UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geologic report and recommendations for the cobalt mission to Morocco sponsored by The Trade and Development Program of the International Development Cooperation Agency

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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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

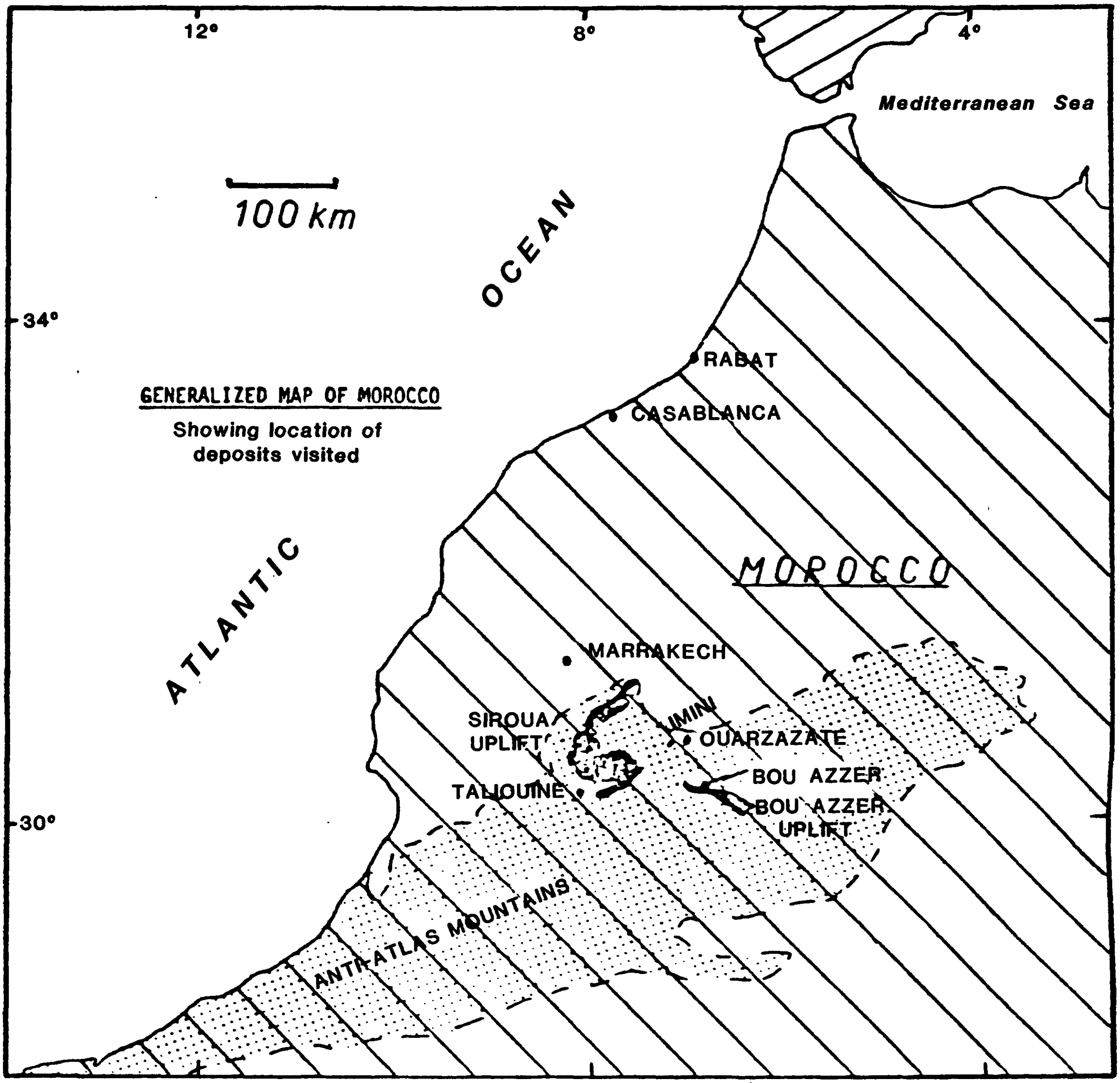

Figure 1. Index map of areas visited showing Morocco (right diagonals), the Anti-Atlas Mountains (stippled), and the Bou Azzer and Siroua uplifts (black).

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 BPRM 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

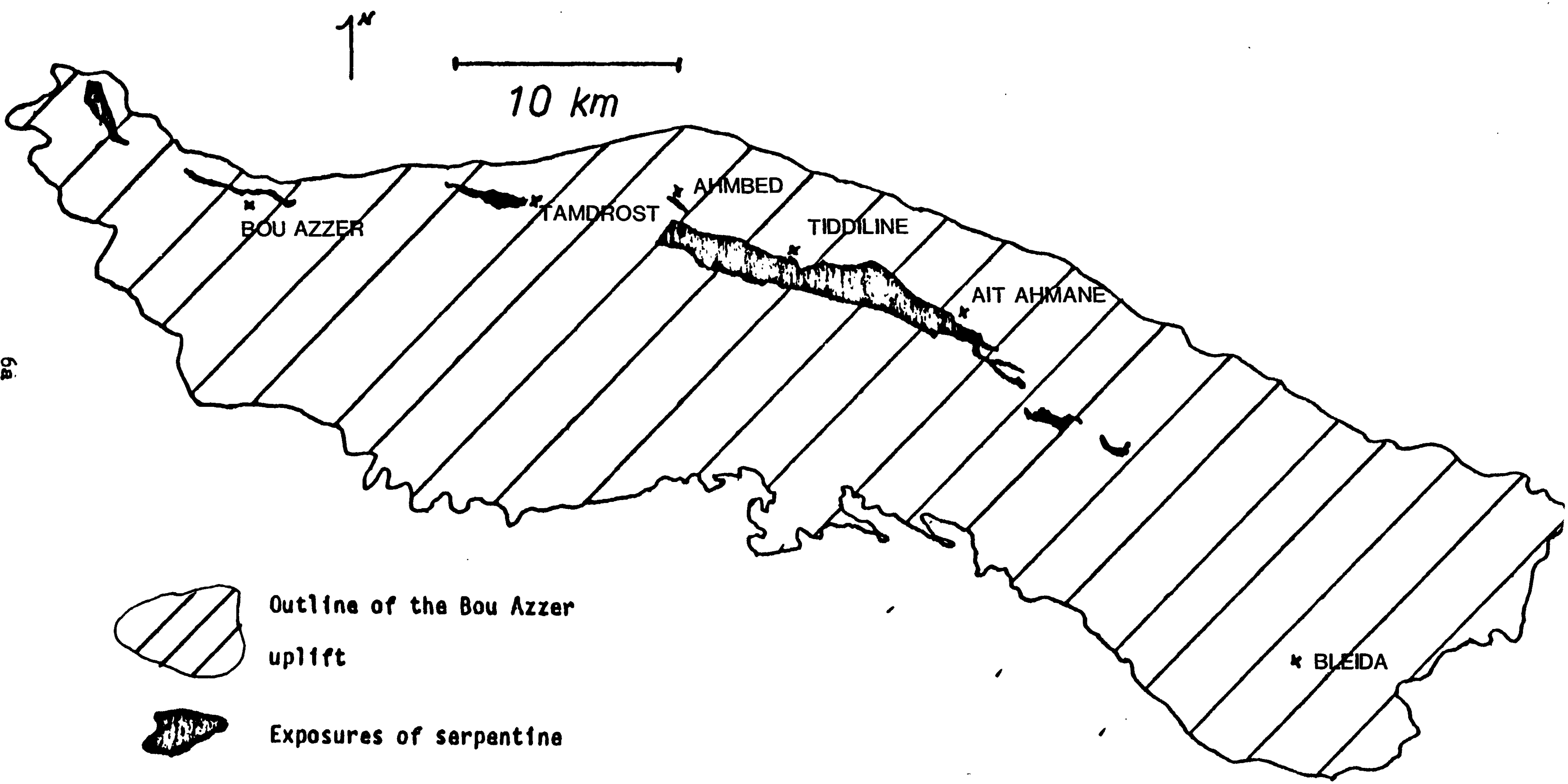

Figure 2. Generalized setting of the Bou Azzer uplift. Proterozoic rocks of the Bou Azzer uplift (left diagonals) contain serpentines that are part of the ophiolite (black), and are surrounded by younger cover rocks (blank).

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 subareal 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.

   <u>Systematic sampling of stream sediments may quickly identify chemical anomalies which merit further evaluation.</u> 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. <u>Consideration should therefore be given to using differences in vegetation as a prospecting guide to locate cobalt.</u> 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).

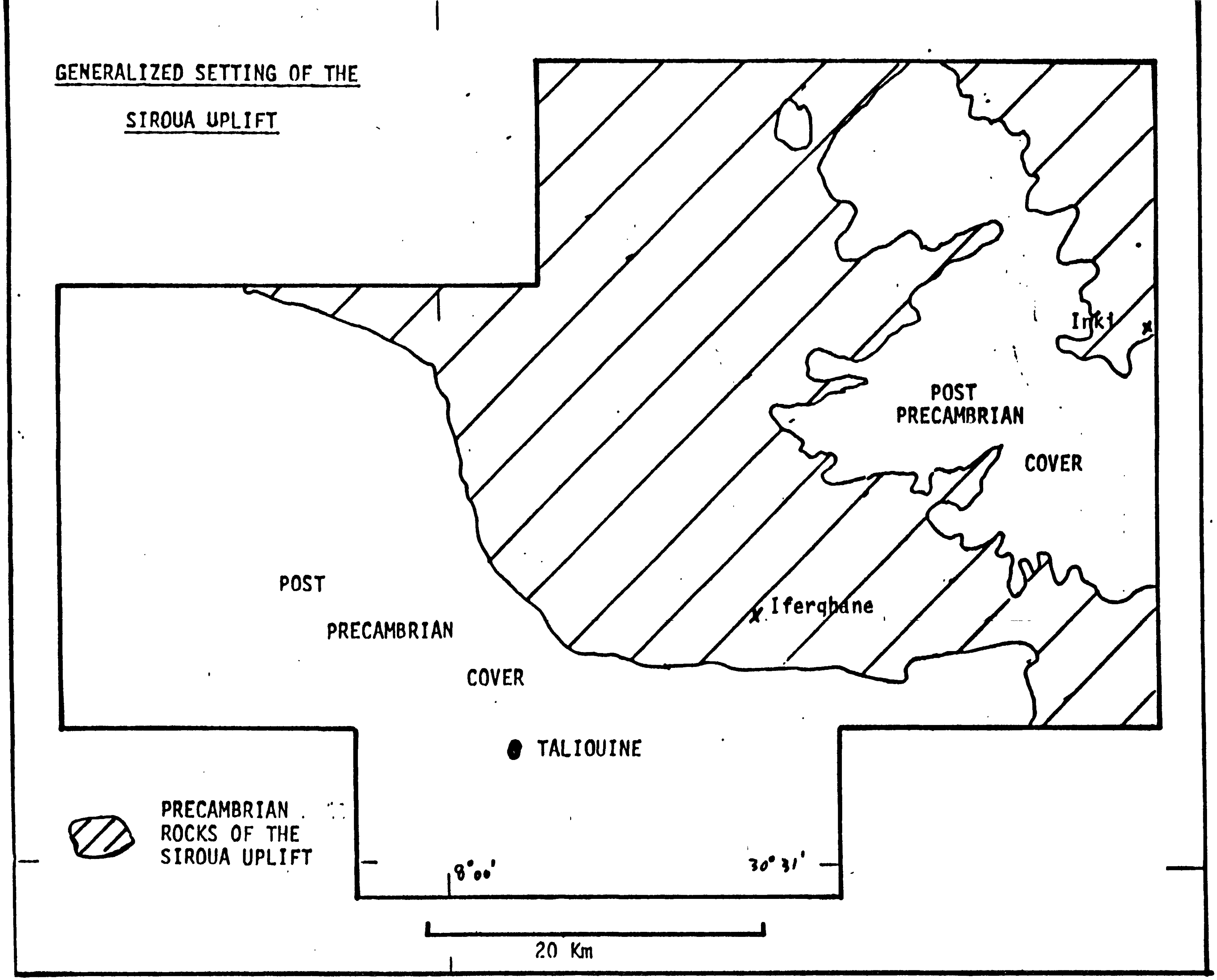

Figure 3. Setting of the Siroua uplift showing the Precambrian rocks (left diagonals) and younger cover rocks (blank).

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 metasandstones and siltstones of the late Precambrian Tiddiline 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.

Appendex 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).

(Note: Because of the nature of the orginal material, some of these pages may make poor reproductions.)

oOo C O N T E N T S oOo

APPENDEX 2

INTRODUCTION

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.

- Rejuvination :

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, serpe nes, syenites, carbonatites, limestones, dolomites, conglomerates, sandston 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 minig 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 Touissit

- Mining laws

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 exemplted 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 limestones.

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 indicividuals or corporate bodies who are authorized to carry ont 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 capita

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

- State contribution towards the Infrastructure.

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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 ontside 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 TARGENTS 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 baryts 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 950 g/T of silv

Project cost estimate : 53.350 000 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	-	52 790	117 610
Expenditure	-	25 586	50 041
Cash flow	-	37 212	67 569

.../...

PROJECT OUTLINE

Project title : BOU MADINE

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	L981	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	3750	900	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.

Administrative location : Midelt

Objet and description of de project :

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

The smelter will handle 105.000 T/year of concentrates conta ing 68,8 % lead, with silver an copper as by products. Il will produce abo 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 fusi and pyrometallurgical up grading. All the anti-pollution devices at the wo site have been envisaged conforming to the standards applied in the indust alized 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	3000	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.

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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 inrernal 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.

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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 friassic, 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 survegs 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.

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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 colcanic tuffs. The deposit may bac considered having 4000 tons of uranium of a grade aroond 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.

OUARZAZATE 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.

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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 meterials 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 sarvey
- Emanometry and radon measurement
- Strategic and tactical geochemical exploration
- Exploratory work in promising zones

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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 : 1 800 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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PROJECT OUTLINE

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 Hereynian 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 Peleozoic 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 500.000 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. Cousequently, exploratory work and investigations on a regional scale are considerad necessary to evaluate fully the potential of the area.

A gold-Silver deposit occurs equally at TIOUIT 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 500 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 mineralisation is localized in the quartz lodes cutting across the granite.

The mineralization with quartz/chlorite and gangue consists of microscopic native gold associated mainly with chalcopyrite, pyrite or 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.

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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 strdies on the ores of these two deposits by flotation in a pulot plant have produced 50 % Zn concentrates.

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PROJECT OUTLINE

TUNGSTEN

The activity of the BRPM in this fiew 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-Tamlalt 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 adjaeent 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 reveated 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.

TAOURIRT N'TAMELALT :

Province : OUARZAZATE

Situation : 20 km SE of Boumalne du Dadès and 460 km from Agadir port.

The scheelite mineralization occurs in fractures in the granite. Exploratory work consisting of drill hales, adits and trenches is undersway. A preliminary estimation of reserves is 800,000 tons having 0.20 % W03.

ZGUIT

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.

HASSIAN 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.

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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 coontries namely Italy, greece and Turkey, where important lignite deposits have been discovered.
The inveestigations 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 BOUDKEK Sector was selected as e 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

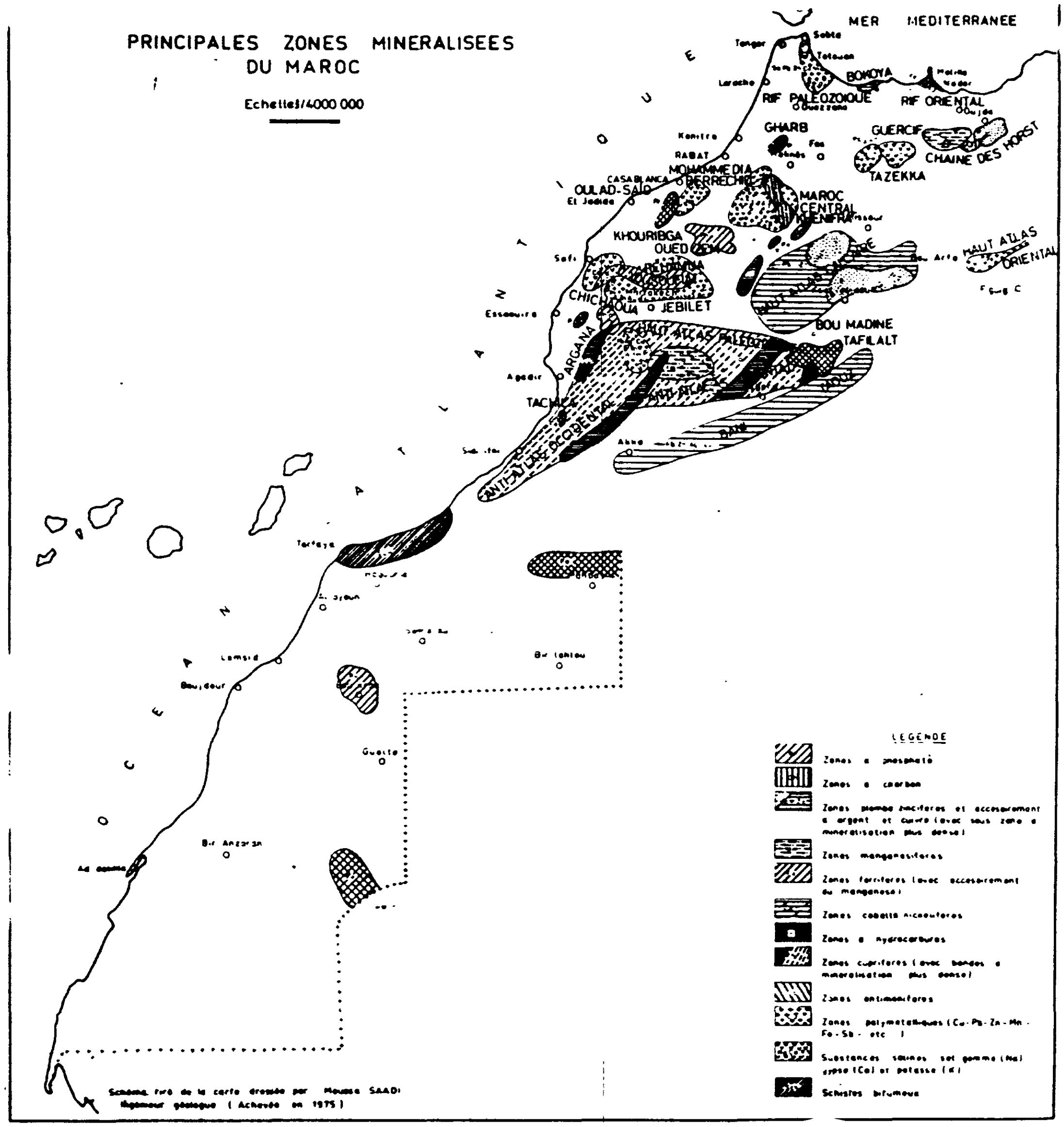
The principal known asbestes deposits are situated in the Anti-Atlas Massif in the OUARZAZATE Province. Geographically and geologically these occur in the following two distinct sectors :

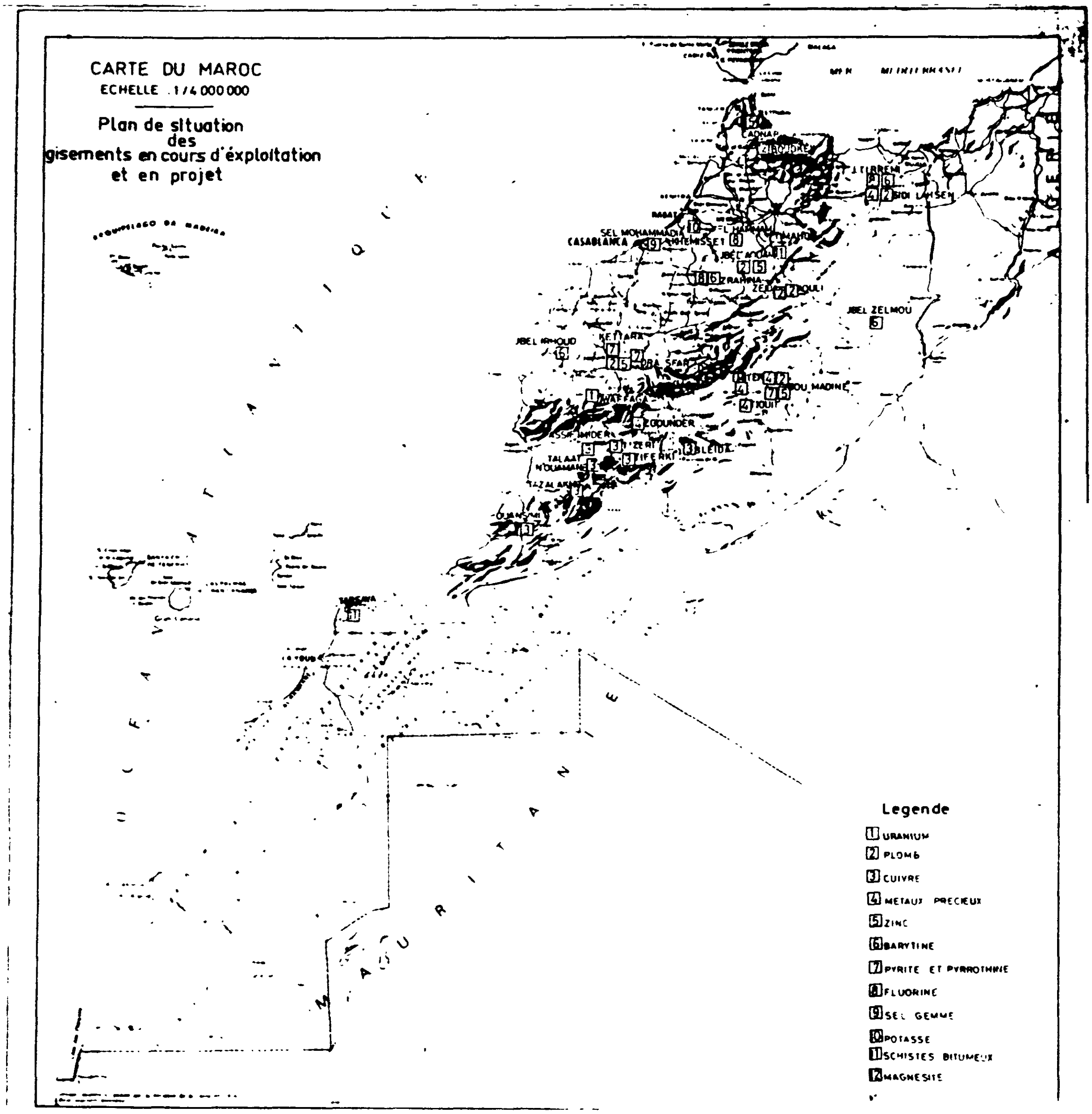
- Bou AZZER Sector.
- Northern and Southern flanks of SIRWA.

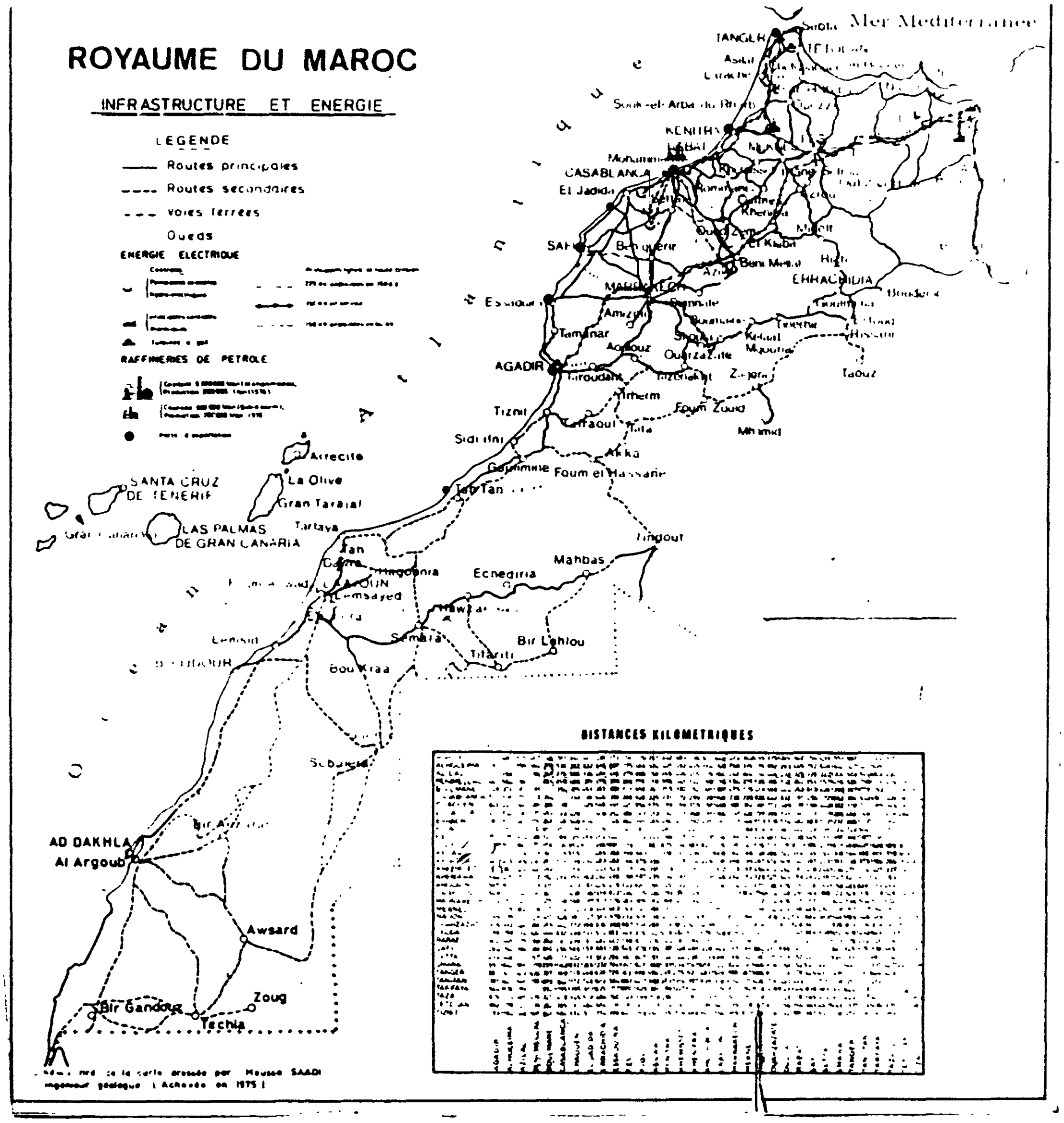
They are Situated 500 and 400 Km east of AGADIR, respectively.

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
Echelle1/4000 000
MER MEDITERRANEE
RIF PALEOZOIQUE
BOKOYA
RIF ORIENTAL
GHARB
GUERCIF
CHAINE DES HORST
TAZEKKA
OULAD-SAID
MOHAMMEDIA
BERRECHID
MAROC
CENTRAL
KHOURIBGA
HAUT ATLAS
ORIENTAL
JEBILET
ARGANA
BOU MADINE
TAFILALT
ANTI-ATLAS OCCIDENTAL
LEGENDE
Zones à charbon
Zones à hydrocarbures
Schistes bitumeux


CARTE DU MAROC
ECHELLE 1/4 000 000
Plan de situation des gisements en cours d'exploitation et en projet
CASABLANCA
SEL MOHAMMADIA
KHEMISSET
JBEL ZELMOU
JBEL IRHOUD
KETTARA
DRA SFAR
WAFFAGA
ZGOUNDER
TIFERKI
BLEIDA
TALAAT N'OUAMANE
SIDI LAHSEN
ZRAHINA
ZELMOU
TIOUIT
Legende
1 URANIUM
2 PLOMB
3 CUIVRE
4 METAUX PRECIEUX
5 ZINC
6 BARYTINE
7 PYRITE ET PYRROTHINE
8 FLUORINE
9 SEL GEMME
10 POTASSE
11 SCHISTES BITUMEUX
12 MAGNESITE


ROYAUME DU MAROC
INFRASTRUCTURE ET ENERGIE
LEGENDE
Routes principales
Routes secondaires
Voies ferrées
Oueds
ENERGIE ELECTRIQUE
RAFFINERIES DE PETROLE
Mer Mediterranee
TANGER
KENITRA
RABAT
CASABLANCA
El Jadida
SAFI
Essaouira
MARRAKECH
AGADIR
Taroudant
Tiznit
Sidi Ifni
Ouarzazate
ERRACHIDIA
Beni Mellal
Tan Tan
Tarfaya
Arrecife
La Olive
Gran Tarajal
SANTA CRUZ DE TENERIF
LAS PALMAS DE GRAN CANARIA
Foum el Hassane
Akka
Tindouf
Mahbas
Ecnedirra
Semara
Bir Lehlou
Tifariti
Bou Kraa
AD DAKHLA
Al Argoub
Awsard
Zoug
Bir Gandouz
Techla
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