MOROCCO COBALT MISSION

International Development Cooperation Agency

U.S. Trade and Development Program

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M O R O C C O C O B A L T M I S S I O N

Prepared enroute by combined Team
from
U.S. Geological Survey
U.S. Bureau of Mines
Trade & Development Program (TDP)

Rabat, Morocco
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Final reports of:

Harold A. LeSieur	Team Leader/TDP Representative
Dr. Robert Coleman	U.S.G.S.
Dr. Michael Foose and Darwin Rossman	U.S.G.S.
Josiah Royce	BuMines
John Lucas	BuMines

Appendix - Mining Projects Presented by B.R.P.M.
(Foose & Rossman Appendix II)

MEMORANDUM

TO : Christian Holmes, Director, Trade & Development Program (IDCA/TDP)

FROM : Harold A. LeSieur, AID/ST/ENGR, Team Leader

SUBJECT: Final Report on Cobalt Reconnaissance to Morroco, January - February 1982

INTRODUCTION

The primary purpose for this reconnaissance mission was to define the supply side of the Moroccan Cabalt equation. A subsequent investigation on the demand side, involving possible U.S. private sector cooperation, is to be undertaken on completion of the reconnaissance mission to Morocco.

General agreement appears to have been reached by Team members that mineralization in the Bou Azzer region is associated both with serpentine boundaries and with faulting and folding of ophiolites, although the specifics of locating such deposits are complex and not entirely predictable. The potential for additional deposits can be determined only by a careful geophysical and geochemical test program.

Known and potential Cobalt mineralization in the Bou Azzer area is described by Team members as "considerable." In addition, the neighboring Siroua block is considered to offer "an excellent target for further exploration." There is also Cobalt potential reported in the South of Morocco, at the border area approximately 600 miles Southwest of Bou Azzer.

WORK ACCOMPLISHED TO DATE

Data may have been developed on the Bou Azzer and other deposits by French scientists dating back some 100 years. In more recent years an impressive array of scientific investigation has been accomplished by Moroccan scientists under the leadership of ONA Chief Mining Geologist Mr. Pierre Billaud. Mr. Billaud is co-author of technical papers on the Bleida copper and other deposits with Professor Marc Leblanc, whose original work on Bou Azzer and Bleida is fundamental to this investigation.

From the standpoint of counterpart Moroccan geologists, their geochemical reconnaissance has been concentrated on outcrops. Rather modestly they characterize their geophysical searches as not having been made yet on a "grand scale." On the other hand, Dr. Michael Foose praises the "large amount of excellent technical work" accomplished by the Moroccans. Team members generally

concur on this point. Adding that Moroccans have done so much work in the Western end of El Graara, Dr. Robert Coleman notes that nothing substantial can be added. He concludes, however, that the same approach--with some additional techniques--might be utilized for the eastern end of this mineralization region.

Before reaching Morocco, USGS team members reviewed the pertinent thesis and papers on Bou Azzer of Dr. Leblanc. After several traverses of the Bou Azzer region, a question arose among these team members as to the completeness and possibly the validity of these data, when comparing Leblanc's hypotheses with the facts, as observed in field traverses.

One team member observed that Leblanc makes no mention of geophysical techniques. In his opinion, a geophysicist should work out actual structures from field geologist's samples and observations, to arrive at a final interpretation. It is presumed that this would be accomplished in a subsequent and more detailed exploration and analysis.

No assessment of Bou Azzer mining development could be complete without acknowledgement of the prior very extensive Soviet team effort. On a theoretical basis, the U.S. team has questioned the methodology of sampling (on a uniform grid basis) and need for such a large number of samples collected (60,000). In the opinion of one U.S. team member, more meaningful results could be achieved at a sampling level of 10% (6,000), providing stream or soil sediment sampling is employed. In fairness, however, it must be noted that the fee-paid Soviet consultation (a $3 million effort with 65 technical and semi-technical personnel) resulted in locating a cobalt mine currently operating at Tandrost, 12 km east of Bou Azzer.

Mention should also be made of aeromagnetic data reported by Hunting Geology & Geophysics, Ltd. of Great Britain in 1977. This data is considered by Dr. Robert Coleman as having had but little interpretation.

TECHNIQUES AND IMPROVEMENTS AVAILABLE

Exhibit B displays an abbreviated summary of techniques employed to date by the Moroccans. It also itemizes those improvements or added techniques which ocuild be considered in future exploration, as suggested by Team scientists.

One major area of innovation as stressed by Drs. Coleman and Foose, is electric self-potential techniques, especially aeromagnetic studies. In Coleman's opinion, an aeromagnetic survey of the entire area is needed, with sound geophysical interpretation of data. Isotope and metalogenesis studies are also recommended by Coleman, with approximately six (6) weeks of careful laboratory studies thereafter. These techniques would

enable Moroccan scientists to "make better guesses" as to when and where mineral veins were formed. This information can feed back directly and guide prospecting, according to Coleman.

Soil-sediment sampling is a geochemical technique which can also lead to useful information. Rather than sample on a uniform grid (Russian) basis, Dr. Foose and Darwin Rossman recommend collecting reconnaissance samples within drainage patterns --to benefit from the "halo" effect from mineralized outcroppings. According to Mr. Rossman, this will give information on higher elevation sources, but must be limited to new areas (not Bou Azzer, where stream pollution can interfere with results).

Percussion drilling is a technique suggested by John Lucas as a expeditious means to check mineralization areas, to be used as a low cost and fast supplement to the more precise diamond core drilling method presently used. Likewise, Joe Royce has recommended consideration of shallow seismic apparatus to delineate mineral target areas in the Zeida region.

NON-COBALT MINERALIZATION INVESTIGATION

In addition to the primary exploration effort by the entire team on Cobalt, a portion of the group (Royce, Lucas, LeSieur) undertook a separate trip to view deposits at Imiter (Silver), Zeida (Lead and Barium) and Boumaine or Bou Madir (a multi-medal deposit consisting of zinc, lead, silver and gold,. The entire Team previously visited the copper deposits at Bleida, and observations on findings are noted elsewhere in this report.

In addition to responding to the kind invitation of their Moroccan hosts to view successful mining ventures, it was the purpose of this side effort to assess tentatively the possibilities of mining potentials for U.S. companies. Especially since the low world price of cobalt could militate against very much U.S. private sector interest, the possibility of other exploration (to spread the risk of any venture) should be considered. In the case of Imiter and Zeida, it appears that the situation is well in hand by the Moroccans working alone, and the entree for U.S. firms here is not attractive. The story may be different for Bleida and Boumaine, however.

Electromagnetic detection techniques may be readily applicable to the massive vein deposits of Boumaine, together with geochemical analyses, and could together permit rather rapid assessment of exploration and mining potentials. This entire domain, between the Haut Atlas and Anti-Atlas appears to offer good exploration potential, and BRPM is encouraging to such exploration on a cooperative basis with U.S. interests. A beneficiation plant for such a multi-metal deposit would require expert selection of processing equipment and careful attention to plant design and construction.

In the case of Bleida, areas southeast are said to have exploration and possibly mining potential, including for the strategic metal vanadium. The richness and extent of apparent reserves makes this a prospect of possible interest to U.S. mining companies also concerned with Bou Azzer.

Thus, even in this relatively brief survey of non-cobalt potentials, these prospects could be worthy of investigation by U.S. firms. Together with several other matters, this subject will be discussed with interested companies in the American mining industry on return of Team from Morocco.

Detailed reports and conclusions by each member of the TDP reconnaissance team follow this introduction.

Exhibit 3

TECHNIQUES EMPLOYED AND AVAILABLE

Techniques Employed

1. Diamond core drilling to 5 [illegible] meters

2. Geochemical surveys
   - 2.1 Uniform grid sampling
   - 2.2 Russian methodology

3. Electromagnetic surveys, ground

4. Extensive mapping
   - 4.1 Topographic maps
   - 4.2 Gravity intensity maps
   - 4.3 Metallogenic map
   - 4.4 Supporting data file

Improvements/Techniques Available

1. Percussion drilling
   - 1.1 A faster and cheaper supplement
   - 1.2 Disadvantage: Less precision
   - 1.3 So. African model reaches [illegible]00 meters

2. Geochemical surveys
   - 2.1 Soil-sediment sampling
   - 2.2 "Pathfinder" analyses (63 elements)

3. Airborne Techniques
   - 3.1 Electromagnetic surveys
     - 3.1.1 Regional modelling
     - 3.1.2 Computer profiling
   - 3.2 Satellite imagery
   - 3.3 Aerial photography

4. Geophysical sampling
   - 4.1 Metalogenesis studies

5. Isotope tracing
   - 5.1 Stable isotopes
   - 5.2 Isotope dating methods

6. Hydrothermal phenomena
   - 6.1 Surface measurements

7. Basic Research
   - 7.1 Fluid inclusion studies
   - 7.2 Vein layering, chemistry of
   - 7.3 Isotope studies (c.f. #5)
   - 7.4 Model building

8. Computerization
   - 8.1 Selection of computers
   - 8.2 Computerized mineral data syste

9. Training
   - 9.1 Basic research
   - 9.2 Geochemistry and geophysics
   - 9.3 Map production
   - 9.4 Exploration techniques
   - 9.5 Graduate scholarships
     - 9.5.1 Thesis projects: Ore De[illegible]sits of Morocco

MEMORANDUM

TO : Harold A. Le Sieur, P.E.

FROM : R. G. Coleman, U.S.G.S.

SUBJECT: Bou Azzer Cobalt District

During the period January 30 to February 4, I accompanied a special team brought together in order to evaluate the future potential for cobalt exploitation in Morocco. The basis for my evaluation is a result of a series of briefings on the geology and mining methods in the district. In addition, we made a number of goelogic traverses over the important geologic sections. All of this was done under the expert guidance of Pierre Boullard, Chief Mining Geologist for ONA.

Your request to accompany the group was based on the fact that I had experience with ophiolite problems and that this would be of value in regards to Bou Azzer because it is now considered to be a dismembered ophiolite at Proterozoic age. Therefore my remarks will be confined to the area of my expertise.

The recently published works of Dr. Marc Le Blanc form the basis for the current geologic thinking in the area. The Bou Azzer cobalt deposits are situated along the boundaries of a serpentinized periodotite but not in it. Wherever we observed this contact the serpentinite was sheared and highly altered. Nowhere did we find an original pre-tectonic contact. There are tectonically juxtaposed against or incorporated in serpentinite, rocks which can be assigned to ophioloitic parentage but nowhere did we see displayed a continuous cogenetic igneous sequence of undisturbed ancient oceanic crust (i.e., ophiolite). Because the Bou Azzer district occupies a prominent antiformal dome, the major geologic structures also conform to this major tectonic feature. It is clear that the serpentinite has been remobilized many times and now occupies a diapiric axis along this antiformal structure. Therefore the serpentinized periodotite has separated from its original basal position within the ophiolite and has undergone multiple periods of deformation and alteration (mineralization). The cobalt mineralization is somehow related to this alteration and tectonic movement. The present model of Le Blanc whereby the Ambed Formation represent a weathered rind that has later been mobilized into ore was not substantiated by our geologic observations. Therefore, we suggest that additional geologic research be carried out on the genesis of this ore district. This could be done by supporting modest research by graduate students from the U.S. in collaboration with the local geologists.

Recommendations:

1. The basic geologic mapping of 1:100,000 by Le Blanc and bigger scale mapping of the Moroccan geologists is adequate. I would not recommend future mapping at these scales except for promising areas.

2. The Russian geochemical sampling was uninspired and could be supplemented by using North American exploration techniques, such as using pathfinder elements and geologic reasoning as related to known structures.

3. Review of geophysical techniques by a mining geophysicist would be be useful in order to establish the effectiveness of the modern geophysical techniques used in the district. A regional aeromagnetic survey properly interpreted would provide a better idea on the size and shape of the serpentinite.

4. Strong effort should be made to have exchange visits of Moroccan geologists with USGS & USBM so that they could team about other techniques of geochemistry and geophysics.

5. Education of Moroccan geologists in U.S. Universities with thesis projects on the ore deposits of Morocco could provide a means of carrying out basic research needed to better understand their ore deposits.

Post Script

Dr. Coleman has concurred with the following suggested supplement to his preliminary findings:

"Unlike the more commonly encountered ophiolite which may exhibit an orderly succession of component rock types, the ophiolite structure of Bou Azzer and environs has undergone a continuous faulting and folding with a much more complex end configuration. Since mineralization is often associated with such faulting, it may reasonably be expected that extent of mineralization is more favorable in this region of Morocco."

(Harold A. Le Sieur)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROJECT REPORT
Morocco Investigations
(IR)MO-3

GEOLOGIC REPORT AND RECOMMENDATIONS FOR THE COBALT MISSION TO MOROCCO

SPONSORED BY

THE TRADE AND DEVELOPMENT PROGRAM

OF THE INTERNATIONAL DEVELOPMENT COOPERATION AGENCY

Report prepared under the auspices of the Trade and Development Program
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The project report series presents information resulting from various kinds of scientific, technical, or administrative studies. Reports may be preliminary in scope, provide interim results in advance of publication, or may be final documents.

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ABSTRACT

A mission sponsored by the Trade and Development Program (TDP) of the International Development Cooperation Agency (IDCA) went to Morocco to evaluate the possibility of finding additional sources of cobalt in that country, as well as other types of mineralization. Information obtained during this trip shows Morocco to be a country for which much geologic information is available and in which there are many favorable target areas for future exploration.

Work in the Bou Azzer district (Morocco's principal cobalt district) shows that much excellent geologic work has been done in searching for additional deposits. However, a number of useful approaches to locate cobalt have not been tried, and their use might be successful. The potential for undiscovered deposits in the Bou Azzer region seems very high.

The cobalt mineralization in the Siroua uplift is different from that in the Bou Azzer district. However, geologic similarities between the two areas suggest that a genetic link may exist between the two types of mineralization. This further indicates that cobalt deposits of the Bou Azzer types might be present in the Siroua region.

Examination of the Bleida copper mine shows it to be a well-exposed volcanic-hosted stratabound copper deposit. Large unexplored areas containing similar rocks occur near this deposit and may contain as yet undiscovered copper mineralization.

INTRODUCTION

The major objective of the TDP Cobalt Mission to Morocco was to evaluate the possibility of locating additional sources of cobalt within Morocco. A second goal was to identify other localities that contain potentially important types of mineralization, with emphasis on locating deposits of strategic commodities. The ultimate objective was to seek information that might encourage joint ventures on mineral deposits between Morocco and the U.S. private sector.

To this end, the TDP - sponsored team to Morocco was involved in 2 days of meetings in Rabat and 8 days of meetings and field work in Morocco's major cobalt district, Bou Azzer. The work near Bou Azzer also included a one day visit to the nearby Bleida copper deposit. After the work at Bou Azzer, the U.S. Geological Survey members of the TDP team separated from the other team members and examined additional cobalt prospects in the Siroua uplift, near the areas of Iferghane and Inki, and the manganese deposit at Imini (fig. 1). The TDP team was then reunited for 2 days of concluding discussions with Moroccan officials in Rabat.

This report summarizes the activities and conclusions of the U.S. Geological Survey's members of the TDP mission. The report is in four parts. The first summarizes activities and conclusions derived from the Rabat meetings (January 28-29, 1982), the second summarizes work and recommendations based on field work in the Bou Azzer cobalt district, the third presents our evaluation of the Bleida copper district, and the fourth is our evaluation of the Iferghane and Inki cobalt occurrences. Because of inclement weather and the absence of adequate English translations, little information was obtained

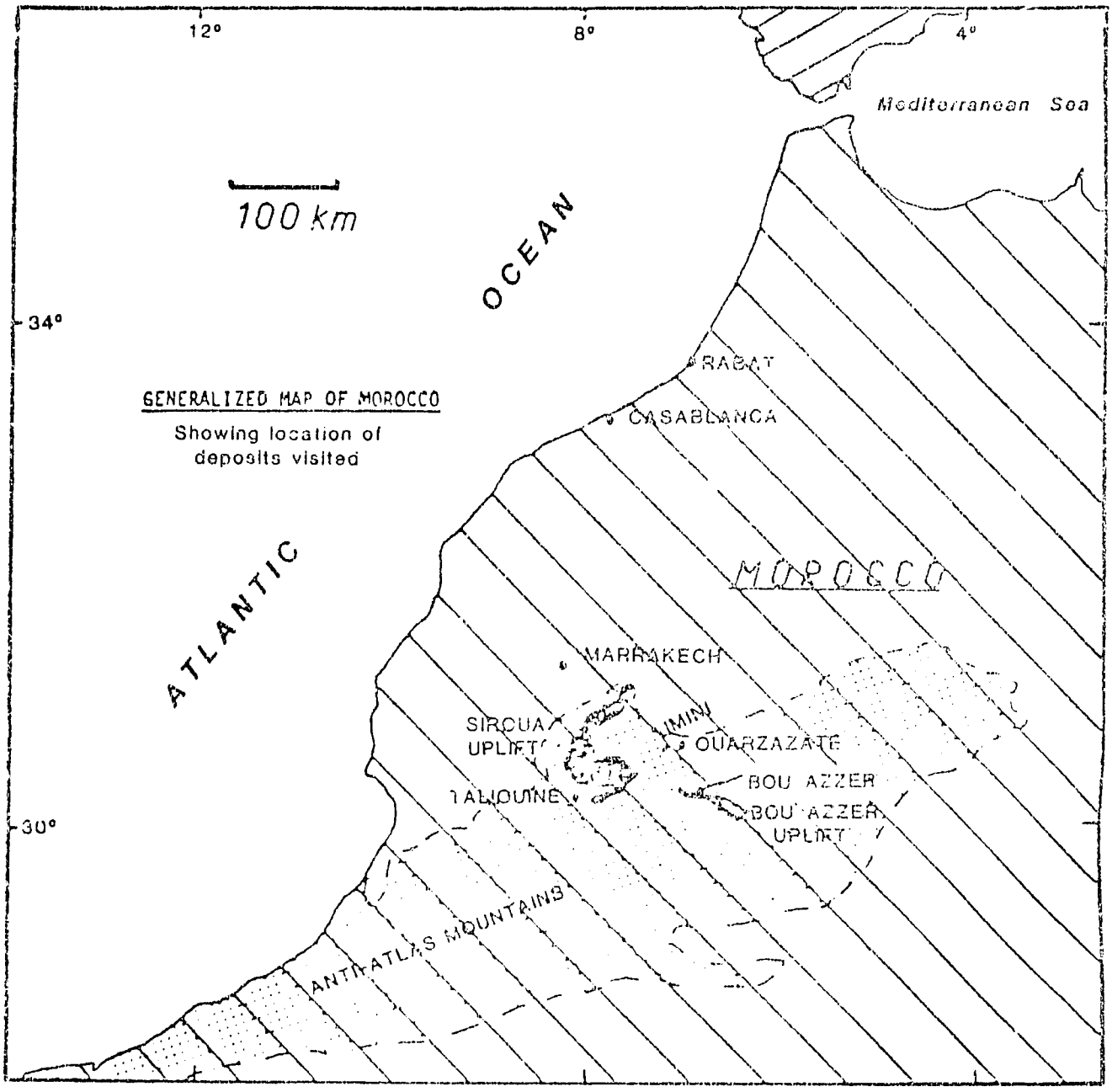

Figure 1. Index map of areas visited showing Morocco (right diagonals), the Anti-Atlas Mountains (stippled), and the Bou Azzer and Siroua uplifts (black).

at the Inki manganese mine, and thus no summary is given for that deposit. Appendix 1 chronologically lists our activities.

RABAT MEETINGS

Summary

Meetings with the Bureau de Recherches et de Participations Minieres (BRPM) (Morocco's major mining company) and Moroccan Geological Survey clearly indicate that Morocco has a well developed appreciation for the need of systematic mineral exploration and for the evaluation and development of mineral prospects. They are now carrying out a number of excellent mineral-resource-related studies.

The following lists some of Morocco's major geological programs and accomplishments and some areas in which they plan future work:

1. Fifty to sixty percent of the northern provinces of Morocco are mapped at a scale of 1:200,000;
2. Parts of the Rif area (northern Morocco) are mapped at a scale of 1:50,000;
3. The central part of the country is being mapped at a scale of 1:100,000;
4. Gravity surveys have been completed at a scale of 1:500,000 except in sedimentary basins where more detailed surveys have been made.
5. A metallogenic map has been completed (1:500,000 scale) and represents a compilation of geologic, tectonic, and mineralogic data that was compiled at a scale of 1:100,000.
6. A national stream sediment sampling program is to be started.
7. BRPM has been active in identifying and evaluating mineral prospects.

As a result BRPM possesses a large number of documents detailing geologic and other data on a wide variety of mineral deposits. An example is given in Appendix 2 (Report prepared by BRPM, attached as Appendix 2) which outlines mineral projects regarded as worthy of cooperative ventures. A more detailed prospectus is available from BRPM for each of the listed projects.

8. In addition, BRPM has identified a large number of other mineralized areas that contain a variety of commodities including rare earth elements, lead, zinc, precious metals, and copper. BRPM is particularly enthusiastic about copper deposits in the Alous area where at least 1,800,000 tons of ore with 1.0 percent copper and with 15 gr/ton Ag has been proven to exist in rhyolite (volcanic rock), largely as chalcocite with lesser chalcopyrite, bornite, and pyrite. Other copper deposits exist in the Alous area with at least 3,000,000 tons of ore containing 1.5 percent copper and 54 gr/ton Ag.

9. Although aggressively working on geologic problems, the Moroccan Geological Survey has emphasized the desire, during our meetings, for assistance. Areas in which they would like assistance include:

a. Remote sensing techniques;

b. Mineral deposit detection methods;

c. Training in sedimentology, petroleum geology, and in geophysical prospecting;

d. Isotopic dating problems;

e. Development of less expensive map preparation and printing techniques; and

f. Aid in selecting computers and development of a computerized mineral data system.

The above clearly indicates that geologic work in Morocco has considerable maturity. This is important because it further shows that the Moroccans appreciate the information essential for developing effective exploration programs. Particularly impressive is the metallogenic map and supporting data files which will be immensely useful in identifying favorable regions for mineral exploration.

Recommendations

Review of the above geologic information leads us to the following conclusions:

1. Morocco possesses numerous identified exploration targets and many virtually unexplored areas. Basic geologic data for much of this area is adequate to select specific exploration targets. In addition, the Moroccan Government is anxious to foster ties with foreign companies. Thus, Morocco represents a favorable area for consideration for new exploration for economic mineral deposits.

2. Although geologically advanced in many areas, the Moroccan Geological Survey desires assistance (item 9, above). Many of these problems are areas in which the U.S. Geological Survey can be of help. It is recommended that TDP explore the development of a cooperation program with the USGS. However, it should also be noted that assistance in some areas may also be given by private companies that have expertise in sedimentology, remote sensing, cartographic processing, regional exploration, and computer systems. Thus, both the U.S. government and U.S. private sector may be able to help Morocco increase its geologic capabilities. It is

further indicated that short-term training of Moroccan geologists by the USGS would be of great help in developing their expertise in exploration research and map production.

BOU AZZER COBALT DEPOSITS

From January 30 to February 5, 1982, geologic activities focussed on the cobalt deposits in the Bou Azzer area. Work included briefings on the regional geology, geologic field traverses, and underground examination of deposits. These activities were carried out to evaluate the potential for finding additional cobalt in the Bou Azzer district.

An assessment of Bou Azzer's future cobalt potential hinges largely on:

1. The adequacy of geologic information and the attendant understanding of the geologic setting of the ore deposits; and
2. The techniques used in mineral exploration.

For this reason, these two points are evaluated separately below. Figure 2 shows some of the geologic and geographical features of the Bou Azzer district.

Geologic setting of the Bou Azzer mineralization

The geology and genesis of mineral deposits in the Bou Azzer area are complex and controversial topics that have been the subject of numerous lengthy works (for example: Gaudefroy, 1953; Goloubinow, 1956; Jouravsky et al, 1960; Clavel and Leblanc, 1969; Technoexport, 1969-1971; Routhier et al, 1970; Leblanc, 1969, 1973a, 1973b, 1981; Choubert et al 1974; Michard, 1976; Choubert and Faure-Mauret, 1976; Clauer and Leblanc, 1977; Besson and Picot, 1978; Vinogradova et al, 1980; Leblanc and Billaud, 1982). These studies and our observations identify the following important geologic features.

GENERALIZED SETTING OF THE BOU AZZER UPLIFT

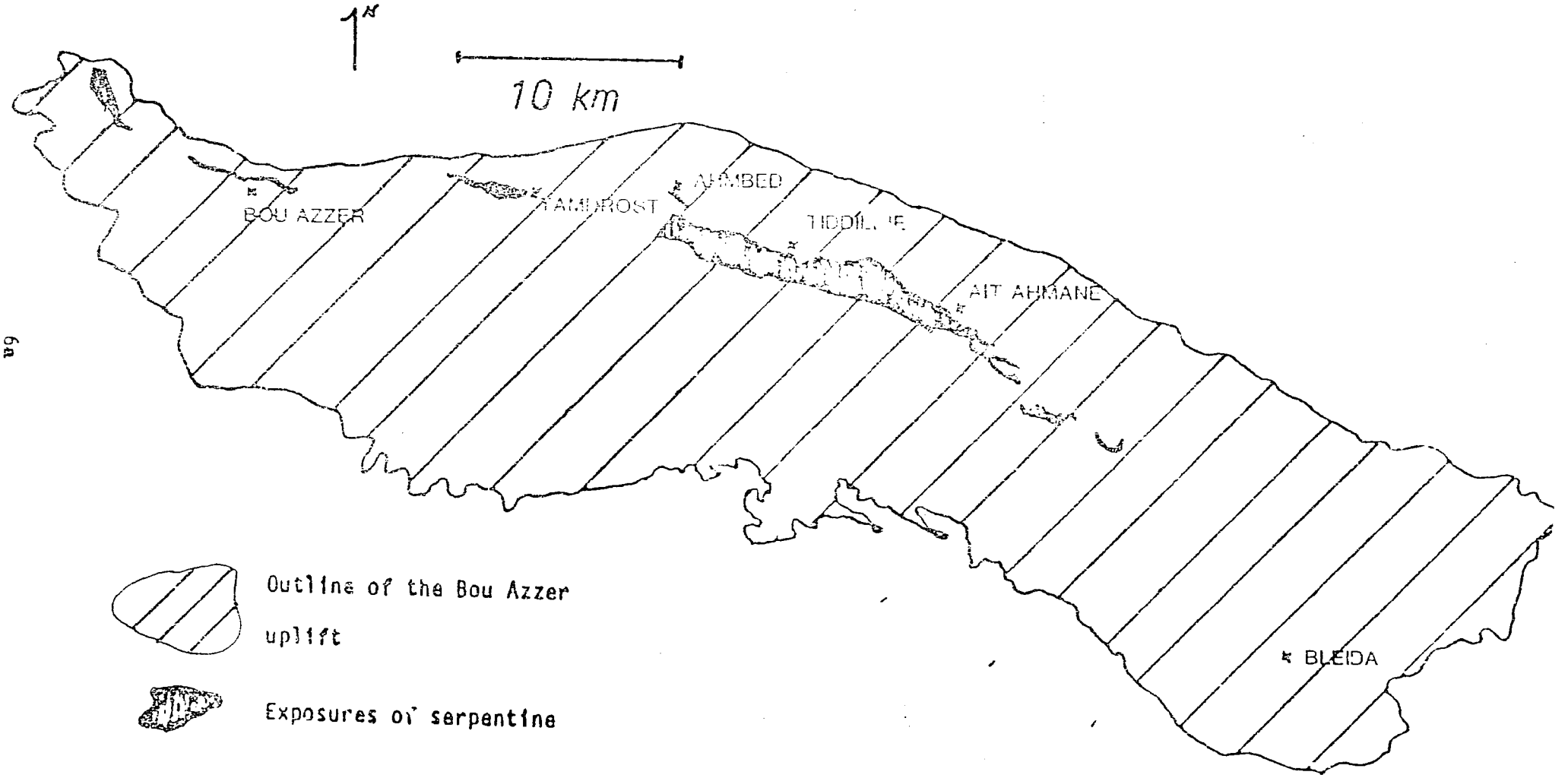

Figure 2. Generalized setting of the Bou Azzer uplift. Proterozoic rocks of the Bou Azzer uplift (left diagonals) contain serpentines that are part of the ophiolite (black), and are surrounded by younger cover rocks (blank).

The Bou Azzer district lies on the border between the north edge of the West African Eburnean craton (2000 million years old (Ma)) and the south part of the Pan-African orogenic belt (680-580 Ma). The mineralization in this district is associated with a dismembered, fragment of Precambrian ocean crust (an ophiolite). More specifically, cobalt is associated with serpentine that probably once was the lower part of a coherent succession of rocks that from bottom to top were tectonized peridotite, ultramafic cumulate, gabbro, diabase, and volcanics. This succession of rocks was emplaced on an old continental margin about 685 million years ago during the major Pan-African orogenic event (B-1 deformation). Subsequently, it was overlain by a 1500 m thick detrital deposit (the Tiddiline Formation) after which horst blocks of the ophiolite were exposed to erosion and weathering, deformed by the last Pan-African event (615-580 Ma; B-2 deformation), covered by a thick sequence of volcanics and sediments, and again subjected to slight folding and faulting (Hercynian deformation). In recent times the area has undergone rapid uplift along a roughly east trending axis that produced the Bou Azzer uplift or "boutonniere", in which the Bou Azzer mining district is now exposed.

An important result of this complex history is that the more plastic, serpentine-rich parts of the ophiolite have moved into contact with a wide variety of other rocks. The Bou Azzer ophiolite has thus been dismembered and is now similar to tectonized ophiolites found throughout the world. However, the extensive alteration of the serpentine at Bou Azzer, which has resulted in the destruction of virtually all primary structural features in the serpentine, is not so common, and marks the Bou Azzer area as an unusually complicated and altered ophiolite complex.

All the 60 or so known cobalt deposits in the Bou Azzer district are in contact with serpentine. Mineralization within these deposits, however, is almost never within serpentine; instead it is in a distinctive silica-carbonate gangue that is along the serpentine contact or within rocks immediately adjacent to the serpentine. Because the serpentine has moved into contact with a variety of rocks, mineralization can thus be found within rocks that are older, the same age, or younger than the ophiolite.

On a regional scale, serpentines are exposed at the western end of the Bou Azzer uplifted block. It is, therefore, in this region that most of the cobalt deposits have been found. Farther to the east, the serpentines are mostly covered by younger rocks. Although some buried deposits (for example the Tamdrost deposit) have been located in this area, much of this covered area is not well explored and may contain additional and undiscovered deposits.

The cobalt deposits have a wide variety of shapes and sizes. Most economic deposits contain several hundred thousand tons of ore containing 1.2 percent cobalt, 0.15 percent nickel, and 4.7 percent arsenic; of the larger deposits, only two have produced over one million tons of ore. Shapes of deposits range from lodes concentrated within crosscutting faults, to small veins, to rare low-grade pockets that are localized along and conformable with the serpentine contact. Deposits seldom exceed 20 m in thickness. Virtually all economic conentrations of cobalt and associated gangue have been mobilized into crosscutting B-2 and Hercynian fault structures.

The mineralogy of the deposits is complex and varied. Most of the mineralization is in Co-Fe-Ni arsenides of which skutterudite, safflorite, rammelsbergite, loellingite, gersdorfite, and arsenopyrite are the most abundant. Minor amounts of chalcopyite, bornite, chalcocite, and molybdenite are also present. Erytherine is a common supergene alteration mineral. The gangue is mostly quartz and calcite, but Mn-Fe dolomite, talc, magnesian chlorites, and serpentine minerals are locally present.

The silica-carbonate gangue that hosts the cobalt mineralization represents an important and poorly understood aspect of these deposits. This rock is made up of at least two lithic types. The first is a layered series of carbonates and jasper; the second is massive and in places coarsely crystalline calcite and dolomite that commonly contains blocks or inclusions of the layered series. Both types occur in veins within a wide variety of rocks. However, they are mineralized only where they are near serpentine. Further, the important cobalt-arsenic mineralization is almost all within the coarsely crystalline carbonate phase of the rock, although minor amounts of uneconomic sulfide mineralization may occur within parts of the layered rock.

Evaluation of existing geologic data and interpretations

There is a large volume of geologic information on the Bou Azzer region and the basic geologic relationships are well known. In addition to the excellent work by CTT geologists (CTT is the company that operates the Bou Azzer deposits), the area has received extensive study by a variety of

French geologists and by a team of Soviet scientists (Technoexport). Geologic mapping is generally good and the features associated with mineralization are well established. Thus, further routine field examination in this area is probably not warranted.

The adequacy of the geologic interpretation of these relationships, however, is less clear. Despite the extensive study, it is our opinion that the origin of the cobalt deposits is still uncertain. Two genetic interpretations have been stressed in the past. Traditionally, these deposits have been considered to be of hydrothermal origin developed by alteration of the serpentine during the B-2 and/or Hercynian deformations (Jouravsky, 1952; Krutov, 1970; Garcia, 1979). More recently, Leblanc (1981) has related the mineralization and its gangue to a weathering and depositional event that preceeded the B-2 deformation. He postulates that the host for the mineralization formed as subaereal sedimentary deposits laid down on serpentine and that later diagenesis and meteoric alteration enriched these rocks in cobalt. This interpretation, thus, asserts that the deposits thus were stratabound concentrations developed on top of of serpentine and were then reconcentrated by later deformation. These contrasting interpretations are important as they may determine the most effective method for locating additional cobalt. For example, the first hypothesis may indicate that mineralization is localized in small areas of hydrothermal alteration, whereas Leblanc's hypothesis may indicate that the minerals may have formed along a widespread weathering surface.

During the few days of field work within the Bou Azzer district, we were unable to substantiate Leblanc's hypothesis that the silica-carbonate rock and the cobalt ores were genetically tied to a weathering event. Our tentative feeling is that the host rocks for the ores probably formed as an alteration rim on serpentine as a result of movement of either hydrothermal or meteoric fluids, that this alteration process was facilitated by the repeated deformations to which the serpentine has been subjected, and that faults which cut the serpentine provided favorable sites into which these hydrothermal solutions could deposit cobalt. Additional movements along these faults acted to remobilize and further concentrate much of this mineralization.

Clearly, however, the origin of the cobalt deposits is still not resolved and is a central problem in developing effective regional guides for locating additional deposits. Without a clear understanding of the origin of the cobalt deposits, a basically sound exploration program to find more cobalt will not be possible.

The following are some of the kinds of additional basic work needed to understand these deposits.

- Study of light stable isotopes may determine the source of the fluids which deposited the minerals;
- Fluid-inclusion studies could determine the temperature of ore deposition;
- Radiometric dating could determine the age of mineralization; and
- Systematic study of the chemical and mineralogic zoning of the mineralized veins may determine the history of ore deposition.

In addition to developing a more clearly focussed program for cobalt exploration, the study of the temperature of ore deposition, chemistry of mineralization, and origin of mineralizing fluids might reveal systematic patterns of mineralization within the Bou Azzer district which could either define the limits of ore deposit formation or show where mineralization may occur in areas that have not yet been examined.

Evaluation of the adequacy of exploration in the Bou Azzer area

Exploration for cobalt in the Bou Azzer region has been intensive. In addition to the work done by CTT, a 2-year program sponsored by the Soviet Union extensively sampled and drilled much of the western part of this district (Technoexport, 1969-1971). Exploration has mostly used a combination of geological, geophysical, and geochemical methods. The approach that has been used is to first locate the favorable serpentine contact zone by either geologic mapping or aeromagnetic surveys (serpentine shows a good aeromagnetic anomaly). Faults were then identified by either mapping, aeromagnetic patterns, or other geophysical surveys. Mineralization was located by geochemical rock sampling, electrical anomalies, and by drilling.

The exposed parts of the serpentine have been extensively explored. Thus chances for finding additional large, near-surface ore deposits have been considerably reduced. However, it is important to note that veins associated with economic deposits are commonly very small (generally less than 1 m thick) and may be easily missed. Thus, the use of some new exploration techniques may locate deposits in already prospected areas. Further considerable potential exists for finding deposits in areas

where serpentine is now covered by younger rocks.

We believe that use of the following techniques may help identify cobalt deposits:

1. Geochemical stream-sediment sampling. Sampling of this type is the cornerstone of much of the exploration carried out by private U.S. companies and most of the land assessment programs conducted by the United States Government. It has repeatedly been shown to be an effective exploration tool in arid climates where there has not been much eolian transport. It has been repeatedly and successfully used in parts of Arizona and New Mexico where the climate, physiography, soil cover, drainage, and geology is similar to conditions found at Bou Azzer. Sampling of this type has not been done in the Bou Azzer area, even though such sampling is superior to the rock geochemistry method that has been used in this region in its ability to detect mineralization over large areas. Further, the method can be adapted to locate specific sites by decreasing the size of drainage areas from which samples are taken. In many cases, it may also detect buried deposits where faults and veins have allowed water to leak up to the surface.

   Systematic sampling of stream sediments may quickly identify chemical anomalies which merit further evaluation. Samples should be analyzed for a large number of elements, as deposits are often located by "pathfinder" elements and not the principal metal associated with the deposit (for example: Hg, B, Ba, Mo). Additionally, the heavy-mineral fraction of the sample should be examined for "indicator" minerals

that may also show the presence of cobalt. In order to test the effectiveness of geochemical sampling in this region, 28 stream sediments were collected over areas which are known to be either mineralized or barren. These samples will be analyzed in the laboratories of the U.S. Geological Survey and will serve as an orientation survey which may show the usefulness of this sampling technique.

2. Airborne geophysical surveys on closely spaced flight lines may identify electrical anomalies in deeply buried rocks or may show the presence of unrecognized faults favorable for mineralization. With the exception of the magnetic surveys, all geophysical work has been by ground surveys, and has only had a relatively shallow penetration. Airborne work may provide quick, relatively detailed, and comprehensive coverage of larger areas than have been covered in the past and also reach greater depths than previous ground surveys.

3. Remote sensing techniques may be valuable in identifying fault or shear zones. Subtle features that identify these zones may be detected by infrared photography, side-looking radar, or other airborne sensing techniques. As an example, reactivation of faults associated with a buried deposit may propagate fractures through the overlying cover. After a heavy rain, these fractured zones may be detected on infrared photographs.

Landsat images were obtained for the Bou Azzer area in order to evaluate their usefulness in finding deposits. On the images areas of serpentine show in a distinctive blue-green color.

However, geologic mapping in this area has been so complete that the Landsat images do not show any new serpentine areas. Further, the size of the cobalt deposits is such that individual deposits are probably smaller than the reolution of these satellite images. Thus Landsat images probably would not be helpful in locating specific target areas.

4. Vegetation that is "stressed" often differs in size, color, and other characteristic features from "unstressed" vegetation. Traces of cobalt and arsenic in the soil near mineralization may effect the growth of plants and thus provide a "stress" environment. Plants in these areas may thus act as a guide to locating mineralization. Although mostly carried out in areas having extensive plant cover, exploration using "stressed" vegetation in areas of sparse vegetation should also be possible. Consideration should therefore be given to using differences in vegetation as a prospecting guide to locate cobalt. Particularly, recent advances that allow one to measure the "stressed" condition of individual plants with a hand-held radiometer should be investigated.

5. Mercury sensing devices have been used in some exploration programs. Although a somewhat cumbersome technique, this may be a useful approach if the cobalt deposits can be shown to be associated with mercury.

6. A less conventional approach to finding more cobalt would be to train dogs to locate arsenic minerals. As odd as this may seem, exploration by means of dogs that locate sulfide ore has been highly successful in Sweden where glaciation has covered most ore deposits. A similar program, with dogs trained to find arsenic ores, may be successful in the Bou Azzer area.

Conclusions and recommendations

1. The Bou Azzer area is geologically well known. Thus additional routine geologic mapping studies are not needed in this area.

2. Mineralization in the Bou Azzer area is associated with serpentines that probably are part of a dismembered ophiolite. The complex geologic history is this area has resulted in alteration of this dismembered ophiolite so that it is now virtually unique. This in turn indicates that the cobalt mineralization at Bou Azzer is probably unique. Thus, much of the information learned from other cobalt deposits may not directly apply to this area.

3. The economic mineralization is associated with serpentine, is in a silica-carbonate rock, and is concentrated in faults. At present, these are the three major guides to finding ore.

4. The manner of ore deposition is not well understood. Until there is a better understanding of the ore genesis, exploration for these deposits will lack a clear focus. Basic research on fluid inclusions, vein isotopic compositions, and vein chemistry may show regional patterns of mineralization, relationships between mineralization and the fault structures, and the relationship of mineralization to the silica-carbonate host, as well as revealing how the deposits formed. These data, in turn, could more effectively direct exploration towards other targets.

5. The carbonate-silicate rock associated with the serpentine is host to the cobalt deposits. Its origin is clearly central to understanding how these deposits formed and where other deposits can be found.

We were unable to substantiate LeBlanc's hypothesis that this rock formed as a subaerial deposit laid down on serpentine. Instead we feel it probably formed as an alteration product on the edges of repeatedly mobilized lenses of serpentine.

6. Good potential exists for additional cobalt deposits. Because of previous extensive prospecting, the best chance for finding mineralization is in areas covered by younger rocks. However, new exploration techniques may locate deposits in areas that have been previously explored.

7. Exploration in the Bou Azzer region has not utilized many of the methods that often are successful in finding mineralization. Exploration by stream-sediment geochemistry, airborne geophysical surveys, study of vegetation patterns, and airborne remote sensing may be extremely useful in this area. The use of mercury sniffers and arsenic sniffing dogs may be other additional exploration approaches. Because of the small size of the deposits compared to the relatively large size of the area resolved by satellite imagery, Landsat imagery will be of little use in finding ore deposits.

8. The best targets for additional cobalt will probably be in covered areas where geophysical data show serpentine to be present at depth, where geochemistry shows an anomaly to be present in "pathfinder" type elements, and where faults are shown by both geophysics and remote sensing techniques. Of course drilling will be necessary to confirm the existence of mineral deposits.

9. Exploration costs will probably rise considerably over the next few years as it will probably be necessary to use increasingly expensive and sophisticated exploration techniques.

EVALUATION OF THE BLEIDA AREA

On February 4, 1982 a geologic visit was made to the Bleida copper deposit. Both underground and surface exposures were examined. The following summarizes our observations and conclusions as well as synthesizes some of the information presented on this deposit by Leblanc and Billaud (1978).

Summary of findings

The Bleida deposit consists of two major ore bodies. They are both located near the contact between underlying volcanic rocks and overlying sedimentary rocks. The volcanics are mostly a mixed sequence of felsic and mafic rocks. Toward the top of the volcanic pile are a number of ferruginous quartzite layers that contain some barite. These layers are directly associated with copper minerals and probably are exhalite layers precipitated from nearby volcanic vents. The sedimentary sequence that overlies the ore deposits is mostly greywacke and siltstone, and minor volcanic interlayers.

The richest mineralization is concentrated in faults into which the minerals have been mobilized. Away from these faults, the deposits are clearly stratabound, that is, the mineralization is conformable with the rock layering.

Bleida is clearly a volcano-sedimentary copper deposit. The features that are diagnostic of this deposit are its 1) occurrence in a series of felsic and mafic volcanics, 2) association with sediments that probably were deposited as chemically precipated layers (layers rich in silica or barium), 3) association with hydrothermally altered aluminum-rich rock layers (andalusite and cordierite schists), and 4) a chalcopyrite-pyrite mineralogy (no zinc or lead). These features are also found in many

other volcano-sedimentary copper deposits elsewhere in the world. An important characteristic of these deposits is that many occur at a well defined stratigraphic horizon along which several zones of mineralization are present. Leblanc's 1981 regional map shows several other areas of copper mineralization that apparently lie in the same stratigraphic zone as the Bleida deposit, but we have not determined the extent of exploration along these showings.

We feel that the above geologic information indicated that excellent potential exists for additional undiscovered copper mineralization in the Bleida region. Such deposits are often easily found by airborne magnetic and electromagnetic surveys. CTT is apparently planning such surveys. Clearly, this area has much further potential and, if CCT is interested in partnerships, would represent an area where U.S. private concerns may wish to become active.

SIROUA REGION COBALT OCCURRENCES

The Siroua uplift is located approximately 100 km west of Bou Azzer. This region shares a number of geologic similarities with the Bou Azzer area, including the existence of some serpentine bodies that are believed to be part of a Precambrian ophiolite. This uplift is thus considered to be an extension of the belt of rocks exposed in the Bou Azzer uplift.

In addition to having geology that is similar to the Bou Azzer region, the Siroua area also contains some cobalt mineralization. After the deposits of Bou Azzer, these showings of cobalt represent the most important cobalt prospects in Morocco. For this reason, two days were spent examining cobalt-bearing veins within the Siroua area (locations on fig. 3).

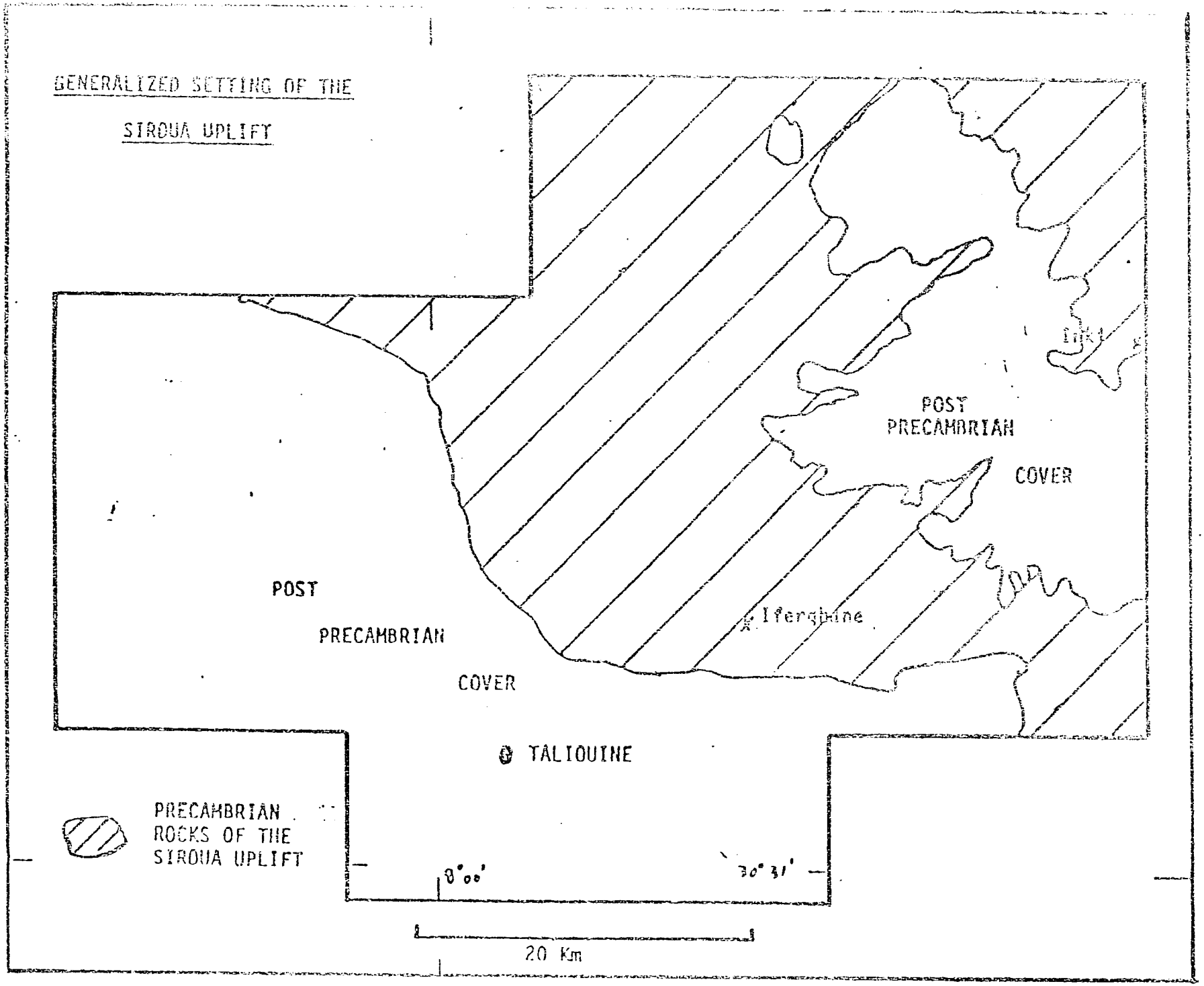

Figure 3. Setting of the Siroua uplift showing the Precambrian rocks (left diagonals) and younger cover rocks (blank).

Iferghane

Several cobalt-bearing veins crop out northeast of the town of Taliouine (south Morocco Lambert map coordinates X = 271.4, Y = 403.35) and about 2 km south of the small village of Iferghane. Of the several cobalt localities in this area, only one was examined in detail.

A carbonate vein, emplaced within a north-trending normal fault, cuts highly deformed and metamorphosed sediments of the Imerlech formation and a diorite which intrudes and encloses blocks of that formation. The vein is only a few centimeters wide and shows visible mineralization over a vertical distance of 30 m, mostly skutterudite, safflorite, arsenopyrite, pyrite, and chalcopyrite with traces of galena. This vein has been explored by small underground workings at 5 levels.

The cobalt mineralization at Iferghane is similar in age and mineralogy (predominantly arsenides) and general setting (it is located near the axis of a large block uplift) to the mineralization at Bou Azzer. However, it differs markedly from the Bou Azzer deposits in that serpentine is not associated with the vein.

Inki

The Inki prospect on the east edge of the Siroua uplift (X = 295.5, Y = 419.7; Lambert south Morocco coordinates is another cobalt locality. Unlike the Iferghane deposit, for which little information is available, this occurrence has been the subject of extensive study by means of trenching, tunnelling, and geochemical sampling. Reports detailing the results of this work are on file at the BRPM office in Rabat.

The vein occurs in a north trending fault which cuts a series of meta-

sandstones and siltstones of the late Precambrian Tidiline Formation. Also present is a younger series of diorite dikes which cut both the fault and the metasediments and which appears to be spatially associated with the mineralization, is mostly cobalt-bearing arsenopyrite, pyrite, and chalcopyrite. The vein is exposed over approximately 300 m and is commonly from 1 to 3 m thick.

Summary and conclusions

The cobalt veins exposed at Iferghane and Inki are probably not of economic interest. However, we feel that they indicate that additional cobalt mineralization may exist in the Siroua area. These prospects are in a geologic block that probably is an extension of the rocks exposed at Bou Azzer.

Although the geology of the cobalt veins at Iferghane and Inki is very different than that associated with the Bou Azzer deposits, some similarities between the two areas are present and may suggest that the two types of mineralization are related. At Iferghane, the host for the mineralization is a carbonate vein that appears to be identical to the mineralized veins at Bou Azzer; at Inki, the cobalt mineralization is associated with high concentrations of Cu, Ni, and Mo, a geochemical association that is also present at Bou Azzer. If a genetic link between the Bou Azzer and Siroua mineralization exists (for example, the Siroua veins may represent Bou Azzer deposits that have been remobilized by later diabasic intrusions), then the serpentine bodies known to exist in the Siroua Region may be associated with economic deposits of the Bou Azzer type.

The mineral potential of the Siroua area is poorly known, but we feel it is a favorable area for additional cobalt mineralization as well as for

deposits of other metals. We suggest that regional geochemical stream sediment studies be carried out to locate target areas worthy of more detailed studies. We view the Siroua area as a good region for further exploration and a region in which U.S. exploration companies might wish to become active.

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APPENDIX 1

Summary of U.S.G.S. activities in Morocco

1-27-82	Meetings in Rabat with U.S. Embassy and staff of BRPM
1-28-82	Meetings in Rabat with staff of BRPM, the Moroccan geological survey, and the Director General of BRPM.
1-29-82	In transit to Bou Azzer
1-30-82	Arrive at Bou Azzer. Meet with C.T.T. geologists and receive briefing on the geology of the Bou Azzer deposits.
1-31-82	Examined geologic relationships at deposits Ahmbed 1, Ahmbed 2, and Ahmbed 3.
2-1-82	Traverse the Bou Azzer ophiolite complex at Ait Ahmane. Examine cobalt deposits vein 58 and vein 53E in the Ait Ahmane area. Collect representative samples through the ophiolite and at these two ore deposits. Traverse through parts of the volcano-sedimentary sequence that overlies the ophiolite to the north of Ait Ahmane.
2-2-82	Underground and surface examination of geology and mineralization at the vein 61 deposit. Rossman examined area adjacent to Bou Azzer east deposit; Foose examined workings and geologic relationships at the Ahmbed 3 deposit.
2-3-82	Underground and surface examination of the geology and mineralization of the Tamdrost deposit. Surface examination of volcano-sedimentary rocks near the village of Tidaline.
2-4-82	Underground and surface examination of the Bleida copper deposits at the east edge of the Bou Azzer uplift.

2-5-82	Stream sediment sampling over a 1 Km^2 area which includes areas both known to be mineralized and to be barren. Samples collected to be analyzed by the U.S. Geological Survey and are meant to demonstrate the usefulness of stream sediment sampling in a regional exploration program in the Bou Azzer area. Preparation of report on geologic findings.
2-6-82	Preparation of reports plus social gathering with C.T.T. company officials at Bleida.
2-7-82	Field an underground examination of the Iferghane cobalt occurrence within the southern part of the Siroua uplifted block.
2-8-82	Field examination on the Inki cobalt occurrence within the eastern part of the Siroua uplifted block.
2-9-82	Visit to the Imini manganese mine. Examine some ore processing facilities and some surface rock exposures. In transit to Rabat.
2-10-82	In transit to Rabat. Arrive in Rabat and unload samples and equipment.
2-11-82	Pack and mail rock samples. Met with U.S. Embassy officials and with members of B.R.P.M. to report findings.
2-12-82	Meeting with Director General of B.R.P.M. Final meetings with members of U.S. Embassy.
2-13-82	Left Rabat travel via Paris to U.S.

Appendix 2

Bureau of Recherches et de Participations Minieres, mining projects under consideration (unedited summary listing of projects which BRPM would like outside assistance in developing).

oOo C O N T E N T S oOo

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I N T R O D U C T I O N

I. MINERAL PROSPECTIS OF THE KINGDOM OF MAROCCO

The kingdom of Morocco considering its vast Territory carries excellent chances of producing economie mineral deposits.

The chances are further enhanced by the varied geologic environments of the country.

- géologic setting :

Starting from the south towards North, Morocco forms a part of the west african Shield followed by the Anti-Atlas zone which has been affected by many successive Pre-Cambrian Orogenie activities.

These orogenic movements were taken over by the Caledonian orogeny which has left very few exposures.

The next, the Hercynian formations are widely distributed in Morocco.

A pre-Alpine orogenic event gave rise to the High Atlas and the Middle Atlas Ranges.

The northern part of Morocco ends up with the Alpine Orogeny.

- Pejuvination :

Geochronologic studies have demonstrated many rejuvenations particularly in the Precambrian areas. These rejuvenating processes indicate reactivation producing remobilization of metallic elements.

.../...

TECTONIC EFFECTS

Besides numerous faults, there are a number of discordance: in the country, namely the Anti-Atlas Great fault and the South Atlas Thrust, as well as many Protorifts.

LITHOLOGIC VARIATION

Morocco inherits very diversified lithologic sequences favourable for the formation of ore deposits intrinsically as well as due to their geochemical, chemical and geologic properties.

There are virtually all rock types in Morocco : granites, rhyolites, diorites, trachytes, andesites, trochtolites, ultrabasics, serpen nes, syenites, carbonatites, limestones, dolomites, conglomerates, sandstone siltstones, marls, clays, etc.....

GEOCHEMICAL DISPERSION

The known mineral occurrences in Morocco display a very large geochemical spectrum which indicates an interdependence among these element In fact, there are deposits of, Pb, Zn, Cu, Fe, Mn, Sb, Au, W, Sn, Mo, P, F, Ba, lignite, Coal, Oil Shales, etc..... in the country. In view of this broad geochemical spectrum there is a strong probability of discovering hitherto unknown deposits.

GITOLOGIC SETTING

Various metallogenic processes are characterized by many different type of deposits, such as dessiminated, vein, volcandetritic, sedimentary, Karst, pyrometasomatic deposits and so on. This shows a whele range of mineralizing conditions and host rocks.

IMPORTANCE OF ORE DEPOSITS OF MOROCCO

Morocco is reputed for its world ranking deposits, such as those of phosphates, lead - zinc and Oil Shales. A recent discovery of copper deposit adds to this list. The chances of discovering other world ranking ore deposits in the vast metallogenic provinces of Morocco cannot be ruled out.

II. MINERAL PROSPECTS OF THE KINGDOM OF MOROCCO

- Geologic studies

There is a high quality infrastructure for geologic studies organized and conducted by the Directorate of Geology.

The organization has produced excellent geologic maps at different scales, geophysical maps (magnetic and gravity), metallogenic maps, bibliographic and compilation studies and numerous publications as well as it has a well equipped laboratory. ../...

- Mineral Development

The mineral exploration is carried out by a reputed organization, Bureau de Recherches et de Participations Minière (B.R.P.M.) which is competent to promote all activities contributing to the mineral exploration and development in the country, as well as to undertake exploratory work for other parties.

As a matter of fact, this organization possesses advanced know-how acquired for over 50 years, and a solid infrastructure for the execution of drilling, exploratory and mining operations, laboratory analysis and mineral treatment and metallurgical testing.

- Status of mineral exploration

Although geologic studies are very advanced in Morocco, the mineral exploration activity is still lagging, hence there is scope for finding new deposits. It should be mentioned that large scale mineral exploration programs are essentially carried out by the B.R.P.M. The various mining companies have been confined since the beginning of the new phase of mineral exploration only to their mining ventures.

- Infrastructure of the country

An infrastructure is vital to the development of mineral resources of a country. This has very well developed and is spread throughout the country and has been continually increasing. The existence of a lead smelter in the NE of the country at Oujda and the proposed lead and copper smelters at Midelt and Agadir respectively are worth mentioning as a part of the regular infrastructure.

- Personnel and labor force

Morocco inherits a long mining tradition. It possesses a skilful and industrious labor force. The personnel have received practical training and experience on the mines. There are a number of technical institutions in Morocco such as follows.

- Ecole Mohammadia des Ingenieures
- Ecole Nationale des Industries Minières
- Ecole de Marrakech
- Ecole de Tounsit

- Mining law

The mining law in Morocco is liberal. Exploration licenses for minerals other than phosphates, oil and uranium are granted to the first applicant, on the first come first serve basis.

As for uranium, the concession is granted by the Mines Directorate on the basis of the financial and technical capabilities of the applicant.

.../...

The mining agency may constitute a fund for Development of the deposit, out of the profit exempted from tax, for devloping additional reserves or to carry out further exploration in other fields or to participate in improving the quantity or the quality of the ore.

III. STATE INCENTIVE - INVESTMENT RULES

The state has always sought to attract private investments by laying down such investment rules as to provide certain benefits and guarantees.

As such, new legislative provisions stipulating clauses so as to induce private capital were introduced on August 13, 1973.

These clauses have been draw up in a spirit of efficient and automatic working in granting promoters the previlages so as to simplify their work to the maximum.

Furthermore, to induce investment in Exploration, development, mining and enriching of ores, the mining agencies enjoy certain benefits under the terms laid down in the Dahir (Official Decree) promulgating the Act N° 173412 dated 13 th August 1973.

The term mineral substance stands for all minerals except phosphates and liquid, gaseous and solid hydrocarbons excluding the bituminous shales and limestone.

The term mining agencies means an individual of Moroccan nationality, cooperative institutions, public agencies specialized in the field of mineral exploration and mining activities and companies, at least 50 % of whose capital is held by Moroccan indiciduals or corporate bodies who are authorized to carry out exploration, mining and benficiation of mineral substances in a defined field conforming to the mining laws in force.

The mining agencies, their contractors whose capital investments include exploration and mining equipment of a tax free price of 100,000 DH would be entitled to the following benefits either directly or through the organization "credit bail".

- Exemption from duty on new equipment, tools and machiery and used equipment. import of which is allowed by the Minister of Energy and Mines.

- Exemption from duty on the equipment, tools and material imported or purchased locally.

- Reduction of Registration tax to 0,5 % for constituting or enhancing the capital

- Complete exemption from Licensing tax for the first five consecutive years of mining operation.

- State contribution towards the infrastructure.

.../...

The mining agencies who invested in the development, mining and beneficiation of mineral substances and whose investment program includes production equipment of a value more than 500,000 DH, creating at least 50 employment are entitled to state assistance.

This would relate to expenditure on infrastructure outside the domain of mining operation. The infrastructure includes connection to the highways and to the water supply, interconnection to the main Power line, constructing and furnishing educational and health centers.

The state contribution in the form of the infrastructure is equal to 50 % of the total expenditute incurred, in a manner, however, that this contribution does not exceed 15 % of the total investment planned.

- Reduction of interest by two percent on the loans accorded by the Banque Nationale pour le Developpement Economique (B.N.D.E.).

- Provisions concerning foreign exchange Regulations

The remittance of the proceeds of liquidation sale is guaranteed to the extent of the funds invested by a foreigner.

The remittance of dividends after income tax deductions distributed to the non residents is guaranteed without limit.

IV. PROSPECTIVE ZONES AND TARGETS FOR MINERAL EXPLORATION

- SOUTHERN PART OF THE KINGDOM

This region is particularly promising for iron, copper and uranium deposits.

- ANTI ATLAS

This is the most promising zone for copper, silver, cobalt, gold, uranium, lead, zinc and iron deposits.

- HERCYNIAN ZONES

Occurrences of silver bearing lead, zin, antimony, tungsten, tin, uranium, fluorite and baryte are known in these zones.

- ATLAS AND HIGH PLATEAU ZONES

These regions have excellent host rocks for lead and Zinc deposits.

- RIF ZONE

This is a prospective zone for lead, zinc, antimony, mercury, nicked and magnesite deposits.

.../...

PROJECT OUTLINE

Project title : TIZERT

Administrative province : AGADIR

Object & description of the project

The implementation of the project will allow the development of a copper - silver deposit. The total reserves amount to higher than 3 million tons with the following grades :

- 1,69 % Cu
- 54 g/T Ag.

under a first phase only the economically exploitable reserves could be developped at a yearly capacity of 84 000 tons allowing the recovery of about 4000 tons of concentrated metal yielding 40 % of copper and 930 g/T of silv

Project cost estimate : 53.330 000 DH

Financing sources

- Government budget
- Bank loans.

Possibilities of association : to be defined with B.R.P.M.

Expenditures schedule : (Thousand DH).

.../...

YEAR	BEFORE 1981	1981	1982	1983	1984	1985	Total
Amount	14.850	150	8 400	12 675	12 475	5 000	53 550

Project progress

The completed feasibility studies justify the development of this deposit. Work completed up to now represents 27 % of the whole project.

Employment generated : 150

Cash flow Estimate (Thousand DH).

	PERIOD 1981/83	PERIOD 1984/85	PERIOD 1986/90
Turn over	-	32 790	117 610
Expenditure	-	25 586	50 041
Cash flow	-	37 212	67 569

.../...

PROJECT OUTLINE

Project title : ZOU MINE

Administrative province : ERRACHIDIA

Object and description of the project :

The implementation of the project will allow the development of a polymetallic deposit. The total estimated reserves amount to 5 million tons, with the following grades :

- 1,3 % Pb
- 5 % Zn
- 150 g/T Ag
- 3 g/T Au
- 38 % S.

The projected capacity production under a first phase will be 60 000 tons (of raw materials) per year which could be rapidly increased.

Financing sources :

- Government budget
- Bank loans

.../...

Project cost estimate :

DH 42 million (for the first phase).

Possibilities of association :

To be defined with B.R.P.M.

YEAR	BEFORE 1981	1981	1982	1983	Total
Amount	10 000	3 500	17 100	11 400	42 000

Project progress :

The feasibility studies have been already completed. They show that the development of the project is profitable.

Employment generated : 120 under the first phase.

.../...

PROJECT OUTLINE

Project title : ZRAHINA

Administrative province : KHENIFRA (Middle Atlas)

Object and description of the project :

The implementation of the project shall allow the development of a fluorine deposit. The total reserves amount to one (1) million tons containing :

- 31 % CaF_2
- 10 76 % $BaSO_4$
- 1,83 % Pb
- 63 g/T Ag
- 0,60 % Zn

In the first phase, the production would amount to 70.000 T/year yielding :

1400 T/year concentrates containing Ag : 2 kg/t ; Pb : 65 %

3500 T/year of concentrated barytes at 95 % $BaSO_4$.

.../...

14 700 T/year of concentrated fluorine at 96 %.

Project cost estimate : DH 37 million.

Financing sources :

- Government budget
- Bank loans.

Expenditures schedule : (DH million).

YEAR	BEFORE 1981	1981	1982	1983	1984	1985	Total
Amount	3700	500	5500	12300	6150	6400	37000

Project progress :

The geological and feasibility studies completed up to now showed that the deposit can be profitably exploited.

Employement generated : 132

Cash flow estimate : (DH Thousand)

	PERIOD 1981/83	1984/85	1986/90
Turn over	-	50.326	148.151
Expenditures	-	31.679	100.569
Cash flow	-	18 647	47.582

.../...

PROJECT OUTLINE

Project title : The central lead smelter (FONDERIE CENTRALE DE PLOMB - F.C.P.

Administrative location : Midelt

Objet and description of de project :

The setting up of this smelter will allow a better development of concentrated lead of whichi Morocco is since a long time a major producer and exporter. Lead will be exported in the first phase, and later "trealted in Morocco as finished product in the second phase.

The smelter will handle 105.000 T/year of concentrates containing 68,8 % lead, with silver an copper as by products. Il will produce about 70 000 T/year of soft lead, 50 000 kg/year of fine silver and 560 tons of 45 % copper concentrates.

The projected treatment will be carried out according to a classical and flexible process including :

Agglomerate reasting, water jacket tank kiln reducing fusion and pyrometallurgical up grading. All the anti-pollution devices at the worsite have been envisaged conforming to the standards applied in the industrialized countries.

The analysis of the economic results shows an increase of aboit 35 % en on the turn over.

.../...

- Project cost estimate : 205 000 000 DH

- Financing sources :

  . Government budget

  . Bank loans.

- Possibility of association : to be defined with B.R.P.M.

- Expenditures schedule (Thousand DH)

YEAR	BEFORE 1981	1981	1982	1983	1984	1985	Total
Amount	4000	0000	30 000	90 000	90 000	68 000	285 000

- Project progress :

Technical, economic and commercial studies have been completed. Tenders have been called and the offers received are under study.

- Employment generated : 335.

.../...

PROJECT OUTLINE

PROJECT TITLE : Moroccan copper smelter.

ADMINISTRATIVE LOCATION : AGADIR

OBJECT AND DESCRIPTION OF THE PROJECT :

The smelter will allow a better development of concentrated copper as Morocco is to become a major copper producer, particulary after the opening of the BLEIDA mine. The copper produced will be exported in the first phase, and in a second phase it will be "treated" in Morocco to obtain finished products. The capacity of the smelter is scheduled at 50.000 T/year of copper wire bars.

The facility will also handle the by-products : gold and silver as well as sulfur (sulfuric acid).

The smelter's product break down is as follows : 75 000 T/year of concentrate from Moroccan mines containing 33 % Cu and 110 000 T/year of imported concentrate containing 27 % Cu. The metallurgical process includes matte fusion followed by converting. Thermal and electrolytic refining would produce copper metal and anodic pulp which would be refined by electrolysis into fine gold and silver.

The economic results show a global internal profit of 8.23 %.

Project cost estimate : 900 000 000 DH

Financing sources :

- Government budget
- Bank loans.

.../...

Possibility of association : to be defined with B.R.P.M.

Expenses schedule : (Thousand DH)

YEAR	BEFORE 1981	1981	1982	1983	1984	1985	Total
Amount	2 500	1 000	3 000	155 000	153 000	185 500	500 000

Project progress : The preliminary technical and economic studies are under way.

Employment generated : 340.

.../...

PROJECT OUTLINE

URANIUM

Uranium exploration in Morocco was started by the French C.E.A, first in 1946 and the efforts were accelerated by deputing a team to the service Geologique du Maroc, which studied the phosphate and coal basins and granites.

In 1953, the Moroccan Mineral Exploration Company (Societe Marocaine de Recherches et Etudes Minieres) was created and the uranium exploration for the entire country was undertaken. Several showings were studied in detail and the Triassic, Jurassic and Cretaceous basins were reconnoitred.

Thre was little activity between 1956. The B.R.P.M. then activily restarted the exploration in 1970. Carborne and airborne radiometric surveys were un dertaken by the Scintrex, CANADA under the auspices of UNDP project which revealed several important radiometric anomalies.

Further radiometric surveys and systematic geological studies by the B.R.P.M. between 1970 and 1976 indicated new anomalies and prospective zones. Detailed exploration in these zones revealed uranium showings and mineralized structures which are now under active exploration by means of drill holes and adits.

Among notable deposits are WAFFAGA in the Western High Atlas, AKKA BOU TIOUIT and ASSAKA in the ANTI ATLAS.

.../...

The Western High Atlas project zone covers 3000 Km^2 130 Km to the SW of MARRAKECH. The mineralization occurs in the Hauterivian continental sandstone in the lower cretaceous formations. The uranium minerals are carnotite and pitchblende associated with organic matter. The deposit has a potential of 2000 tons of uranium having grade around 0.15 to 0.2 % U_3O_8

The ANTI ATLAS Project zone contains the mineralized zones of ASSAN and AKKA BOU TIOUIT.

- ASSAKA : It covers an area of 2400 Km^2 and is situated 260 Km to the east of AGADIR. Uranium mineralization occurs in northerly fractures and alteration zones in the upper Precambrian granites and in the overlying tertiary volcanic tuffs. The deposit may bac considered having 4000 tons of uranium of a grade around 0.15 % U_3O_8.

- AKKA BOU TIOUIT : It covers an area of 1400 Km^2 and is situated at 570 Km to the east of AGADIR. Uranium mineralization occurs in NE-SW trending fault zones cutting upper Precambrian leucocratic granites. The veins resemble those of French Massif Central. The potential may be of the order of 2000 tons of uranium with a grade around 0.075 % U_3O_8.

QUARZAZATE TERTIARY BASSIN :

Pertinent geologic conditions exist for selecting this basin for uranium exploration. Thick continental clastic sediments of Tertiary age fill the bassin. These sediments are derived from the Precambrian eruptive and crystalline complex of the ANTI ATLAS and the High Atlas, which are considered as the best source rocks for uranium. The continual and intensive leaching of the basement as well as the Tertiary volcanic tuffs could have washed uranium bearing solution in to the basin.

../...

The mobile uranium would be concentrated and precipitated in the arkosic sandstone by evaporation and chemical interaction of urani ferons solutions in presence of organic and carbonaceous materials and clay minerals.

Considering the geological critaria a systematic exploration is programmed consisting of :

- Geologic and Radiometric reconnaissance of the basin
- Zones
- Air borne radiometric survey
- Emanometry and radon measurement
- Strat gic and tactical geochemical exploration
- Exploratory work in promising zones

.../...

PROJECT OUTLINE

PROJECT TITLE : WAFAGA

ADMINISTRATIVE: PROVINCE : MARRAKECH

SITUATION : 130 km SW of MARRAKECH

Uranium mineralization in the JBEL WAFAGA discovered in 1977 occurs in the paleochannels in the fluvio-deltaic sandstones of the Hauterivian continental series in the Imni Tanout region (Western High Atlas).

Exploration studies revealed the existance of 50 paleochannels of which about 12 are highly radioactive. Uranium occurs as carnotite impregnated in the Sandstone. The grade is between 0.15 to 0.2 % U_3O_8

The exploratory work undertaken consists of :

Percussion holes : 10 000 m

Diamond Drilling : 1 300 m

Adits and Crosscuts : 570 m

In view of the promising results obtained as well to locate the paleochannels and to ascertain the reserves further exploratory work will be required.

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PRECIOUS METALS

Morocco presents three metallogenic units for the precious metals. These units are SIRWA, OUGNAT et SAGHRO, all in the ANTI-ATLAS. The precambrian formations had been eroded at the end of Precambrian and hawe been covered by sediments ranging from the Infracambrian to late carboniferous. These regions were later uplited and deep folded during Hercynian and Alpine orogenies.

The SAGHRO chain extending East-West consists of an axial zone produced by bulging at the end of Middle Precambrian P II-III), accompanied by granitization and is covered by the Adoudounian and Paleozoic formations. The upper part of the Precambrian II formations are characterized by intrusions of granite, granodiorite and diorite.

The Precambrian III represents various lithological units. The sedimentary formations consist of conglomerates, schists, sandstones, etc. interbedded or covered by andesite flows. Thick rhyolite nappes join then to the East and West.

The SIRWA Massif constitutes of Precambrian II-III volcano-detritic series containing dolerite dykes, gabbro, granite, granophyre and rhyolite. This zone appears as a window (inlier) between younger formations to the East and granite to the West.

The exploratory work by the B.R.P.M. in this region resulted in the discovery of several deposits containing primary gold and silver mineralizations. The following deposits are being mined or in the final stage of preparation for mining.

.../...

IMITER Silver deposit is situated at the northern flank of SAGHRO. The proved reserves amount to 900.000 tons having a grade of 1500 g/t Ag. The deposit is being mined since 1968. A subsidiary company of the B.R.P.M. produces precipitates containing 92 % Ag.

The IMITER deposit may have additional reserves of several millions of tons of silver. Consequently, exploratory work and investigations on a regional scale are considered necessary to evaluate fully the potential of the area.

A gold-Silver deposit occurs equally at TIGHIT having a reserve of 1 million tons with a grade of 10.5 g/t Au, 54 g/t Ag and 0.35 % Cu.

The Silver deposit of ZGOUNDER is situated to the NW of SIRWA amounting to reserves of 600.000 tons of ore having 100 g/t Ag and is being prepared for mining by the "Societe Metallurgique du SIRWA".

The IMITER and ZGOUNDER deposits are rare primary silver mineral types in the world.

In general terms and taking the geologic and geographic situation of these deposits in to consideration, the Anti-Atlas would represent a metallogenic province for precious metals. Consequently exploration Work should be necessary to discover new deposits similar to those already known.

.../...

PROJECT OUTLINE

PROJECT TITLE : TIOUIT

ADMINISTRATIVE PROVINCE : OUARZAZATE

LOCATION : The gold-Silver deposit is located at 45 Km SE of BOUMALN du DADES and at 475 Km from AGADIR port.

The regional geology constitutes of the granite massif bordered to the North by lightly metamorphose schists of middle Precambrian age and covered uncomformably by the upper Precambrian rhyolite complex.

The mineralization is localized in the quartz lodes cutting across the granite.

The mineralization with quartz/chlorite gangue consists of microscopic native gold associated mainly with chalcopyrite, pyrite and quartz and with Silver bearing cuprite, sphalerite and galena.

The exploratory work undertaken on this vein deposit consists of :

trenches : 1300 m^3, bore holes 11000 m

adits : 3000 m

This work has established a reserve of 1 million tons of ore having 10,5 g/t Au, 54 g/t Ag and 0,36 % Cu.

.../...

PROJECT OUTLINE

PROJECT TITLE : CADNAR

ADMINISTRATIVE PROVINCE : CHAOUEN

This zinc deposit is situated at 18 Km East of CHAOUEN and 120 Km from the Tangiers port.

The mineralization occurs as layers of sphalerite and smithsonite a part of which can be mined by open pit.

The exploratory work has established reserves amounting to 7 500 000 tons having grade of 3 % Zn. The potential of this deposit could be as high as 40,000 000 tons.

In the same region, the preliminary exploration at the KHEMIS TIKENZIGUEN deposit has ascertained reserves of 500,000 tons hawing 10 % Zn and rich in Germanium and specially in Cadmium.

The metallurgical stedies on the ores of these two deposits by flotation in a pilot plant have produced 50 % Zn concentrates.

.../...

PROJECT OUTLINE

TUNGSTEN

The activity of the BRPM in this field consists on the one hand of reopening of old partially working mines Azegour, Sidi Bou Azzouz, Zguit and Hessian Diab, and on the other hand exploring new areas such as Taorirt-Tamlelt in the Saghro.

The is cooperation with the German Company KLOCKNER has under taken the development of the Azegour and Sidi Bou Azzouz deposits.

AZEGOUR /

Province : Marrakesh

Situation : 80 Km South of Marrakesh and 230 Km from Safi port.

This is a contact pyrometasomatic type of deposit situted in the Central High Atlas.

The Skarns and garnetiferous rocks mineralized in Scheelite from leses adjacent to the granite.

The exploratory work undertaken jointly by BRPM-KLOCKNER has revealed 500,000 tons of are having 0.20 % WO_3.

SIDI BOU AZZOUZ

Province : Marrakesh

Situation : 160 Km from Casablanca port

The scheelite deposit is in quarts veins in the Rehamna Paleozoic basement in the vicinity of a hercynian granite bath olith.

The exploratory work undertaken jointly by BRPM - KLOCKNER has revected 1 million tons of are having 0.25 % WO_3.

These two deposits are in the final stage of development which includes feasibility studies and Engineering for the realisation of e projects.

.../...

TAOUNIAT N'TAMELALT :

Province : OUARZAZATE

Situation : 20 km SE of Boumaine du Dades and 460 km from Agadir port.

The scheelite mineralization occurs in fractures in the granite. Exploratory work consisting of drill holes, adits and trenches is undersway. A preliminary estimation of reserves is 800,000 tons having 0.20 % WO3.

ZOBIT

Province : KHEMISSET

Situation : 160 km from Kenitra port.

Wolframite occurs in quartz veins in the aureole of contact metamorphism in the southern border of the Oulmes granite massif.

Exploratory drilling is underway which have indicated encouraging results.

MASSIAN DIAB :

Province : OUJDA

Situation : 60 km south of Taourirt ; 160 km from the Nador port.

The deposit consists of quartz veins mineralized in chalcopyrite and wolframite associated with granites altered to greisen, in a paleozoic inlier.

In view of favorable geologic setting present for an economic tungsten deposit, this project requires exploratory work program.

../...

PROJECT OUTLINE

LIGNITE

The lignite exploration in Morocco dates back to about 50 years hence. Many regions were prospected and explored on surface indications. Since the Second world war the oil exploration gained much more importance and partly replaced the solid hydrocarbon exploration.

Since the energy crisis of the 70's, lignite exploration was restarted by the BRPM, mostly with the cooperation of German experts notably that of Professor Luttig.

The investigation were logically guided by the results of exploration in various Mediterranean countries namely Italy, greece and Turkey, where important lignite deposits have been discovered.
The investigations were under taken in the first place in the regions having identical conditions of formation, deposition and preservation of lignite.

The logical inference led BRPM to select several regions in the country, such as

- Guercif basin in the north eastern Morocco.
- Fes - Meknes basin
- Mellila - Oujda region
- Gharb and Tangiers - Tetouan Plains in North Western Morocco.

Among the above mentioned regions, the BRPM concentrated its efforts on the Guercif basin, on Gherb plains and more particularly on the Fes - Meknes basin.

The Fes - Meknes basin constitutes the eastern part of the south Rif depression filled in by Miocene marine formations and Pliocene - Quaternary lacustrine sediments. The lignite occurs in the Pliocene - Quaternary formations.

.../...

The exploratory work resulted in the discovery of the Oued NJA deposit amounting to 50 million tons of lignite having a carolific value of 1.300 Kcal/Kg.

Exploration is underway in other basins to evaluate their reserve potentials.

PROJECT OUTLINE

MAGNESITE

PROVINCE : CHAOUEN

A magnesite bearing zone 30 Km long occurs in the Paleozoic Rif. Il is situated 60 Km south of the port of CEUTA. The crystalline magnesite deposits in this zone present a potential resource of 40 millions tons.

The BOUDKHK Sector was selected as a Pilot project, for exploratory work which revealed a reserve of 9 million tons of magnesite having 43 % MgO of which 1 million tons have grades more than 44,5 MgO.

A part of the deposit could be mined by open pit.

PROJECT OUTLINE

ABSESTOS

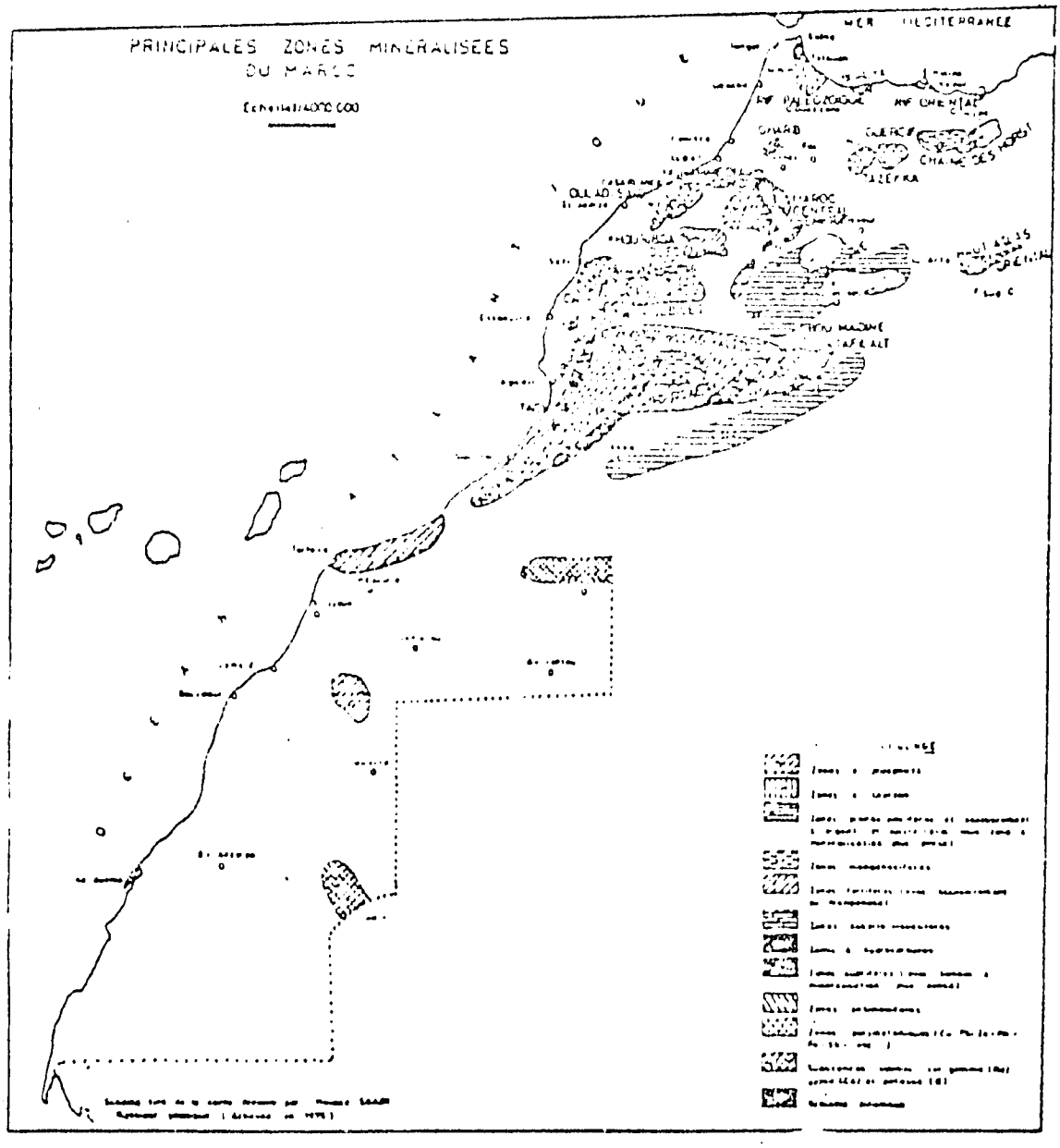
The principal known asbestes deposits are situated in the Anti-Atlas Massif in the OUARZAZATE Province. Geographically and geologically these occur in the following two distinct sectors :

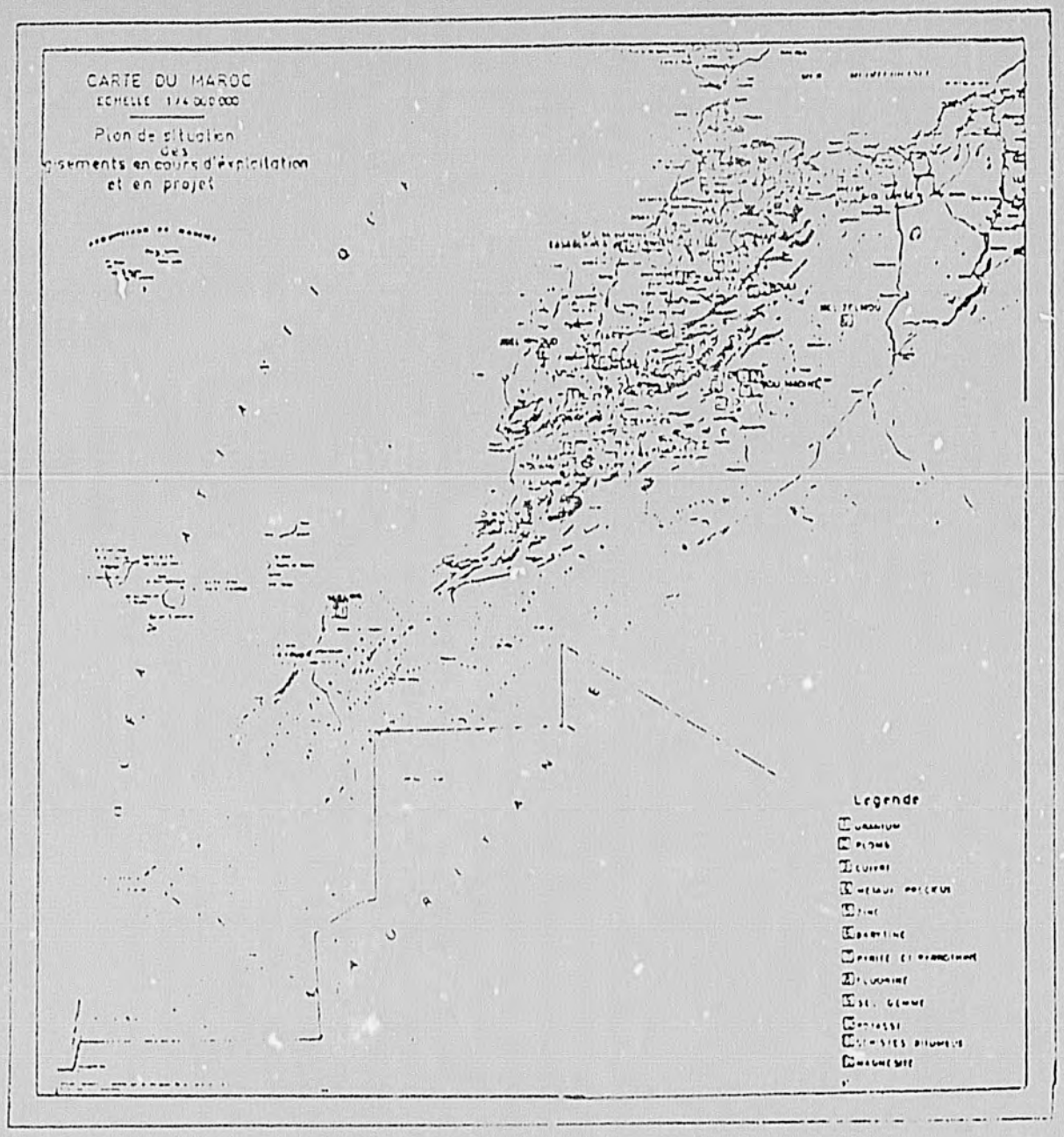
- Bou AZZER Sector.
- Northern and Southern flanks of SIRWA.

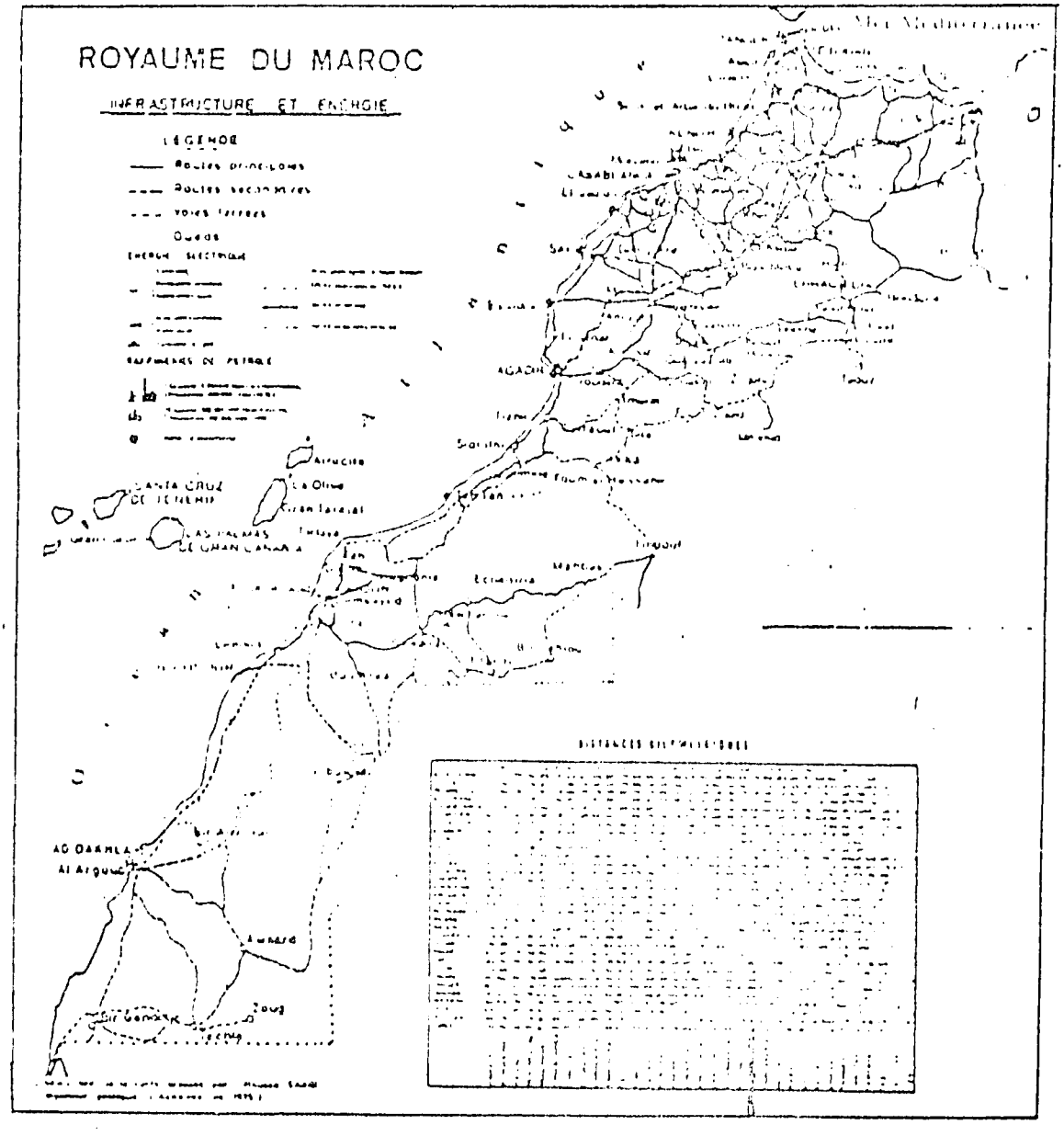
They are Situated 500 and 400 Km east of AGADIR, respectively.

The deposits generally occur as chrysotile veins and are the products of serpentinization of the ultra basic Precambrian rocks as well as of the metamosphosed dolomites.

The following asbestas deposits were selected for evaluation studies based essentially on their reserve potential, grades and fibre quality.


PRINCIPALES ZONES MINERALISEES
DU MAROC


CARTE DU MAROC
Plan de situation
des
gisements en cours d'exploitation
et en projet
Legende


ROYAUME DU MAROC
INFRASTRUCTURE ET ENERGIE
LEGENDE
Mer Méditerranée
AGADIR
AD DAKHLA
Al Arguin

March 23, 1982

MEMORANDUM

To: Director, Bureau of Mines
United States Department of the Interior

Through: Deputy Director, Minerals Information and Analysis
Director, Division of Minerals Availability

From: Foreign Minerals Specialist, Division of Minerals Availability

Subject: Project Definition Mission to Morocco

Introduction

The Trade and Development Program (TDP) sponsored a Project Definition Mission to Morocco from January 26 through February 15, 1982, to appraise the economic potential of cobalt mineral deposits and other underdeveloped or partly developed economic mineral concentrations in Morocco with emphasis on strategic minerals. The objective of this mission was to evaluate, as far as possible in three weeks, the potential for development of the resources by joint venture activities of U.S./Moroccan mining enterprises, and to outline appropriate activities by which TDP could stimulate participation in such joint ventures by U.S. firms.

The team mobilized for the reconnaissance was composed of a team leader from AID, two members from the Bureau of Mines, and two from the U.S.G.S. In addition, an expert on ophiolites from Stanford University remained with us for one week, in the Bou Azzer - Bleida area only.

Conclusions

The team was essentially unanimous in the following conclusions:

1. There is a good possibility of finding additional cobalt deposits within the limits of the already developed strike-length of the Bou Azzer mining area by utilizing established exploration methods hitherto untried at Bou Azzer.

2. There is a good possibility of finding additional cobalt mining areas in that part of the Bou Azzer uplift which has not yet been subjected to detailed geological, geochemical and geophysical examination.

3. The Siroua uplift has cobalt occurrences which, although not important in themselves, are favorable ground for detailed exploration. (Only the U.S.G.S. members of the team visited the Siroua area in the field.)

4. Exploration for copper in the vicinity of Bleida is proceeding, but could be accelerated by judicious use of geochemistry, geophysics, remote sensing, and other methods and equipment commonly used in U.S. explorations.

The conclusions below result from the visit of the team leader and two Bureau of Mines members (U.S.G.S. personnel were at Siroua) to other deposits northeast of Bou Azzer.

5. The Imiter silver development (Figures 1 and 2) is proceeding in an orderly manner on the known deposit. Assistance in regional exploration and beneficiation metallurgy would be welcome. Geophysics, and geochemistry, coupled with judicious use of remote sensing is unlikely that this is the lone economic deposit in the area.

6. The Bou Madine deposit of zinc and lead (Figures 1 and 2) contains small amounts of silver, gold, and other metals. The deposit occurs in Precambrian volcanics and metasediments crisscrossed with mineralized faults. Massive sulfides in some should be detectable by electromagnetic methods, and many of the veins contain massive barite which should show up on aerial photographs. The entire area merits further exploration.

7. The Zeida lead mine (Figure 3) near Midelt is a modern, well-equipped mine run by the Societe de Development Industriel et Miniere de la Haute Moulouya (SODIM), a joint venture, 50 percent government, and 50 percent private Moroccan capital. Exploration, now employing diamond drilling on the grid system, could be accelerated by use of seismic and/or electrical methods to locate gutter-like depressions in the basal granite which channel the lead mineralization.

8. The Government of Morocco, and those private sector people interviewed by the team, unanimously indicated a desire for U.S. exploration and mining technology to be applied to their mineral development and were looking forward to mounting joint mineral undertakings with U.S. mining firms. The mining laws in Morocco have been modernized to permit capital, technical, and even management participation by foreign firms in Moroccan mining operations.

9. Morocco has not been thoroughly explored by French or Moroccan earth scientists and is a mineralized area fronting on both the Atlantic and the Mediterranian. It represents an excellent opportunity for mining development in an African country, well-disposed toward the U.S., and with relatively well-established infrastructure.

DISCUSSION

In response to a request from the Government of Morocco, transmitted to the Trade and Development Program (TDP) in Washington by the U.S. Embassy in Rabat, Mr. Harold Le Sieur, the Industrial Development Engineer from AID, led a team on a Project Definition Mission to Morocco from Tuesday, January 26 until Saturday, February 13, 1982. John Lucas and the writer represented the U.S. Bureau of Mines, while Dr. Michael Foose, cobalt specialist, and Darwin Rossman represented the U.S.G.S. In addition, Dr. Robert G. Coleman, a professor of Stanford University, who wrote the book "Ophiolites" (ophiolite is often the host rock for nickel and cobalt), joined the team at Bou Azzer on January 30th and remained with us there and at Bleida until February 6th. Bob Coleman consults for the U.S.G.S. and has worked on ophiolites in Oman and Saudi Arabia.

The request for this Project Definition Mission was a direct result of a U.S. sponsored trade mission to Morocco in 1981, led by Dr. Thomas Henrie, Chief Scientist of the U.S. Bureau of Mines.

On January 27, 1982, the team met with American Embassy officials in Rabat, officers of the Government of Morocco's Ministry of Energy and Mines, and the directors and managers of the Bureau de Recherches et de Participations Minieres (B.R.P.M.) B.R.P.M. is a government-owned entity which explores, develops, mines, and/or invests in varying percentages of the shares of Moroccan mineral projects. It is this group primarily, which would participate in Moroccan joint ventures with U.S. mining firms, although private sector firms in Morocco may also wish to be included, and could contribute both expertise and capital.

The Rabat meetings prepared the ongoing itinerary of our reconnaissance in the field and we learned the following:

1. Morocco, conscious of the role minerals could play in its economy, has developed an active geological survey program with some activities listed below:

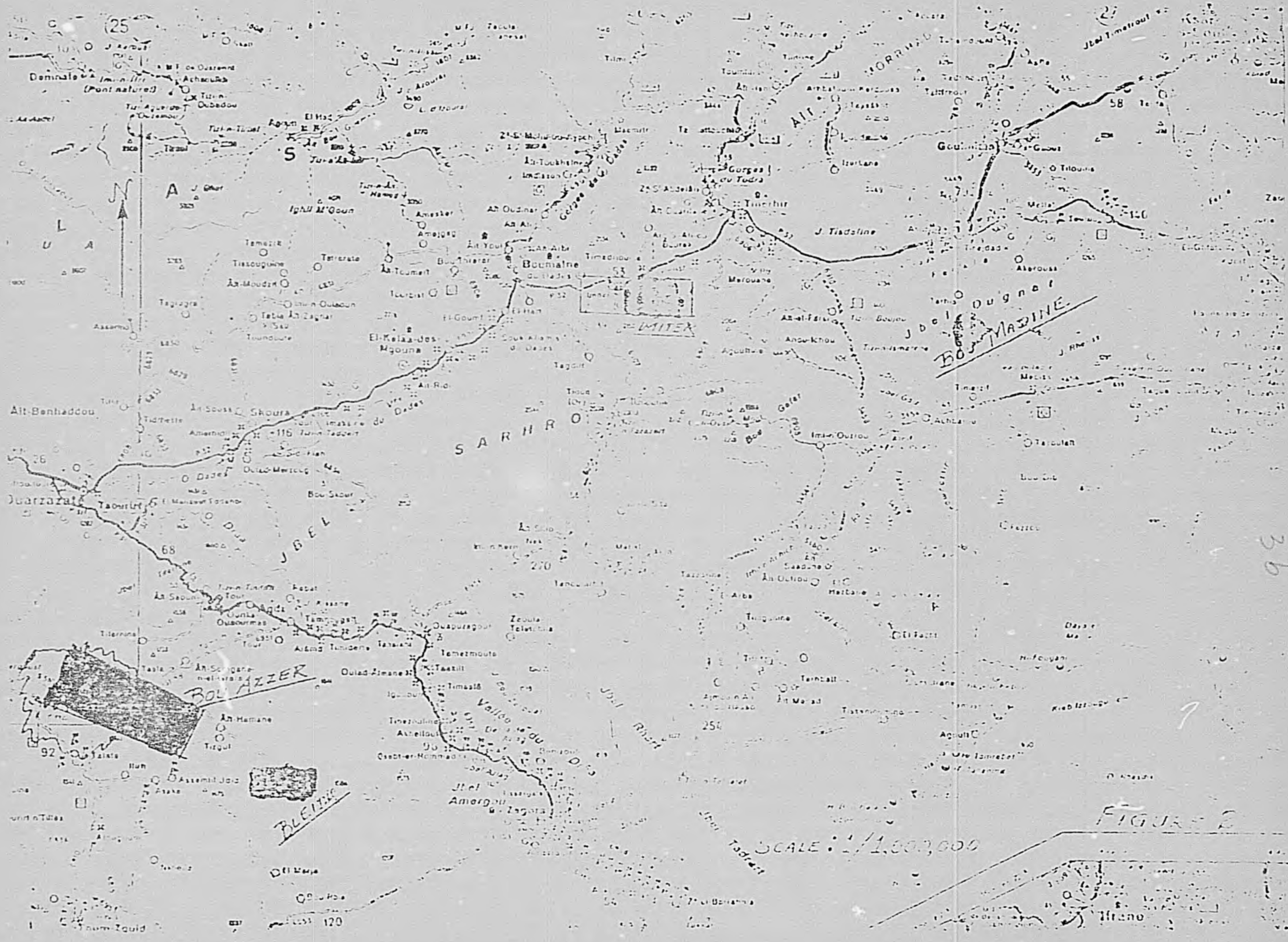
   a. Sixty percent of the northern provinces are now mapped at a scale of 1:200,000.

   b. The Rif portion of Northern Morocco has been partially mapped at a scale of 1:50,000.

3a

FIGURE 1.

N
RABAT
CASABLANCA
ATLANTIC OCEAN
Essaouira
MARRAKECH
Agadir
Tiznit
Taroudannt
Tafraoute
Goulimime
HAMADA DU DRAA
ROUTE OF TEAM
16
17
SCALE: 1/4,000,000 (1 INCH = 63 MILES)


3b
Ouarzazate
Ait-Benhaddou
Skoura
El-Kelaa-des Mgouna
Boumalne
Tinerhir
Gorges du Todra
Goulmima
Ighil M'Goun
Jbel Sarhro
Jbel Amergou
Zagora
Tazzarine
Imiter
Bou Azzer
Bleida
Bou Madine
Jbel Ougnat
J. Tiadaline
Vallée du Dra
Jbel Rhart
Jbel Tadrart
Agoun
Taouirt
Imi-n-Ouzrou
Alnif
Ait Hamane
Assemil Jdid
Ouled Amane
Tinezouline
Agdz
Jbel Timetroui
Dadès
SCALE: 1/1,000,000
FIGURE 2

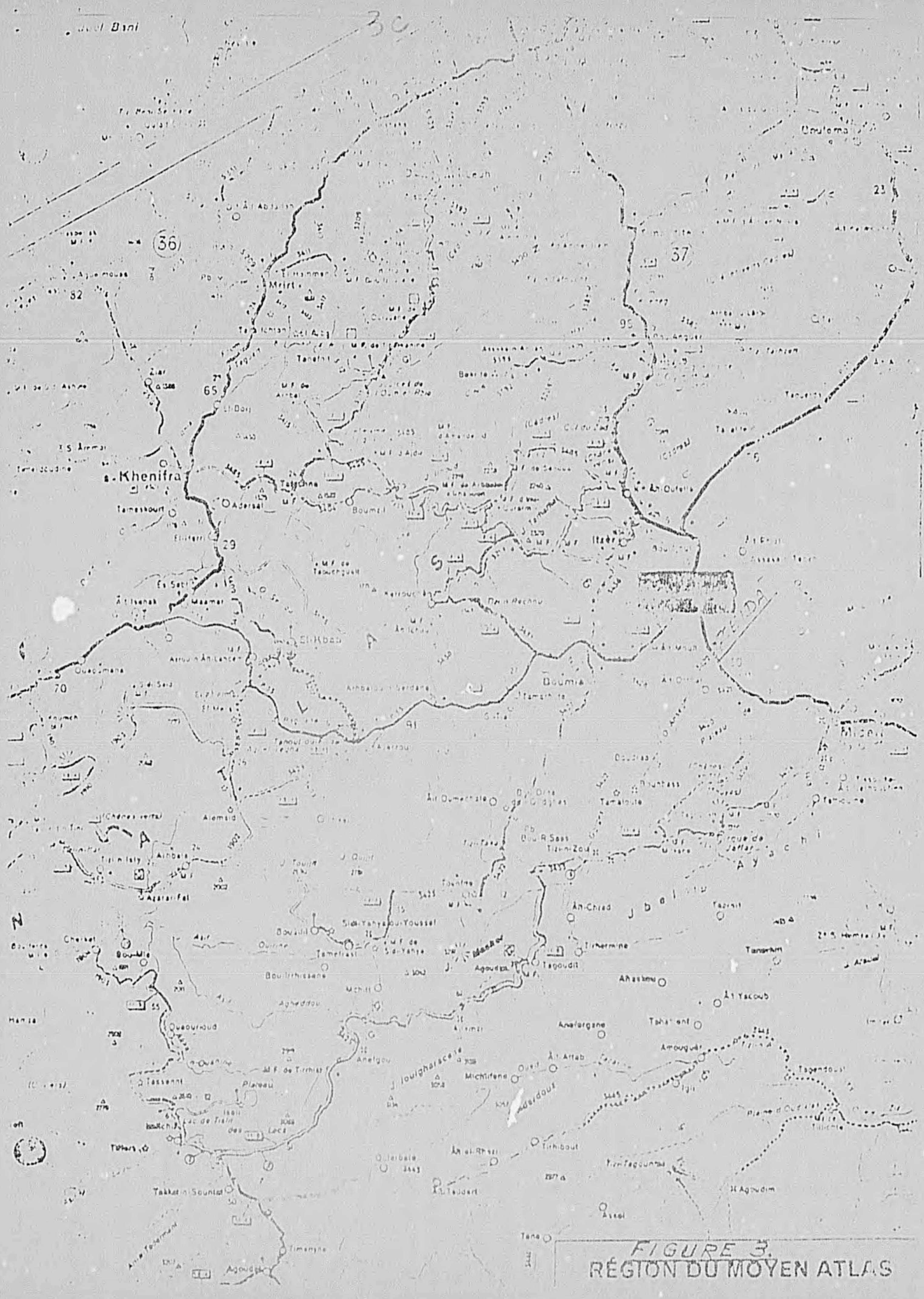


FIGURE 3.
RÉGION DU MOYEN ATLAS

c. Central Morocco is being mapped at a scale of 1:100,000.

d. Gravity surveys have been completed on a scale of 1:500,000 with more detailed surveys done in the sedimentary basins.

e. A stream sediment sampling program is planned with samples to be collected at intervals of one sample per 10 km^2.

f. A metallogenic map at 1:200,000 compiles geologic, tectonic, and mineralogic data for the whole country.

2. B.R.P.M. has located numerous mineralized areas containing potentially economic deposits, and they continue to evaluate prospects and maintain extensive open files on mineral zones. A document of theirs describing mineral projects considered as potential sites for cooperative mining ventures is appended as the final document to this team report.

3. Besides barite, rare earths, lead, zinc, and precious metals, BRPM is enthusiastic about a copper mine at Alous in Precambrian rhyolite containing 4,230,000 metric tons of ore running about 1 to 1.5 percent copper and 15 to 54 grams per ton of silver.

4. The Geological Survey of Morocco, hard-pressed to complete their numerous programs, feels the need for assistance in the following areas:

   a. Techniques of remote sensing (with emphasis on computer enhancement of imagery).

   b. Methods of detecting mineral deposits.

   c. Techniques and practice of isotope dating.

   d. Training in:

      1. Petroleum geology
      2. Geophysical prospecting
      3. Sedimentology

   e. Modern, fast, cheap methods of map preparation and printing.

   f. Aid in selecting computers for, and actually setting up a computerized data system. (Perhaps the Bureau of Mines MAS system might provide an example of a good complete system which works).

On Friday, January 19th, we drove from Rabat to Marrakesh, and over the High Atlas to Ouarzazate where we passed the night, proceeding on over the Anti-Atlas to Bou Azzer the next day. (See Figure 1).

Mining in the Bou Azzer-El Graara uplift of Precambrian rocks is not a new development. The copper deposits of Bleida, on its southern edge, were operated from the 9th to the 12th centuries. After the discovery of cobalt at Bou Azzer in 1930, and the beginning of cobalt mining in 1932, operations proceeded until, in 1968, the French experts believed that all commercially significant cobalt mineral had been removed. At that time, B.R.P.M. took over and summoned a Russian team of advisors (more than 60 in number! whom they are reported to have paid a fee of $3 million. These advisors found substantial additional cobalt deposits now thought to be depleted to within two or three years of exhaustion. B.R.P.M., at present, retains thirty-five percent of the ownership of the cobalt mining concessions, but has invited Omni Nord Africain, a private sector concern owning just under sixty percent of the concessions, to manage the mines through an operating company, Compagnie de Tifnout Tiranimine (CTT).

Geology of the Ore Deposits

In the time available for field work, little could be added to the findings of numerous competent Moroccan and French earth scientist like Dr. Marc Leblanc of the Universite des Sciences et Techniques du Languedoc at Montpellier, France, and Pierre Billaus of CNA (See Figures A through G in Appendix, taken from their recent maps). The cobalt concentrations are located along the borders or the top of a 30 km long serpentine mass of Upper Proterozoic age. The ore zones occur where faults, particularly cross faults, have fractured the serpentine and surrounding rocks, providing channels for the entry and deposition of cobalt minerals and nickel-bearing cobalt minerals.

The average chemical analysis of the crude ore presently mined by CCT is 1.2 percent cobalt, 0.15 percent nickel, 0.6 percent iron, 4.5 percent arsenic, and 1 percent sulfur, with an average cobalt to nickel ratio of eight to one.

For the prospector, the mode of occurrences in this zone provide fortuitous circumstances for the finding of more ore. Geophysically, the serpentine mass can be outlined and probably traced beneath overlying rocks to the southeast because of its magnetic character. The ore itself is probably traceable by locating nearby geochemical anomalies and may also be detectable by electromagnetic methods. Another adjunct to these procedures would be the judicious use of aerial photographs, (Lucas has recommended trying infra-red photography to locate fault zones and the writer concurs), and computer-enhanced satellite imagery. These methods cannot be expected to eliminate the need for detailed ground examination followed by percussion and/or diamond

drilling, but can speed up the search and narrow the target areas with a cut in cost.

Reserves

CTT officials provided us with the figures on remaining reserves of cobalt ore from west in the Bou Azzer area (See Figures B and C). It sould seem reasonable (unless further slashes in the price cobalt occur) to consider the following demonstrated economic reserves in the measured category.

Name of Deposit or Mine	Tonnage	Analysis
1. Tarouni (See Figure C)	30,000	0.9% Co, 0.1% Ni
Concentrates analyze 12% Co and 3% Ni. (All concentrates shipped to the refinerary at Marseille, France run 50-65% arsenic!)		
2. Bou Azzer East (See Figure D)		
No reserves - research only is conducted by a 40 meter shaft. (This mine was CTT's main producer for 10 years).		
3. Bou Ismas (See Figure C)	200,000	1% Co
(Will be mined by a contractor - much iron arsenide).		
4. Oumlil (Sometimes spelled Oumlill)	5,000	N/A
(Will close at the end of 1982). (See Figures C & F)		
5. Tamdrost (See Figures C & F)	85,000	1% (+) Co
160 CTT employees - Mined by cut and fill. (Fill is cemented below the 135 meter level).		
6. Ightem (See Figure C)	Mined out	
Costly exploration here did not expand the reserve.		
7. Ait Ahmane (See Figure C)	18,000	0.6% Co
Low grade disseminated crude gives a 17% Co concentrate!		

From these figures, it would seem that the cobalt ore, found during the flurry of exploration engendered by the Russian geochemical work, is approaching exhaustion. The principle mine thus found, Tamdrost, is almost mined out, and this situation may have prompted the recent Moroccan initiatives which resulted in our Mission.

Mining

At Bou Azzer a labor strike was in process upon arrival by car from Rabat on Friday, January 2, due to economy measures necessited by the low price of cobalt, (then about $10.00 per pound on the spot market), and this inhibited underground visits in the operating cobalt mines for several days. However, the Deputy General Manager of CTT at Bou Azzer, Mr. Robert Arnodeau, took time to discuss

mining matters with Mr. Lucas and the Writer on Wednesday, February 3, 1982, in spite of the ongoing labor negotiations. The following figures were obtained:

1. The average worker receives 40 dirhams (5.28 dirhams to one U.S. dollar at the time) per day as wages.

2. Electric power costs 0.80 dirhams per kilowatt hour. The National Grid, provides electricity at 0.50 dirhams per kilowatt hour where available.

3. Horizontal cut and fill stoping is employed underground.

4. Water is expensive, being pumped to Bou Azzer from Taloust (30 km away) at a cost of 2 dirhams per cubic meter, for a daily cost of 800 dirhams.

5. Cemented fill, pumped into the mines, costs an average of 150 dirhams per cubic meter.

6. Ore concentrates are trucked, by a subsidiary of Omnium Nord Africain, to the Port of Agadir, 320 km away, at a cost of 140 dirhams per ton.

7. Mining cost at Bou Azzer underground operations is said to be 130 dirhams per ton.

Future Exploration

Within the area of the Bou Azzer Uplift much remains to be done in spite of French, Russian, and Moroccan work which has kept cobalt mining going for 50 years.

The 1970 Russian work found its deposits largely by chemical analysis of many thousands of samples of ledge. To locate an attractive target containing anomalous chemical analysis, such methods must sample rock within a meter or two of ore. Samples of stream sediments, or soils composed of rock fragments, begin to encounter anomalous results up to hundreds of feet or even more from ore bodies. Thus fewer samples need be collected and analyzed with resulting reduction in cost and increased speed of discovery. Geochemical work of this sort may well encounter the chemical environment which indicates another Tamdrost.

Another idea, for whose germ the writer is indebted to a young Moroccan geologist, Ahmed Ait Azza, is depicted on Figure H, a longitudinal section from the Aghbar Mine through Tamdrost to the Ambed II deposit. Whereas there is no doubt that ore is localized by cross faults which are nearly ubiquitous in the Uplift, examination of the longitudinal section reveals a mirror symmetry in the emplacement of ore in Aghbar and Tamdrost at a point where the footwall serpentinite reaches a depth of some 200 meters after

plunging steeply from an outcrop. This hypothesis would indicate the advisability of investigating a target area shown in orange highlighter on Figure H. With luck, one might duplicate the Russian Tamdrost find. Geochemistry and study of the cross-faults are required.

Outside of the Bou Azzer mining area, but still within the Uplift, geochemistry, magnetic and electromagnetic surveys should be employed in areas selected after study of the known geology. Where the serpenting underlies other rock, computer programs applied to magnetic data can indicate depth to serpentinite and eliminate drilling in areas too deep for exploration and/or mining. Electromagnetic methods may locate massive sulfides and thus possibly find copper ores similar to those at Bleida.

Copper, Silver, Tin, Lead, Gold

Whereas the team's primary objective was to increase the uni-product cobalt reserves of Bou Azzer, the secondary objective was to assess other potential minerals and sites which might prove favorable for joint mineral ventures.

a) Bleida (See Figures 1 and 2)

Two main ore bodies are being mined at Bleida, and a third is under development. The mineralization occurs along faults near the contact between overlying sediments, (greywackes and siltstones with minor interleaving of volcanics), and the underlying felsic and mafic volcanics.

The mine is producing 800 tons per day from depths up to 134 meters out of present reserves of 2.5 million tons running 7.5 to 8.0 percent copper. The economic minerals are bornite and chalcopyrite, and it is planned to mine to a depth of 234 meters, dropping the ore to the primary crusher at that level. From the bottom level the crushed material will be brought, by conveyor belt, up a series of inclines to the mill on surface which has a capacity of 1500 tons per day. This over-capacity reflects the company confidence in future ore finds and expanded production.

At the present rate of 800 tons per day, 200 tons of copper concentrates are produced running 30 - 34 percent copper. These concentrates are trucked 400 km. to Agadir for shipment to Europe.

b) Imiter (See Figures 2 and 3)

We visited this property, where native silver is now being mined along the north flank of Jbel Sarhro at an altitude of 1500 meters. The deposit has been known

for more than 300 years and the present firm, Societe Metallurgique d'Imiter (SMI), was created in 1969 to mine 600,000 tons of tailings running 350 grams of silver per ton. SMI is managed by BRPM who own 69 percent of the stock. The 31 percent minority share is owned by Omnium Nord Africain. The ore is localized in E - W faults in Precambrian andesites and schists. The veins thus formed are nearly vertical and in places contain massive sulfides. Mining is done by cut and fill stoping. At least 500,000 tons of ore (and possibly much more) remain in the deposit whose mill recovers silver by the cyanide process.

Recent production in kilograms is given below:

Year	Kilograms of Silver
1970	9,387
1971	25,307
1972	26,421
1973	29,966
1974	23,843
1975	23,344
1976	19,423
1977	19,832
1978	20,399
1979	25,597
1980	24,752

The Sarno Uplift does not appear to have been thoroughly explored, and a company interested in silver should study the geology of the area and its aeromagnetics. Following this a program of airborne electromagnetic surveying might pinpoint targets for drilling, since massive sulfides occur in the same faults which carry the silver values. Favorable anomalies and fault configurations could then be drilled.

c) Bou Madine (See Figures 1 and 2)

On the south flank of the High Atlas on Jbel Ougnat, BRPM is readying a multi-metal project based on more than 2 million tons of an ore analyzing 4.1 percent zinc, 1.25 percent lead, and containing 117 grams per ton of silver and 1.2 grams per ton of gold. The mineralization occurs along steep N - S faults in Precambrian andesite. The veins are up to 15 meters wide and contain at various places massive sulfides and massive barite. Within the limits of the Ougnat Uplift shown in Appendix as Figure A, exploration for multi-metals and/or barite would seem a logical step using aerial photography, geophysics, and geochemistry to delineate targets.

One must admire the tenacity of the Portuguse who mined the area first in the 16th century, when access over the mountains must have been arduous.

It is particularly in this nearly roadless environment that John Lucas' suggestion of dirt bikes for field crews would be most appropriate.

d) Zeida (See Figures 1 and 3)

In a much younger geological environment 20 kilometers from Midelt, the Societé de Developpement Industriel et Minier de la Haute Moulouya (SODIM) is mining lead with minor amounts of silver, and minor barite (no zinc) by open pit methods. The galena occurs in a Permo-Triassic arkose in gutter-like channels eroded into the basal granite.

Figure I shows the presently known ore bodies which are said to contain more than 8 million tons of ore of variable grade, (up to 15 percent lead), but averaging 3.4 percent. Some 6.5 million tons of waste are removed annually to permit mining 1,200,000 of ore. The ore is concentrated by crushing, grinding, cyclones, flotation, and spirals according to the flow-sheet, Figure K.

Some 40,000 tons of lead concentrates are produced each year running about 69 percent lead and shipped mainly to European refineries through the Atlantic port of Kenitra (See Figure 1).

Presently exploration of the arkose-filled valleys is proceeding by diamond drilling. It is suggested that a considerable reduction in cost could be obtained by employing simple seismic apparatus to profile the basel granite, thus locating the ore-forming channels which are the shallow drilling targets.

Since the potential exploration area is about 70 km by 25 km, the known reserves may be significantly enlarged and the scope for a joint venture may exist in this part of Morocco as well.

The exploration opportunities encountered by the team (the USGS members were quite sanguine about the potential of the Siroua Uplift) cover only a small part of the potentially mineralized area of Morocco. The final Appendix to this team report outlines other prospects of BRPM. In addition it is likely that a comparison of the anomalies on the magnetic and gravity maps covered by index maps (Figures M, N, and O and Annex II attached), may reveal possible exploration targets when compared with satellite imagery and the geologic maps of the country.

Mining Laws and Business Climate

Aware of the favorable geology of their country, King Hassan II and his minerals officers have modified the mining codes of the country to favor foreign participation in joint mineral ventures. Approved projects are exempted from customs fees on equipment, both new and used, whether brought over by the mining enterprise or purchased from Moroccan firms. Mining capital is only charged a registry fee of .5 percent instead of 2.5 percent as are other businesses. A rebate of two points is granted on interest paid to the Banque National de Developpement Economique (BNDE) and the State will pay 50 percent of infrastructure costs of mining projects up to a total of 15 percent of the overall projected mining investment.

Our impression of the business climate we encountered was optimistic, but for further information it is suggested that the Economic and Commercial Counselor of the American Embassy in Rabat, Joel Spiro, be contacted, or the appropriate officials in the Department of State and Commerce here in Washington.

The above facts, observations, and deductions have led to the conclusions and recommendations cited at the beginning of this paper. Contacts made are attached as Annex IV.

Josiah Royce

Attachments

A P P E N D I X

Figures A through G ..... Morocco Geological Maps

Figure H ..... Schematic Longitudinal Section, Bou Azzer Area

Figure I ..... Bleida Copper Flow Sheet

Figure J ..... Plan Map of Zeida Lead Deposits

Figure K ..... Zeida Lead Flow Sheet

Figures M through O ..... Aeromagnetic and Gravimetric Coverage Maps

Exhibit P ..... Nomenclature Des Etudes Gravimetriques

Annex I ..... Miscellaneous Government of Morocco Maps

Annex II ..... Fiscal Aspect

Annex III ..... Contacts (Met by TDP Team in Morocco

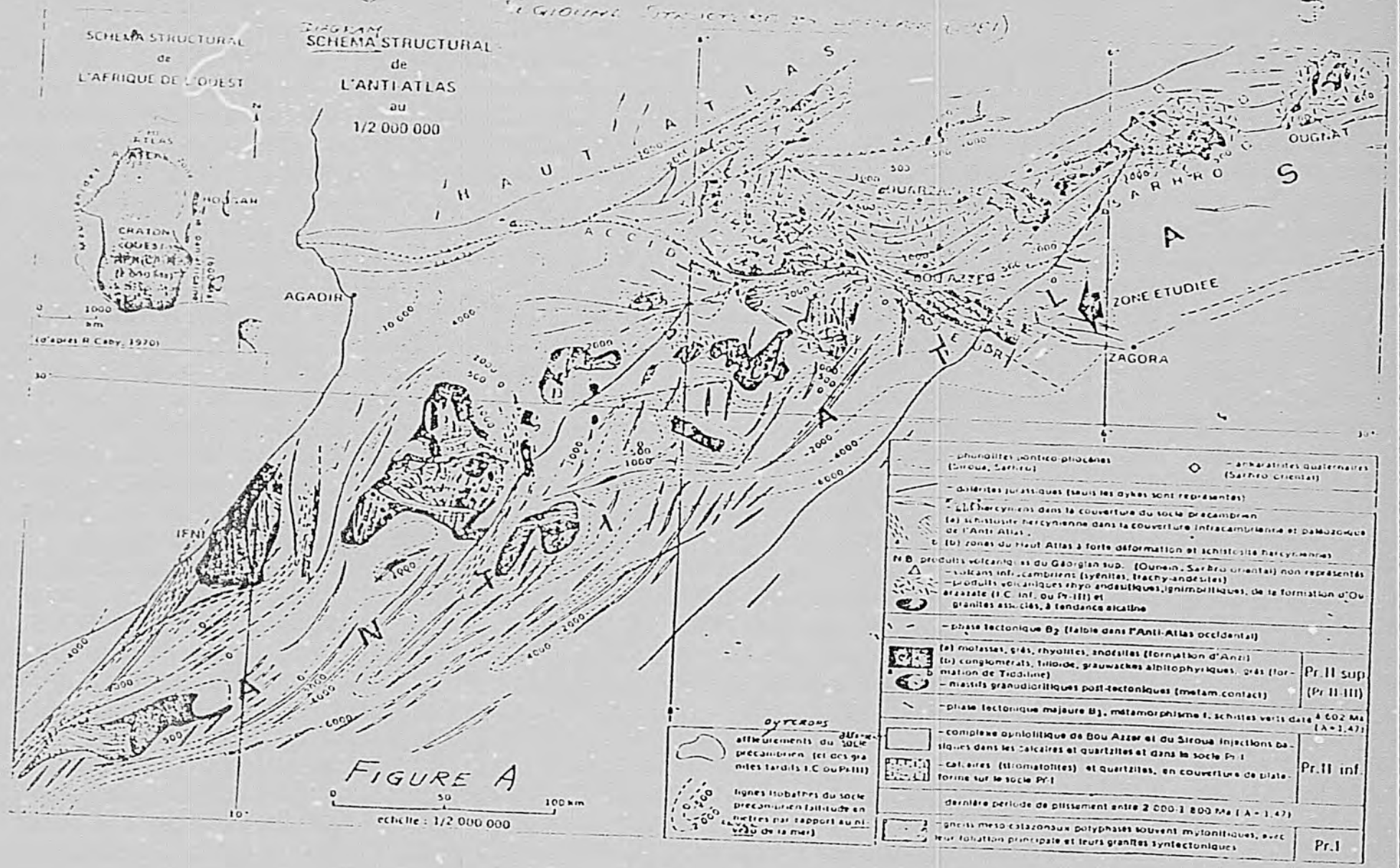
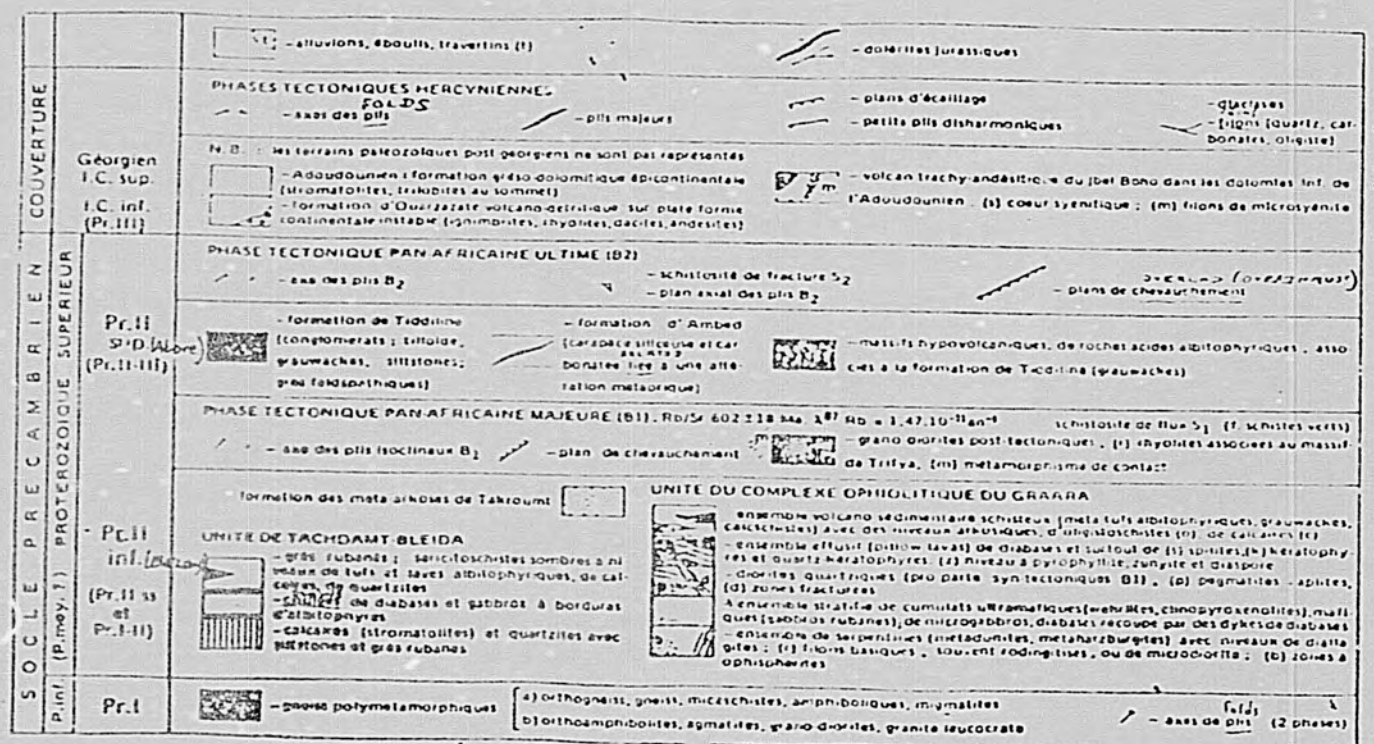

SCHEMA STRUCTURAL
de
L'AFRIQUE DE L'OUEST
CRATON OUEST AFRICAIN
(d'après R Caby, 1970)
SCHEMA STRUCTURAL
de
L'ANTI-ATLAS
au
1/2 000 000
HAUT ATLAS
ACCIDENT
AGADIR
IFNI
ANTI ATLAS
BOU AZZER
ZONE ETUDIEE
ZAGORA
OUGNAT
SARHRO
- phonolites sontico-pliocènes (Siroua, Sarhro)
- ankaratites quaternaires (Sarhro oriental)
- dolérites jurassiques (seuls les dykes sont représentés)
- L.L.C. hercyniens dans la couverture du socle précambrien
(a) schistosité hercynienne dans la couverture infracambrienne et paléozoïque de l'Anti Atlas
(b) zones du Haut Atlas à forte déformation et schistosité hercyniennes
N.B. produits volcaniques du Géorgien sup. (Ouneim, Sarhro oriental) non représentés
- volcans infra-cambriens (syénites, trachy-andésites)
- produits volcaniques rhyo-andésitiques, ignimbritiques, de la formation d'Ouarzazate (I.C. inf. ou Pr-III) et granites associés, à tendance alcaline
- phase tectonique B2 (faible dans l'Anti-Atlas occidental)
(a) molasses, grès, rhyolites, andésites (formation d'Anzi)
(b) conglomérats, tillonde, grauwackes albitophyriques, grès (formation de Tiddiline)
- massifs granodioritiques post-tectoniques (metam. contact)
Pr.II sup (Pr II-III)
- phase tectonique majeure B1, métamorphisme f. schistes verts date à 602 Ma (A = 1,47)
- complexe ophiolitique de Bou Azzer et du Siroua injections basiques dans les calcaires et quartzites et dans le socle Pr.I
- calcaires (stromatolites) et quartzites, en couverture de plate-forme sur le socle Pr.I
Pr.II inf.
dernière période de plissement entre 2 000-1 800 Ma (A = 1,47)
- gneiss méso catazonaux polyphasés souvent mylonitiques, avec leur foliation principale et leurs granites syntectoniques
Pr.I
OUTCROPS
affleurements du SOLE précambrien (et des granites tardifs I.C ou Pr.III)
lignes isobathes du socle précambrien (altitude en mètres par rapport au niveau de la mer)
0 50 100 km
échelle : 1/2 000 000

FIGURE A

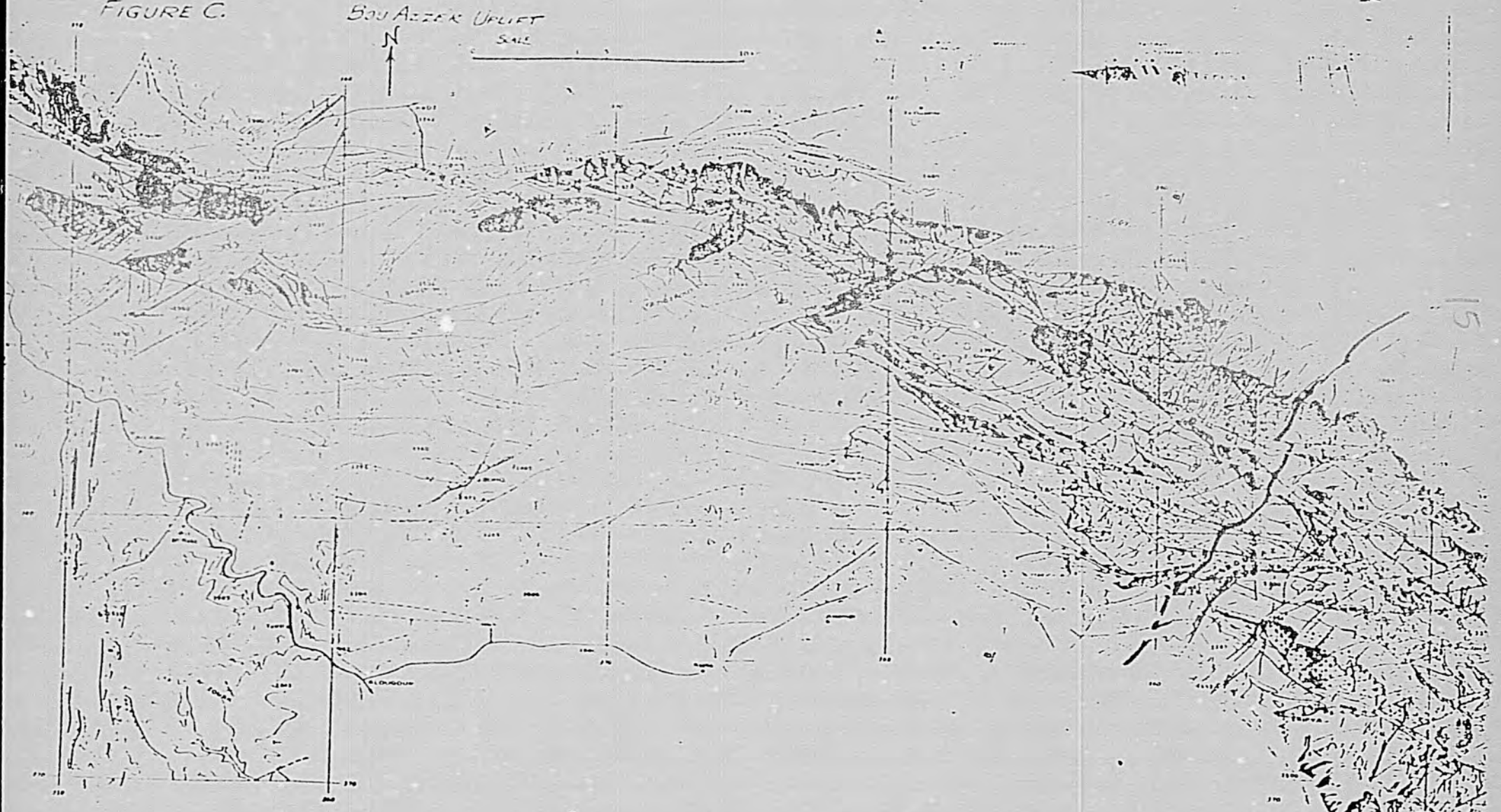
13

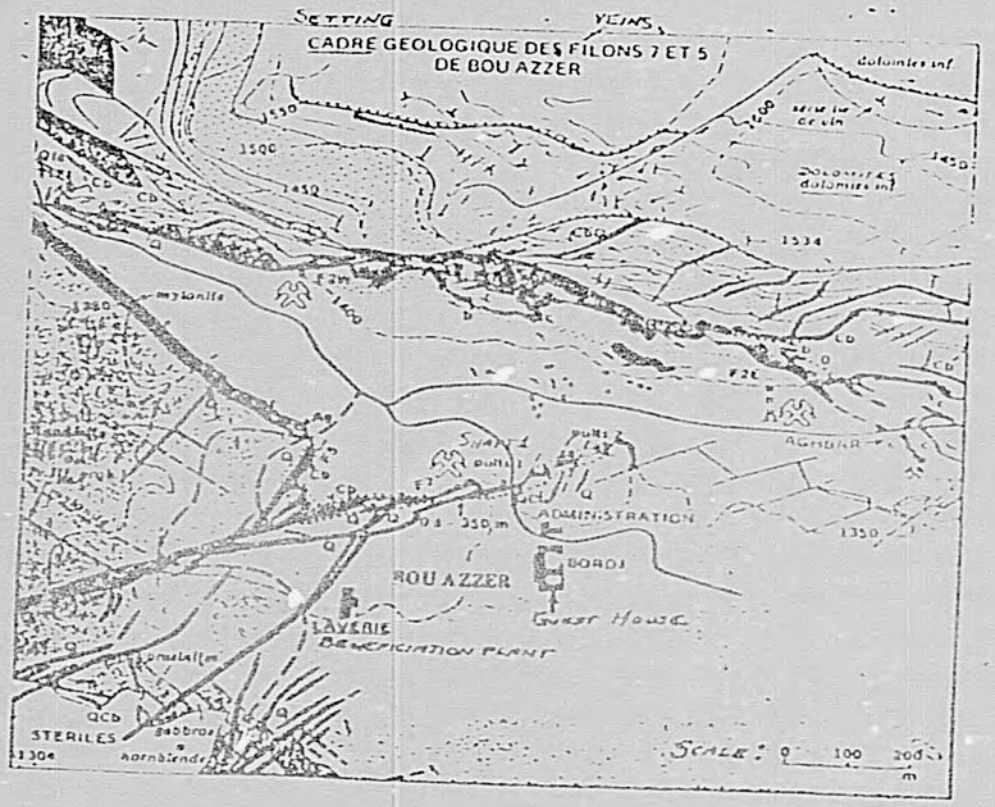


LEGEND: GEOLOGY BY LEBLANC (1981)

FIGURE B. (LEGEND FOR FIGURE C.)

FIGURE C.




SETTING VEINS
CADRE GEOLOGIQUE DES FILONS 7 ET 5
DE BOU AZZER
dolomies inf.
AGNDIAR
ADMINISTRATION
BOU AZZER
BORDJ
GUEST HOUSE
LAVERIE
BENEFICIATION PLANT
STERILES
SCALE: 0 100 200 m

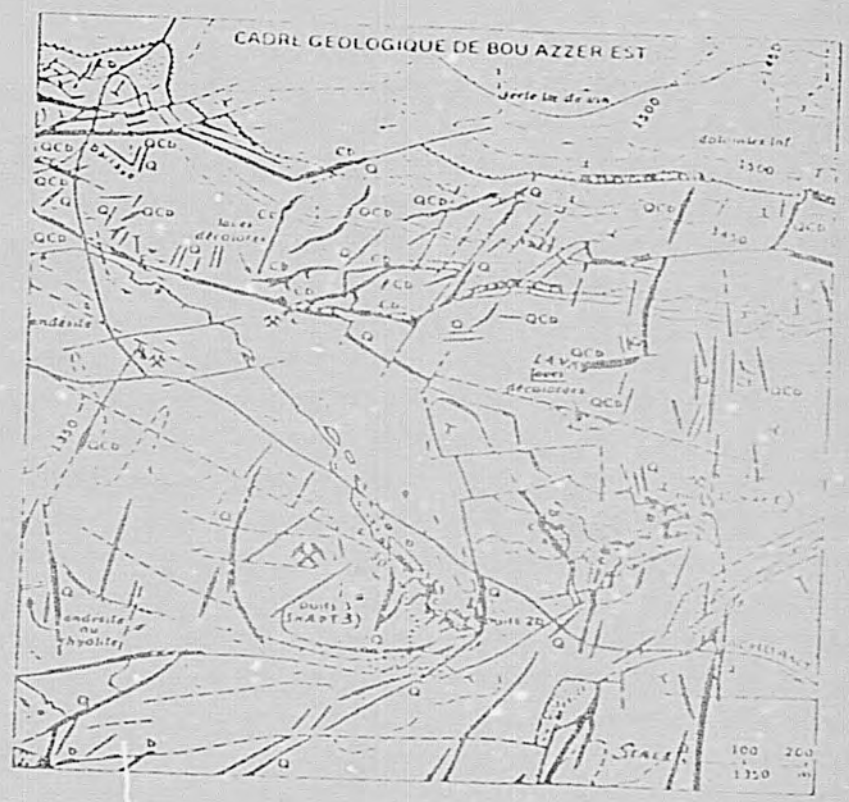

CADRE GEOLOGIQUE DE BOU AZZER EST
dolomies inf.
SCALE

FIGURE 2.

16

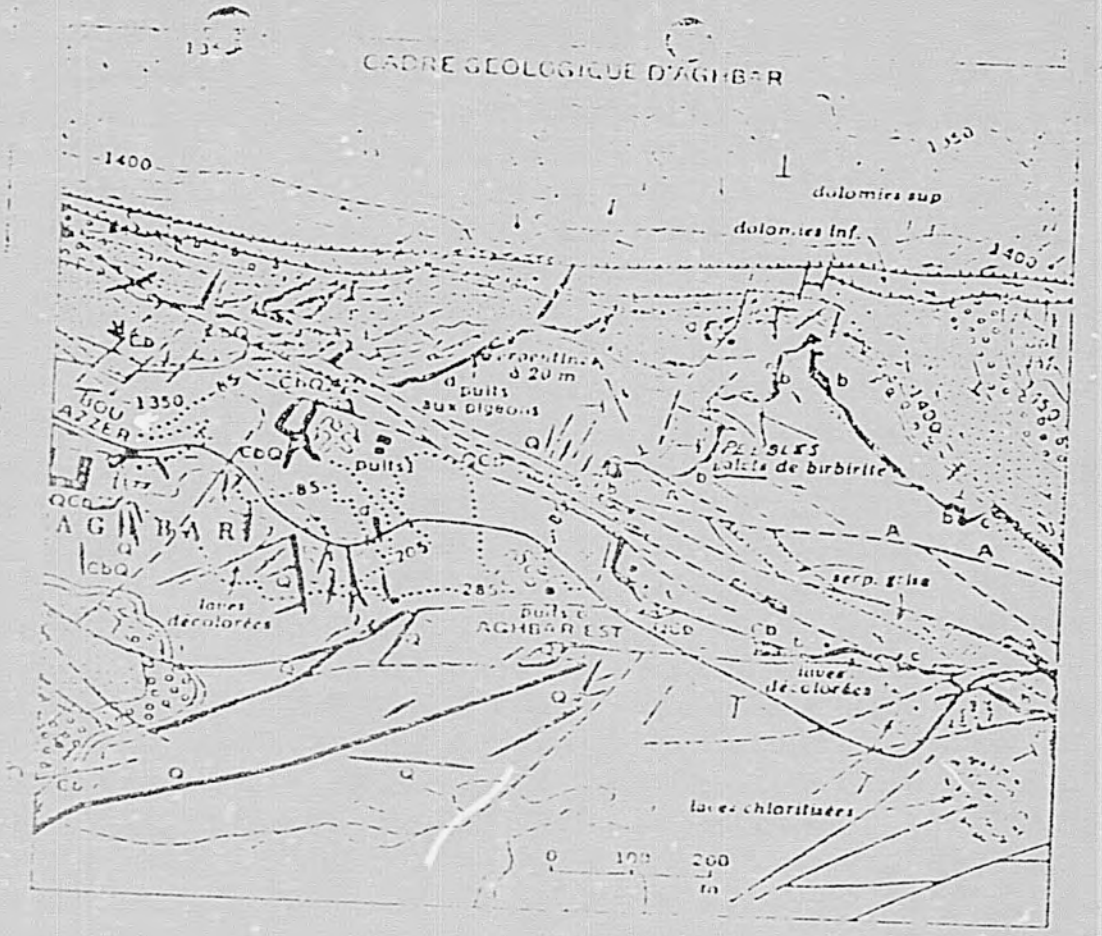
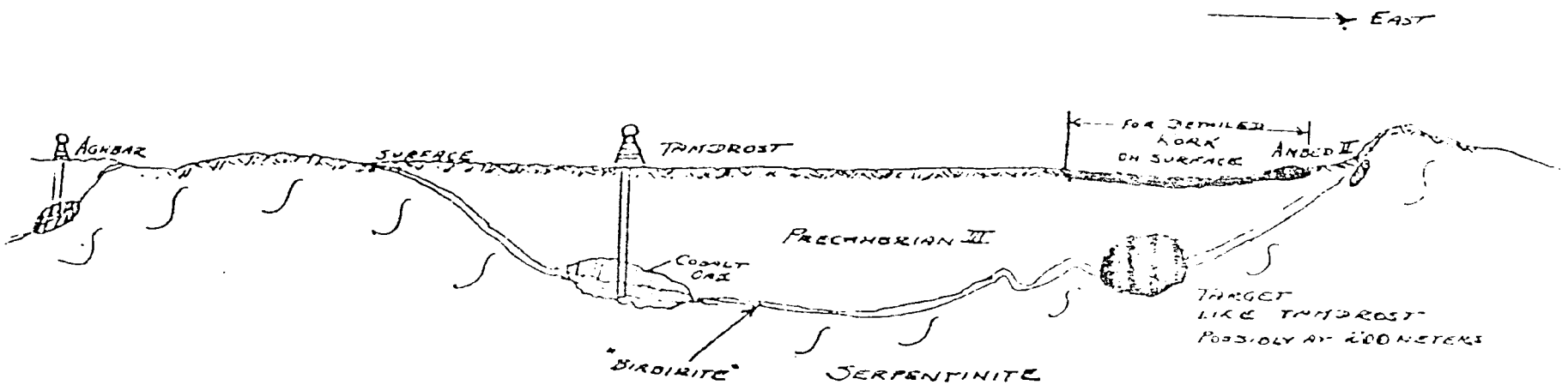

CADRE GEOLOGIQUE D'AGHBAR
1400
dolomies sup
dolomies inf.
1400
à 20 m
puits
aux pigeons
1350
AZZER
puits
AGHBAR
laves
décolorées
serp. gris
puits
AGHBAR EST
laves
décolorées
laves chloritiées
0
100
200
m

FIGURE E.

CADRE GEOLOGIQUE DE TAMDROST
galets de birbirite
galets de gneiss et de birbirite
lentes chloritiques
galets de birbirite
boule de calcite
inclusions (micromonzonite, rodingite)
boule de calcite
POUISMA
QCb
1350
1400
1150

FIGURE F.



SCHEMATIC LONGITUDINAL SECTION
(NOT TO SCALE)

BOU AKKAR AREA

FIGURE H.

COMPLEMENTS POUR LES CARTOUCHES AU 1/10 000

- tranchée TRENCH
- puits SHAFT
- galerie ADIT
- centre minier en activité Active mining center
- centre minier abandonné Abandoned mining center
- petit chantier (abandonné) Little working
- courbe de niveau CONTOUR
- projection des niveaux minéralisés
- apophyses filoniennes de la gangue se rattachant à des filons hercynien
- roche altérée Altered Rock
- conglomérats sous les rhyolites (i.C. inf.) à galets de diorite quartzique, de roches basiques, de gneiss et (en rouge) à galets de la formation d'Amed
- formation d'Amed : (b) brèche, (c) carbonatée
- gangue des gisements : (Q) quartzeuse, (k) carbonatée
- serpentine carbonatée t : talc g : globertite m : magnétite fibreuse s : stichtite

FIGURE G.

ANALYST D.E. DeTra

REPORT NO. [illegible]

	Field No.	Tag No.	(10) Pb	(100) Sb	(5) Sc	(10) Sn	(100) Sr	(10) V	(50) W	(10) Y	(200) Zn	(10) Zr	(100) Th
			13						14				
		71-78	1-7	22-28	29-35	36-42	43-49	64-70	1-7	8-14	15-21	22-28	
1	GAR-6		150	N	30	N	N	200	N	15	200	150	N
2	TE-1	[illegible]	20		15		100	200		30	N	200	
3	-2	601	30		15			150		50		700	
4	-3	602	20		20			200		50		500	
5	-4	603	30		20			150		50		700	
6	-5	604	50		20			200		30		500	
7	-6	605	50		20			200		30		500	
8	-7	606	50		20			200		50		500	
9	-8	607	70		15			200		50	N	500	
10	-9	608	20		15		100	200		70	L	500	
11	-10	609	30		15		N	100		50	N	700	
12	-13	610	20		15		100	200		50		500	
13	-14	611	30		20			200		70		500	
14	-15	612	20		20			300		50		500	
15	-30	613	20		20			200		50		500	
16	-31	614	70		20		100	150		70		500	
17	32	615	20		15		N	150		50		500	
18	TE-33	616	10	N	10	N	100	150	N	30	N	200	N
19													
20													
21													
22													
23													
24													

G = Greater than value shown N = Not detected at limit of detection, or at value shown. L = Detected, but below limit of determination, or below value shown.

FILM NO. 7-150m

REPORT NO. 60283

SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSIS--BRANCH OF EXPLORATION RESEARCH

6-Step D.C. Arc

Requested by Michael P. Fredrie Date 4/25/82

Sheet #1

	Field No.	Tag No.	(.05) Fe %	(.02) Mg %	(.05) Ca %	(.002) Ti %	(10) Mn	(.5) Ag	(200) As	(10) Au	(10) B	(20) Ba	(1) Be	(10) Bi	(20) Cd	(5) Co	(10) Cr	(5) Cu	(20) La	(5) Mo	(20) Nb	(5) Ni
	//////////	71-78	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70
1	GXR-6	//////////	7	.7	.1	.7	1500	L	200	N	20	1500	1	N	N	15	150	50	L	N	N	30
2	TE-1	RAL 600	5	2	1.5	.7	1000	N	N		200	500	1.5			15	150	10	50		L	30
3	-2	601	5	2	1.5	.7	1000				500	700	2			15	150	20	70		L	30
4	-3	602	7	3	1	1	1500				300	1000	2			20	100	20	70		L	30
5	-4	603	7	3	2	1	1500				500	700	1.5			20	200	20	70		N	30
6	-5	604	7	5	1	1	1500				200	500	2			20	100	30	50		N	30
7	-6	605	7	3	1.5	1	1000				300	700	2			20	150	20	100		N	30
8	-7	606	7	3	2	G1	1500				500	700	1.5			20	150	30	50		L	30
9	-8	607	5	3	2	1	1000				300	700	1.5			15	100	20	70		N	20
10	-9	608	7	2	3	1	1000				500	500	1.5			20	200	15	50		N	30
11	-10	609	5	2	5	1	1000				200	1000	1.5			15	100	15	70		L	30
12	-13	610	7	2	2	1	1000				200	500	1.5			15	100	10	70		N	30
13	-14	611	7	3	2	G1	1000				200	500	1.5			20	150	30	70		L	30
14	-15	612	10	2	3	G1	1500				300	1000	1			20	200	20	50		N	30
15	-30	613	10	5	3	G1	2000				300	700	1			30	300	30	50		L	200
16	-31	614	7	2	1	1	1000				200	700	2			20	150	50	70		L	30
17	32	615	5	2	1.5	.7	1500				500	500	5			15	100	20	100		L	30
18	TE-33	616	3	1.5	15	.5	700	N	N	N	300	500	3	N	N	10	100	10	100	N	N	20
19																						
20																						
21																						
22																						
23																						
24																						

REMARKS: Fe, Mg, Ca, and Ti reported in %; all other elements reported in ppm. Results are in the series 1, 1.5, 2, 3, 5, 7, 10, etc.

22

FILM NO. 7-151m1

REPORT NO. 60283

SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSIS--BRANCH OF EXPLORATION RESEARCH

6-Step D.C. Arc

Requested by MICHAEL P. FOOTE

Sheet #1

Date 4/22/82

Field No.	Tag No.	(.05) Fe %	(.02) Mg %	(.05) Ca %	(.002) Ti %	(10) Mn	(.5) Ag	(200) As	(10) Au	(10) B	(20) Ba	(1) Be	(10) Bi	(20) Cd	(5) Co	(10) Cr	(5) Cu	(20) La	(5) Mo	(.0) Nb	(5) Ni
//////////	71-78	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70
GXR-6	////////	7	.7	.1	.7	1500	.5	200	N	20	1500	1	N	N	20	200	70	L	N	N	20
TE-34	KAL 617	7	5	3	1	1500	N	N		200	1000	1			30	500	20	70		L	300
-35	618	7	2	1	1	1000				200	700	2			20	200	20	150		L	20
-36	619	10	7	3	G1	1500				300	700	1.5			50	700	30	100		L	300
-37	620	7	2	1	1	1000				300	700	2			20	150	30	100		L	30
-38	621	7	2	2	G1	1000				200	500	1.5			20	150	20	100		20	30
-39	622	10	2	1.5		1500				200	700	1			30	100	20	100		L	30
-40	623	7	2	1		1500				200	500	1			20	100	15	50			50
-41	624	7	2	2	G1	1500				200	1000	1			20	150	50	50			50
-42	625	7	2	10	1	1000				200	700	1.5			50	150	10	50			30
-43	626	10	2	2	G1	1500				200	1000	1			20	200	20	70	N		50
TE-44	627	7	5	3	1	1500	N	N	N	300	1000	1	N	N	30	200	30	70	5	L	50

REMARKS: Fe, Mg, Ca, and Ti reported in %; all other elements reported in ppm. Results are in the series 1, 1.5, 2, 3, 5, 7, 10, etc.

23

[illegible] 151m

REPORT NO. [illegible]

ANALYST [illegible]

Field No.	Tag No.	(10) Pb	(100) Sb	(5) Sc	(10) Sn	(100) Sr	(10) V	(50) W	(10) Y	(200) Zn	(10) Zr	(500) Th
		13						14				
//////////	71-78	1-7	22-28	29-35	36-42	43-49	64-70	1-7	8-14	15-21	22-28	
[illegible]	//////////	200	N	30	N	N	200	N	20	200	150	N
[illegible]	[illegible] 617	15		20		150	150		30	N	200	
[illegible]-35	618	20		30		100	200		50		300	
[illegible]-36	619	20		30			200		50		200	
[illegible]-37	620	20		20			200		50		300	
[illegible]-38	621	30		20			200		50		700	
[illegible]-39	[illegible]	30		20			200		30		200	
[illegible]-40	[illegible]	30		30			200		20		200	
[illegible]-41	624	70		30			200		30		200	
[illegible]-42	[illegible]	20		20			200		30		300	
[illegible]-43	[illegible]	10		30			200		50		200	
[illegible]-44	627	20	N	30	N	100	200	N	50	N	300	N

G = Greater than value shown. N = Not detected at limit of detection or at value shown. L = Detected, but below limit of determination, or below value shown.

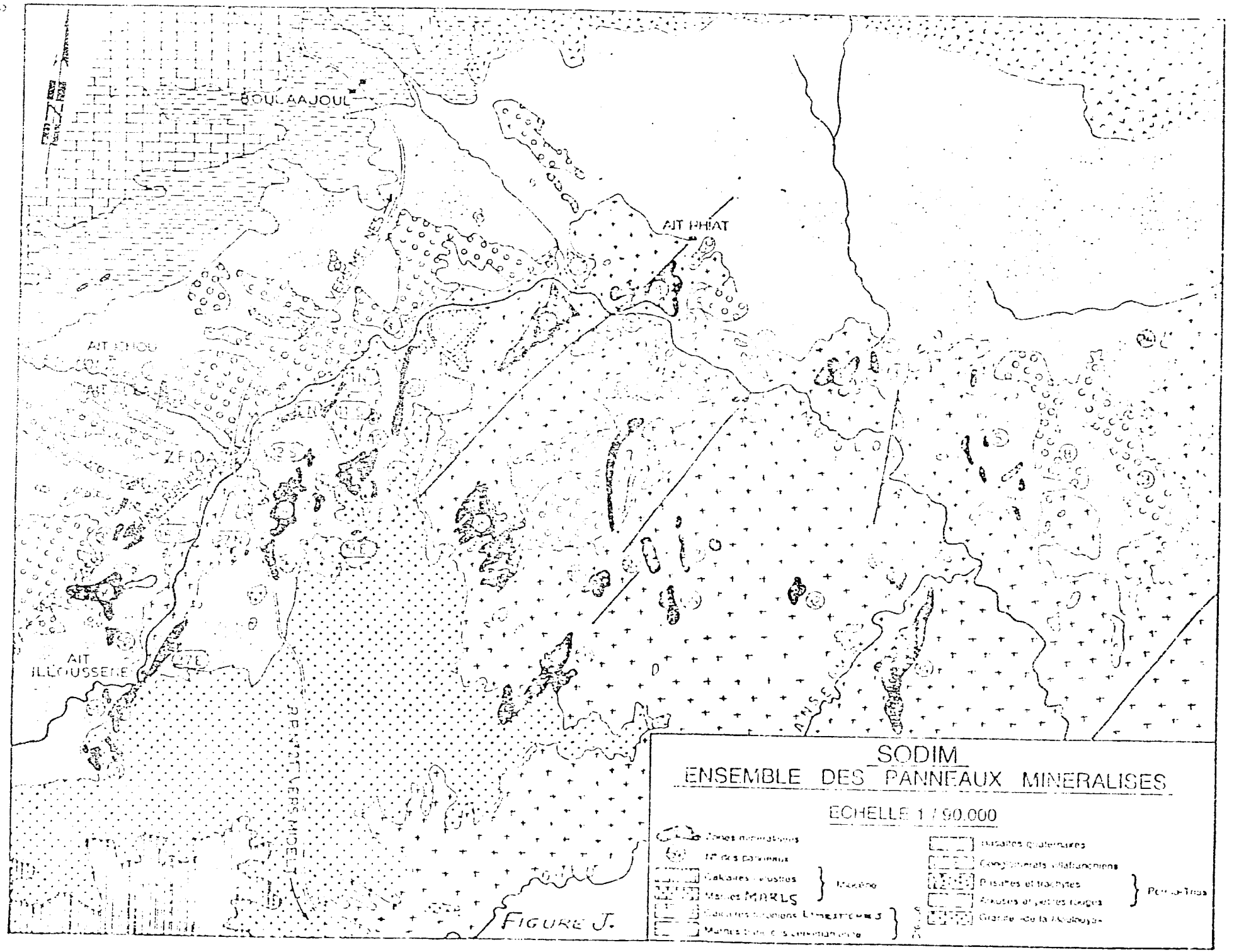

SODIM
ENSEMBLE DES PANNEAUX MINERALISES
ECHELLE 1 / 90.000
BOULAAJOUL
AIT PHAT
AIT ITHOU
ZEIDA
AIT ILLOUSSENE
MARLS
Pliocène
Pernio-Trias

FIGURE J.

FLOW SHEET DE TRAITEMENT

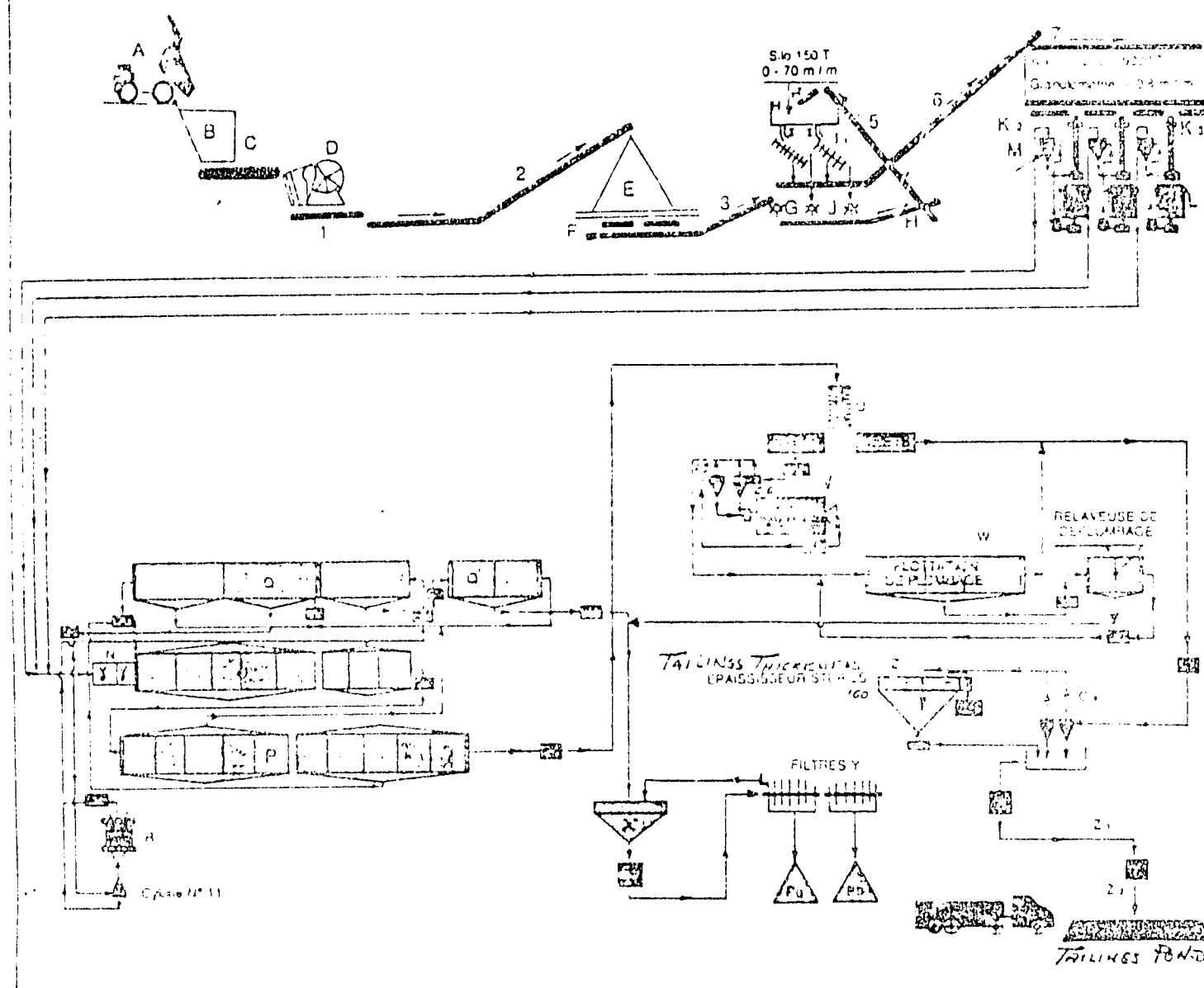
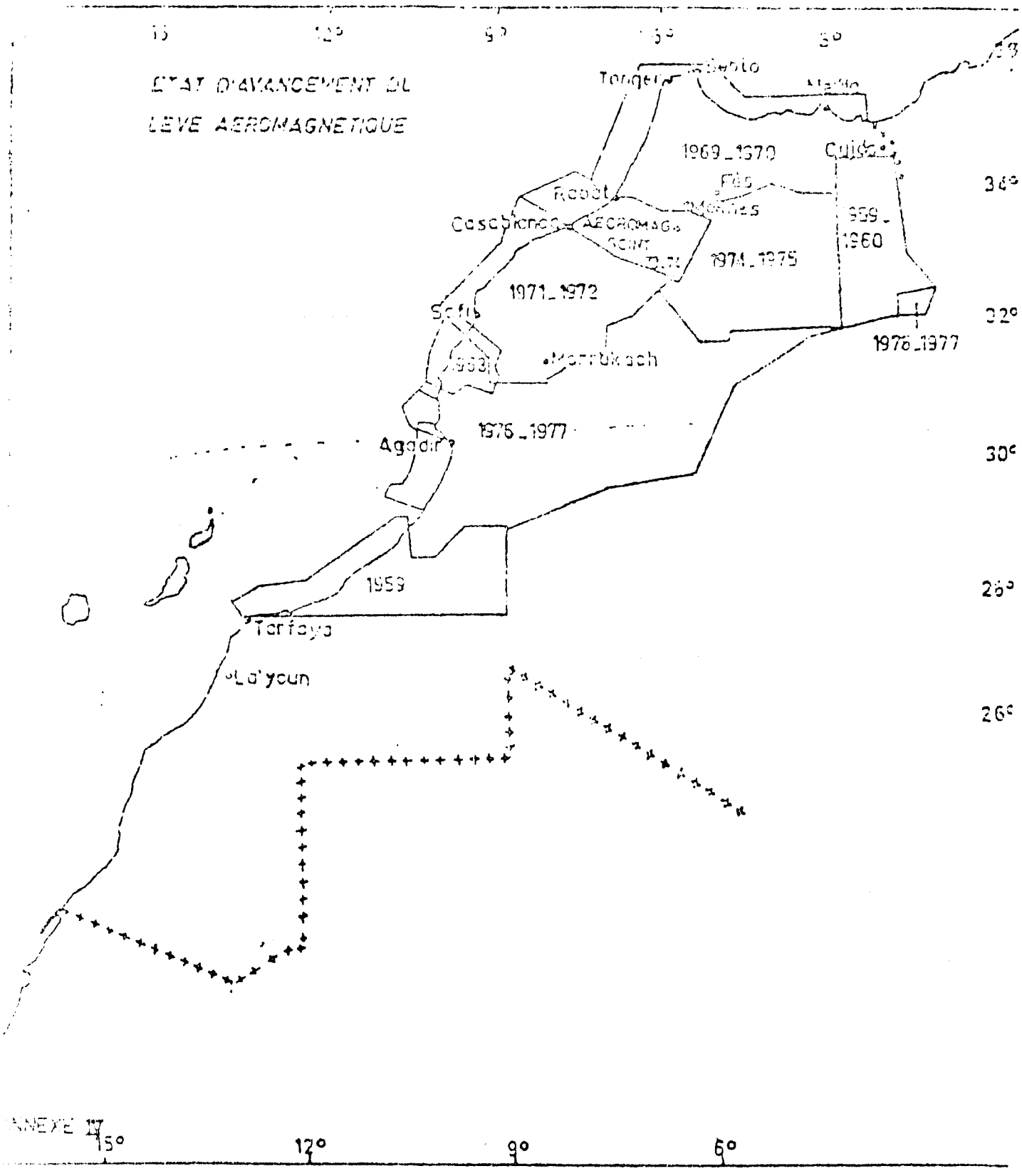


FIGURE K.



ANNEXE 17

FIGURE A1

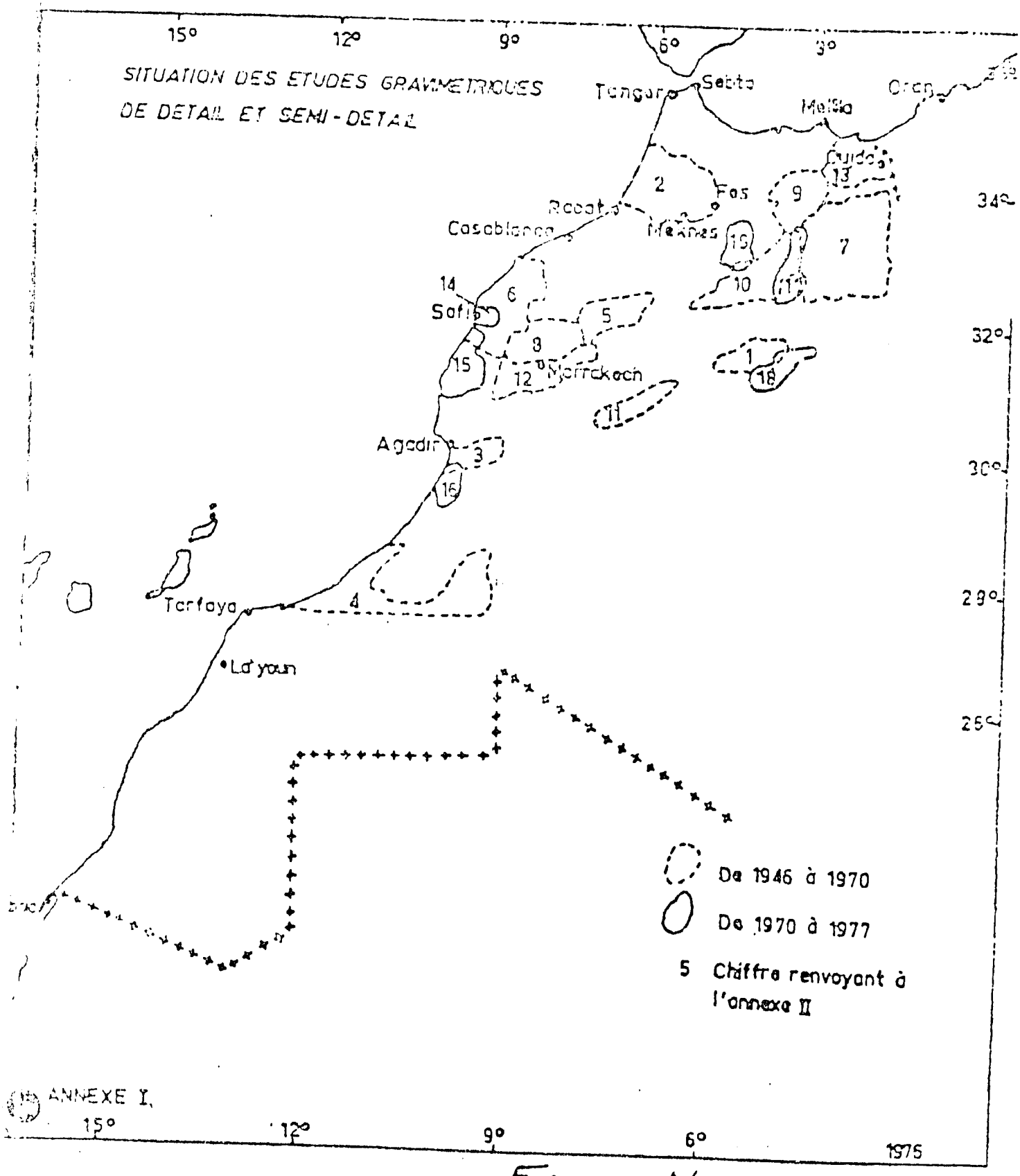
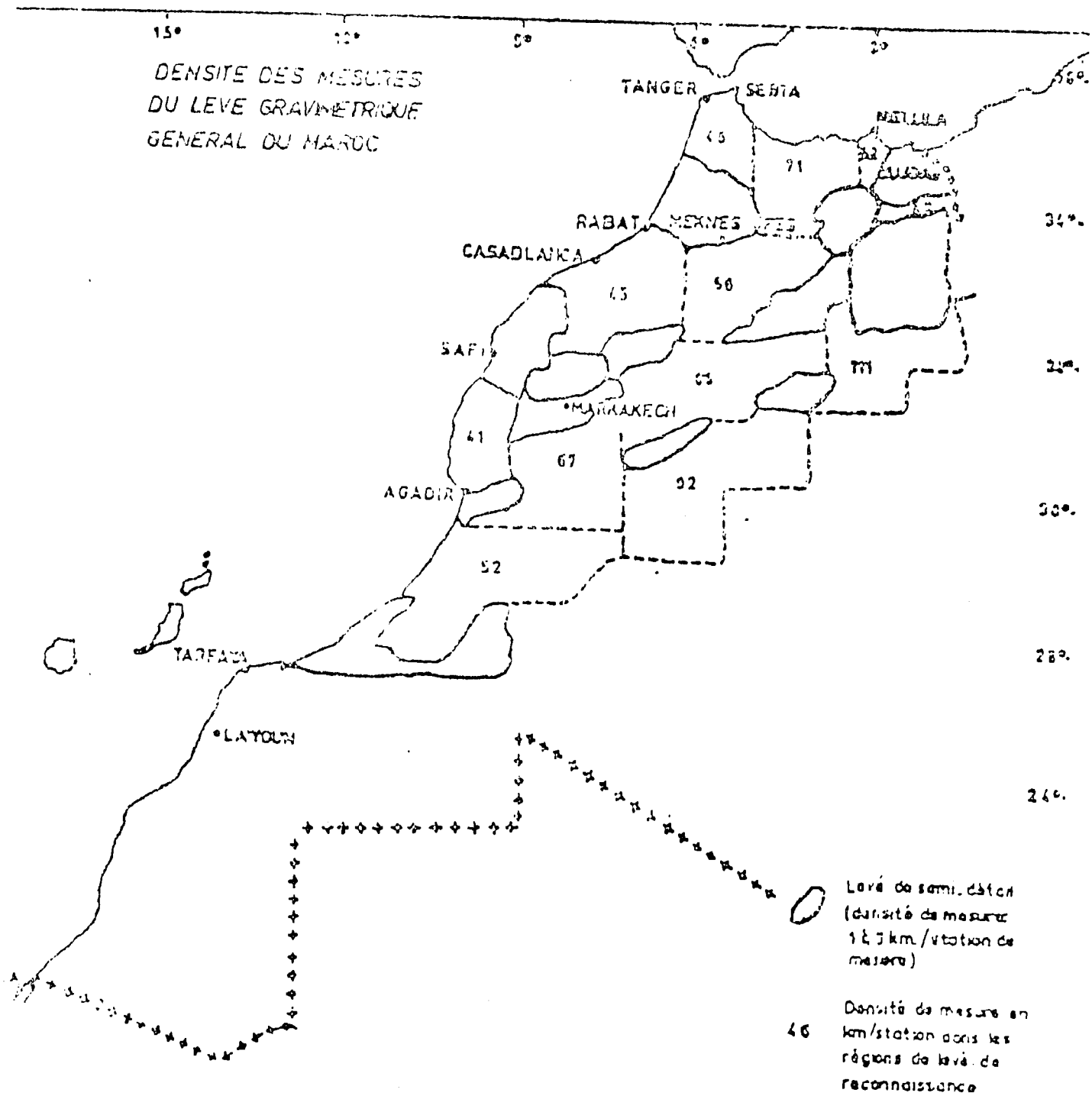

SITUATION DES ETUDES GRAVIMETRIQUES
DE DETAIL ET SEMI-DETAIL
15°
12°
9°
6°
3°
34°
32°
30°
29°
25°
Tangar
Sebta
Melilla
Oran
Fes
Rabat
Casablanca
Meknes
Safi
Marrakech
Agadir
Tarfaya
Laayoun
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
18
19
De 1946 à 1970
De 1970 à 1977
5 Chiffre renvoyant à l'annexe II
ANNEXE I.
1975

FIGURE N



ANNEXE III

FIGURE 0

EXHIBIT P

NOMENCLATURE DES ETUDES GRAVIMETRIQUES

1 - Région de (Ksar-es-Souk) Errachidia, levée en 1948-49 par CAG pour BRPM

2 - Bassin du Rharb, levée de 1946 à 1956 par CAG et CGG pour SCP

3 - Vallée du Sous, levée en 1956 par CGG pour SCP.

4 - Province de Tarfaya, levée en 1959-1960 par l'Agip-Mineraria pour SCMIP

5 - Région de synclinale du Tadla, levée en 1961 par CPGNA pour DMG

6 - Région de Doukkala, levée en 1962-63 par CAG pour BRPM.

7 - Hauts Plateaux, levée en 1962-63 par CAG pour DMG

8 - Plaine de la Bahira, levée en 1963 par Lerici pour DMG

9 - Plaine de Guercif, levée en 1963-64 par Lerici pour DMG

10 - Bassins de Moyenne et de la Haute Moulouya et d'Itzer-Enjil, levée en 1963-64 par Lerici pour DMG

11 - Plaine de Ouarzazate, levée en 1965par ABEM Atlas Copco pour DMG

12 - Plaine de Haouz, levée en 1965 par CAG pour DMG

13 - Région Oujda- El Aioun - Berkane, levée en 1967 par Lerici pour DMG

14 - Région de Safi, levée en 1961 par CPGNA pour BRPM

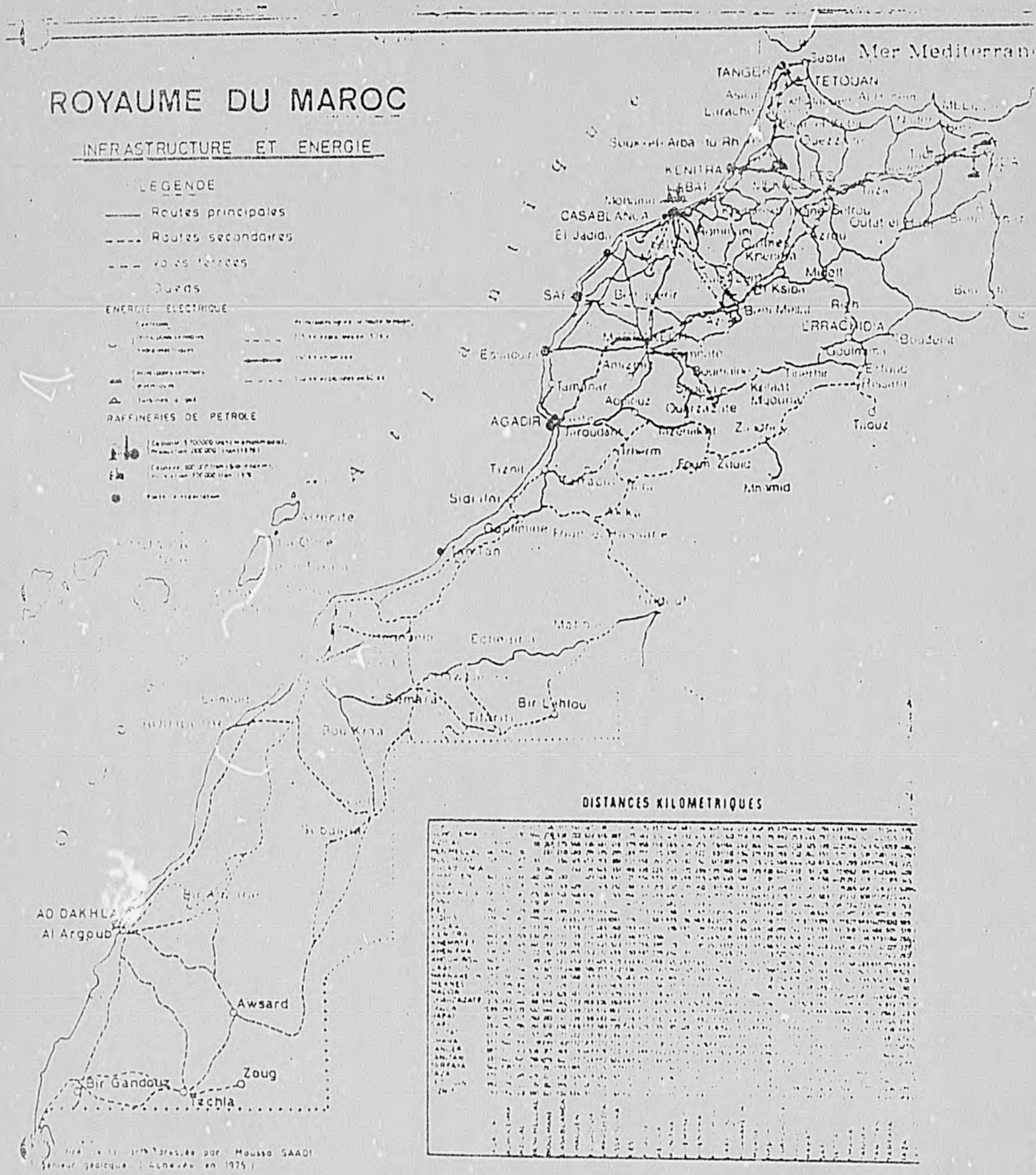
15 - Région d'Essaouira - Talmeste, levée en 1975 par CAG pour BRPM.

16 - Région d'Agadir - Tiznit, levée en 1975 par CAG pour BRPM

17 - Région de Missour , levée en 1975 par CAG pour BRPM

18 - Région de Boudnib, levée en 1975-76 par CAG pour BRPM

19 - Région de Boulmane, levée en 1976 par CAG pour BRPM.


ROYAUME DU MAROC
INFRASTRUCTURE ET ENERGIE
LEGENDE
Routes principales
Routes secondaires
Oueds
ENERGIE ELECTRIQUE
RAFFINERIES DE PETROLE
Mer Mediterran
TANGER
TETOUAN
KENITRA
RABAT
CASABLANCA
El Jadida
SAFI
Essaouira
AGADIR
Tiznit
Sidi Ifni
Midelt
ERRACHIDIA
Ouarzazate
Taroudant
Foum Zguid
Bir Lehlou
Samara
AD DAKHLA
Al Argoub
Awsard
Zoug
Bir Gandouz
Tichla
DISTANCES KILOMETRIQUES

33

PRINCIPALES ZONES MINERALISEES DU MAROC

Echelle 1/4000 000

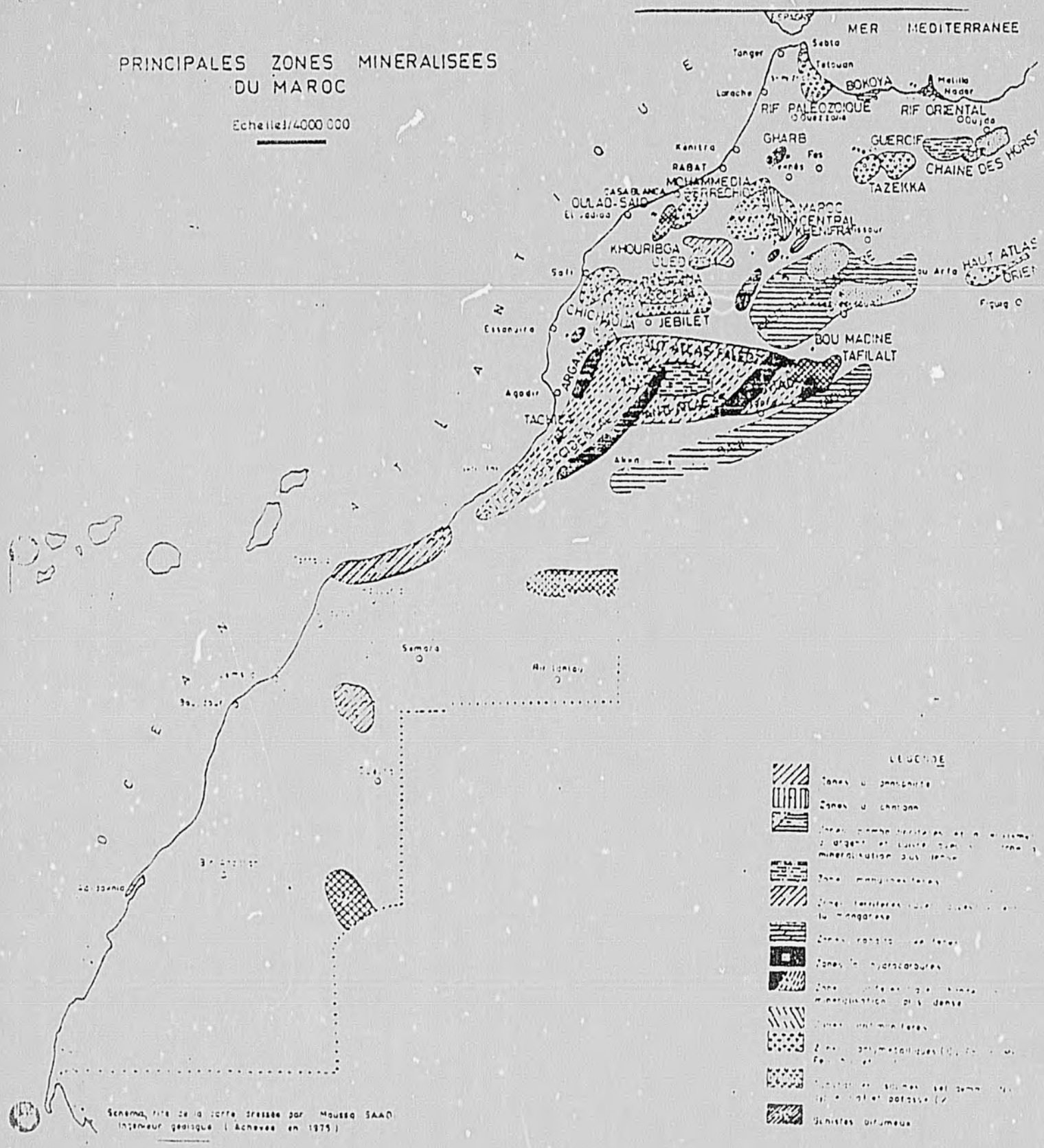


Schéma tiré de la carte dressée par Moussa SAAD Ingénieur géologue (Achevée en 1975)

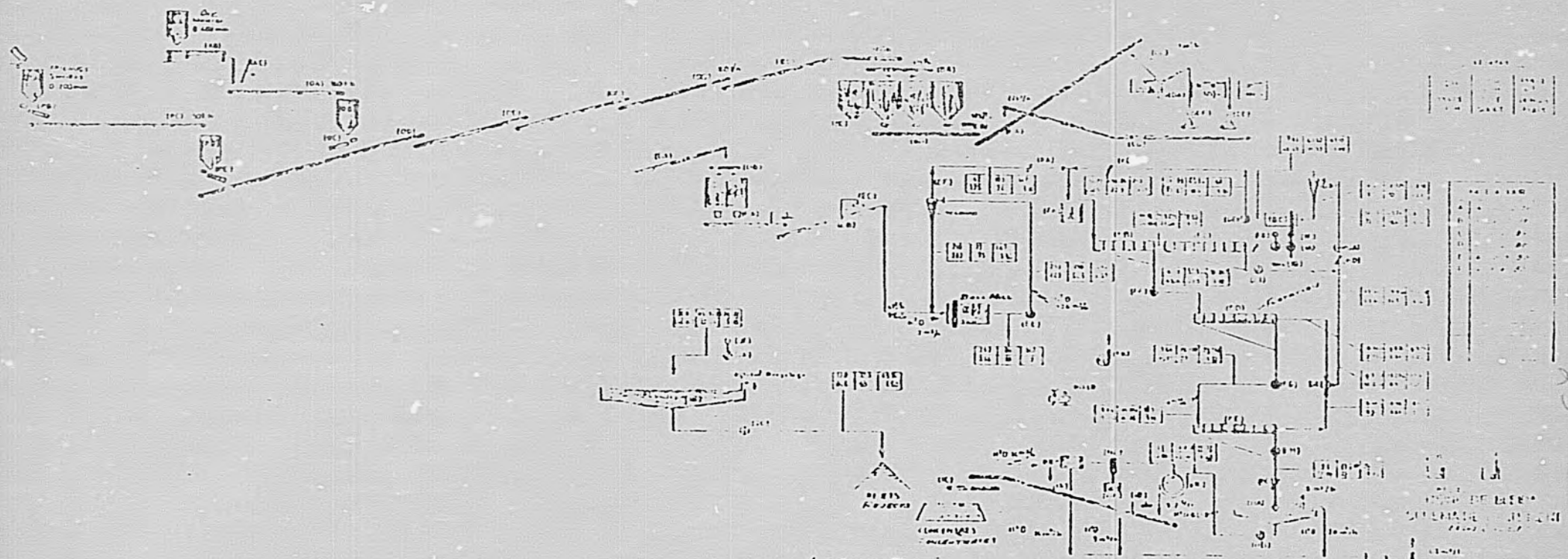


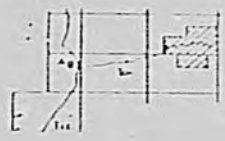
FIGURE I.

CARTE GEOLOGIQUE PROVISOIRE DU MASSIF OUEST DU SIROUA

Par G. CHOUBERT et A. FAURE-MURET

Documents utilisés, levés de L. NEETNER et de H. HOLLARD

Feuilles TIZI N'TEST et TALIOUINE au 1/200000



CARTE GÉOLOGIQUE DU MASSIF DU KERDOUS

(Ait Bahu - Tanalt - Anzi - Tafraoui)

par G. Choubert (1938-1957) et A. Faure-Muret (1960-1967)

LÉGENDE

Quaternaire

Alluvions

Cailloutis (Sahel)

Glacis

Cailloutis anciens

Travertins

Adoucissement Moyen

Adoucissement Inférieur

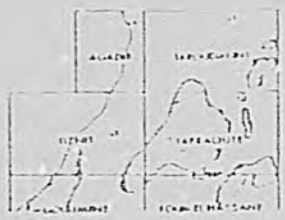
Précambrien III

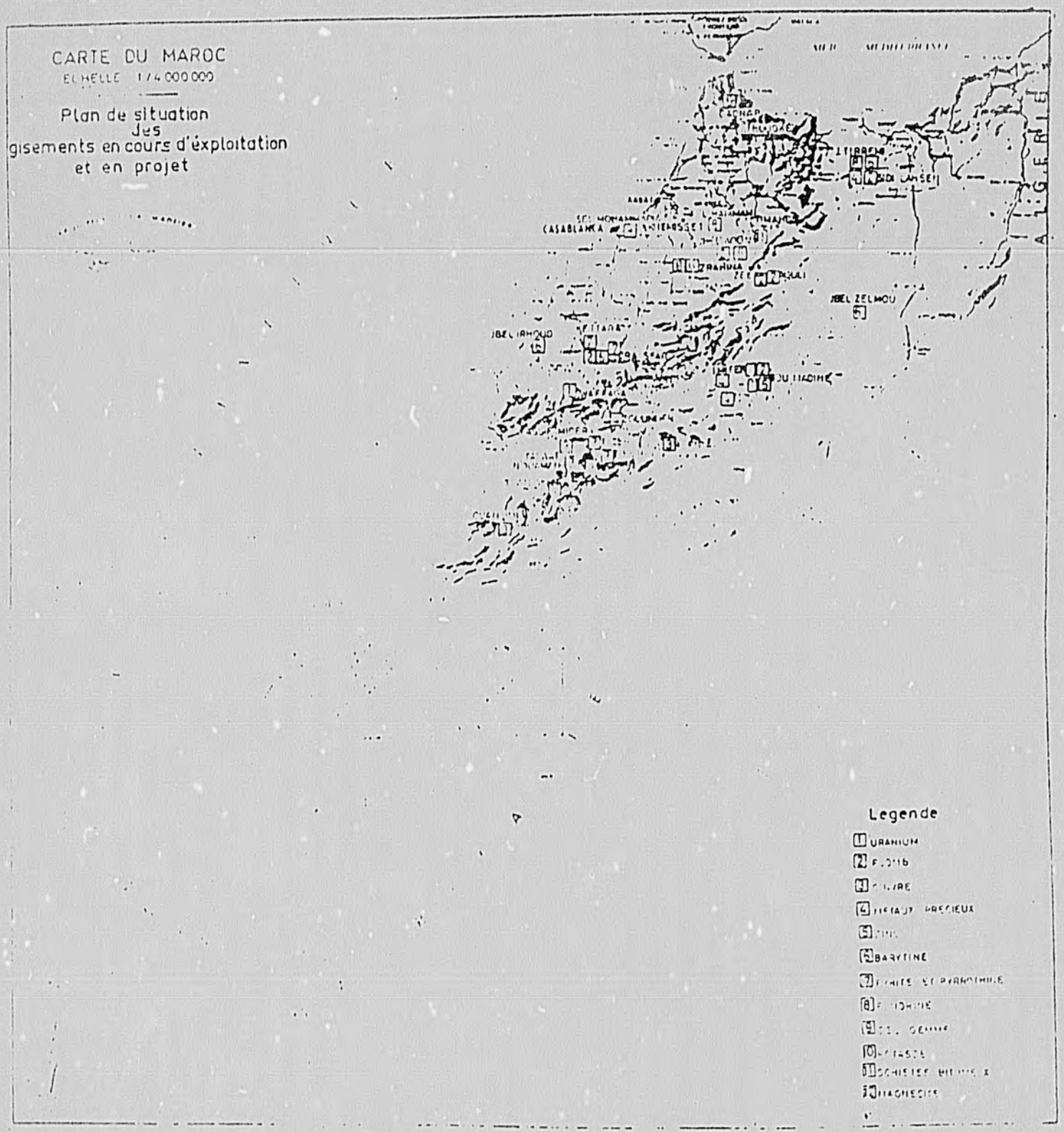
Précambrien II

Précambrien I

Précambrien G

Échelle 1/200 000




CARTE DU MAROC
ECHELLE 1/4 000 000
Plan de situation
des
gisements en cours d'éxploitation
et en projet
CASABLANCA
JBEL ZELMOU
JBEL IRHOUD
Legende
1 URANIUM
2 PLOMB
3 ARGENT
4 METAUX PRECIEUX
5 ZINC
6 BARYTINE
7 PYRITE ET PYRRHOTINE
8 FLUORINE
9 SEL GEMME
10 ARGILE
11 SCHISTES BITUMEUX
12 MAGNESITE

ANNEX II

ABRIDGED SUMMARY OF MOROCCAN MINING LAW

II.3 - Fiscal aspect

In parallel with the task of setting up an adequate legal framework the Moroccan State devoted a special attention to the fiscal aspect, because of its great impact on the promotion of the mining sector. In this field, Morocco took a special care that the rules of the game are clear, stable and efficient. Thus, if the general rule applied throughout the world, either in developed or developing countries, makes that the state is entitled to a number of royalties under the mining rent, always complex and changing to determine, nothing of the kind has been instituted in Morocco. In fact, the Moroccan mining fiscal system is presently composed of two principal elements:

- Tax on professional profits,
- Tax ad valorem on exports.

The impact of the tax on professional profits is attenuated by several fiscal measures including:

- The depletion allowance, which will be dealt with later,
- The possibility for the fiscal administration to grant companies the witholding, under some conditions and when determining the basis of taxation, of several elements, among them the most important ones are differed amortizations and losses during the past trading years.

Concerning the ad valorem tax, the applied rate corresponds to the volume produced, the market value of the product and the international conjuncture concerning the prices of mining products. On the other hand, only the gross exported products are subject to this tax, which makes it an incentive to the local valorization of these products. Last it is applied only to the pithead, which reduces its basis to a great extent.

As I mentioned earlier, the Moroccan mining fiscal system grants attenuating measures which constitute a geniune transfer to the mining companies of an important part of their fiscal charges. Instead they can be considered a return on taxes and duties. Thus, mining companies can, being exporters, recover the greatest part of taxes on capital goods and consumer goods used in the production process, as well as on services.

Anyway, the fundamental element in the field of fiscal attenuation and incentive is the depletion allowance. Indeed, in accordance with a dahir (a law), the state authorizes the mining company to withold, tax free, at the end of the trading year, up to 50% of the professional profits or net income and 5% of the turnover as a financial provision to be devoted, during the three years period of time following the date of its formation, to a number of development operations relating to its mining activity, mainly:

- Works and immobilizations for prospection and mining research and the improvement of the recovery of exploited substances,

- The acquisition of shares in companies having for objective mining exploitation,

- The setting up of transformation units of mining products.

Through this measure, the state aims at encouraging the reinvestment of a part of the mining appreciation in order to uphold and develop this activity.

II.4 - Code for mining investment

The importance of the mining activity, on one hand, and the natural and financial constraints affecting this activity, on the other, urged Morocco to support companies through promulgating a code for mining investments, which can be considered one of the most advantageous ones presently in force all over the world. Without going into details, as they can be supplied elsewhere, I will confine myself to briefly citing the major advantages granted by this code:

1) Exemption from fees for clearence through customs:

On brand new equipment and tooling as well as second hand equipment.

2) Exemption from taxes on products

All equipment and tooling, imported or locally purchased either directly or through a leasing company, are exempted from taxes on products.

3) Reduction of registration duties

The proportional capital brought into a business is reduced from 2.5% to 0.5% in case of a formation of a company or an increase of capital.

4) Interest rebate: a two points rebate on loans by the Banque Nationale de Developpement Economique (B.N.D.E.) is granted.

5) Participation of the state to infrastructure expenses

Up to a ceiling of 15% of the overall projected investment, the Government takes charges of 50% of the investments devoted to infrastructure namely the construction of electric lines and road to give access to the site, supplies in water, the construction of social, educational and sanitary accomodations.

6) Exchange regulations - The foreign investor is allowed:

- an automatic transfer of the result of the liquidation up to the invested capital, for all investments carried out in hard currency, through a clearing account or the debit side of a capital account. The transfer of an eventual appreciation is subjected to authorization.

- guarantee of transfer of dividends without limitation.

All these advantages are granted

- If the 50% of the capital of the company is held by Moroccan individuals or legal entities. The contribution of the state to the infrastructure requires a minimum investment effort (presently 500,000 DH) as well as a minimum generated employment (50 employees).

Starting from an amount of investment (30 million DH, 7.5 million US dollars), the mining project can be the object of an agreement between the state and the promoter granting him more important advantages.

ANNEX III

CONTACTS MET BY TDP TEAM IN MOROCCO

1. Moroccan Ministry of Energy and Mines:
   Dr. Mohammed Benaid
   Director of Geology
   Telephone 751-51
   Rabat, Morocco

2. Omnium Nord Africain (O.N.A.)
   a) Mr. Murad Cherif
      Director of Mining
      52 Avenue Hassan II
      Casablanca, Morocco Tel. 22-41-02

   b) Mr. Pierre Billaud
      Geologist
      52 Avenue Hassan II
      Casablanca, Morocco

3. Bureau of Recherches et de Participations Minieres (B.R.P.M.)
   a) Mr. Mohamed Chahid
      Director General
      5-7 Avenue Moulay Hassan
      Rabat, Morocco Telex 310-66

   b) Mr. Assou Lhatout
      Secretary General
      5-7 Avenue Moulay Hassan
      Rabat, Morocco

   c) Mr. Hassan Seggat
      Chief of the Division of Mergers
      5-7 Avenue Moulay Hassan
      Rabat, Morocco

   d) Mr. Ali Bennani
      Chief of the Division of Cooperation
      5-7 Avenue Moulay Hassan
      Rabat, Morocco

   e) Mr. Bachir Barodi
      Chief of the Minerals Exploration Division
      B.R.P.M.
      Quartier Industriel
      Charia Al Fadila
      Rabat, Morocco Tel. 733-47

   f) Mr. Rachid Alaoui
      Chief of Management
      Quartier Industriel
      Charia Al Fadila
      Rabat, Morocco Tel. 737-64

g) Mr. Abderrahim Chbihi
Geologist
B.R.P.M.
BP 99
Rabat, Morocco Tel. 737-64

h) Mr. Benyacine Moulay Ahmed Idrissi
Legal Counselor
B.R.P.M.
1, Rue Khouribka
Rabat, Morocco Tel. 605-34

4. Compagnie de Tifnout Tiranimine (CTT)

a) Mr. Robert Vaudiau
General Manager
Mines of Bou Azzer and Bleida
CTT
BP 600
Marrakech - Principal
Morocco

b) Mr. Robert Arnodeau
Assistant Manager
Bou Azzer
CTT
BP 600
Marrakech - Principal
Morocco

c) Mr. Ait Azza
Geologist
Bou Azzer
CTT
BP 600
Marrakech - Principal
Morocco

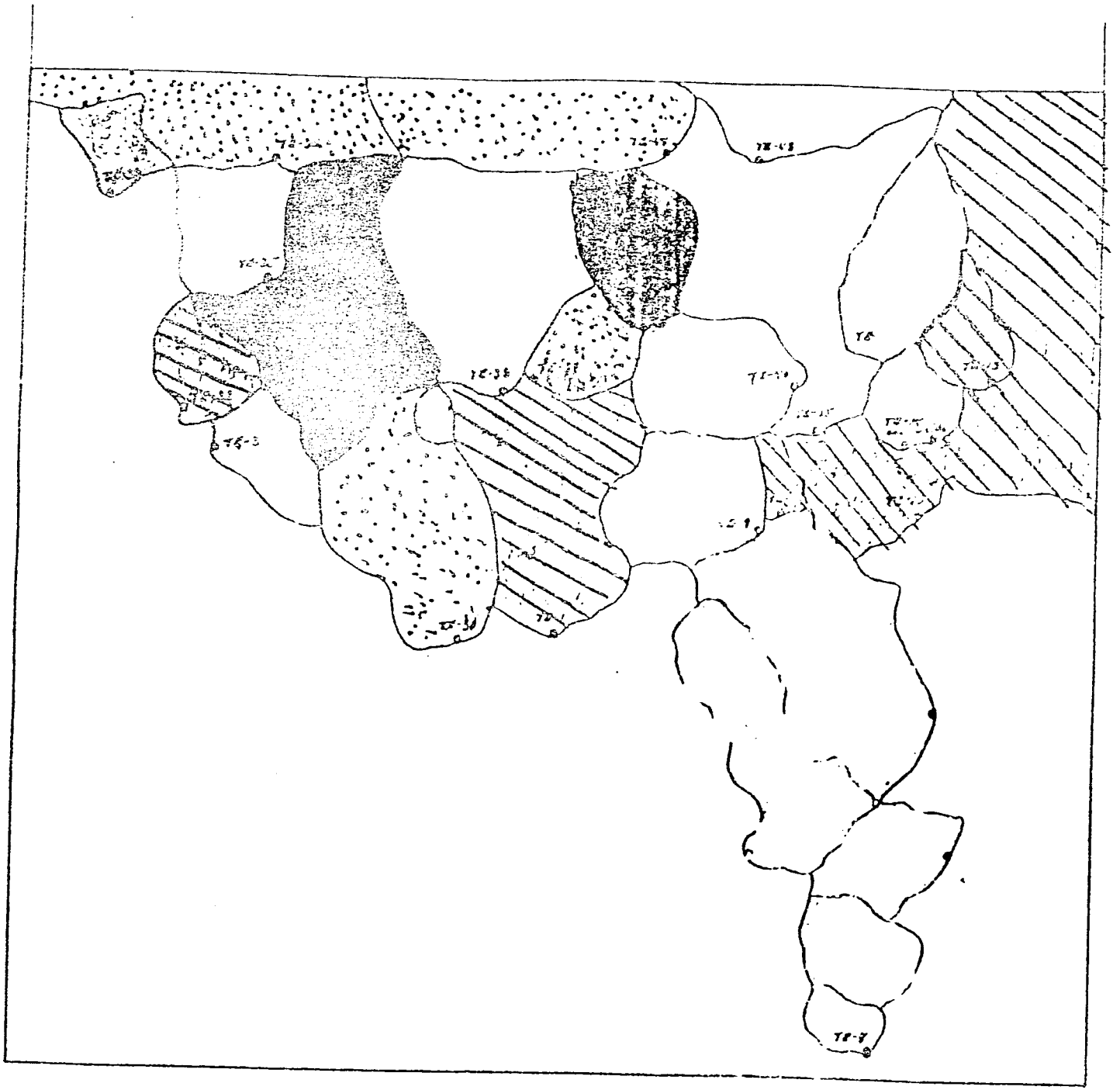
d) Mr. Abdellah Kaddouri
Metallurgist
Bou Azzer
CTT
BP 600
Marrakech - Principal
Morocco

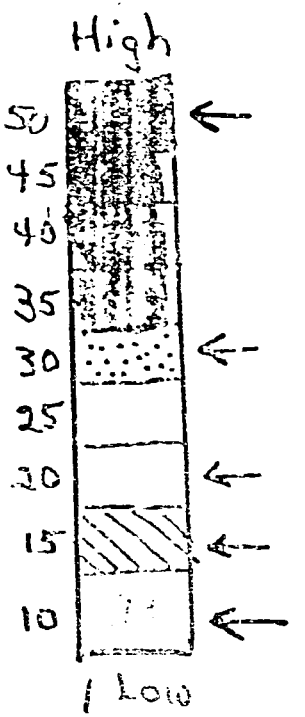
5. Societe de Developpement Industriel et Minier de la Haute Moulouya (S.O.D.I.M.)

a) Mr. Hassan Maghabi
Mine Manager
S.O.D.I.M.
78, Avenue de Chellah
Rabat, Morocco
Tel. At Zeida via Midelt (058) 22-87
At Rabat 623-78

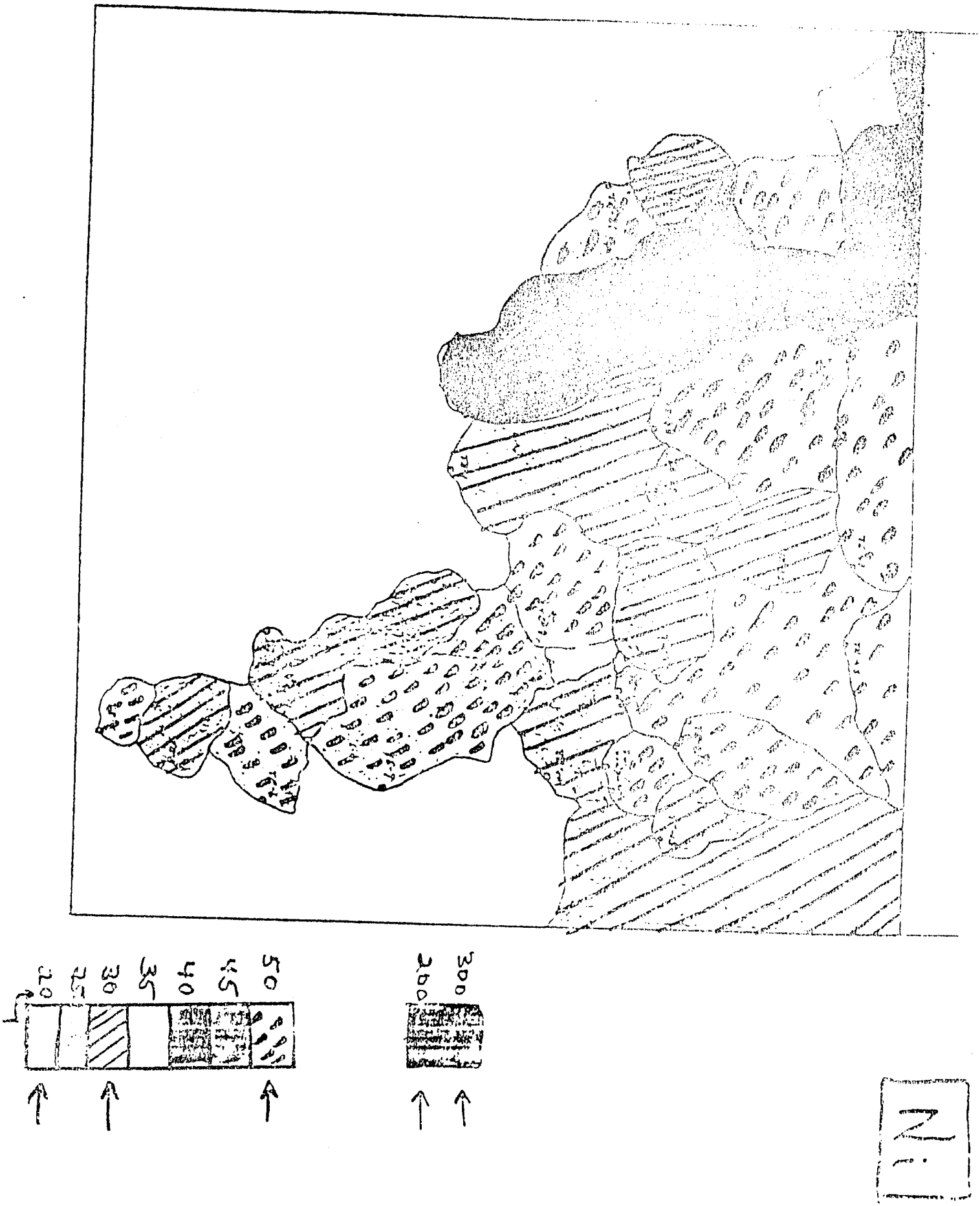
b) Mr. Mohamed Gsabi
Geologist
S.O.D.I.M.
78, Avenue de Chellah
Rabat, Morocco

Co

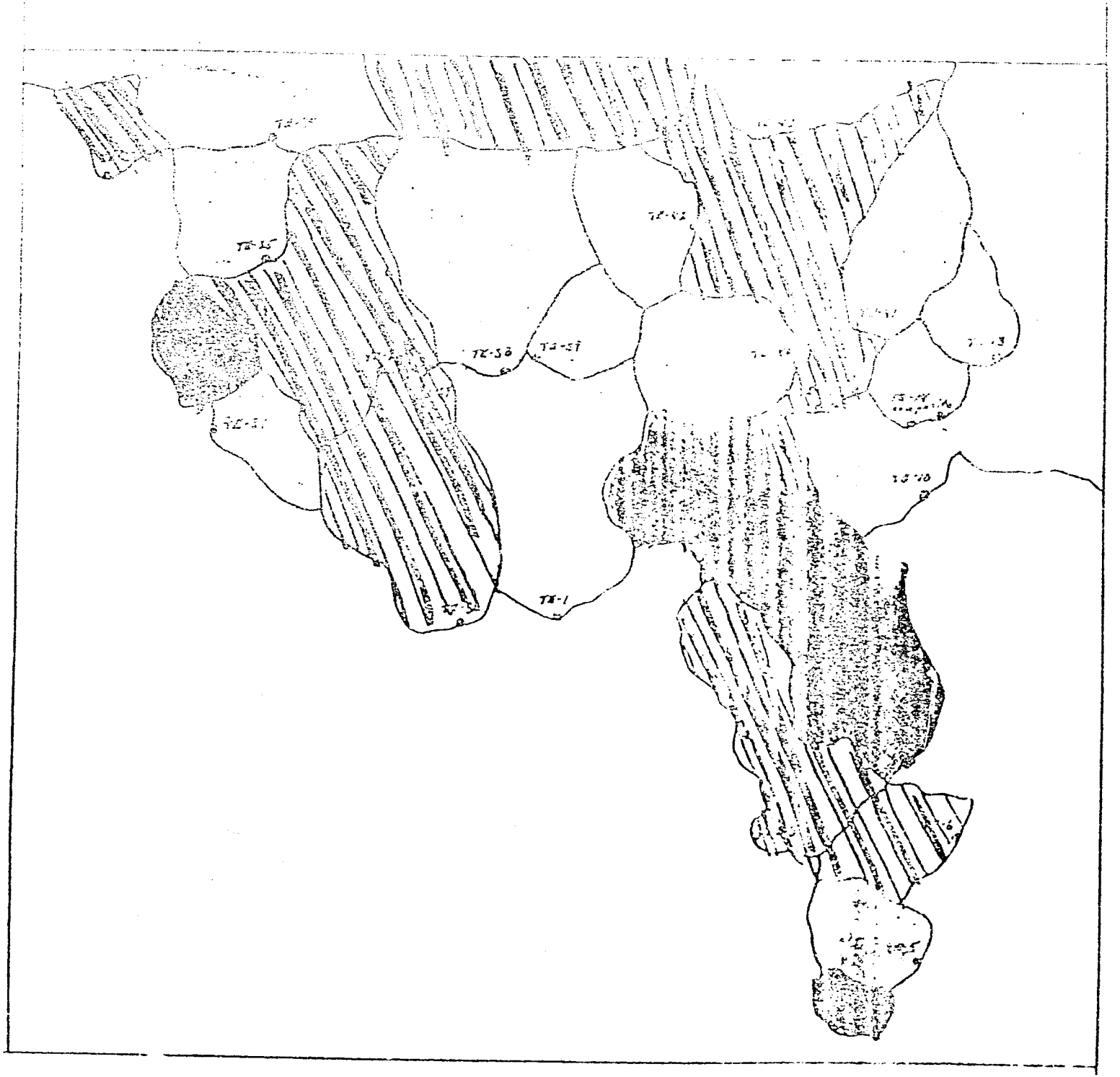


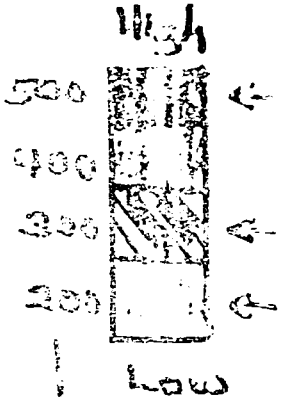


43

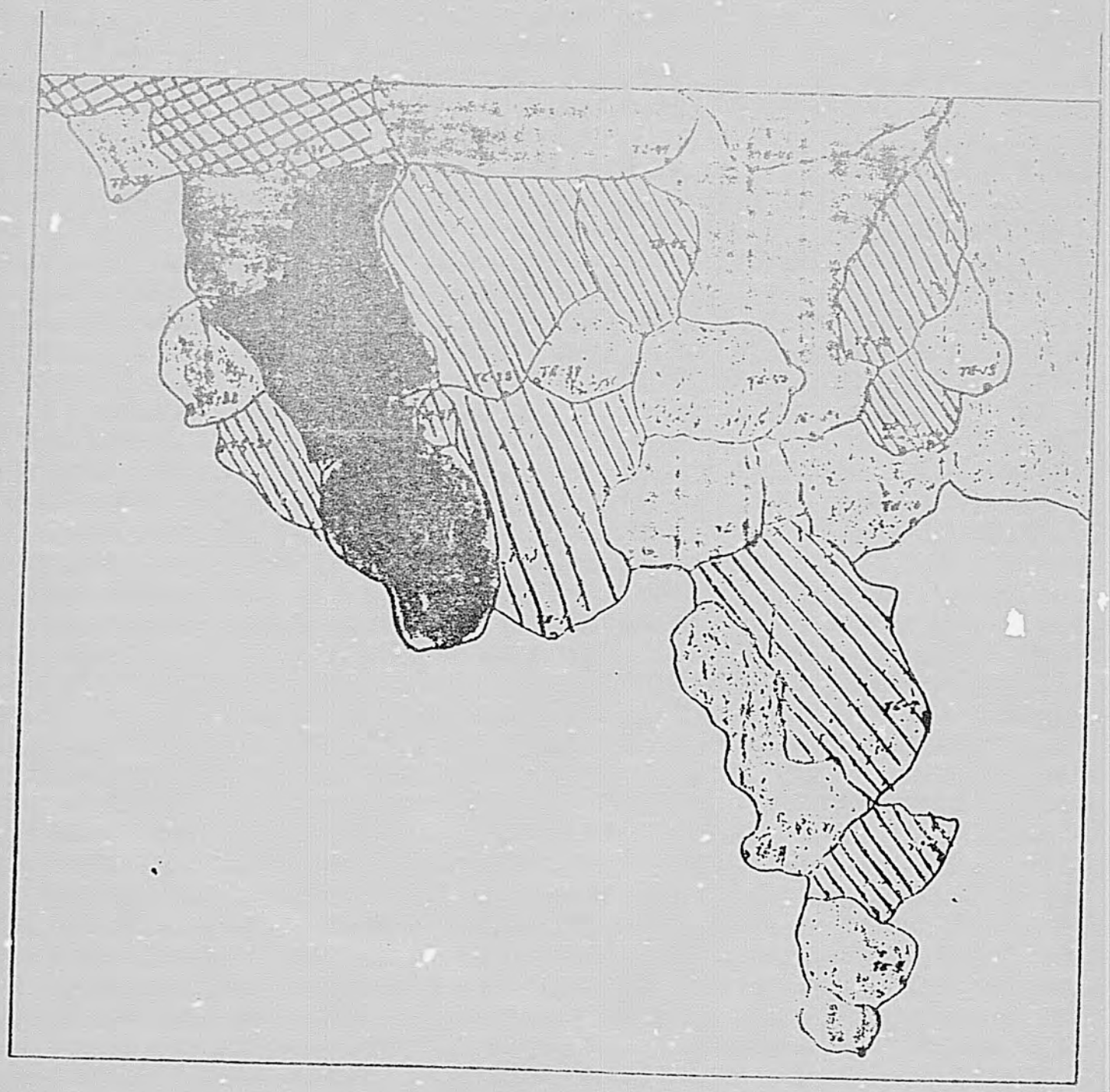


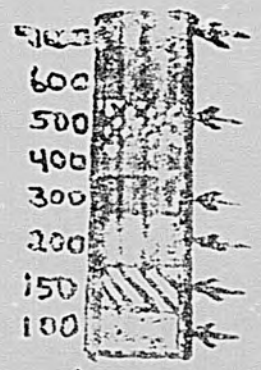
2.




High
500
400
300
200
Low

Ba.




600
500
400
300
200
150
100

TE-34
TE-32
TE-31
TE-3
70
60
50
40
30
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10

TO : Mr. H. A. Le Sieur, TDP Project Leader

FROM : John M. Lucas, U.S. Bureau of Mines
United States Department of the Interior

SUBJECT: Preliminary Report for TDP Mission -
Period 28 January to 13 February, 1982

Preliminary discussions with GOM officials in Rabat followed by visits to mining operations at Bou Azzer and Bleida have demonstrated that the level of expertise in mining and mineral exploration here is well developed. I have been especially impressed with the competence demonstrated by professional geological and engineering staffs at Bou Azzer and Bleida.

Following examination of the various deposits in the region and discussions with the professional staffs of the Compagnie de Tifnout Tirnamine (CTT) and Omnium Nord-African (ONA) at both Bou Azzer and Bleida, I have found that both the methodologies and the techniques employed in the discovery and exploitation of new cobalt and copper ore bodies have been on a much more sophisticated level than I had earlier anticipated. Essentially the same may be said for the professional staffs encountered later at the Imiter silver mine, the Bou Madine polymetallic deposit and the Zeida lead mine.

As Dr. Coleman aptly pointed out earlier, the cobalt deposits of Bou Azzer are unique. Consequently, in the interpretation of the genesis of the cobalt deposits and during the selection of applicable exploration techniques one cannot draw upon the vast storehouse of knowledge which has been assembled over the years for other types of cobalt deposits and apply them directly at Bou Azzer with any assurance of success. For example, porphyry copper deposits have been discovered and exploited under relatively similar geological conditions worldwide - genetic variations from one deposit to another have been thoroughly studied over a period of many years and the exploration techniques which may be applicable for a particular region may be applied with a high degree of success elsewhere. That is to say, the results of these many efforts serve as a guide in the exploration for porphyry copper in unexplored areas of favorable geology.

The adequacy of the theories for the formation of cobalt deposits in the Bou Azzer area have been found by the CTT/ONA staff and the members of the TDP geological Team to be somewhat flawed and therefore open to further interpretation. Correct interpretation of the genetic and geochemical and geophysical peculiarities of the Bou Azzer deposits should result in the further discovery of economic deposits of cobalt.

The CTT/ONA staff has developed and successfully applied a variety of exploration techniques in those areas which are accessible within the limits of their budgets and equipment. Unfortunately, the current world economic recession and the decline in the price of cobalt may overshadow the possibility of any near-term expansion in the funds available for exploration and equipment. When and if the price of cobalt improves, I feel that CTT/ONA may wish to consider some of the following recommendations which may lead to the discovery of new deposits - especially in those deeper unexplored areas of serpentine which exist in that portion of the El Graara block from the Tamdrost to the Ait Ahmane deposits and elsewhere:

RECOMMENDATIONS FOR FURTHER COBALT EXPLORATIONS

1. CTT/ONA may wish to solicit the expertise of the U.S.G.S. and/or private exploration groups which have a proven track record for the successful application of geochemical, geophysical, and advanced petrogenesis and rock dating technology; especially those techniques which have been developed to indicate the presence of buried structural features such as faults which, in the Bou Azzer area, appear to be one of the principal features related to the development of economic cobalt mineralization.

2. To test the validity of the information obtained through #1 (above) within a reasonable timeframe and without the excessive costs associated with diamond drilling, CTT/ONA may wish to investigate the possibility of leasing or otherwise acquiring a high capacity percussion drill capable of rapidly drilling and sampling to a depth of 500 meters or more. The South Africans have recently successfully tested a percussion drill capable of reaching depths of over 900 meters. I plan to send information which I have (in my office) relative to this drill to Messrs. Billaud and Ahmed of the CTT geological staff - ASAP.

3. Aerial infrared photography may, if appropriately applied by experts in that field, be used as a tool to locate the presence of faults or zones of weakness which would otherwise be undetectable. This technique is something that the USGS staff may be able to expand upon.

4. Time consuming surface geological work such as sampling, mapping, drill supervision, etc., may be speeded up considerably with the use of small motorcycles such as the Honda trailbike, etc. Most of the terrain so far observed would be ideal for this type of inexpensive transport. If the user is properly coached in the use and obvious hazards associated with trailbikes, the end results should be positive from the standpoints of economy of time and money.

5. One idea in passing which may provide returns to the GOM may

be to provide rudimentary training in prospecting techniques to local inhabitants of highly mineralized areas such as Bou Azzer, Bleida, Imitir, etc. Country folk often as not possess an extraordinarily keen eye for unusual features which exist within their own 'Turf' especially when incentives such as a prize or participation in the rewards of a significant find are extended on an equitable basis.