation is distributed around the basements. It has a gentle slope, and consists, from the bottom upward, of conglomeratic coarse-grained sandstone beds, coarse-grained and fine-grained sandstone beds, fine-grained sandstone and mudstone beds and mudstone beds.

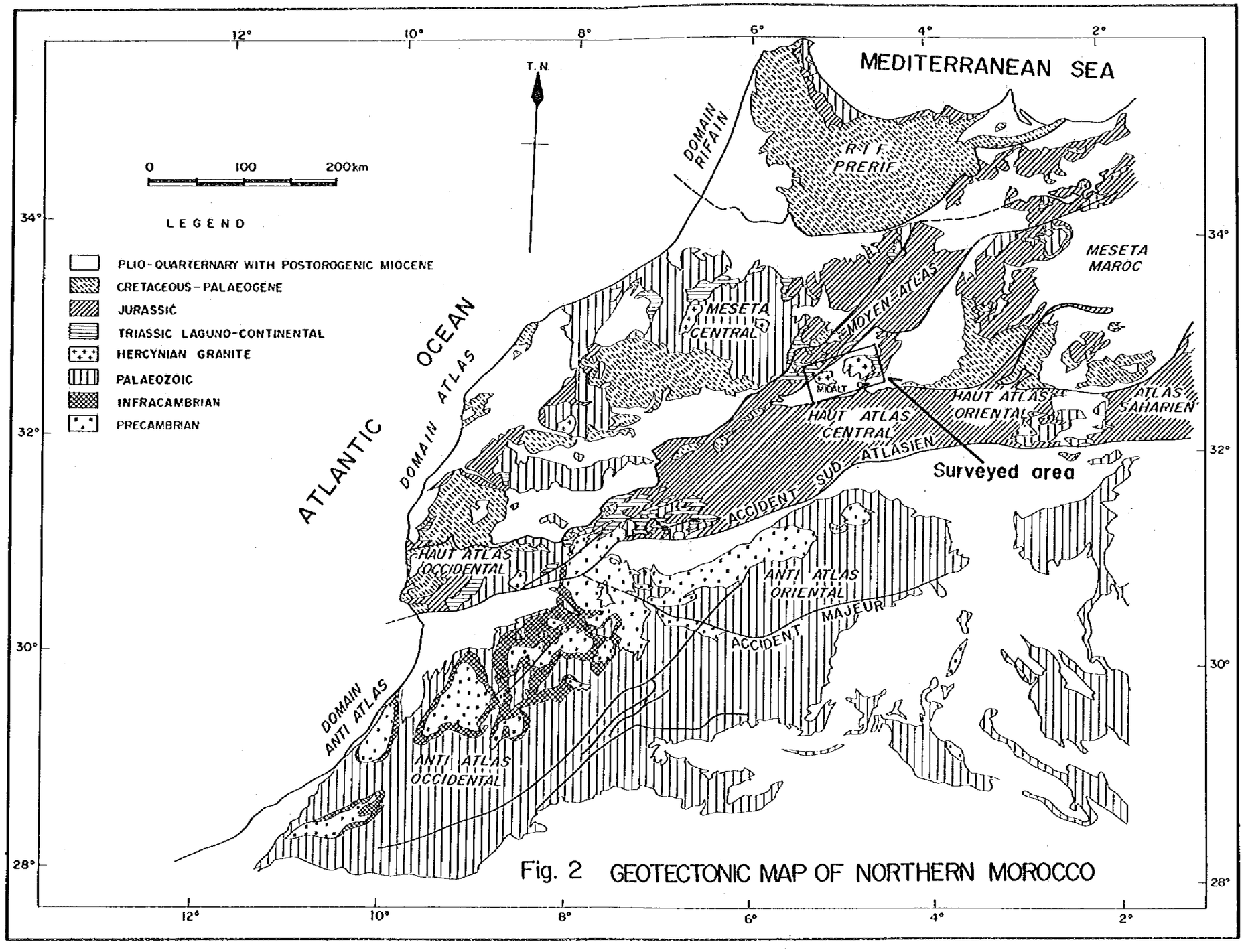


Fig. 2 GEOTECTONIC MAP OF NORTHERN MOROCCO

GEOLOGICAL AGE AND UNIT				STRATIGRAPHIC COLUMN		THICKNESS		DESCRIPTION	
Era	Period	Formation		Moyen Atlas	Haut Atlas	M. A	H. A	Moyen Atlas	Haut Atlas
Cenozoic	Quaternary		Q_3					Terrace deposit	
		β_{Q_2}	Q_2			15 m ±	30 m ±	Basalt (lava), calcareous conglomerate, sandstone, siltstone, calcareous siltstone.	Basalt (lava), conglomerate, siltstone, mudstone.
			Q_1			25 m to 100	25 m to 100	Conglomerate, siltstone.	
	Tertiary		T_3			45 m ±	35 m ±	Calcareous conglomerate, calcareous siltstone, sandstone, marl, reddish brown siltstone-mudstone, sandstone.	Calcareous conglomerate, reddish brown siltstone-mudstone.
			T_2			60 m ±	70 m	Limestone, yellowish grey siltstone-mudstone, marl, calcareous conglomerate.	Marl, limestone, siltstone.
			T_1			40 m to 60 ±	15 m	Micritic limestone, light brown siltstone conglomeratic sandstone.	Light brown siltstone, conglomerate.
Mesozoic	Upper Cretaceous	Turonian	K_2t			80 m ±	140 m ±	Limestone included molluscas and brachiopodas, calcareous siltstone included molluscas.	Micritic limestone, muddy siltstone, calcareous siltstone, turbidite.
		Cenomanian	K_2cm $K_2^{cm_2}$			50 m	90 m ±	Limestone included molluscas, calcareous siltstone, poly-colored siltstone intercalated with gypsum beds, sandstone, conglomerate.	Siltstone intercalated with gypsum beds.
			$K_2^{cm_1}$				20 m to 40		Alternation of red mudstone, shale, sandstone and limestone.
	Middle Jurassic	Dogger	J_2d_2				50 m		Alternation of limestone and thin shale included shell fossils.
			J_2d_1				70 m ±		Grey mudstone.
	Lower Jurassic	Lias	J_1			0 m to 250 ±	230 m ±	Limestone included coral fragments, calcareous siltstone, marl, sandstone, conglomerate.	Thick limestone, intercalated with mibladane Pb-Bo ore deposit. Calcareous to sandy siltstone intercalated with turbidite, limestone, dolomite.
	Permo-Triassic		β_{P-T}			0 m to 200		Basalt (lava), sandstone, conglomerate. Manganese ore bed, coaly shale.	
			P-T			30 m to 300		Red sandstone, arkose sandstone, siltstone, mudstone, partly turbidite, gypsum beds. U. mineralization, Zayda Pb-Bo ore deposit.	
Proterozoic - Paleozoic	Precambrian - Paleozoic		Basement complex					Granite, contaminated granite, porphyritic granite, aplitic granite, granodiorite. Dykes (aplite, granite porphyry). Metamorphic rocks (chlorite-sericite schist, quartz-sericite schist, amphibole schist, amphibolite).	

Fig. 3 Schematic Geological Column of the Surveyed Area

The conglomeratic-coarse grained sandstone beds is a few meters thick around the granite but it has developed in the northwestern part of this area to several tens of meters thick, and is detected rather high measured values of radioactivity than other beds.

The β_{P-T} Basalt Formation is about 150 m thick, and occurs in the northeastern and northwestern part of this area. It mostly consists of basaltic lava but includes a black shale beds, sandstone beds and thin layer of conglomerate in places.

The Jurassic sedimentary rocks consist of limestone of the Lias system, distributed in the northwestern and eastern parts of this area, and mudstone, and an alternation of limestone and shale of the Dogger system distributed is small scale in the southern part.

The Cretaceous sedimentary rocks are distributed over nearly the whole surveyed area and cover the P-T Red Sandstone Formation directly in the central basin. They consist of a lower mudstone beds and upper limestone beds.

The Cenozoic, consists of the Tertiary and Quaternary, occurs widely in the central basin. The Tertiary is subdivided to three strata - T_1, T_2 and T_3, and the Quaternary is formed by four strata - Q_1, Q_2, βQ_2 and Q_3. Of these, βQ_2 represents Quaternary effusive rocks.

The geological structure of this area is characterized by the distribution feature of the basements, sedimentation mechanism of sedimentary rocks of Permo - Triassic, and the structure of the faults which cross these rock and formations.

The granites of the basements are exposed east of Zayda and west of Bou Mia over 400 km^2 and 300 km^2, respectively. And, as the result of the previous geophysical prospecting, it is presumed that the granites are distributed in an elliptical form including these 2 areas, about 30 km south and north, about 60 km east and west, and elongated in the direction of

N 75°E. In the early period of Permo - Triassic sedimentation, graben shaped submerged zone have been formed in the Moyen Atlas, northwest and in the Haut Atlas, south of this area. The P-T Red Sandstone Formation are made up of erroded fragments of the basement and deposited in depressions of the basements and along rivers under the continental environment. The direction of sedimentation in this area has a tendency toward the northwest submerged zone (the Karrouchan sedimentation basin). In particular the arkose sandstone beds which occupied the bottom part of the formation exists abundantly to the north of the central granite zone and the thickest distribution is observable in the southeastern part of the Karrouchan sedimentary basin.

The β_{P-T} Basalt Formation was effused under the continental or local lake existing environment. However, in the Lias period a neritic sedimentation environment occurred. In the Doggar period, graben deforming in the Southern Haut Atlas was progressed, and abyssal sediments were deposited thickly in this area. But even in this period, a part of the basements which included the central granite area remained as a island. Sedimentary rocks of the middle Cretaceous period occur almost horizontally or with a gentle slope always centered around the hilly area of the basements. This fact indicates that a new marine transgression in this period occured and the whole area had submerged into the sea.

In the Miocene period of Tertiary the entire area of Morocco was upheaved and formed into land with the Alpine Orogeny, and was subjected to the stress in the south-north direction. Especially in the surveyed area both areas of the Moyen Atlas and Haut Atlas were uplifted and suffered deformations such as faulting, folding, etc., and in the central basements area a principally N 30°E fault system developed.

IN the Moyen Atlas area, the Yahia-Oufalla fault and many other faults were chiefly accompanied by vertical displacements and the basements became

higher than the central part in some places.

During this time, sedimentation of the Tertiary occurred under the inland basin environment, but erosion to the granite body had not occurred. Granites are considered to have appeared on the land surface for the first time when in the Quaternary.

As ore deposits and mineralizations in the surveyed area, lead ore deposits occur as a stratified sandstone type in the P-T Red Sandstone Formation (Zayda), a stratified dissemination type in the Jurassic dolomite and limestone (Mibladane), and a fissure filling fault vein type (Hawli) etc.

As uranium ore, a vein type mineralization is observed in the sheared zone in granites, or along dykes, a sandstone type mineralization is observed in the P-T Red Sandstone Formation, and a Quaternary conglomerate type and Carapace type mineralizations are observed on the surface of granite. The granite in the central part of the surveyed area is considered to be a source rock of uranium supply.

4-3 Geological Survey

(1) Karrouchan northeastern sector

This area is located in the northwestern part of the project area. It is a sedimentary basin neighboring the Itzar basin which lies on its east side of the border formed by the Yahia-Oufalla fault, and it is an area where a great amount of clastics inflow from the Zayda-Bou Mia granite zone is thought to have occurred as a result of first phase survey. Therefore in this survey, lithology, distribution, structure and others aspects of this sedimentary rocks were investigated sedimentologically, and examination was made on the possibility of existence of uranium and lead ore deposits in this area.

The geology of this area consists of the P-T Red Sandstone Formation

and β_{P-T} Basalt Formation of the Permo - Triassic; J_1 Limestone Formation of the Jurassic; K_{2cm} Mudstone Formation and K_{2l} Limestone Formation of the Cretaceous; T_1 Mudstone Formation, T_2 Mudstone Formation and T_3 Sandstone Formation of the Tertiary and the Quarternary; and the basements and the lowermost beds of and the P-T Red Sandstone Formation are observed in the northwest and south of this area.

The P-T Red Sandstone Formation is thick in the vicinity of Karrouchan (about 300 m thick) while it thins on the southeast side of the Yahia-Oufalla fault (about 200 m). These facts suggest that the existence of a basin at the time of deposition.

The geological structure of this area is characterized by the folded structure with the axial direction NE-SW and 2 kinds of faults of NE-SW and N-S direction. The fold structure is conspicuously observed on the northwest side of the NE-SW system Yahia-Oufalla fault which runs through the southwestern part of this area. Anticline and syncline of wave length 7 km are observed, and the plunge of the axis is 5° to 10° southwestward. The Yahia-Oufalla fault is an important fault. It produced a downward displacement on its southeastern side and it divides the strong folded structure on the northwestern side in contrast to the southeast side which is a monotonous and gentlely dipping structure pointing to the southeast.

In this area, conspicuous mineralizations could not be confirmed, since there is no exposures of the bottom beds of the P-T Red Sandstone Formation which is the impregnated beds of lead and uranium, and granite is considered to be the source rock of it. Measured values of radioactivity in each formation were not higher than the background. But in the valley of the Marrout river which neighborers the northeastern part of this area, measured value of radioactivity 150 c/s, about 1.5 times the background were observed. As this area forms a basin structure and the stratum is

considered to have deposited thickly and widely, the above fact suggests the possibility of lead and uranium concentrations in some parts of this formation underlying.

(2) The Bou Mia northern sector

This area is located on the northern border of the Bou Mia granite body. The "Carapace" type uranium mineralization in the lowermost of the P-T Red Sandstone and lead-barite mineralized zone in the arkose sandstone of the P-T Red Sandstone Formation were clarified last year. In this survey, semi-detailed geological survey and detailed survey for above subject areas, were carried out to clarify the structures of the basement, the palaeo-channel in uranium deposits and the scale and quality of lead-barite mineralized zone and the extension of it.

The geology of this area consists of the basements granites and the P-T Red Sandstone Formation which covers widely the southern part of the surveyed area, K_{2cm} Mudstone Formation, K_{2l} Limestone Formation of the Cretaceous, T_1 Mudstone Formation, T_2 Marl Formation of the Triassic the Quaternary alluvial sediments in the northern part. As principal faults, there are NNE-SSW trending faults represented by the BM-1 fault which passes through the central part of this area and NW-SE trending faults. The NNE-SSW trending faults are particularly related to the block movement.

The P-T Red Sandstone Formation covering unconformably the granites was deposited filling depressions in granite bodies. Owing to the distribution and sedimentation structure of arkose sandstone at it's bottom, a palaeochannel was presumed to run NNE or N.

As mineralizations in this area, lead and uranium mineralizations were observed in the exposed granite area in the southern part, but no mineralizations were observed in the BM-1 fault east side area nor in the northern area.

Lead mineralization is indicated by the stratified dissemination ore in arkose sandstone of the lowermost of the P-T Red Sandstone Formation, that were observed in the Boutazart mineralized zone and near the "Carapace" type uranium mineralization site. The thickness of the former mineralized zone is 1.90 to 4.50 m (average 3.18 m), Pb ore grade is 0.13 to 6.00% (average 1.52%), Ba ore grade is 4.20 to 9.20% (average 6.74%). It is recognizable about 700 x 500 m, and the high quality parts have a tendency to concentrate toward the central part of the palaeochannel. The thickness of the latter mineralized zone is 1 to 1.8 m (average 1.2 m), Pb ore grade is 0.19 to 4.20% (average 1.30%), Ba ore grade is 0.60 to 4.20% (average 2.04%), and the length of the outcrop is about 150 m. The BM-1 fault runs on the east side of both zones, and since the east side is submerged, there is a possibility that the eastward extension of the mineralized zone underlying on the eastern side of the fault.

As uranium mineralizations, there are a Carapace type uranium mineralization on the northeastern border of the granite body and a small scale anomalous radioactivity in the granite body about 500 m west of Ait Said. The Carapace type uranium mineralization shows a nearly horizontal lenticular shape along the border line of granite and arkose sandstone with a maximum thickness of 30 cm and width of about 2 m. It was formed in a depression in the aplitic granite surface. The measured values of the radioactivity had a maximum of 1,600 c/s and the results of analysis showed U = 0.072%, V = 0.030%, and Th$<$ 0.002%. By XMA analysis, it was confirmed that these uranium minerals are secondary minerals as carnotite $K_2(UO_2)_3(V_2O_8) \cdot 3H_2O$ and tyuyamunite $Ca \cdot (UO_2)_3(V_2O_8) \cdot 5_2H\ O$.

The spot-like small scale anomalous radioactivity in the granite body accompanies small fissures was not continuoslly but measured values of radioactivity were 400 to 1,200 c/s.

From the above facts, it is considered that the uranium ore deposit in this area come from a granite body source. After oxidised and dissolved uranium was transported along the palaeochannel, combined with vanadium and reduced, then deposited in the above mentioned depression of Carapace namely the central part of the palaeochennel. Conspicuous uranium mineralization was not observed in the arkose sandstone of the P-T Red Sandstone Formation. However, as it was confirmed that palaeochannels running down from the Bou Mia granite body to the north at its sedimentation and 5 spots of anomalous value were revealed in the radon-etch survey, it is suggested that there is a possibility that place exists north of this area in which uranium mineralization is concentrated.

(3) The Zayda northeastern sector

This area is located on the northern border of the Zayda granite body. In this survey, semi-detail geological survey and detailed geological survey were carried out on the vein type uranium ore deposit in the sheared zone which was determined in previous phase, and at the same time to clarify the uranium mineralization distribution and scale, a study was also made on the mechanism of uranium concentration.

The geology of this area consists of the basement granites which are distributed widely and the P-T Red Sandstone Formation which overlies T_1 Mudstone Formation of the Triassic, Q_1 Siltsonte Formation, Q_2 Siltsone Formation and βQ_2 Basalt Formation of the Quaternary.

In this area, especially in granites, sheared zones and faults of various sizes are developed, showing NNE-SSW or N-S directions, and some of them such as the Amaragh fault, the G-P vein sheared zone, to sheared zones around Paneau-1, and the Ansagmir fault, etc.

The P-T Red Sandstone Formation, comformably covers the granites, has a gentle slope of less than 5^{o} toward the north, and the lowermost arkose

sandstone thickens in depressions or valleys of the basements, and it is presumed that a palaeochannel ran northward.

There exists in this area a stratified lead ore deposit impregnated in the arkose sandstone of the P-T Red Sandstone Formation and a vein type uranium mineralization impregnating from the sheared zone developed in granites to the arkose sandstone located just above it. Among the lead ore deposits, major ones have already been excavated by Zayda mine, but as recognized mineralized zones which have not been mined yet, mineralized zones of Ikhf Ouganbou in the central area and AŸt Rahhou in the eastern end part are known. Scales and qualities of both ore deposits are as follows:

Name of the ore deposit	Scale of the ore deposit	Thickness	Ore Grade	
			Pb	Ba
Ikhf Ouganbou	Outcrop length 400 m	0.2~0.6m	0.28~ 2.10%	3.60~ 8.80%
AŸt Rahhou	400 m x 1000 m	0.2~1.70m	6.47%	4.85%

Both show a tendency for the quality to improve at the center of the depression. The lead ores are cerucite ($PbCO_3$) and galena. All uranium mineralizations in this area are vein type ones closely related to dykes and sheared zones in the granite.

Major ones are the Dique vein, the Assaka-n-Tabhirt vein, the GP vein, the Paneau-1 West vein, the Paneau-1 vein, the Paneau-1 East vein, the AŸt Rahhou North vein, the AŸt Rahhou South vein, etc. Details are given in Table I-6. The sheared zones having these mineralizations are highly diversed such as their width from 3 ~ 30 m, but it is possible to track a length up to 3,500 m. All of them have many ferruginous quartz veins of 3 to 15 cm breadth, but quartz porphyry is occasionally injected. Generally, the measured values of radioactivity in the sheared zones are 100 c/s to 150 c/s, but high values of more than 300 c/s are shown in places.

The maximum indication of measured value is 13,500 c/s in Assaka-n-Tabhirt; and in addition the Paneau-1 vein showed 8,000 c/s, the Dique vein, 4,200 c/s; the Paneau-1 West vein, 3,000 c/s; etc. But these high measured values of radioactivity are limited within 1 m and have no continuity. If the scope of measured values above 300 c/s is regarded as the uranium mineralized zone, its scale is 0.10 to 5 m width and 40 m or less length.

In this survey, it was clarified that these uranium mineralizations exist chiefly in the ferruginous quartz veins among the sheared zones or along minute fissures and also in the arkose sandstone just above the sheared zone. The maximum value of analyzed ore grade was U=0.33% in the Paneau-1 vein, but generally it was U=0.07% or less. And the results of XMA analysis in this year showed that these uranium minerals are primary minerals such as uraniite UO_2, pitchblende UO_2 etc. and the secondary minerals such as carnotite, bequerelite $CaO \cdot 6UO_3 \cdot 11H_2O$ etc. Thus it is considered that the uranium in this area was formed following the ferruginous quartz and a portion of it has oxidized and resolved by the effects of rain water and others, then deposited as secondary minerals.

As mentioned above, vein type uranium mineralizations in this area are small-scale and of low grade on the whole, and it is not possible to set a target for possitive prospecting in the future. But anomalous radioactivity in this area is distributed densely compared with other areas and a high-grade part of U=0.33% partially exists. Especially, in this area, most of the P-T Red Sandstone Formation has been erroded and the resulting effluence of uranium is considerable, the northern part of this area should be noted in future because the arkose sandstone has not been erroded.

4-4 Radon Etch Survey

The subject area of this survey is on the north of the Zayda-Bou Mia

body covering 300 km². In the first phase survey, the existence of a large basin structure between the granite body and the Moyer Atlas mountains to the north of the surveyed area was made clear. This basin consists of strata in which the P-T Red Sandstone Formation is the major component, and all palaeochannel at the time of its sedimentation were assumed to have flowed northward. On the other hand, in the Zayda-Bou Mia granite body numerous uranium mineralizations occured within the sheared zone and the arkose sandstone above it, and it was considered that this granite body is the source rock of uranium ore and there is a possibility of uranium concentration in the sedimentary rocks in the basin, especially in the lowermost arkose sandstone of P-T Red Sandstone Formation. Therefore to investigate the existence of impregnated uranium ore deposit, a radon-etch survey was scheduled this phase. In the survey, distribution of measuring points was arranged in a grid pattern with spacings of 500 m or 1,000 m, so that detection of anomalous values would cover the entire area.

The results of this survey showed measured values from 4.1 T/sq.mm. 30 days to 798 T/sq.mm.30 days and these values were processed statistically taking the geology of the measuring points into consideration. As a result, the following area were clarified as sites possessing anomalous values. Anomalies observed in the P-T Red Sandstone Formation in the northern part of Zayda granite body are as follows:

(1) North of Paneau-1 ~ Immayn-Aït-Rahhou : 34 anomalous points are concentrated in this area, and the reading values are from 153.8 T/sq mm.30 days to 798.0 T/sq mm.30 days. There are 8 points which present over 500 T/sq mm.30 days.

(2) North of Assaka-n-Tabhirt : 5 anomalous points are concentrated, and reading values are from 219.8 T/sq mm.30 days to 357.1 T/sq mm.30 daya.

(3) Idamrane Micha area : 8 anomalous points exist, and the reading values

are from 274.0 T/sq. mm.30 days to 472 T/sq mm.30 days.

(4) Around Ilaghmane-n-Amar : 6 anomalous points exist, and the reading values are from 146.5 T/sq mm.30 days to 215.2 T/sq mm.30 days.

Anomalies observed in other areas are as follows:

(5) North of Bou Mia granite body : 5 anomalous points exist spaced rather closely. The reading values are 184.6 T/sq mm.30 days. Among the anomalies in this area, those on the Cretaceous are also included.

(6) North of Zayda village : 4 anomalous points lie dispersed. The reading values are from 153.8 T/sq. mm.30 days to 200.0 T/sq mm.30 days, and these anomalies are rather weak compared with that of other areas.

At the same time in the above survey, radioactivity measurement at the ground surface was carried out, but the results revealed no spots which show extra high measured values of radioactivity and a correlation to the measured values by radon-etch was not observed. And the above fact is considered to indicate that the anomalous values of the radon-etch survey originate in the radon gas producing material existing at depths underground. And especially that, the anomalous value concentration between north of Paneau-1 and Immayn-Aït-Rahhou coincides with the extension of the NE-SW trend sheared zone in which anomalous radioactivity was detected at Zayda granite body, and also it is the area where the existence of palaeochannels runing northward was presumed by the results of gravity measurement, this spot is worth noticing as possibly containing underlying uranium ore deposits. Some of the anomalous values observed in the granite area to the north of Bou Mia were obtained in the Cretaceous formations of the upper strata and as palaeochannels during deposition of the P-T Red Sandstone Formation in this area are assumed to be northward. Therefore, the existence of a uranium ore deposit in the arkose sandstone in the deeper part of this area is expectable.

4-5 Geophysical Prospecting (Gravity prospecting)

The subject area of this survey is located on the north of the Zayda-Bou Mia granite bodies covering about 400 km² and the above mentioned radon etch-survey was performed in this area. As described the existence of a large basin structure in this area was made clear in the first phase survey, and in this basin the lower beds (arkose sandstone) of the P-T Red Sandstone Formation deposited just above the basements and it was presumed that there is a possibility of lead and uranium ore deposits existing in this stratum. And also, these ore deposits are assumed to have concentrated when Zayda-Bou Mia granite bodies was scraped off, carried down and deposited. Therefore, gravity prospecting in this phase was carried out to clarify the depth of basements and palaeotopography and especially palaeochannels in this area, and to clarify the sedimentation environment.

Using a Bouguer anomaly map compiled in this survey, various investigations and discussions were made and as a result the following conclusinns were obtained.

(1) Most of the basements in this area is the granites, but in the eastern and on the northwest side there are anomalous gravity values which are considered to correspond to the existence of crystalline schists.

(2) Slightly under ground, in the area which connects the Zayda granite body and the Bou Mia granite body in the southern end of the surveyed area, a dormant saddle-like structure stretching nearly horizontally in E-W direction was assumed. This saddle-like structure and the Bou Mia-Zayda granite bodies show the shape of a dividing ridge in the basements at present. But according to the result of geological survey, the dividing ridge is considered to have been located more southerly at the time of palaeotopology formation. In the north side, the height of the basements tends to decrease northward with this saddle-like structure as the summit.

East of Itzar (located in the west) a basin structure as a depression in the basements is observed.

(3) The sedimentary rocks which cover the basements differ remarkably in the east and west of the surveyed area. Namely while in the eastern part rather thin sedimentation of up to about 200 m is present, in the western part the sedimentation structure gets thicker toward the northwest becoming 400 m or more at the thickest part.

(4) In the surveyed are, the fault structure (NE-SW or NNE-SSW strike) was found in several places. Also ridge-like swells of the basements stretching in the same direction was found in several places. Representative of this ridge-like structure, there are ridges east of Itzar and on the west side of the fault-like structure in the central part of the surveyed area. The former is a factor in the basin structure formation mentioned previously, and the latter divides the western border of the high anomalous radon-etch area.

(5) On the surface of granites which comprise the basements several belt shape grooves were observed in several places. They are considered to indicate vally-like structures directed northward from the southern part of the surveyed area. The major distributed areas and thier respective features are as follows:

i) The valley-like structures concentrating to a basin structure east of Itzar, may have once have acted as a reservoir like lakes or marshes and then outflowed north again.

ii) In the east side of the NNE-SSW fault structure in the central part of the surveyed area, several valley-like structures are assumed that they joined together into a main valley and ran north. In this area, many anomalous radon-etch values were found in roughly in conformity with them.

iii) In the graben structure which lies between two fault like structure, in the eastern part of the surveyed area, existence of a valley-like structure is assumed.

As mentioned above, the gravity prospecting carried out in this phase showed the structure of the basements and sedimentation environments, and it has been made clear especially that the northern part of the Zayda granite body is in an environment having the possibility of uranium and lead ore deposits.

4-6 Drilling

Four drilling holes in total were performed in this phase where lead and uranium ore deposits were forecast to exist by the first phase survey, namely, the MR-1 hole in the Tanfi-Micha area, 2 holes (the MR-2 and MR-4 holes) in the Itzar basin area and the MR-3 hole in the Bou Mia eastern area.

Tanfi-Micha area is located north of the Zayda granite body. It is a zone of very stable geological structure running north with a gentle slope from the veinlike uranium mineralization sites of Assaka-n-Tabhirt, Paneau-1, etc., in the granite body. And also, the lead ore deposits, and concentrations of uranium in the P-T Red Sandstone Formation and Quaternary were expected. The MR-1 hole in this area was drilled at a site about 5 km north from the northern border of the Zayda granite outcrop. It revealed a P-T Red Sandstone Formation 5.00 m under the ground surface and reached the granite basements at a depth of 144.8 m (1295.20 m above sea level). The P-T Red Sandstone Formation consists chiefly of mudstone intercalating siltstone of about 1 m thick, accompanying decolored zones of about 10 cm thick and thin gypsum beds in places. In radioactivity well logging, an anomalous value of 90 c/s, about 5 times the background was observed at

about 75 m. A decolored zone of about 80 cm existed near the anomalous zone and black minerals exist in part of it. Investigation of this specimen by XMA analysis revealed that it was a minute aggregation of galena, chalocite and sphalerite but no uranium mineral has been confirmed. The analysis value of uranium in this spot 30 cm width was U=0.005%.

The Itzar basin area is located north of the Zayda-Bou Mia granite bodies, it is a basin structure zone of the Tertiary formed by upheaval of the Yahia-Oufalla fault northeast block, but the area is assumed to contain the P-T Red Sandstone Formation which was transported and deposited from the Bou Mia granite zone toward Karrochan basin in the Permo-Triassic, and lead and uranium ore deposits were expected in this formation. A drilling made in this area (MR-2 hole) was made on the northern border of this basin. Siltstone beds of the Tertiary exists from the ground surface to a depth of 32.00 m, Kzcm Mudstone Formation of the Cretaceous from depth 32.00 to 100.00 m, β_{P-T} Basalt Formation from depth 100.00 to 108.00 m, and P-T Red Sandstone Formation from depth 108.00 to 264.90 m. The basements granite was reached at a depth of 264.90 m (1280.10 m above sea level). The P-T Red Sandstone Formation in this hole consists of the mudstone beds down to nearly 243 m, and includes discolored zones in places, gradually it changes to coarse grains downward and arkose sandstone becomes the major component from about 251 m downward. In radioactivity logging, at about 165 m and about 240 m, measured values of 50 c/s and 40 c/s, nearly 2 times background was detected. Near the first point, at 169.70 m, minute disseminations of galena in the discolored zone was observed and U=0.015% of width 1.00 m was detected in uranium analysis.

One of the drilling holes carried out in the Itzar basin, the Mr-4 hole, was on the northeastern border of the basin. Surface soil and Quaternary deposits were found from the ground surface to the depth 7.15 m.

T_2 Marl Formation and T_1 Mudstone Formation of the Tertiary are from 7.15 to 57.40 m, K_2t Limestone Foramtion and K_2cm Mudstone Formation of the Cretaceous is from 57.40 to 198.45 m; the P-T Red Sandstone Formation is from 198.45 to 372.00 m and the basements granite at 372.00 m (1258.00 m aboved sea level) sere found.

The P-T Red Sandstone Formation in this hole forms mudstone beds containing of gypsum down to almost 328.00 m, from this point it became gradually more coarse, and downward from depth 350.00 m arkose sandstone was found. In radioactivity logging in this hole no high anomalies were found, and in geological observation no mineralization was ascertained also.

The drilling MR-3 hole was carried out in the palaeochannel of P-T Red Sandstone Formation sedimentation in the basin south of the Zayda-Bou Mia granite bodies which was estimated by gravity prospecting in the first phase survey. From the ground surface to the depth of 102.65, T_2 Marl Formation and T_1 Mudstone Formation of the Tertiary were found, from 102.65 to 136.50 the P-T Red Sandstone Formation was found, and at a depth of 136.50 m (144.40 m above sea level) the basements granite was reached. The P-T Red Sandstone Formation in this hole was siltstone down till the basements, and decolored zones of width 1 ~ 110 cm were observed in some places. But in radioactivity logging, only a weak anomaly about 2 times of the background value was observed in the lower part of this formation and no remarkable mineralization was recognized.

The results of the above 4 holes drilled this year show that the altitude of the basements becomes deeper northward to the north of Zayda-Bou Mia granite outcrops and slopes gently toward the west, and the P-T Red Sandstone Formation deposited on it also get thicker westword. Moreover it is observed that a tendency of the lower arkose Sandstone beds

increase in thickness toward the west. And also, in the two holes of the eastern side (MR-1, Mr-2), weak uranium anomalies and lead mineralizations were observed that in the P-T Red Sandstone Formation, and these facts suggest that the existence of ore deposits in this area is note-worthy.
On the southern side of the Zayda-Bou Mia granite bodies, the sedimentary Environment is markedly different from that on the north side. The P-T Red Sandstone Formation on the basements on the southern side lacks arkose sandston, and mudstone of this formation is deposited directly on it.
This fact is considered to indicate that in this area supply of materials from the southern crystalline schists was greater than that from the northern granite body. And on the P-T Red Sandstone Formation, the Tertiary formations are deposited directly, and the Mesozoic formations are missing. It means that this area was a land in the Mesozoic era.

Chapter 5 Summarization of Survey Results

5-1 Survey Methods

The subject areas of this phase survey are areas considered to contain lead and uranium ore deposits in the first phase survey, principally as a result of the general geological survey, the surface radioactivity survey and gravity prospecting. In survey, various methods were adopted simultaneously according to the aims in each area. That is, in the Karrouchan area, to obtain information about the status of the strata embedding the ore deposits and about lead and uranium mineralization, a detailed geological survey and a surface radioactivity survey were performed; in the Bou Mia northern area and the Zayda northeastern area, to clarify existing condition of lead and uranium ore and geologic structural restrictions, a detailed geological survey, a trenching survey of mineralized sites and a detailed sketching survey were performed; and in the sedimentation basin north of the Zayda-Bou Mia granite body, to clarify the basement structure and sedimentation environments and to get informations on uranium ore deposits underlaying, a gravity prospecting, drillings and a radon-etch survey were performed. Furthermore in the sedimentation basin, south of the granite body, to clarify the sedimentation environments and existence of mineralization and to allow comparison with the results of gravity prospecting in previous year, a drilling was conducted. Through survey mentioned above, geological structures, deposition mechanism and geological control on mineralization were clarified, and areas where is the possibility of embedded ore deposits were selected.

Especially, the radon-etch survey method which was adopted for the first time in this phase, has been succeeded in detecting an area north of the Zayda granite body, in which anomalous values of radon density are

concentrated, and this method was able to reveal the existence of a underground radioactivity source which had not been detected in the earth surface radioactivity survey. Whether this anomalous value zone is actually induced by existence of underground uranium or not and whether such could be mined can only be determined by the results of further prospecting, but it is certain that the radon-etch survey is an effective method to determine target sites for prospecting in this area.

Moreover this area coincides with the vally-like structure of the basements found by the gravity prospecting carried out simultaneously, therefore this area is considered to have favorable geological conditions for uranium concentration and sedimentation. And geological information such as the depth of bedrock, contents of sedimentary rock, etc., obtained by three drillings is utilized in determining underground structures in gravity prospecting to improve it's accuracy, and on the other hand it played an important role in clarification of the geological structures and sedimentation mechanisms of the whole area.

The surveying method, combining the geological survey, radon-etch survey, gravity prospecting, drilling, and so on, is exceedingly effective in clarifying geological structure of the survey area and for selection of the targets of prospecting, so application of similar surveying method with improved precision is desirable in further prospecting.

5-2 Considerations on Geological Structures

(1) Structure of the basements

The basements in the surveyed area are assumed to be granite for the most part, including the area covered by sedimentary rocks. But there are highly anomalous gravity zones in the eastern part and northwestern parts; Karrouchan area, and these are considered to correspond to crystalline schists.

In shallow underground, connecting the Zayda granite body and Bou Mia granite body, a saddle-like structure stretching E-W almost horizontally is considered to lie hidden, and bordering this saddle structure, the north side tends to decrease the height of the basements toward the north and south sides to the south in a similar manner.

The saddle-like structure shows a dividing ridge shape in the present basement, but at the time of palaeotopology formation the dividing ridge is considered to have been located further southward from the results of the geological survey.

And from the result of gravity prospecting the existence of fault-like structures of NE-SW or NNE-SSW strike in the basements and ridge-like upheaval of the basement in the same direction were presumed to exist in several places. As representative ridge-like structures, there is a ridge north of Itzar and a fidge on the west of the central fault structure. The former is a factor in formation of the basin structure on the east side. And another basin structure in this region is also assumed south of Bou Mia.

On the upper surface of the basements granite, belt shaped grooves in the direction of NE-SW, N-S and NW-SE are regarded to give the valley-like structure in a few spots. These valley-like structures are seen as being sloped, from the height of the basements, toward the north in the north side of the Bou Mia-Zayda granite body, and sloped southward in the south side of that, but from the results of geological surveying and drillings, at the time of palaeotopology formation the slope dominated from south to north as a whole, and thereafter, by sinking or tilting of the south side block the present status is considered to have been formed. The distinctive features in the principal area are as follows:

i) Valley-like structures distributing in the basin structure to the east of Itzar appear to lead north after forming the basin or lake-like reservoir.

ii) In the east side of the fault-like structure in the NNE-SSW direction in the central part of the surveyed area, several valley-like structures are assumed to meet and to run northward.

iii) A valley-like structure in the graben structure is presumed to lie between 2 fault-like structures in the eastern part of the surveyed area.

The heights of the basements were made elear by drillings in this phase. It was confirmed to become lower from east to west. And in the Karrouchan area west of them, the basements is higher than on the east side at present as a result of the uplifting of the northwest side block caused by the Yahia-Oufalla faulting, but from the fact that the thickness of sedimentary rocks just above the basements gets thicker toward west, it is considered that at the time of palaeotopographic formation the basements height in this western area was low and a large graben-like or basin-like structure existed to the northwest.

The basin-like structure is assumed from the results of gravity prospecting to have existed in the Itzar eastern area and Bou Mia southern area as mentioned above.

As to whether this basin-like structure already existed at the time of palaeotopotraphic formation or not, there are several problems remaiuing and a conclusion can not now be drown, but at least concerning the basin-like structure of the former, since the lowermost arkose sandstone bed of the P-T Red Sandstone Formation shows a tendency to get thicker (7 m to 22 m) as found in drillings made around it and since the Cretaceous stratum appears not to have sunk compared with that on the peripheries, it is considered that this structure had already been formed at this time. However, concerning of the later, the ground surface is covered with a

Quaternary formation and drilling was not tried, therefore the contents of this basin can not be clarified. But since formation of the large graben in the east-west direction occurred after the Jurassic period to the south of this area, it is very possible that the subsidence occurred in later period.

(2) Sedimentary environments

Sedimentary rocks in the surveyed area are accumulated in the sedimentation basin located between the Moyen Atlas mountains to the northwest and Haut Atlas mountainous region to the south of the surveyed area, generally speaking. But detailed observation reveals that there is a difference in constituents and stratum thickness between the northern area, southern area and northwestern (Karrouchan) area which bordering the Bou Mia-Zayda grinite body in the central part of the survey area, and the environment at the time of sedimentation is considered to have differed fairly each area.

It is imaginable naturally that sedimentation of the Permo-Triassic formations directly covering the basements was greatly controled by the palaeotopology of the basements. On the north side of the Bou Mia-Zayda granite bodies, formations are deposited on a gentle northward sloped the basements, while the arkose sandstone beds of the P-T Red Sandstone Formation tends to become thicker toward the north and west, and the upper basalt formation is roughly horizontal at present as clarified by drilling carried out in this phase.

These facts suggest that the present basement structure is nearly the same as the palaeotopography of the basements at that time, and the sedimentation advanced from the south to the north or northwest. Also it shows that in the early stage, sedimentary materials were supplied from granites because arkose sandstone exists in the bottom layer.

In the Karrouchan area in the northwest of this area, the P-T Red Sandstone

gets gradually thicker, and arkose sandstone also tends to increase in thickness. This indicates that in the Permo - Triassic sedimentation period, this area was connected to the former area and a graben-like or basin-like structure existed in the northwest. In spite of the fact that the basements in this area is crystalline schist, thick arkose sandstone exists which indicates that supply of materials was carried from the south-eastern granite body.

In contrast to the above 2 areas, in the area south of the Bou Mia-Zayda granite bodies, the arkose sandstone is very thin or missing though the basement has a southward slope, and mudstone covers the granites of the basements as shown by a drilling in this phase. These facts show that sedimentary materials were carried from the southern crystalline schist, and they are considered to show at the same time that the basement is higher in the southern part than in the central part.

On the other hand, among valley-like structures made clear by gravity prospecting, those in the NNE-SSW direction are developed, and are situated roughly in parallel and extend comparatively far. They become lower toward the northeast, in the north of the central part, and become lower toward the southeast in the south. But if it is assumed that the south side occupied a higher position at the time of palaeotopographic formation, as mentioned above, then both sides is assumable to have been connected together and it can consider to be a valley-like structure that ran wholly toward the northeast. Besides these, as secondary valley-like structures, there are compartively short ones in the NW-SE direction and N-S direction, and they are considered to reflect a dam-like structure against the principal direction. The direction of sedimenents of arkose sandstone which is clarified by the cross-bedding and sole marks observed in the geological survey indicate that the north or north-northeast direction dominates, and that

sedimentation was governed by the palaeotopographic valley-like structures.

As a results of above surveys in this area, the Permo - Triassic sedimentary environments can generally be considered to be as follows:

The palaeotopography of that time indicates overall a stepwise shape tilting a little to the north, arranged in several NE-SW trend faults in parallel, and considered to have decreased in height gradually toward the Karrouchan graben zone which occurs in the northwest. The clastic materials deposited on it are assumed that overall supplied from the southeast side toward northwest throughout the entire period. However, in the early period of sedimentation, materials flowed down toward to north or northeast along the valley-like structure strongly influenced by the topography of the basements, and the sedimentation is considered to have progressed froming thick deposits on depressions and valleys.

There is no great change in the post-Jurassic sedimentation environment from the conditions clarified in the first phase survey, generally speaking. Jurassic formations were observed almost throughout the whole region of the surveyed area, except the Bou Mia-Zayda granite body and the north area of it. This fact indicates that during the Jurassic, the granite body around the central part and its northern area were land, and it's peripheries were areas of sedimentation. And as sedimentary rocks of this period consist chiefly of limestone containing abundant fossils and siltstones. Sedimentation is considered to have occurred under a neritic environment. But in the Haut Atlas area, south of the surveyed area, a trough in the NEE-SWW direction has developed especially in the Dogger period, in which abyssal dark gray mudstone is deposited and a slightly different sedimentary environment is reported (I. Evans and others : 1976).
This tendency is confirmed by the drilling results which revealed an increase in thickness of sedimentary stratum in the south of the surveyed area.

The Cretaceous formations are distributed over almost the entire surveyed area, and it is considered that in this period the entire area including the central part was submerged beneath a sea. And sedimentary rocks in this period are mainly limestone and mudstone containing much gypsum. A sedimentary environment of bay type is considered to have been formed by repeated drying and inundation. The sedimentation from the Permo-Triassic to the Cretaceous progressed under rather stable conditions suffering no tilting (though there was partial development of troughs) thus unconformity of between each formation is rarely observed. But changing to the Cenozoic, by Alpine orogeny activated in the Miocene, both zones of the Moyer Atlas and Haut Atlas suffered deformations such as upheaval, faulting, folding, etc., and faults trending N 30° E developed principally in the central basements area. The area that suffered the severest influence is the Karrouchan area in the subject area of this phase survey, which lies on the northwest side of the Yahia-Oufalla fault. And in this area anticline and syncline structures with NE-SW axes, and faults of a NE-SW direction N-S direction, etc., are well developed. The Tertiary formation are deposited around the central part of the survey area, and these correspond to the inland basin formed by upheaval of the Moyer Atlas and Haut Atlas. These formations chiefly consist of materials originated from surrounding rocks such as siltstone, marl, conglomeratic sandstone etc., and there was no deposition of clastic rocks from weathering of the granite body. Therefore, it is presumed that the granite body was not eroded during the Cretaceous to the Tertiary.

At the end of the Tertiary, this area upheaved as a whole and erosion developed and exposed the granite body in the central part. The sedimentation of the Quaternary is considered as have happened around this inland basin. Especially in this period, it is assumed that the Karrouchan area

was uplifted relative to the inland basin, and at the same time south of Bou Mia, formation of subsided topography followed the middle Tertiary.

5-3 Consideration of Mineralization

The first phase survey investigated ore deposits and mineralizations in this area. Concerning the mineralizations the following was clarified.

Lead ore deposits: sandstone type, stratified dissemination type, vein type.

Uranium mineralization: vein type, sandstone type, conglomerate type, Carapace type.

This phase survey carried out for the selected areas in which sandstone type lead ore deposit and uranium ore deposits are expected.

(1) Lead ore deposits

Sandstone type lead ore deposits exist in the arkose sandstone beds which is the bottom beds of the P-T Red Sandstone Formation, and around the Zayda granite body mining is already in operation about a portion of it. In this surveyed area, in addition to the low-grade ore observed in the arkose sandstone which fills the valley-like depression in the granite body in the Bou Mia northern area, several ore bodies not yet mined have been clarified around the Zayda granite body. In the former, the sedimentary direction of sandstone containing the embedding beds is indicated as northeastward and the ore deposit also extends in that direction. But on the east side which lies in the direction of its continuation, a block is cut by a south-north fault, therefore the existence of a concealed deposit is expected though its location, scale and so forth are not clear.

Concerning the lead ore deposits around Zayda, ore bodies are arranged, on or along both sides of the valley-like structure of the basement which was made clear by gravity prospecting in this phase, and it has been shown

that the ore deposits are closely related to the palaeochannel at the time of arkose sandstone sedimentation.

On the other hand, the drilling carried out south of Zayda in this phase, has shown that the basement is directly covered by mudstone, and that the arkose sandstone beds which contains ore minerals is missing, and so existence of an ore deposit is unexpectable in this area. Therefore in future prospecting, it is necessary to make clear the existing scope of arkose sandstone and to look for valley-like structure on the basements. Generally judging from the results of this phase's gravity prospecting and drillings, the favorable area of ore deposits is expected to be limited to north of the line extended from Bou Mia village toward East-Northeast. The area along the valley-like structure which runs forwards the Itzar basin in particular shows the tendency of the arkose sandstone to get thicker, so this is a promising area for lead ore deposits, and prospecting in this area should be performed.

(2) Uranium mineralizations

In the Zayda northeastern area surveyed this year, the character of the vein-like uranium mineralization which lies just above or in the dyke in the sheared zone of the granite body were clarified. Uranium minerals in this area chiefly consist of primary minerals, such as uraninite, pitchblende etc., and secondary minerals, such as carnotite, etc. Analized ore grade is U = 0.03% or less an average, so these minerals are not suitable for mining. But the uranium mineralizations in this area are distributed more densely than in other areas, and analized values of U = 0.33% are observed in a place. Especially in this area, most of the P-T Red Sandstone Formation has been erroded off and has been carried away. Since it is considered possible that uranium was dissolved and transferred with it, this area is regarded as an important supply source of uranium.

In the Bou Mia northern area, Carapace type uranium mineralization was observed. Which were confirmed as tyuyamunite, a secondary uranium mineral, that exists in depressions of the basements presenting a roughly horizontal lenticular shape. And also, in this granite body, existence of a highly anomalous zone of radioactivity is known. This Carapace type uranium mineralization is considered to be uranium minerals in the granite body that had dissolved and been carried by water, then reduced in the depression of the basements, deposited and concentrated. In this year's survey in the Karrouchan area, no conspicuous uranium mineralization was confirmed, and only measured values of radioactivity of 150 c/s in the bottom arkose sandstone beds of the P-T Red Sandstone Formation were observed. But this value is a high value compared with the radioactivity measured value 100 c/s of similar strata in this area, therefore it should be noted.

As mentioned above, in the survey of the surface, a uranium ore deposit suitable for mining has not confirmed, but in the radon-etch survey which was carried out to detect underlying deposits this year, a highly anomalous value zone in the P-T Red Sandstone Formation distributed area, northeast of the Zayda granite body; medium anomalous value zones located rather closely together in the Cretaceous formations area, north of the Bou Mia granite body; and weak anomalous value zones scattered in the Cretaceous formations distributed zone, northwest of Zayda were detected. However no anomalous value indication was detected in the ground surface radioactivity survey in each area. This shows that these anomalous values originate in uranium concealed underground.

The relation between the results of gravity prospecting and geological surveys, performed simultaneously in this phase and these anomalous valued areas is summarized below.

Anomalous value zone northeast of Zayda granite body:

The anomalous value zone in this area is about 7 km wide and distributed in the northwest direction. It is divided into several anomalous value sub-zones. Among them, the zone north of Paneau-1 ~ Immayn-n-Aït Rohhou located in the southwestern part attracts attention as an area where high anomalous values 10 times the background and 34 anomalous values are concentrated. This site lies on the extension of NE-SE sheared zone in which uranium mineralization was confirmed in the above mentioned Zayda granite body. Gravity prospecting shows that in this area the velley-like structures of the basement concentrate in the northwest direction with rather gentle slopes at a depth loss than 100 m, and that the basements structure changes towards the northwest. On the other hand, the direction of sedimentation observed in arkose sandstone remaining on Zayda granite body is almost northeast and roughly coincides with the valley-like structure of the basements. From these facts, the high anomalous value zone found by Radon-Etch survey in this area can be considered to indicate that a vein-like uranium ore deposit of comparatively high uranium content in the Zayda granite body of the hinterland dissolved in water after oxidazation and flowed down along the valley-liked structure (:alaeochannel) northeastward and was reduced and deposited where the valley-like structure curves. The oxidation, dissolution, transportation, reduction sedimentation of uranium, besides occurring during the arkose sandstone sedimentation may also have continued from the Quaternary to the present age, and in this case besides arkose sandstone, mudstone in upper portion may have accumulated concentrations of imprognated uranium. On the other hand this anomalous value zone is also located in the extension of the NE-SW trend sheared zone and dyke as already mentioned. Accordingly this anomalous value zone may perhaps only reflect the vein type uranium mineralization as can be seen on the Zayda granite body. But even if this is the case, leaching

in the present age must have been avoided, and in fact possibly Canadian Key Lake type concentration is takeing place.

It is said generally that the detection depth of radon-etch survey is within 200 m, and strength of anomalous values are recorded at the same value for a high-quality ore deposit located in a deep position and a low-quality ore deposit located in a shallow position. Therefore it is not clear whether the anomalous value indicates a grade and scale that could be recommended for mining. To resolve this problem it is necessary to determine the scale and nature of the uranium mineralization by a detailed radon-etch survey with close spacings, and to undertake core boring.

· Anomalous value zone north of Bou Mia:

The anomalous values in this area show 2.5 ~ 4 times the average background value, and the values themselves are not particulary high. But, since many of the spots which show this anomalous value are located in areas where the Cretaceous strata are distributed, this cannot be regarded as simply the same as values in the P-T Red Sandstone Formation. In the results of the geological survey of this area, high radioactivity measured values were reported for the crushed zone in the Bou Mia granite body and Carapace type mineralization were also observed in places. Furthermore, the area showing these anomalous values is a place at which the basements decrease its height from Bou Mia north, and also shows a graben structure, and the sedimentary direction of the arkose sandstone on the basements appears to be leading north. Therefore it is possible that the uranium in these granite boodies dissolved and was carried away and concentrated underground near this anomalous value during arkose sandstone sedimentation. As also described in the previous paragraph, it is known that radon detection becomes weak in proportion to the depth, accordingly if values are not so high as anomaly values at a site where the upper part is covered

by Cretaceous formations as here, this indication must be noted as a subject area for future investigation.

In this phase survey of this area, the radon-etch survey with a large spacing between measuring points was performed and gravity prospecting and drilling were not performed. Accordingly the accurate depth of the basements and valley-like structures are not known. Prospecting to collect information on these points is required hereafter.

· Anomalous value zone northwest of Zayda village:

In this area anomalous values of 1.9 to 3.4 times the average background value are dispersed. By treating areas of more than 1.25 times the background value, including these anomalous values, as a sub-anomalous area, it can be observed that its direction of extension shows a tendency to correspond to the valley-like structure of the basement and depression in the basement found by gravity prospecting. The basements depth of this sub-anomalous area is assumed to be 100 to 200 m, and considered to be close to the limit of the detection depth, therefore it has the possibility of being an anomalous zone. On the other hand, the sub-anomalous zone corresponds to the peripheries of the basin structure, especially to the inlet part of the valley-like structure in the south and to the part considered to be an outlet in the north. Also, since the basements depth around here is estimated to be as deep as 200 to 300 m. There is a possibility of radon-producing elements not only in arkose sandstone bed but mudstone beds or in the Cretaceous formations above it.

5-4 View to Future program

Recently many uranium ore deposits have been discovered in various parts of the world, and detailed surveys and investigations have been performed and results of the studies on the origins reported. Hitherto, in

studying the origin of uranium ore deposits, there was a tendency to classify existing forms, but lately research has progressed to discussion of origins emphasizing the behavior of uranium ions. The following table R.H. McMillan gives the latest classification of ore deposits taking the above into consideration.

Classification of important uranium deposits

Genetic type of deposit		Structural or Petrographic Association	Characteristic Elements	Characteristic Minerals	Examples
IGNEOUS		Carbonatite, Alkaline syenite	Nb, U, Th, Cu, P, Ti, Zr, REE	uranothorianite, pyrochlore, betafite, perovskite, niocalite, ilmenite apatite, zircon	Prairie Lake, Ont.; Nova Beaucage, Ont.; Poços de Caldas, Brazil
METAMORPHIC		Pegmatite (alaskite), Skarn	U, Th, Mo, REE, Nb, Ti	uraninite, uranothorite, molybdenite, betafite, fluorite, zircon	Bancroft, Ont.; Rössing, S.W. Africa
DETRITAL	Placer	Pyritic Quartz Pebble Conglomerate	U, Th, Ti, REE, Au, Zr, C	uraninite, brannerite, pyrite, monazite, native Au	Elliot Lake, Ont.; Witwatersrand, S. Africa
HYDROGENIC	Hydrothermal	Volcanogenic	U, Th, REE, Mo, Cu, F, Sr	uraninite, uranothorite, fluorite, celestite, pyrite	Rexspar, B.C.
		Hydrothermal Veins	U, Th, REE, Be, Nb, Zr	uraninite, brannerite, thorite, allanite, quartz, fluorite, carbonates, sulphides	Bokan Mtn., Alaska
	Syngenetic	Shale, Phosphorite, Evaporitic Limestone Duricrusts (Calcrete)	U, P, V, Cu, Co Ni, As, Ag, C	pitchblende, carnotite, apatite, gypsum, carbon	Ranstad, Sweden; Kitts, Labrador; Todilto Limestone, New Mex.; Yeelirrie, W. Australia
	Epigenetic	Sandstone (Tabular, Roll, etc.)	U, C, Cu, V, Se, Mo	pitchblende, pyrite, coffinite, carnotite	Colordo Plateau; Wyoming, Texas Basins
		Channel Conglomerate	U, C	pitchblende, marcasite, coffinite, autunite	Kelowna-Beaverdell District B.C.; Ninge Toge, Japan
		Lignite	U, C, Mo, V		Cypress Hills, Sask.; Dakotas
		Classical Veins	U, Cu, Ag, Co, V, Ni, As, Au, Mo, Bi, Se	pitchblende, pyrite, chalcopyrite, Ni-Co arsenides, native Ag, Au	Beaverlodge, Sask.; Port Radium, N.W.T.; Schwartzwalder, Colo.
	Syngenetic, Supergene and Epigenetic	Unconformity Veins	U, C, Cu, Ag Co, Ni, As, V, Se, Au, Mo	pitchblende, pyrite, Ni-Co arsenides, chalcopyrite, native Au, Ag	Wollaston, Key and Cluff Districts, Sask.; Midnite, Washington
	Supergene	Cappings, Enrichments	U, Si, Ca, Cu, Ag, Ni, As	'gummite', uranophane, carnotite, coffinite	Bolger, Eldorado, Sask.; Poços de Caldas, Brazil; Rössing, S.W. Africa

After R.H. McMillan, Update on Uranium Deposits (CIM Bulletin Vol. 72, No. 802, 1979 pp.152)

This classification provides rough division into the deposits in which uranium concentrated in the form of primary minerals as it is; such as igneous rocks, metamorphic rocks and conglomerates; and other deposits which uranium once dissolved into water then deposited again by physical and chemical reactions caused by geological factors, then concentrated into other rocks. The origin of the uranium in the former is obvious - ore deposits are formed in situ or by similar conditions. In the latter, the source origin is located in a place apart the deposit, and the origin is occationally quite unknown. Various forms resulted from geological components on the recieving side; and dia-strophysm occurring later. It is known that this takes different features in each area. Geological surveys have revealed uranium ore deposts in this area as the vein-like mineralizations attending sheared zones or dykes in Bou Mia-Zayda granite body of the basements. The portion of this ore deposit which lies on the ground surface is considered to have been leached by rain water after the Quaternary, and its quality is very low. But in the area exposed by lead ore deposit mining, high anomalous radioactivity is indicated along these veins, and as uranium minerals, beside the secondary minerals - carnotite and becgerelite, primary minerals -- uraninite and pitchblende are observed. These are considered, to belong to the Igneous type as stated. On the other hand, the results of radioactivity measurement in the first and second phases showed high radioactivity measured values of 100 to 150 c/s for granites - average 80 c/s for P-T Red Sandstone Formation (partially 130 c/s in Karrouchan area) - therefore there is a possibility of hydrogenic ore deposits, in the P-T Red Sandstone Formation, that were formed at or later than its sedimentation, as granites were source rocks.

For the formation of this type ore deposit, the processes of oxidation, dissolution, reduction, and sedimentation of uranium are required.

And, it is considered that physical and chemical conditions to form a reductive environment have an especially important meaning for concentration. As areas where the existence of this type of ore deposits in this area is expected, several anomalous value zones have been found by radon-etch survey. These anomalous value zones are located in valley-like structures and their confluencies. As for the physical conditions, since these are peculiar spots in the area, the reduction conditions are considered to be rather easily attainable.

As hydrogenic type uranium ore deposits expected in these anomalous value zones, the Carapace type observed north of Bou Mia, various sandstone types and classical vein types and others have been considered. But the one north of the Zayda granite body is located on a extension of above mentioned vein type mineralization, so it may be indicate that it is only the vein type ore deposits. The actual status of its contents is a theme for future investigation and these discussions are based on assumptions at present. The areas where a possibility of embedded uranium ore deposits is considered high and a guiding policy for prospecting in each area determined an integrated investigation based upon the results of surveys are as follows:

(1) North of the Zayda granite body:

The highest anomalous values found by radon-etch survey are concentrated in this area, and as mentioned above, the area have granite in the hinterland which indicates high radioactivity measured values in the surveyed area, and a basement structure that contains concentrating valley-like structures, and the hydrogenic type uranium ore deposts or vein type ore deposits concentrated in the sheared zones of granite is strongly expected in this area.

In the radon-etch survey performed in this phase, the spacings of the

measuring point were arranged at more than 500 m, accordingly the characters of the anomalous values for example the accuracy of distribution, direction of extension and other characters could not be clarified. Therefore next phase performance of a radon-etch survey in a anomalous value concentrated area over about 85 km at measuring point intervals of 100 to 200 m, or more densy as circumstances require is desirable. And at the same time, to clarify the cause of these anomalous values, core drilling should be performed and by performing a simultaneous core observation, radioactivity well-logging and core uranium content analysis, it will be possible to make clear the actual status of the uranium concentration underground.

In deciding boring depth, in consideration of the existence of the above said vein type ore deposit, granite should be drilled for about 10 m with reference to the basement depth determined in gravity prospecting and by other methods.

(2) North of the Bou Mia granite body

The Cretaceous formations are distributed over this area and radon-etch sub-anomalous zones were observed rather closely in this area. The results of the geological survey confirm vein type and carapace type uranium mineralization in the Bou Mia granite body in the hinterland. And the radon-etch sub-anomalous zones coincide with the graben structure on the north slope of the basements, and furthermore the sedimentation direction of the P-T Red Sandstone Formation is assumed to point to this area. Thus, hydrogenic type uranium ore deposits are expected have deep underground. The spacing between measuring points in this phase radon-etch survey was 500 to 1,000 m, so very approximate. Since, gravity prospecting was not performed, the depth of the basements and valley-like structure are not clear. Accordingly it will be necessary in future surveys to clarify the structure and depth of the basements by carrying

out gravity prospecting for an area of about 100 km and to 4 drilling, or so, to a depth 250 to 400 m. To make the prospecting target clear, performance of a dense radon-etch survey is also desirable.

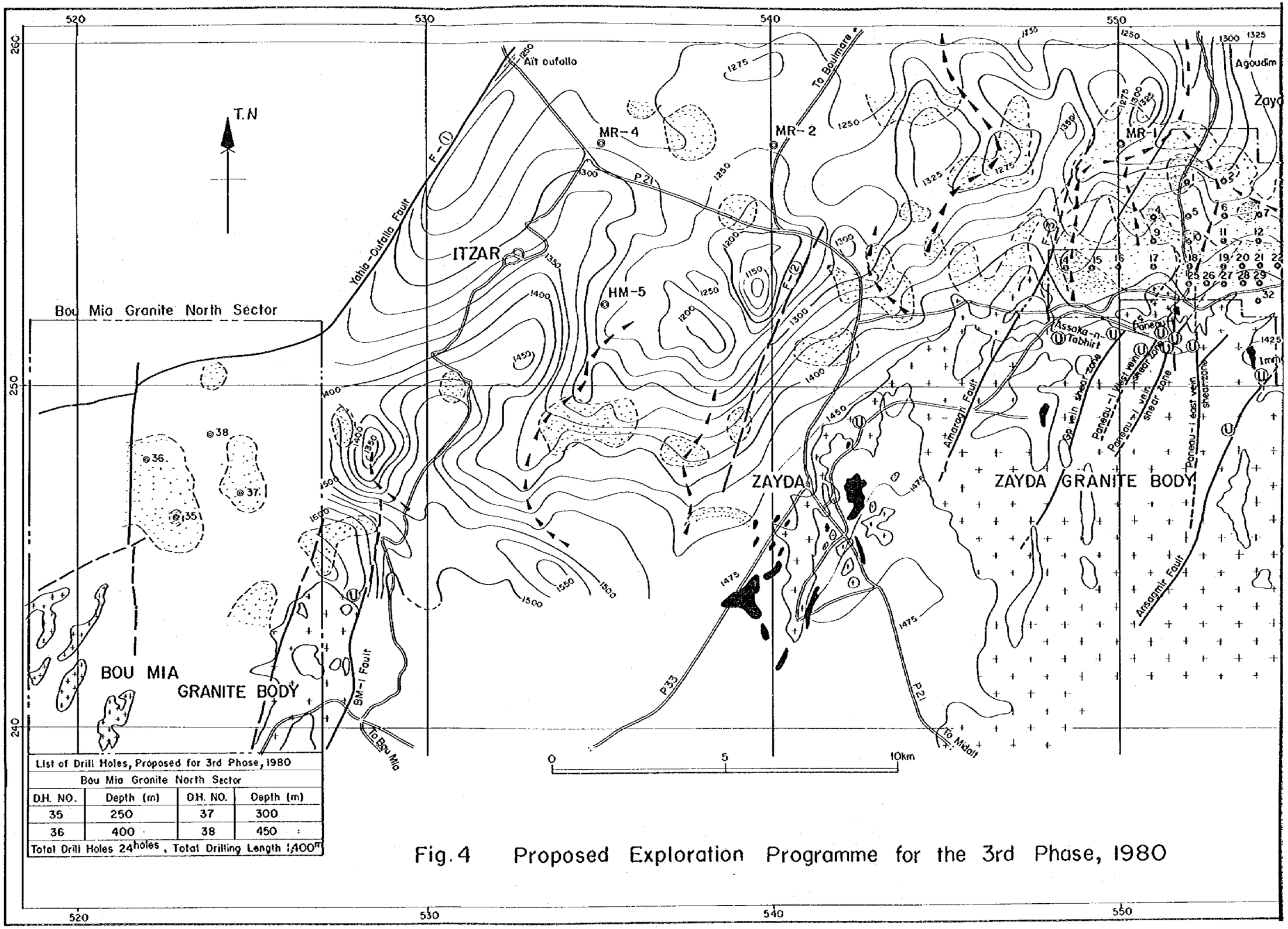
(3) North of Zayda

In this area, the existence of scattered weak radon-etch anomalous values was clarified in relation to the valley-like structure toward the Itzar basin structure determined by gravity prospecting. Given to Itzar basin structure, the existence of hydrogenic uranium ore deposits is expected at more than 200 meters underground.

However, the amount of information on uranium mineralizations in this area is extremely scarce compared with the former 2 areas, therefore it should be excluded from the immediate prospecting targets, and desirably a reinvestigation should be made when more information about the uranium in the peripheral areas is made available.

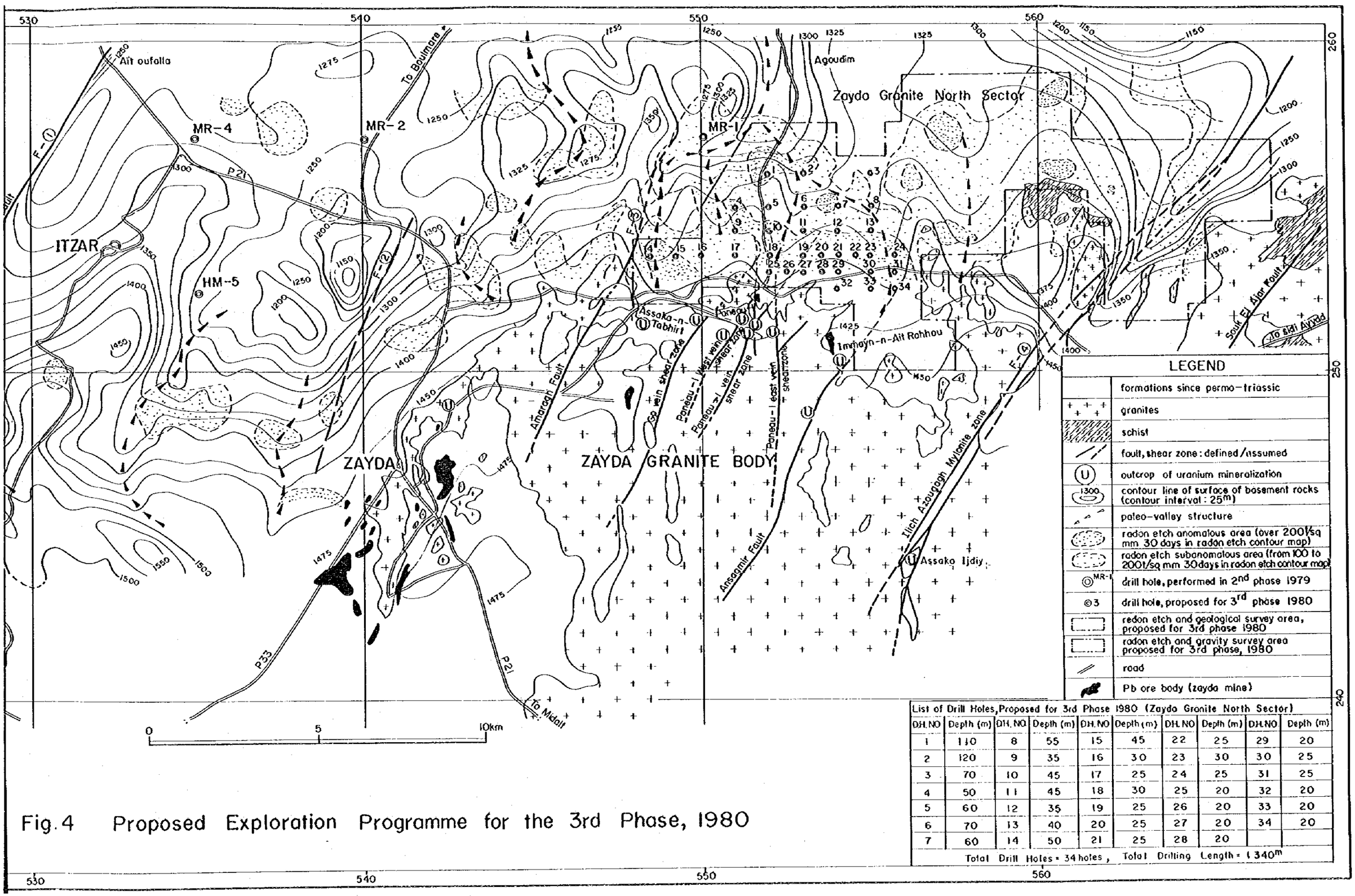
(4) Karrouchan area

In this area, rather high radioactivity measured were values obtained in the P-T Red Sandstone Formation in this geological survey, and hydrogenic uranium ore deposits are expected. However, the stratum is considered to exist at a comparatively deep position underground due to the folded structure of this area, and so though it is necessary to carry out gravity prospecting and a radon-etch survey, it should be excluded from the immediate prospecting targets. On the other hand, the impregnated beds of sandstone type lead ore deposit in the surveyed area is limited to the arkose sandstone beds, at the bottom of the P-T Red Sandstone Formation. The results of a drilling in the sourthern part of the Bou Mia-Zayda granite body performed in this phase, showed that this beds was missing, therefore, in this area the existence of a sandstone type lead ore deposit is not expected. And the known lead ore deposits are assumed to have a close relation with



List of Drill Holes, Proposed for 3rd Phase, 1980			
Bou Mia Gronite North Sector			
D.H. NO.	Depth (m)	D.H. NO.	Depth (m)
35	250	37	300
36	400	38	450
Total Drill Holes 24 holes, Total Drilling Length 1,400m			

Fig. 4 Proposed Exploration Programme for the 3rd Phase, 1980



LEGEND

	formations since permo-triassic
+ + +	granites
	schist
	fault, shear zone: defined / assumed
U	outcrop of uranium mineralization
1300	contour line of surface of basement rocks (contour interval: 25m)
	paleo-valley structure
	radon etch anomalous area (over 200 t/sq mm 30 days in radon etch contour map)
	radon etch subanomalous area (from 100 to 200 t/sq mm 30 days in radon etch contour map)
MR-1	drill hole, performed in 2nd phase 1979
3	drill hole, proposed for 3rd phase 1980
	radon etch and geological survey area, proposed for 3rd phase 1980
	radon etch and gravity survey area proposed for 3rd phase, 1980
	road
	Pb ore body (zayda mine)

List of Drill Holes, Proposed for 3rd Phase 1980 (Zaydo Granite North Sector)

DH. NO	Depth (m)	DH. NO	Depth (m)	DH. NO	Depth (m)	DH. NO	Depth (m)	DH. NO	Depth (m)
1	110	8	55	15	45	22	25	29	20
2	120	9	35	16	30	23	30	30	25
3	70	10	45	17	25	24	25	31	25
4	50	11	45	18	30	25	20	32	20
5	60	12	35	19	25	26	20	33	20
6	70	13	40	20	25	27	20	34	20
7	60	14	50	21	25	28	20		

Total Drill Holes = 34 holes, Total Drilling Length = 1 340m

Fig. 4 Proposed Exploration Programme for the 3rd Phase, 1980

the valley-like structures of the basements. For this reason lead ore deposits are expected in several valley-like structures toward the basin structure which was clarified by this phase gravity prospecting.

Accordingly, as guiding policy for prospecting hereafter, research and prospecting are desired in the arkose sandstone distributed area throughout which lies north of the line drawn from Bou Mia village extending NEE and with importance attached to places where valley-like structures exist.

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PARTICULARS

PART I GEOLOGICAL SURVEY

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Chapter 1 Geological Survey

1-1 Karrouchan Northeastern Sector

This surveyed area is located in the northwest of Haute Moulouya Area. As the result of the first phase investigation, this area belongs the sedimentary basin into which detrital materials were carried from the Zayda-Bou Mia granite area. Therefore, in this survey, the lithofacies, distribution, structure, and character of the sedimentary rock were studied sedimentologically to clarify the geological strucuture and the sedimentary environment. Subsequently, the palaeo-geography and the geological history in the southeastern area, including this area, were examined to make clear the probability of uranium and lead deposits in this area.

1-1-1 Geology

The geology in this area consists of the Permo-Triassic system, the lower Jurassic system, the Cretaceous system, the Tertiary system, and the Quarternary system in ascending order. No outcrops of crystalline schists and granites of the basement are found in this area, but the former is exposed at the Marrout river locating in the northeast part of this area, and the later near Aït Zid 6 Kilometer to east of this area and both are round along the national road 3 Kilometer east of Karrouchan.

(1) Permo-Triassic system

In this area, Permo-Triassic strata are thickly deposited. Especially, these strata are distributed widely in the western part of this area and the neighboring westward area. Since this area has a basin structure, it is called the Karrouchan basin in this report. The Permo-Triassic strata consists of the lower, P-T Red Sandstone Formation and the upper, $\beta_{P\text{-}T}$ Basalt Formation. As this area is relatively hilly, $\beta_{P\text{-}T}$ Basalt Formation is found in the heights, and the P-T Red Sandstone Formation is exposed in the low land areas such as valleys.

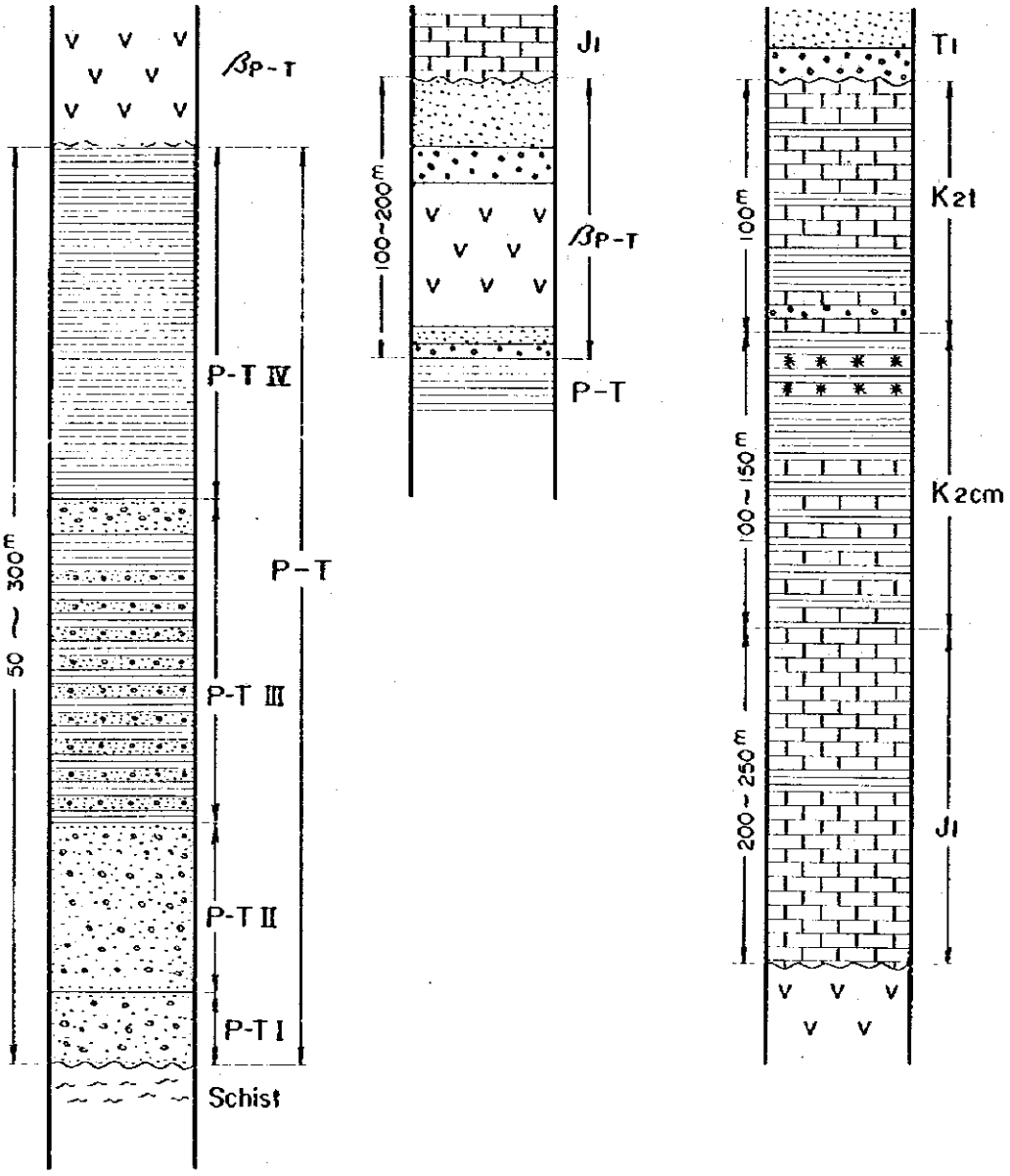

Fig. I-1 Schematic Geological Column of Karrouchan NE Sector

a) P-T Red Sandstone Formation

This formation covers directly on the Basement Complex with unconformity. The grain size of constituents in this formation tends to decrease upward. This Formation subdivides into P-T_I Formation, P-T_{II} Formation, P-T_{III} Formation and the P-T_{IV} Formation, based on the above lithofacies. The lowermost P-T_I Formation is observable in the Marrout river outside of this area. In this valley, the P-T_I Formation is a white conglomeratic coarse-grained sandstone consisting of pebbles, maximum 10 mm in diameter, and coarse-granied sand, 2 mm in diameter. The constituents of this formation are mainly feldspar fragments and small amounts of fragments(of granites, crystalline schists and quartz). This formation is about 30 meter thick, and because it contains large quantity of coarse-grained materials, it has the white massive appearance. However, in which, fine-grained thin layers containing visible bedding plane are rarely discerned. This P-T_I Formation is basal conglomerate stratum of Permo-Triassic system.

P-T_{II} Formation, overlying upon P-T_I Formation is also observed in Marrout river. It is characterized that this formation has been under the oxidized condition during its deposition. This Formation contains particles of 2 mm or less in diameter in large quantities and conglomeratics in small quantities. The main constituents of the particles are feldspar fragments, and also contains small fragments of granite, crystalline schist and quartz. The lithology of P-T_{II} Formation is the same as that of P-T_I Formation. In the exposed area in Marrout rivers, P-T_{II} Formation is about 80 meters thick with a thin shale and has been developed cross-lamina in the sandstone. It is impossible to clarify the detailed structure of this formation because the exposed area was too small. However, it is presumed that a palaeocurrent judging

from the cross-lamina has flowed to the north or northeast.

The P-T_{III} Formation is exposed from the weastern parts to the southwestern parts surrounding Karrouchan of this area. This formation had been deposited upon P-T_{IV} Formation and constitutes most of P-T Red Sandstone Formation, being generally reddish-brown with partially decolored greyish-white portions. This formation is about 100 meters thick, consisting of alternate sandstone and shale beds. The sandstone bed is about 3 meters thick and consists of small fragments of granite and coarse~medium-grained orthoclase, quartz, and mica. Under the microscope, these fragments are subangular and coated with limonite. Quartz shows wavy extinction, and the orthoclase has a perthite structure.
The shale bed is about 1 meter thick, and consists of the grains of quartz, orthoclase and carbonates. Under the microscope, these grains are 0.1 to 0.2 mm in diameter and rounded. Quartz shows wavy extinction, and orthoclase has perthite structure. The bed shows high degree of cross-bedding and sole marks, it is presumed that the palaeocurrent system has flowed in the direction of north by the former, and northeast by the latter. P-T_{IV} Formation, as P-T Formation, is found in the western and the southwestern parts of this area. This formation is the uppermost portion of P-T Red Sandstone Formation and lies under β_{P-T} Basalt Formation. It consists of reddishbrown sandy mudstone with a small amount of a fine-grained sandstone interspersed. Under the microscope, it was confirmed that this formation consists of quartz and orthoclase grains coated with limonite. The matrix consists of limonite, sericite, opaque minerals and carbonate minerals. This formation is 50 to 100 meters thick and has well developed lamina, in places, the slate-like feature.

b) β_{P-T} Basalt Formation

This formation is distributed in the central and southern parts of this area. The formation has conformable relationship with the underlying P-T Red Sandstone and with the overlying Jurassic formation.
The facies of this formation is varying in ascending order such as basaltic breccia bed, basaltic sandstone bed, basalt lava flow, conglomerate bed and red sandstone bed (See Figure I-1). Some beds of aboves are absent in some places, especially the clastic bed has remarkable change in the horizontal but the basalt lava which is main member of this formation does not to be absent.

The breccia bed corresponds to the basal conglomerate and is exposed at the bottom of the valley running in the southeasterly direction from Taghaghat. This bed is generally dark-green, but weathered parts are reddish-brown. The pebble size ranges from about 10 cm to about 1 cm in diameter. This bed contains basalt pebbles in large quantities and granite in small quantities. The maximum thickness of this bed is 3 meters. However, it discontinues frequently. The basaltic sandstone bed is deposited on basaltic breccia. This bed is not well developed, and was also locally observed. It shows dark-green and, generally, consists of fine sand grains of basalt. But, occasionally, this bed contains basaltic pebble of 1 cm or less in diameter. It is about 3 meters thick.

The basaltic lava flow is widely distributed from the northern to southern parts of this area. This bed is the principal member of the β_{P-T} Basalt Formation. It would be presumed that the clastic beds on and under this bed were deposited togather with the lava flow. This bed is generally dark-green with partially reddish-purple parts. Under the microscope, this basalt maily consists of plagioclase, pyroxene and opaque

minerals, and chlorite as altered mineral. The plagioclase is lath-shaped and extremely altered into sericite. Pyroxene shows sector twining of about 1 mm in diameter. The chlorite is alteration product of pyroxene. This lava flow is about 150 meters thick, and has well developed columnar joints.

The conglomerate bed is observed at only one place in the center of this area. It would be presumed that this bed was deposited locally on the lava flow. This bed is dark-grey, consists of football-size basaltic gravel and about 10 meter thick.

The red sandstone bed is visible in the central part of this area. This bed is the uppermost member of the β_{P-T} Basalt Formation. It shows reddish brown with fine grain facies without bedding. It consists of quartz grain in large quantities basaltic fragments in small quantities. It is about 10 meters thick.

β_{P-T} Basalt Formation is, as whole, 100 - 150 meters thick. Generally, in the surveyed area, the thickness is almost constant with little fluctuation. This formation follows the folding structure of the lower formation and has an anticline on the northern side and a syncline on the southern side.

(2) J_1 Limestone Formation, Jurassic system

The Jurassic system occurs widely in the northwest side of the Yahia-Oufalla Fault passing from NE to SW through Aït Oufalla. Especially, in the northeastern part, this Formation is widely distributing except for part of the valley. In the southwestern part, it is found as insular-form at the topographical heights. The folding axis of this formation shows in the NE-SW direction, and it extends in the northeasterly direction along the syncline. This formation becomes thinner toward the southwest. Generally, this formation consists mainly of greyish-white

limestone, which is generally massive in the northern part and stratified in the southern part. This Formation contains thin siltstone in the southern parts, and showed an oolitic structure in the area near Tirouwadine. The thickness is about 350 meters in a maximum, but about 60 meter in the southern part of this area.

(3) Cretaceous system

The Cretaceous system in this area consists of K_{2cm} Mudstone Formation of Cenomanian series and K_{2t} Limestone Formation of Turonian siries.

a) K_{2cm} Mudstone Formation

This formation is distributed in the northeastern and the southwestern parts in this area. It consists of siltstone containing thin gypsum layers, sandstone, marl and limestone. Siltstone, the principal component of this formation, has various colors, such as bluish-green, reddish-brown, yellow, and white. Sandstone is generally red, marl limestone are white and yellowish-grey.

In the northeastern parts of this area, this formation is distributed widely along the northeast-trending syncline axis and because of which is directly covered with the limestone of T_t Mudstone Formation, K_{2t} Limestone Formation is lacked. This formation is about 100 meter thick.

In the southeastern parts of this area, this formation is distributed on the southeastern outerside of the north-south fault running through Aït Obal Lahlam, and the northeast-trending Yahia-Oufalla fault.

It is covered with K_{2t} Limestone Formation and is 40 - 80 meters thick.

This formation strikes NE-SW, and dips about 5^{o} SW.

b) K_{2t} Limestone Formation

This formation is distributed from Jbel ou Zbayr, in the southeastern part of this area to Tirouwadine. It consists of calcareous conglomerate bed, siltstone bed and limestone-siltstone alternation bed in the ascending

order. The calcareous conglomerate bed consists of mainly pebble and semi-brecciated limestone gravel and partially brecciated limestone gravel. It is about 10 meters thick. It continues so clear that it could be traced almost completely in this area. The siltstone bed is white, and has the silky luster. It contains abundant shell fossils.

The limestone-siltstone alternation bed consists characteristically of limestone layers about 3 meters in thickness and siltstone layers of about 1 meter in thickness shows white or yellowish-white. K_{2l} Limestone Formation conformably covers the lower, K_{2cm} Mudston Formation, and is unconformably overlain by the upper, Tertiary system.

This formation strikes NE-SW, and dips 5 to 10°SE. It is 30 meters thick at the north-western end, and 70 meters thick at the southeastern end.

(4) Tertiary system

The Tertiary system occurring in this area consists of T_1 Mudstone Formation, T_2 Marl Formation and T_3 Sandstone Formation from the base upward.

a) T_1 Mudstone Formation

This formation is distributed in Aït Atmane (the northeastern part), and Jbelou Zbayr (the southeastern part), of this area. It covers K_{2cm} Mudstone Formation in the area near Aït Atmane, and covers K_{2l} Limestone with unconformity near Jbel ou Zbayr. The lowermost of this formation is basal conglomerate bed of about 3 to 10 meters in thickness. This bed consists of cobbles of limestone, mudstone and siltstone of 10 cm or more in diameter. The reddish-brown soft Mudstone bed, locally sandy, is deposited on the basal conglomerate stratum. The maximum thickness of this formation is 20 meters.

T_1 Mudstone Formation is exposed at 1900 meters above sea level near Aït Atmane, and at 1700 to 1800 meters above sea level near Jbel ou Abayr.

Between both points, there is Yahia-Oufalla Fault with NE-SW direction. Judging from the positional relation of this formation, it could be considered that the displacement caused by this fault is 150 meters up of the northern block.

b) T_2 Marl Formation

This formation is deposited on T_1 Mudstone Formation, and distributed in the southeastern part of this area. This formation is grey or yellowish-grey with scattered reddish-brown parts. Generally, this formation consists of soft siltstone and about 1 meter-thick limestone locally showing conglomeratic.

This formation generally strikes NE-SW, and dips about 5° SE. It has, constantly, thickness of about 30 meters.

c) T_3 Sandstone Formation

This formation is found on the southeastern side of Yahia-Oufalla Fault, and deposited on the T_2 Marl Formation.

It shows grey or yellowish-grey. The lowermost is the basal conglomerate bed consisting of limestone cobbles of 10 cm in diameter. Siltstone, sandstone and mudstone are deposited on this basal conglomerate. The bedding plane could not be cleared.

This formation is cut by Yahia-Oufalla Fault at Aït Oufalla, and contacts with Jurassic system, and Permo-Triassic system, having drag fold as the result of faulting.

(5) Quaternary system

The Quaternary system occurring in this area consists of β_{Q2} Basalt lava, Q_3 river sediment, and talus sediments.

a) Q_2 Basalt Lava

This lava, found in the southern part of this area, is exposed at places and shows lava-dome of 100 to 1000 meters in diameter in

topologically heights. The lava-dome located 7 km east of Karrouchan is about 1000 meters in diameter.

This rock is black fine-grained, hard lava, with abundant gass pores. Under the microscope, it could be confirmed that all phenocryst were altered into chlorite and sericite. The groundmass consists of subhedral titan-augite and fine felsic minerals.

b) Q_3 river Sediments and Talus Sediments

These sediments are found along the rivers, and also distrituted as talus on the slopes. They consist of silt, sand, and gravels.

1-1-2 Geological Structure

The Geological structure in this area is characterized by the folded structure with NE-SE axis and two kinds of faults trending NE-SW and N-S direction respectively.

As mentioned above, the geology in this area consists of Permo-Traissic system, Jurassic system, Jurassic system, Cretaceous system, Tertiary system and Quaternary system. The fundamentals of the above mentioned folded structure has been framed, in particular, within Permo-Triassic system, Jurassic system and Cretaceous system. Since the J_1 Limestone Formation and K_{2cm} Mudstone Formation have good continuity, this folded structure could be clarified in tracing these formation as key bed. Since β_{P-T} Basalt Formation and P-T Red Sandstone Formation have not a clear bedding plane, it was impossible to clarify their folded structure directly. However their distribution have reflected the above mentioned folded structure.

This folded structure has the wavelength of 7 km with its axis in the NE-SW direction. The axis is plunging in the SW direction by 5 to 10^{o}. An anticline is visible on the northern side and a syncline is visible on the southern side.

The principal faults in this area, are represented by NE-SW and N-S direction systems. The typical one of NE-SW direction systems is Yahia-Oufalla Fault, observed at Aït Oufalla which is the most remarkable fault in this area, and has a shear zone about 20 meters wide. It strikes N 20°E and dips 80° north. In this point, β_{P-T} Basaltic Formation lies in fault contact with the T_3 conglomerate bed. T_3 conglomerate bed near this fault was dragged by this faulting. This is, it shows that the north side block of this fault have been uplifted to the south.
The lower and upper formation are the north and the south respectively.
It is presumed that the displacement by the fault is about 600 meters vertical.

The several north-south faults run across from near Bou Mia to the north cutting the folded structure and the northeast trending.
Of these faults, the fault passing Aït Obal Lahlam has given a drag fold to K_{2l} Limestone Formation. A similar phenomenon is visible in K_{2cm} Mudstone Formation in the Tirouwadine area.
That is, the block consisted of K_{2l} Limestone Formation and K_{2cm} Mudstone Formation was relatively subsided on the east side of this fault.

It is considered that the lower arkose sandstone bed of P-T Red Sandstone containing Pb and U deposits. Therefore, to investigate the occurrence of P-T Red Sandstone Formation in which arkose sandstone is present, the structure contour map of the upper surface of this formation was drawn, and its height was estimated. The depth of P-T Red Sandstone Formation can be calculated by subtracting the height on the structure contour map from the topological height. It is assumed that in these calculations P-T Red Sandstone Formation would be deep near the syncline axis, and shallow near the anticline axis. The estimated depth of P-T Red Sndstone Formation below the ground surface is useful for planning the exploration

(by drilling, etc.) for uranium deposits which may be present in this bed. The P-T Red Sandstone Formation was estimated to be about 300 meters thick in the neighborhood of Karrouchan, and 200 meters or less thick on the southeastern side of Yahia-Oufalla Fault. It could be presumed that the trough or the basin structure would be existing in the Karrouchan area. This structure is distinguishable from the Itzar Basin zone which is adjacent to the southeastern part by Yahia-Oufalla Fault. Given that P-T Red Sandstone Formation thickness is different on both sides of Yahia-Oufalla Fault, and that of the difference of structural features, such as the existence of the folded structure on the northwest side but the monoclinic structure on the southeast side of the fault, it could be presumed that there would be much difference of geological deformation between both sides during the folding.

1-1-3 Radioactivity on Each Stratum

During this geological survey, radioactivity of the exposed rocks was measured with scintilometer (SPP 2NF model).

The measurement results are shown in PL.I-6. Relatively high radioactivity, about 100 c/s on average, was measured in the southwestern part where the P-T Red Sandstone Formation occurs. On the other hand, the measured radioactivity was generally low, less than about 60 c/s, on average in areas where Jurassic system, Cretaceous system, Tertiary system and Quaternary system are found. Higher radioactivity was also measured near the fault. Especially, radioactivity of 100 c/s on average was measured in Yahia-Oufalla Fault passing through AYt-Oufalla.Generally, arkose sandstone shows high radioactivity. However, in this area, upper beds from middle arkose sandstone shale alternation of P-T Red Sandstone Formation are exposed but the lower arkose sandstone is not. Therefore, the possibility of uranium deposits in this area could not be confirmed.

Resulting the first phase survey, radioactivity in P-T Red Sandstone Formation was ranged from 30 to 110 c/s - in Haute Moulouya Area. This radioactivity was almost the same as that in P-T Red Sandstone Formation in this area. The first phase survey report states that the β_{P-T} Basaltic Formation shows radioactivity of 30 to 100 c/s and Jurassic system and its upper strata shows radioactivity of 20 to 80 c/s.

Radioactivity of 50 c/s or less, was measured in the β_{P-T} Basaltic Formation and its upper strata in the Karrouchan northeastern sector. This value was somewhat lower than the radioactivity level measured in the first phase regional survey. However, it could be considered that, the background of radioactivity of these strata would be the same.

1-1-4 Conclusion

The geology of this area consists of: P-T Red Sandstone Formation and β_{P-T} Basalt Formation, Permo-Triassic system: J_1 Limestone Formation: K_{2cm} Mudstone Formation and K_{2l} Limestone Formation, Cretacesous system: T_1 Mudstone Formation, T_2 Marl Formation and T_3 Sandstone Formation, Tertiary system: β_{Q2} Basalt lava and Q_3 River and Talns sediments Quaternary system. Permo-Triassic system, Jurassic system and Cretaceous system are widely distributed in this area.

A folded structure having an axis running in the NE-SW direction has developed in this area. This folded structure has the wavelength of 7 km, and the anticlinal axis on the northern side and synclinal axis on the southern side. Two fault systems, trending NE-SW and N-S, are present in this area. The typical fault trending NE-SW is Yahia-Oufalla Fault. It has a crushed zone and has cut T_3 conglomerate bed at Aït Oufalla, and separated the Karrouchan basin zone from the Itzar basin zone. The fault trending N-S develops by crossing Yahia-Oufalla Fault and the folded structure running in the NE-SW direction which is the principal

structure in this area. The fault passing through Ait Obal Lahlan and Tirouwadine has formed drag-folds in the Cretaceous system.

To clarify the structure of the P-T Red Sandstone Formation which may contain uranium deposits, the structure contour map of its upper surface was drawn. As a result, it has been made clear that P-T Red Sandstone Formation has a folded structure running NE-SW and 300 meters thick in the Karrouchan basin. That is , it may be inferred that the P-T Red Sandstone Formation in the Karrouchan basin is deeper and larger than that in the Itzar basin. Radioactivity in this area was measured with scintillometer (SPP-2NF model). As the result, it has been found that P-T Red Sandstone Formation shows the radioactivity of 60- 100c/s, and other formations shows the radioactivity of 60c/s or less. These levels of radioactivity are almost equal to those in the other areas of this project and both radioactivity values are regarded as the background in this area. In this survey, though no radioactive anomalies have been detected, white arkose sandstone about 80 meters thick was confirmed in the lowermost stratum in the Karrouchan northeastern area, and it shows relatively high radioactivity of 100 to 105 c/s. Therefore, there is a possibility that uranium is concentrated in this stratum. According to the first phase survey report, the radioactivity of the basement granite was as follows:

Aplitic granite : 80 to 200 c/s

Granite : 50 to 170 c/s

These radioactivity values are somewhat higher than those in P-T Red Sandstone Formation, so it has been considered that these granites must be the source rocks of P-T Red Sandstone Formation, as well as the origins of uranium. Therefore P-T Red Sandstone Formation, thickly deposited in this area, has been considered that have a grate importance as the

the stratum to impregnate uranium deposits. Problems regarding to the distribution of this stratum and the palaeocurrent system, etc. are still remains unsolved, so it should be further studied in detail. To resolve these problems, suitable prospecting methods, as gravity survey, radon etch survey and drilling, should be employed.

1-2 Bou Mia North Sector

This area is located on the northeast border of the Bou Mia granite body. In the first phase survey, "Carapace" type uranium mineralization were discovered on the basement rocks, and the existence of a lead/barite mineralization was ascertained in the arkose sandstone bed, lower portion of P-T Red Sandstone Formation. In this phase, the semi-detailed geological survey using topographical maps of 1/10,000 scale and the detailed geological survey using measuring tapes and clinometers were performed. The principal purpose of the survey was to make clear the basement structure and the palaeocurrent in mineral deposition, and to scrutinize its scale, quality and extention to east of lead/barites mineralization.

1-2-1 Geology (See PL. I-7)

In this area, there are the granites of Basement complex, P-T Red Sandstone Formation and β_{P-T} Basalt Formation of Permo-Triassic system, K_2cm Mudstone Formation and K_2t Limestone Formation of Cretaceous system, T_1 Mudstone Formation and T_2 Marl Formation of Tertiary system and Q_s River Sediment of Quaternary system. The distributing features of these formations are that in the southern part, granites and P-T Red Sandstone Formation exist extensively, in the northern part K_2cm Mudstone Formation and K_2t Limestone Formation are widely exposed, and T_1 Mudstone Formation are distributed unconformably, covering almost the whole area. Principal faults are those which strike NNE-SSW, Faults trending NNW-SSE are also noticeable.

(1) Granites

The Granites are classified into granite, aplitic granite and aplite dyke. Granite is gray, and composed of quartz, feldspar and biotite grains of 4 to 5 mm in size, and exposed in the southeast part of this area.

Aplitic granite is pink fine grained. Its main constituent minerals are orthclase and quartz, accompanied by a small amount of muscovite and biotite. It is exposed in the southwest part of this area, and most of it where the sheet-like body is observed near the surface of the granite, and sloping gently toward the east.

Aplite dyke, is less than 1 m in width, and its rock facies closely resembled, aplitic granite but are finer. Many aplite dykes are observed with various direction in the granite, in the southwest parts of this area. Uranium mineralization of "Carapace" type and weak anomalous radioactivity along fissures occur in the Granites.

(2) P-T Red Sandstone Formation

P-T Red Sandstone Formation unconformably covers the granites, and it can be divided into two parts; coarse grain part mainly is made up of arkose sandstone, and fine grain part mainly composed of red siltstone.

Coarse grain part: This is the lowermost bed of P-T Red Sandstone Formation in this area, and chiefly consists of arkose sandstone. Arkose sandstone is hard light-brownish, coarse-grained, and due to the durability for weathering, it remained on tops of hills. Depositing in the depressions of granite bodies, it is distributed on in the southwest Boutazart region and on the northern border of the exposed granite body. By several drived faults of B M-1 Fault in Boutazart, the arkose sandstone bed is subsided stepwise toward the east, where the bed strikes northeast and dips 10^{o} to 30^{o}SE.

As the results of detailed survey for this area, it has been assumed that the palaeochannel trending north-northeast direction exists at the age of sedimentation of P-T Red Sandstone Formation. The thickness of arkose sandstone is 5 to 6 m but it becomes thicker about 15 m toward the east or in the vicinity of BM-1 Fault.

And, at the northern border of the area in which the granite body is exposed, the bed strikes northeast and dips gradually toward the north. Its thickness is about 5 m, but here also arkose sandstone remains in depressions of granite bodies and palaeochannel flowing northward are indicated.

In these palaeochannels and its adjacent, there are lead/barite mineralizations obserbed but in radioactivity prospection performed in parallel with the geological survey, anomalous radioactivity was not detected.

Fine grain part: this is the upper part of P-T Red Sandstone Formation. It mainly consists of non-stratified reddish-brown siltstone, interbedded with thin layers of fine-grained sandstone and gypsum. In the surveyed area, it is distributed extensively east of BM-1 Fault centered around the stream which flows from Aït Said to Radier, and also on the north of the granite body. It is well observed in cliffs along the stream, the discolored yellowish-white fine-grained sandstone of 10 cm thick at Aït Said and Radier, where is recognized in the reddishbrown non-stratified siltstone. The bed is almost horizontal, but inclines moderately (around 2°) toward the west in some places. On the north of the granite body, thick reddish-brown siltstone is distributed. It strikes NW-SE and dips 20°NE. The thickness of this bed is 20 to 30 m.

(3) β_{P-T} Basalt Formation

This formation conformably overlie P-T Red Sandstone Formation. It mainly consists of basalt lava, and occasionally, of basaltic sediments. But in this area, basalt lava was not observed. This formation consists of conglomerate bad 1 to 1.5 m thick, green or dark brown sandstone, mudstone and marl. The conglomerate includes relatively many chloritized basaltic pebbles. This formation is exposed at about 400 m south-east and

the south slope about 700 m north of the Carapace mineralization. It is traceable as the key bed to indicate the upper boundary of P-T Red sandstone Formation.

(4) K_2cm Mudstone Formation

K_2cm Muudstone Formation

It consists of alternation of gray sandstone, colorful siltstone, mudstone, and marl, and characteristically contains gypsum beds. It is distributed extensively in the south slope of Tafachna plateau and in both banks along the Assif Agarsif River. In these area, the alternation of soft siltstones are observed deep green, yellowish-white and reddish-brown. Thick gypsum beds 1 to 2 m are found in places. General strikes of the bed are NW-SE and inclined 5^{o}-20^{o} NE.

(5) K_2t Limestone Formation

This formation conformably covers K_2cm Mudstone Formation. It mainly consists of yellowish-white to white solid and hard limestone and marl, and characteristicaly contains abundant shell fossils (mollusca, oysters).

In this area, this formation is distributed broadly over Tafachna plateau north of the Carapace mineralizations, and marly facies incleasing toward Bou Mia granite Plateau are observed. It is indicated that this area was once a bordering area or a neritic sea region of sedimentary basin.

(6) T_1 Mudstone Formation

T_1 Mudstone Formation unconformably covers and under Cretaceous system. In this area this formation consists mainly of calcareous conglomerate containing gray, 3 to 4 cm pebbles of limestone, but contains partially interbeded soft siltstones. It is distributed widely over most of eastern plateau and in the southern bordering area. In the southeastern part of Side Mhammed Ben Driss, calcareous conglomerate of this formation

covers the K_2cm Mudstone Formation, but in the southern part it covers P-T Red Sandstone Formation and in the northern border it covers K_2t Limestone Formation. In the Assif Agaraif south bank, it is observed that the calcareous conglomerate bed thins and is covered by a soft siltstones in blue, reddish-brown, gray etc.

(7) T_2 Marl Formation

T_2 Marl Formation conformably covers the T_1 Mudstone Formation. It consists of conglomerate, micritic limestone and marl. Its distribution in this area is small, and it occurs at a small hill south of Aït Yahia ou Abiy and in the northern border. Formation of the former consists of pebble bed containing football-sized limestone pebbles, and that of the later is uppermost micritic limestone bed.

(8) β_{Q_2} Basalt lava

This rock is a porous, dark colored basaltic lava, and outcrops at three spots along BM-1 Fault and 1 spot in Sahtwil, the northern border of this area, are small in scale.

(9) Q, Alluvial sediments

This composed of sand and gravel, distributed along the Assif Agarsif, and silty soil distributed on the flat ground extending at the foot of south slope of Tafachna plateau.

1-2-2 Geological Structure

The geological structure in this area is featured with BM-1 Fault which runs from south to north roughly through the central part. MB-1 Fault has caused up and down displacement of the basement rock (granite) and sedimentary rock up the Cretaceous, and is covered by the Tertiary system. Each of sedimentary rocks to the Cretaceous shows monoclinic structure, and dips to the north on the west side of the fault and shows a horizontal or gentle inclination to the north on the east side. At the lowermost of P-T Red Sandstone Formation in the granite area, west of BM-1 Fault, a palaeochannel formed at the time of sedimentation has been observed. It is presumed that the direction is N and NNE and further continuation to the north. Tertiary system shows monoclinic structure sloping gently to the southeast, unlike the strata up to the above Cretaceous.

BM-1 Fault has the strike of N 20°E - S20°W, and dips generally vertical, but in some parts, it strikes N-S to N30°E - S30°W. Its vertical displacement is assumed 50 to 80 m. In the granite area, many derived faults branch off from BM-1 Fault.

1-2-3 Description and Distribution of Mineralizations

In this area, lead and uranium mineralizations are present in the granite region in the south western part of this area, but no mineralization was observed in the eastern part of the BM-1 fault and the northern part of this area.

(1) Lead mineralizations (PL. I-8, PL.I-9 Table I-3)

Stratified type lead mineralizations has deposited in the arkose sandstone of P-T Red Sandstone Formation as Boutazart mineralization and lead mineralization near the "Carapace" type uranium mineralization.

Boutazart mineralization : This is impregnated in arkose sandstone

distributed around Boutazart. This year, detailed survey with measuring tape and pocket compass was performed, and 10 specimens collected from each of 7 spots were analyzed. The results of these showed that the thickness of the mineralization is 1.90 to 4.50 m (average 3.18 m) and analyzed values are Pb : 0.13 % to 6.00 % (average 1.52 %), Ba: 4.20 % - 9.20 % (average 6.74 %). The arkose sandstone in this area is restricted about 700 m x 500 m in distribution. This arkose sandstone thinly covers the granite (5 - 6 m thick), but becomes thicker (15 m) toward the west side of BM-1 Fault and, therefore, in this place there would be presumed the palaeo-valley of NNE direction at the time of sedimentation of P-T Red Sandstone Formation. According to the results of chemical analysis, Pb minerals would be concentrated in the center of palaeo-valley, because high grade mineralization has been observed in the central part of arkose sandstone sediment.

Lead mineralization near the "Carapace" type uranium mineralization: This mineralization is also impregnated in the arkose sandstone upon "Carapace" type uranium mineralization. In the first phase survey, analysis was made of specimens collected at intervals of 30 m along the strike. The exposed portion of this mineralization is 1 to 1.8 m thick, the grade of mineralization is Pb: 0.19 % to 4.20 % (average 1.30 %), Ba: 0.60 to 4.20 % (average 2.04 %), and length of the outcrop is about 150 m. In the east of both above mineralization BM-1 Fault runs from south to north. As the east side of the fault has been subsided, there is a possibility that the eastern extension of the mineralization is underlain in the east side of fault.

(2) Uranium mineralization (PL.I-10, Table 1-1)

As uranium mineralization in this area, there are "Carapace" type uranium mineralization which was found in the first phase survey, and small

anomalous radioactivity in granite about 50 m west from Aït Said.

"Carapace" uranium mineralization : In this phase the detailed survey was performed centering around the "carapace". In the detailed survey, the base line was arranged along the bordering of granite and cross-cut lines intersecting the base line nearly at 90° set up. And geological survey and radioactivity survey were performed along the base line and cross-cut lines, to detect anomalous radioactivity in the zone, which is the stratigraphic horizone of the "Carapace" outcrop, No anomalous radioactivity except that of the "Carapace" outcrop were discovered. The "Carapace" outcrop showing almost horizontal lenticular shape of maximum thickness 30 cm width about 2 m, has been formed in depression in the aplitic granite surface. The radioactivity value was 1600 c/s at the maximum, and results of analysis show U: 0.072 %, V: 0.030 % and Th : 0.0020 %.

Other anomalous radioactivity: Anomalous radioactivity exists 500 m west of Aït Said in minute fissures in the granite, and shows 400 c/s to 1200 c/s of radioactivity. It is spot-like anomalous radioactivity with short continuity and small scale.

1-2-4 Conclusion

Though the first phase and the second phase survey, the geological structure of this area was clarified, and distributions and scales of lead and uranium minerarization were elucidated.

Regarding the lowermost of P-T Red Sandstone Formation which had much possibility of lead and uranium ore deposits, its basement structure at the time of sedimentation clarified chiefly for the granite area west of BM-1 Fault. That is, though P-T Red Sandstone Formation sloped gently toward the north, it has revealed that the palaeo-valleys during the sedimentation of arkose

sandstone, exist at Boutazart in the southwest of this area and at the northern border of the granite outcrops. These palaeo-valleys are valley-shape depressions formed on the surface of the granite body, and in which arkose sandstone was deposited thicker than in other places. The palaeo-valley in Boutazart runs NNE and is cut by BM-1 Fault, and could be assumed to continue further to NNE. Another palaeo-valley in the northern border of the granite outcrops could also be estimated to run and to continue north in the west of BM-1 Fault.

The relation of the structure during sedimentation of P-T Red Sandstone Formation and lead and uranium mineralizations is considered to be as follows:

(1) Lead mineralization

Both Botazart and "Carapace" lead mineralizations are exsisted in the palaeo-valleys and indications of each are generally weak at the surface outcrop but both show high grade indication in places.

In the presumed palaeo-vally at the Boutazart, the central portion of the thicken arkose sandstone indicates tendency to become thicker mineralization and higher lead grade than in peripheral portions of thin arkose sandstone. Moreover in downstream near BM-1 Fault, high analytical result were obtained.

From these points, it is presumable that the existence of high grade lead ore deposits in the extension of the palaeo-valley in east side of BM-1 Fault.

The palaeo-valley endowed with the lead mineralization near "Carapace" type uranium mineralization changes it's original shape according to the form of BM-1 Fault, but from the results of analysis in the first these survey,

the existence of high grade deposit around the center of this palaeo-valley is expected. As this palaeo-valley is presumable to continue northward, these is a possibility that high grade lead ore deposit would be discovered by tracking this structure.

(2) Uranium mineralization

The scale of "Carapace" uranium mineralization is small, but it is within the paleo-valley at the northern border of the granite outcrop, and this fact attracts attention.

This mineralization is considered to have been formed in small depressions on the palaeo-valley near the granite body northern boundary. The randon-etch survey covered the northern part of this area carried out in this phase, but no anomalous point was found in its northward continuation. As thick strata of K_2cm and subsequent formations covered the P-T Red Sandstone Formation in this area, it may be consider that the mineralization, could not be detected in the radon-etch survey, therefore, the results are not conclusive, the development of "Carapace" uranium mineralization in the northern part is hardly promising. However, since the existence of palaeo-valley running northward in the Bou Mia granite body area was clarified and many similar structures are presumable from this area over to western Bou Mia granite body area, and the presence of uranium mineralization is expectable. In the radon-etch survey, five anomalous points were identified in the northwest of this area. These anomalous points are scattered due to the irregular terrain i.e. irregular thickness of covering strata. These facts suggest the possibility of uranium mineralization in palaeo-valley from Bou Mia granite body area, therefore, this area should be considered as one of the important target in further investigation.