Chapter 5 Bazina Kebira Prospect

5.1 Airphoto interpretation

The airphoto interpretation is made for the monochromatic air photographs, obtained in the Republic of Tunisia, covering an area of 25 km^2 that includes the Bazina Kebira prospect. The purposes of the interpretation are to verify faults, beddings and other lineaments and to discriminate lithology in relation with the mineralization in the prospect. The specifications of the used air photographs are shown in Table 35 and the result of interpretation is illustrated in Figure 131.

Table 35 Specifications of Air Photographs

Location	Photo No.	Number of Photos	Remarks
Bazina Kebira	2425--2429, 2413--2417	10 sheets	Project: 74TU359/250 UAG412

A number of lineaments, which are interpreted as possible faults, are observed in association with the Triassic and Tertiary systems. Most of them trend either in the NE-SW, N-S or NW-SE direction, of which the NE-SW trending lineaments are most predominated. Lineaments, possibly indicating beddings, are distinct in the area where the Triassic system distributes. They trend in the NE-SW to ENE-WSW directions that are nearly parallel to the elongation of the Triassic system.

5.2 Geological Prospecting

5.2.1 Methodology

The geological prospecting was carried out by a prospecting team comprising one Japanese and two Tunisian geological engineers. Its purpose was to explicate the relationship between the geology, geological structure and mineralization of the Bazina Kebira prospect, with specific emphasis placed on distributions of dome structures and related Pb-Zn mineralization.

This prospect includes a mine that has ever been exploited. Therefore, the prospecting traverses were laid out centering the mine in order to comprehend the geology with respect to the mineralization. A topographic map at a scale of 1 to 5,000 was prepared, by enlarging published one at a scale of 1 to 50,000, for field use to record detailed descriptions of geology, geological structures, mineralization and so forth at each observation locality (geological base maps). Every observation locality was determined for its coordination using a GIS instrument. Rock and ore samples were collected for various laboratory tests as necessary in the course of prospecting.

5.2.2 Geology

The geology of the Bazina Kebira prospect comprises Triassic, Cretaceous and Tertiary systems overlain by Quaternary system. The stratigraphy and lithology of the prospect is summarized in Figure 131. Its geology is compiled in Figure 132.

The Triassic system distributes in the northern to western part of the prospect and is unconformably overlain by the Oligocene series in its center. The system is the northeastern part of the Jebel Ech Cheid diapir comprising rock salt in its core, gypsum, dolomite, slate, limestone and other minor rock types. Its weathered outcrops show brown to dark brown colors due to oxidation of Fe and Mn bearing minerals contained in the dolomite in minor amount. The limestone, yellowish to dark gray and massive, is generally recrystallized and seldom contains poorly preserved fossils.

The Cretaceous system is divided into Barremian-Aptian (Cba-ap), Albian-Cenomanian (Cal-Cc), Cenomanian-Turonian (Ccc-tu), Coniacian-Campanian (Cco-ca) and Upper Campanian-Maastrichtian (Cca-ma) formations in stratigraphically ascending order. Although the total thickness of the system is estimated at about 480 m in the general area, the exposed thickness in the prospect is about 100 m.

The Barremian-Aptian formation distributes in the northwestern part, from Koudiat Safra to H' zama Lassoued, and is fault-contacted with the Triassic system. Its lower member consists of alternation of gray limestone and green slate, while the upper member is essentially composed of grayish white limestone. Beddings generally strike in the NE-SW direction and dip to the northwest. The thickness is estimated at around 50 m.

The Albian-Cenomanian formation distributes in the vicinity of H'zama Lassoued in the northwestern part and is fault-contacted with the Barremian-Aptian formation. The formation comprises green marl and argillaceous limestone with the combined thickness of about 110 m.

The Cenomanian-Turonian formation, distributing in the central part to the northeast of Koudiat Safra and Koudiat Soda, is fault-contacted with the Triassic system and is conformably overlain by the Coniacian-Campanian series. The formation is divided into the lower, middle and upper members. The lower member consists of gray tabular limestone, the middle member, of alternation of bluish gray marl and limestone, and the upper member, of gray tabular limestone. Beddings generally strike

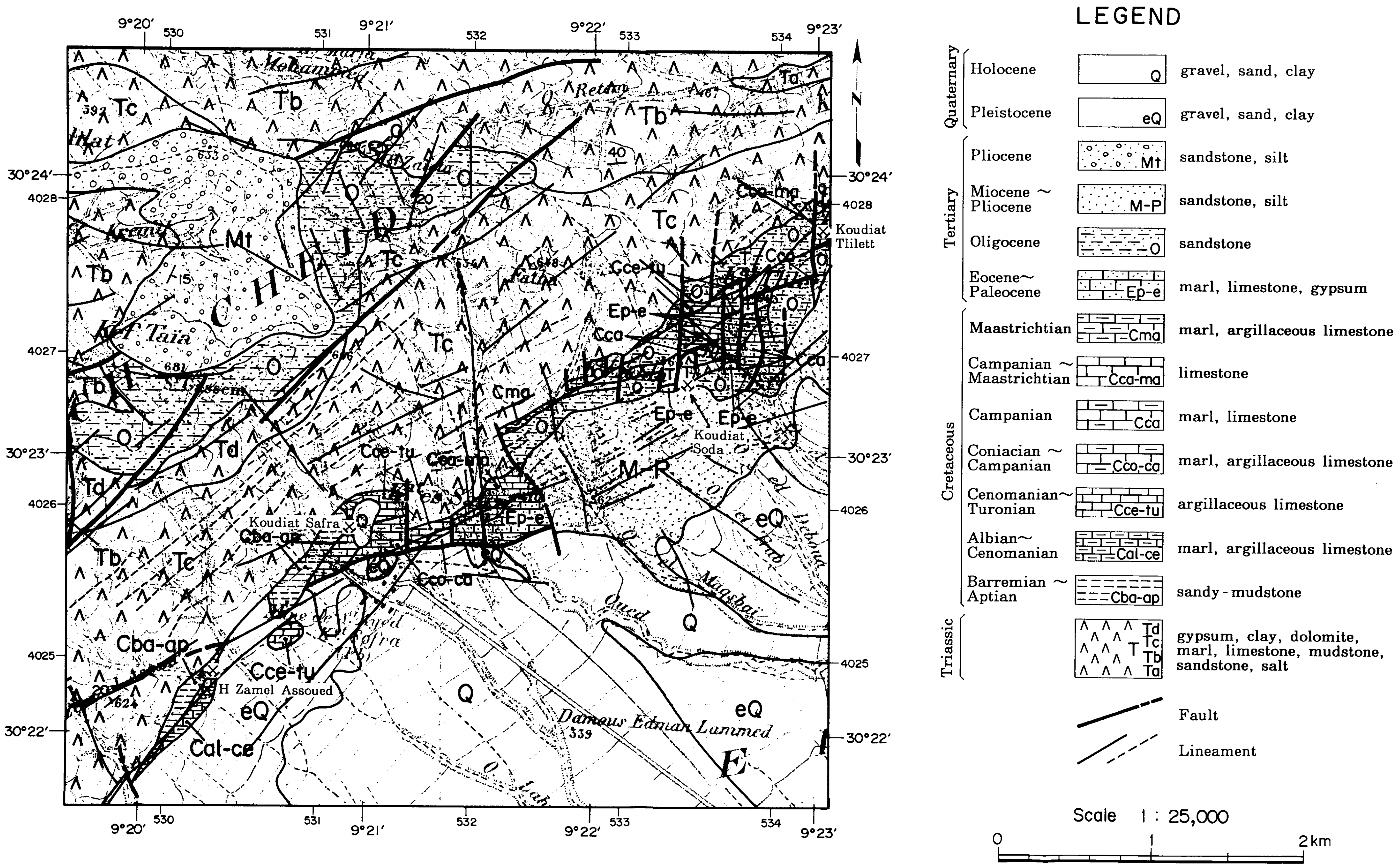


Figure 131 Geological map of Bazina Kebira Prospect

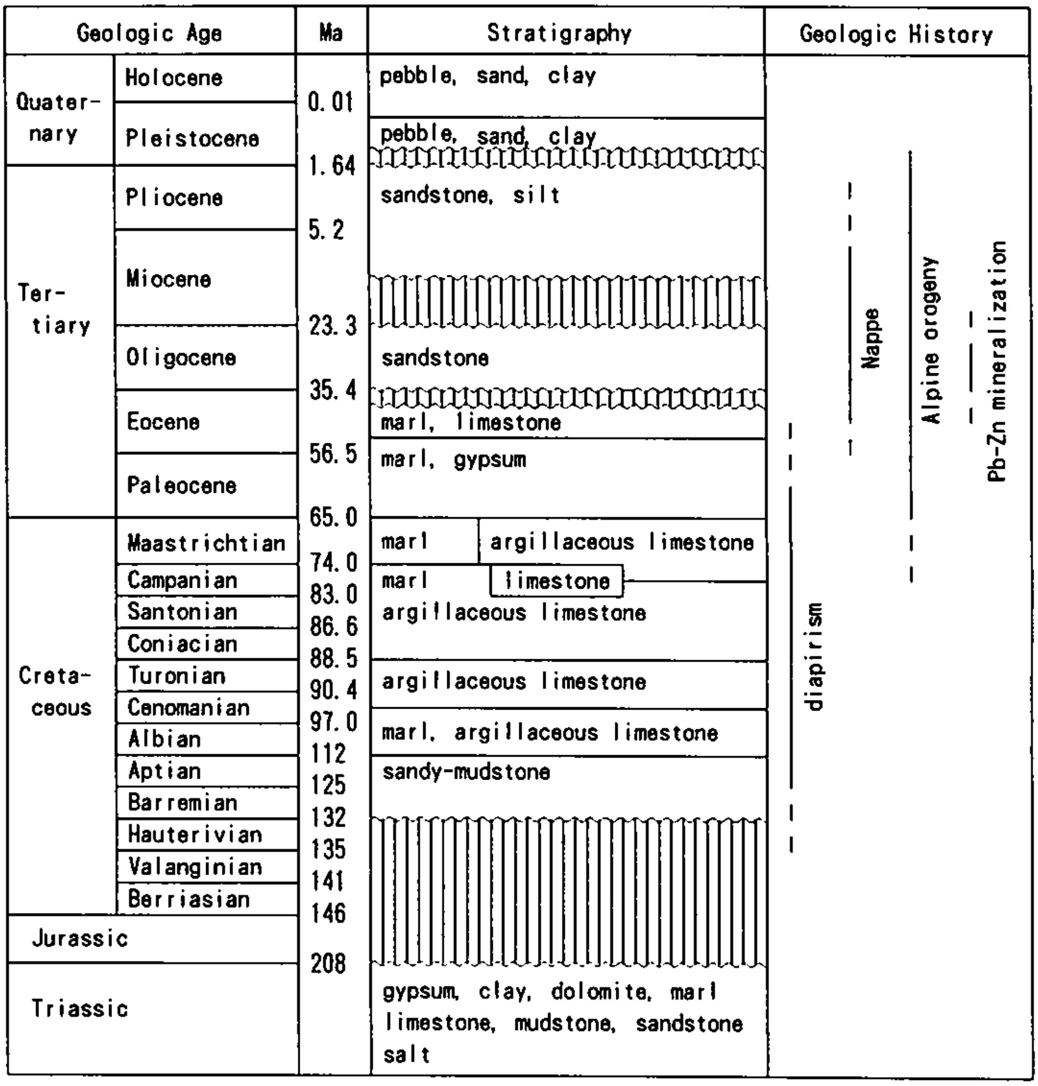


Figure 132 Schematic stratigraphic section

in the NW-SE direction and dip to the northeast. The thickness is estimated at about 140 m.

The Coniacian-Campanian formation, conformably overlying the Cenomanian -Turonian formation, distributes in the vicinity of Koudiat Safra in the central part and mainly comprises gray marl and gray, argillaceous limestone. Beddings generally strike in the NE-SW direction and dip to the northwest. The thickness is estimated at about 160 m.

The Upper Campanian-Maastrichtian formation, mainly comprising gray limestone, distributes in the vicinity of Koudiat Tlilette and Koudiat Soda in the central part and is fault-contacted with the Triassic system. Although beddings generally strike in the NE-SW direction and dip to the northwest, they show somewhat complex attitudes in the vicinity of Koudiat Tlilette where a minor anticline is located. The thickness is estimated at about 20 m.

The Tertiary system, in the northwestern, southwestern through eastern part of the prospect, is divided into Palaeo-Eocene (Ep-lu), Oligocene (O) and Mio-Pliocene (Mc-P) series.

The Palaeo-Eocene series, distributing around Koudiat Soda in the central part, conformably overlies the Upper Campanian-Maastrichtian formation at around Koudiat Soda, while it covers directly the Campanian formation with unconformity to the northeast of Koudiat Soda. The series mainly consists of black marl, containing gypsum and fragments of organic remains. Index fossils yielded from the upper part of this series indicate the Lutetian stage of Eocene. Beddings strike in the E-W direction and dip to the north in general. The thickness is estimated at 50 m in the vicinity of Koudiat Soda.

The Oligocene series, unconformably overlying the stratigraphically lower formations, distributes from Koudiat Tlilette to Koudiat Soda in the northwestern to eastern part. This series consists of reddish brown sandstone containing fragments of organic remains, and is seldom interbedded with layers of marl and conglomerate. Beddings strike in the NE-SW to E-W direction and dip to the north or northwest. Fault development in the series is considerable, which makes it extremely difficult to estimate its thickness.

The Mio-Pliocene series distributes in the eastern part and mainly comprises sandstone, interbedded with lenses of green marl and red slate. Its thickness is undetermined because the upper limit is not exposed. The Quaternary system comprises talus, colluvial and alluvial deposits. Talus and colluvial deposits distribute in hills and foot-hills and consist of gravel, sand and clay. Alluvial deposits are developed in plains along rivers and water courses and consist of gravel, sand and clay.

5.2.3 Geological Structure

The major structural elements that are observed in the Triassic to Tertiary systems in the prospect are diapirs and fault systems trending in the N-S, NE-SW and ENE-WSW directions.

A topographic high, elongated in the NE-SW direction, is located in the northwestern part of the general area including the prospect. This characteristic morphology is an expression of an anticline or dome formed by intrusion of a diapir consisting of the Triassic system. The topographic high has its peak in the vicinity of Jebel Ech Cheid, thus called 'Jebel Ech Cheid diapir', and slopes away towards northwest and southeast.

The Triassic system is in contact with the Cretaceous and Tertiary systems to the southeast bounded by a fault or unconformity. A number of north-south running faults can be assumed to the northeast of Koudiat Safra, where alignments of dolomite and limestone strata are laterally offset step-by-step in the north-south direction. Strata of the Cretaceous and Tertiary systems indicate a homoclinal structure, striking in the NE-SW direction and dipping 25 to 70° to the northwest in general. To the southeastern side of the diapir, however, overturn folds are extensively developed due to diapirism. A particularly complex structural zone runs from Koudiat Safra to Koudiat Tlilett with its width of about 250 m, and continues to an area where a number of north-south trending faults make the structure further complex.

Faults are categorized into the N-S trending and the NE-SW or ENE-WSW trending systems, with the former crosscutting the latter. The fault systems break up the Cretaceous and the Palaeogene systems into a number of blocks, each of which indicates its own geologic characteristics. In addition, a number of small scale folds are commonly formed by intrusion of the diapir.

5.2.4 Mineral Occurrences

There is no operating mine in the Bazina Kebira prospect. Sidi Ayed, located about 7.5 km northeast of Gaafour, is the only mine that has ever been exploited. The mine produced 2571 tons of lead concentrates with an average grade of 50 % Pb from about 28,000 tons of ores containing around 5.5 % Pb. The production was made from two ore deposits, namely Koudiat Safra and Koudiat Soda. However, no production record remains for either of these deposits. The ore deposits were reportedly discovered in 1904 and exploited in the two separate periods, from 1905 to 1914 and from 1924 to 1931. In 1954, ASARCO evaluated its resources attempting re-exploitation and reported the ore reserves of possible category at 230,000 tons containing 10,000 tons of lead metals. Further, a new mineralization zone, H' zama Lassoued, was located about

1 km southwest to the Sidi Ayed mine by the exploration in the period between 1956 and 1957. ONM carried out an exploration consisting of trenching and drilling (5 holes with the total length of 1,006.75 m) in the period between 1971 and 1972, which, however, failed to locate a high grade ore deposit as expected.

The Triassic, Cretaceous and Tertiary systems distribute in the mine area. The ore deposits, as well as other indications of mineralization, occur in association with either the Barremian-Aptian formation of Cretaceous or the Lutetian formation of Eocene. The Barremian-Aptian formation consists mainly of light yellow-gray to gray, fine to medium grained and partly cross-bedded sandstone which is often interbedded with dolomitic limestone and pyritic argillite. The dolomitic limestone contains fossils which suggest a lacustrine sedimentary environment The formation ranges from 10 to 15 m in its thickness and laterally continues for some 450 m. The Lutetian formation also comprises sandstone which is quite similar in its lithology to that of the Barremian-Aptian sandstone. The formation ranges from 10 to 15 m in its thickness and laterally continues for 600 m. Both formations generally strike in the NE-SW to ENE- WSW direction and incline 40 to 50° to the northwest or north. However, they are fragmented into blocks by faults trending in the N-S, NW-SE and ENE-WSW directions.

The Koudiat Safra deposit is located at the coordination of 36° 22' 38" N and 9° 20' 35" E. The ore deposit occurs in the Barremian-Aptian sandstone, presenting a stratiform mode of mineralization along the side of diapir (Figure 133). Its lateral continuation can be traced for some 450 m westwards from its east end where the ore deposit is terminated by a crosscutting fault. Major ore minerals are mostly galena and subordinate sphalerite, accompanying calcite as a gangue.

The Koudiat Soda deposit is located approximately 1.5 km to the northeast of the Koudiat Safra. The ore deposit occurs in the Lutetian sandstone in contact with the Triassic system (Figure 134). The mineralization forms discontinuous veins or tabular bodies filling fractures in the host sandstone. Ore minerals are mainly galena and subordinate sphalerite, accompanying calcite as a gangue. Minor lea mineralization is also observed in association with limestone of the Cenomanian-Turonian and the Campanian-Maastrichtian of Cretaceous.

Besides these major ore deposits, occurrences of lead mineralization are identified at H' zama Lassoued, about 1.2 km to the southwest of the Koudiat Safra deposit, and at Koudiat Tlilett, about to the northeast of Koudiat Soda. Both mineral occurrences are hosted by the Barremian-Aptian sandstone, though too small in their sizes for exploitation.

Table 36 Analytical Result of Ore Samples (Koudiat Safra)

Sample No.	Cu (ppm)	Pb (%)	Zn (%)	Fe (%)	Mn (ppm)	Cd (ppm)	Mg (%)	Ca (%)	Sr (ppm)	Ba (ppm)	Ag (ppm)
BKB01C	33.99	9.0	2.6	1.73	1221	364.1	1186	17.19	1179.2	123.42	31.99

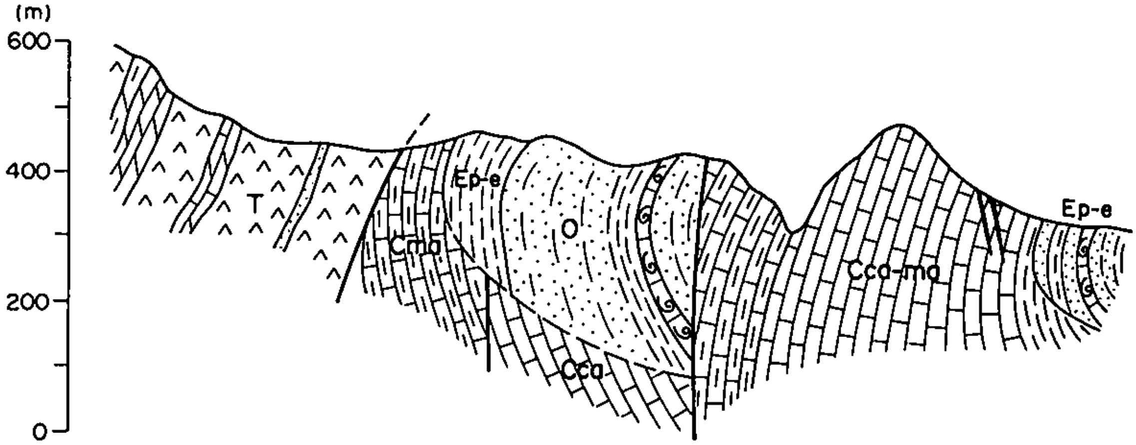


Figure 133 Geological section in Koudiat Safra

Table 37 Analytical Result of Ore Samples (Koudiat Soda)

Sample No.	Cu (ppm)	Pb (%)	Zn (%)	Fe (%)	Mn (ppm)	Cd (ppm)	Mg (%)	Ca (%)	Sr (ppm)	Ba (ppm)	Ag (ppm)
BKB02C	19.5	10.6	1.1	0.99	1118.6	99.3	988	12.08	337.1	101.9	0.61
BKB03C	207.4	17.2	26.0	0.62	631.4	1472	647	8.31	248.3	51.6	0.76

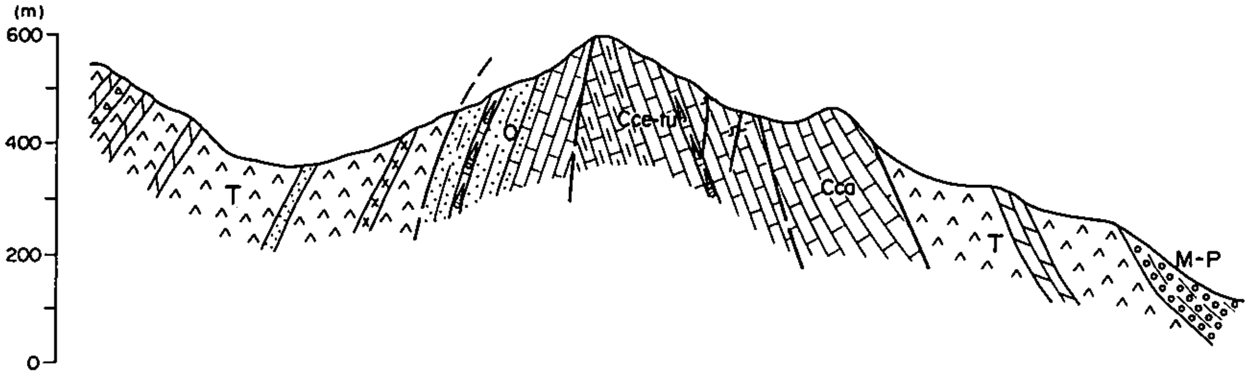


Figure 134 Geological section in Koudiat Soda

Chapter 6 Oued Jebes Prospect

6.1 Airphoto interpretation

The airphoto interpretation is made for the monochromatic air photographs, obtained in the Republic of Tunisia, covering an area of 25 km^2 that includes the Bazina Kebira prospect. The purposes of the interpretation are to verify faults, beddings and other lineaments and to discriminate lithology in relation with the mineralization in the prospect. The specifications of the used air photographs are shown in Table 38 and the result of interpretation is illustrated in Figure 135.

Table 38 Specifications of Air Photographs

Location	Photo No.	Number of Photos	Remarks
Oued Jebes	41--44, 64-- 67	8 sheets	Project: 88TU214/250 OTC

A number of lineaments, which are interpreted as possible faults, are observed in association with the Triassic, Cretaceous and Tertiary systems. Most of them trend either in the NE-SW, NW-SE or E-W direction, of which the NE-SW trending lineaments are most predominated. Lineaments, possibly indicating beddings, are distinct in the area where the Triassic system distributes. They trend in the ENE-WSW direction that are nearly parallel to the elongation of the Tertiary system.

6.2 Geological Prospecting

6.2.1 Methodology

The geological prospecting was carried out by a prospecting team comprising one Japanese and two Tunisian geological engineers. Its purpose is to explicate the relationship between the geology, geological structure and mineralization of the Oued Jebes prospect, with specific emphasis placed on distributions of dome structures and related Pb-Zn mineralization.

Prior to the prospecting on site, the existing documents were thoroughly reviewed in order to lay out adequate prospecting traverses for the above purpose. Topographic maps at a scale of 1 to 5,000 were also prepared, by enlarging those published at a scale of 1 to 50,000, for field use to record detailed descriptions of geology, geological structures, mineralization and so forth at each observation locality (geological base maps).

Every observation locality was determined for its coordination using a GIS instrument. Rock and ore samples were collected for various laboratory tests in the course of prospecting.

6.2.2 Geology

The geology of the Oued Jebes prospects comprises Triassic, Cretaceous and Tertiary systems overlain by Quaternary system as shown in Figure 135. Its stratigraphy, lithology and other characteristics are summarized in Figure 136.

The Triassic extensively distributes in the northwestern part of the prospect and is called 'J. Mouahra diapir'. The diapir is composed of salt rocks in its core and overlying cap rocks such as slate, gypsum, dolomite and so forth.

The Cretaceous System consists of formations of three stages, namely Cenomanian (Cce), Turonian (Ct) and Santonian (Cs) in stratigraphically ascending order, with the estimated total thickness of approximately 300 m.

The Cenomanian formation, unconformably overlying the Triassic, distributes in the northeastern to central part of the prospect and comprises the lower limestone and the upper marl members. The lower limestone member is gray-white to yellow-gray in color and massive, while the upper marl member is gray in color and interbedded with incontinuous lenses of limestone. These members steeply incline southeastward in general with the total thickness ranging from 20 to 60 m.

The Turonian formation conformably overlies the Cenomanian in principle but, in many cases, directly overlies the Triassic with unconformity where the underlying Cenomanian is lacking. The formation distributes in the northeastern to southwestern part and is divided into the lower member, mainly consisting of limestone, and the upper member, consisting of limestone and marl. The limestone of lower member, gray-white, is well stratified and indicates fair lateral continuity, which is a typical limestone facies for the lower Turonian, called 'Bahloul facies'. This member is often mineralized with sulfides and is noted as the major mineralized horizon of the stratigraphic sequence in the general area. These members steeply incline south-eastward in general, and are 10-25 m and 60 m thick for the lower and upper members respectively.

The Santonian formation unconformably overlies the Cenomanian and Turonian formations and distributes in the northeastern part. The lower Santonian is essentially composed of marl, while its middle to upper part comprises alternation of limestone and marl. Its total thickness is estimated at approximately 150 m.

The Tertiary System consists of formations of upper Eocene (E2), Oligocene (O), Oligocene-lower Miocene (O-Ma), upper Miocene (M3) and upper Miocene-Pliocene

(M·Pl).

The upper Eocene, the lowermost of the Tertiary System in the general area, unconformably overlies the Triassic or Cretaceous System and distributes in the southwestern part of the prospect with a limited extension. It consists mainly of marl and argillaceous limestone, and is often interbedded with carbonate rocks in its lowermost marl bed. The argillaceous limestone is dark brown in color and contains planktonic foraminifers. The upper Eocene generally inclines southeastward, with its undetermined thickness due to fault development.

The Oligocene unconformably overlies the Cretaceous System and the upper Eocene, and distributes in the eastern to southwestern part. It mainly comprises alternation of sandstone and argillite with the lowermost limestone. The sandstone is fine to medium grained and massive in general, and shows light yellow-gray to gray white color on fresh surface or brown to light brown color on weathered surface. The mineral composition of sandstone is generally invariable, consisting mainly of quartz with subordinate plagioclase. Foraminifer fossils such as Nummulites occur in association with the sandstone-argillite alternation. The bedding steeply inclines southeastward in general. The total thickness has not been estimated, because its upper limit is not determined.

The Oligocene-lower Miocene conformably overlies the Oligocene and distributes in the southwestern part with a limited extension. It mainly consists of light brown, coarse grained sandstone containing abundant quartz, with the estimated total thickness of about 50 m.

The upper Miocene distributes in the eastern to southern part, unconformably overlying the Triassic and the Oligocene. It is mainly composed of argillite, often interbedded with sandstone, being dark brown in color, massive and relatively soft. The upper Miocene forms a syncline as a whole. Its thickness has not been estimated due to the undetermined lower limit.

The upper Miocene-Pliocene distributes in the southeastern corner of the prospect, conformably overlying the upper Miocene. It consists of conglomerate, sand and clay and inclines gently to the east or southeast. The total thickness is estimated at about 50 m.

The Quaternary System comprises talus deposits, colluviums and alluviums. The terrace deposits and colluviums distribute over hilly terrain or around foothills, comprising gravel, sand and clay, while alluviums, also consisting of gravel, sand and clay, develop along rivers and major streams or over low lands in their vicinity.

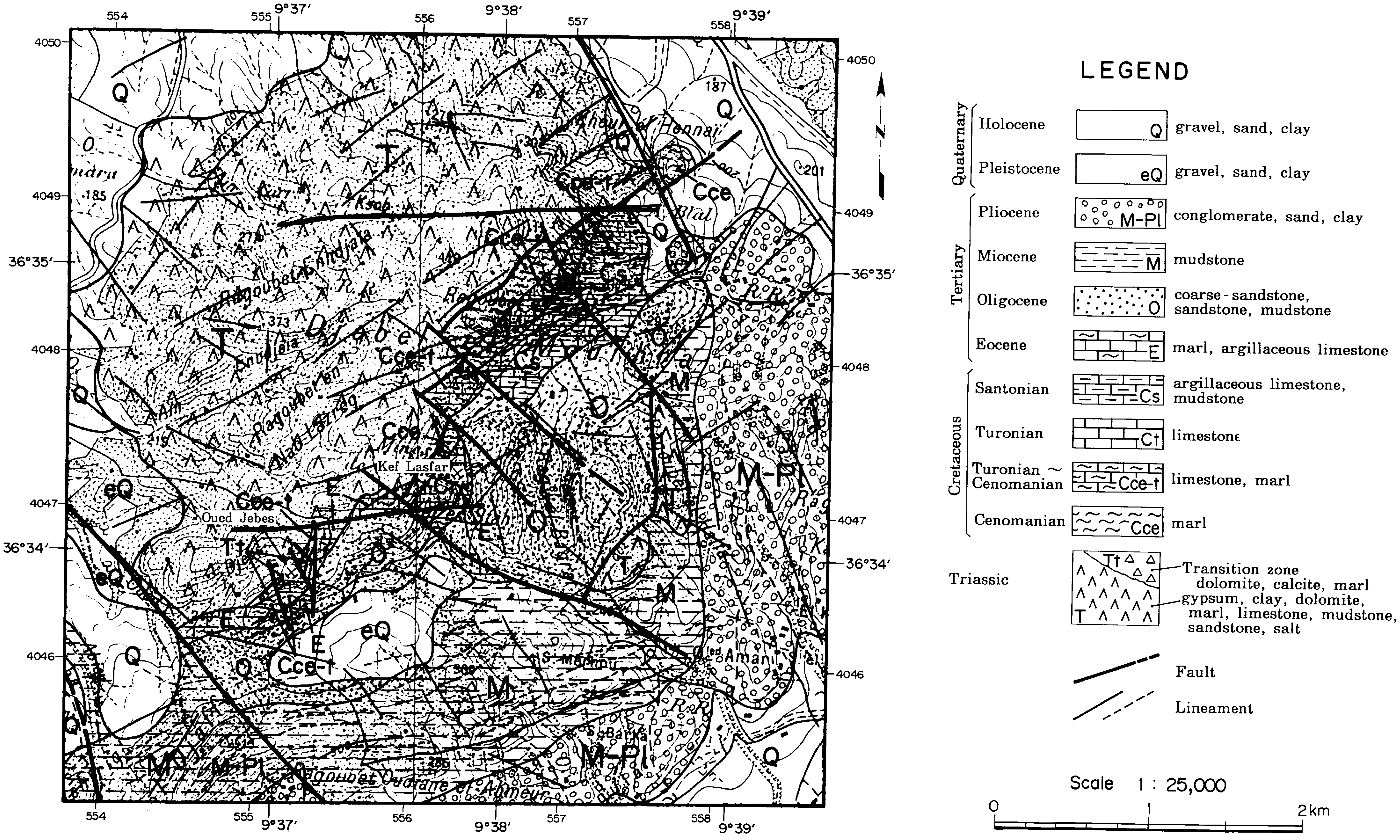


Figure 135 Geological map of Oued Jebes Prospect

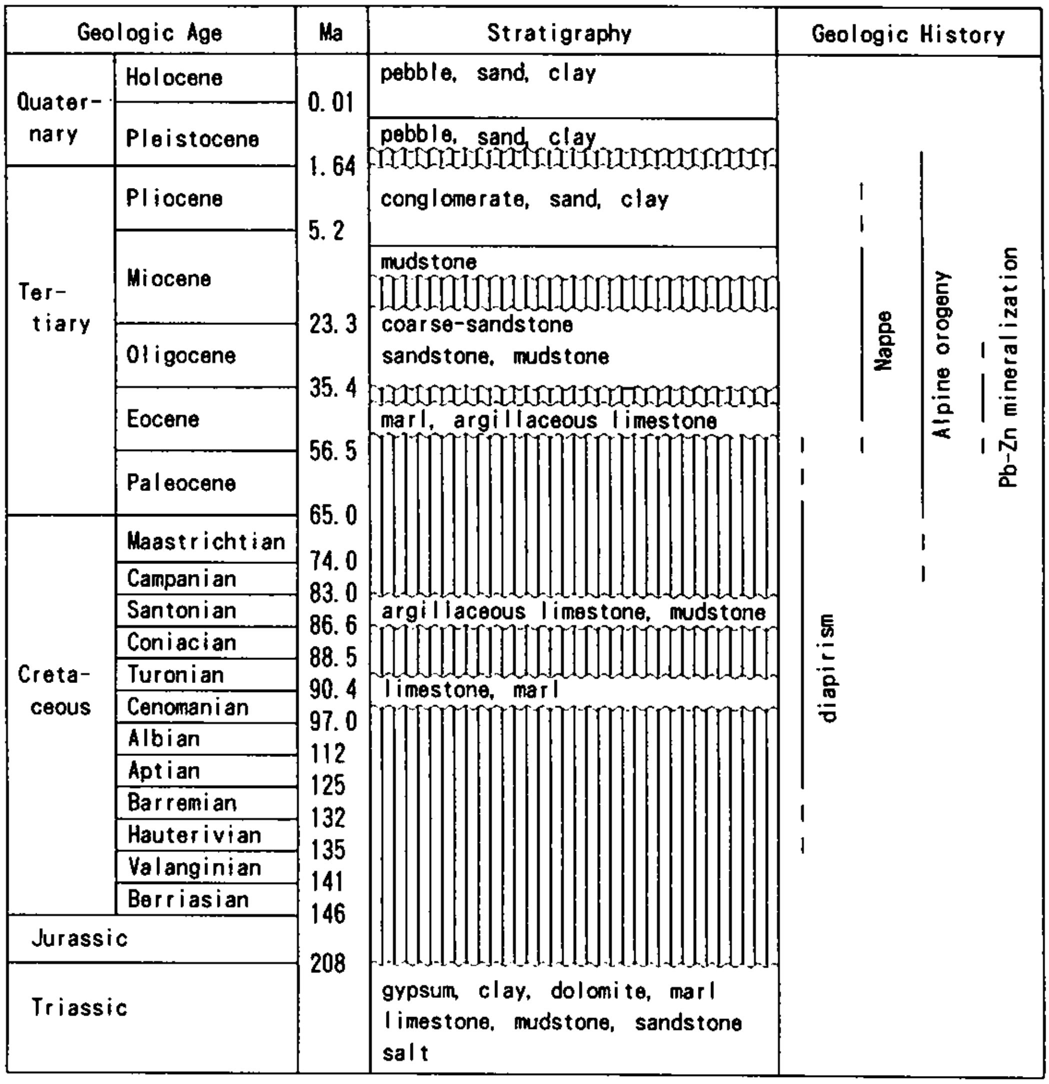


Figure 136 Schematic stratigraphic section

6.2.3 Geological Structure

The geological structure of the general area, hence of this prospect, is characterized by extensive development of diapirs. In fact, the diapir occupies an extensive area of approximately 4 km in length and 2 km in width in the northwestern part of this prospect. It is composed of the Triassic rocks containing rock salt in its nucleus. To its southeastern side, the Cretaceous and Tertiary Systems distribute grading southeastward from the stratigraphically lower to upper sequences as a whole, although a number of faults and folds make the overall structure complicated.

The Cretaceous System, adjacent to the southeast of the diapir, indicates a monoclinal structure striking in the NE-SW direction and dipping 50 to 70° to southeast. The Tertiary System forms a gentle syncline with its axis running in the NE-SW direction. The bedding of Tertiary System strikes in the NE-SW direction, and dips 35 to 50° to the northwest and 40° to the southeast respectively in the southeastern and northwestern flanks of the syncline.

NW-SE trending faults are developed with intervals of 250 to 750 m within the Triassic through Tertiary Systems. These faults have been formed in association with the ascending diapir. The Cretaceous and Palaeogene formations change their thickness laterally across each of these faults. Two E-W trending faults are identified, crosscutting the NW-SE trending faults.

6.2.4 Mineral Occurrences

In this prospect, two ore deposits of the Mississippi Valley type, Oued Jebes and Kef Lasfar, are located and have ever been mined for lead and zinc. However, none of these are in operation at the present time.

(1) Oued Jebes Ore Deposits

The Oued Jebes ore deposit is situated about 9 km south of Mejez el Bab, near a peak of hill at the coordination of 36° 33' 52" N and 9° 36' 54" E. The ore deposit was exploited during the period between 1898 and 1935 by open pit and partly underground, and produced 600 tons and 300 tons of oxide ores of zinc and lead respectively. In recent years between 1992 and 1995, geological survey, geochemical rock sampling and drilling exploration were carried out by ONM-Sachtleben, attempting rejuvenation of the mine. Since then, however, the mine has been idled without any attempt of further work.

Triassic and Cretaceous systems distribute in the vicinity of the mine area.

The Triassic system consists of slate, gypsum, dolomite, rock salt and so forth, and distributes in the northwestern part of the mine area.

The Cretaceous system, distributing in the southeastern part, is divided into three stratigraphic units, upper, middle and lower according to their lithology. The lower unit consists of limestone and marl and is approximately 30 m thick. The limestone is gray-white to yellow-white in color, massive and poor in its lateral continuity. The marl is red-purple to dark brown in color, soft and rarely interbedded with sandstone. The middle unit consists of limestone of the Bahloul facies, the lower Turonian marker, and is approximately 15 m thick. The limestone is gray-white in color, well stratified and laterally continuous. The upper unit consists of marl and limestone, and is approximately 60 m thick. The marl is red in color and soft, and indicates somewhat obscure bedding. The limestone is gray-white in color and forms lenses with poor lateral continuity.

The limestone of middle unit can be correlated to the Turonian stage, based on its characteristic lithology as above mentioned. However, the Cretaceous System, as a whole, is loosely correlated to the Cenomanian-Turonian stage, because no index fossil has been identified in the upper and lower units. A geologic cross-section along the mine area is shown in Figure 137.

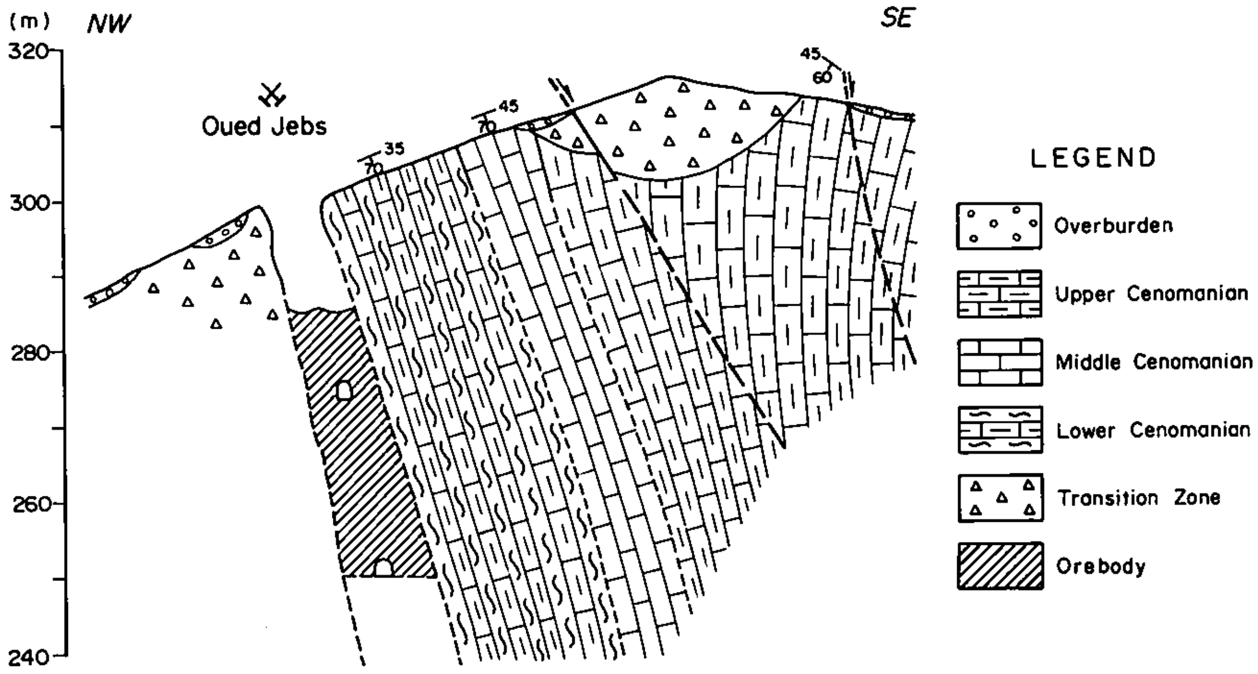


Figure 137 Geological section in Oued Jebes

Pb-Zn mineralization occurs mainly in the contact zone between the Triassic and Cretaceous systems and occasionally within the Cretaceous system. The ore deposit, which was mined in the past, is formed in the contact zone composed of limestone breccia. The mineralization comprises sulfides and oxides filling matrices between angular limestone fragments and forms a single tabular ore body, striking in N 40° E and dipping about 70° to southeast. Ore minerals include sphalerite, galena, hemimorphite and so forth. Veins and vein networks of lead and zinc minerals are also observed in association with the lower Turonian limestone (the middle unit).

Mineralized samples were collected from the ore deposit and submitted for chemical analysis. The result is indicated in Table 39.

Table 39 Analytical Result of Ore Samples (Oued Jebes)

Sample No.	Cu (ppm)	Pb (%)	Zn (%)	Fe (%)	Mn (ppm)	Cd (ppm)	Mg (%)	Ca (%)	Sr (ppm)	Ba (ppm)	Ag (ppm)
OJB03C	38.21	3.3	0.7	2.66	949.34	44.67	673	4.79	2.41	1.52	4.11
OJB04C	12.31	10.0	10.0	0.89	584.53	189.3	926	8.00	4.32	3.60	4.04

(2) Kef Lasfar Ore Deposit

The Kef Lasfar ore deposit is located about 9 km south southeast of Mejez el Bab, in the upstream of Tabia. The ore deposit was ever mined for lead and zinc, with its portal of abandoned adit remaining in the upstream of Tabia, approximately at the coordination of 36° 34' 41" N and 9° 37' 41" E. No mining operation is going on at the present time. Nor record of the past production or mining activity is available either.

A geologic cross-section across the ore deposit is shown in Figure 138. As seen in Figure 138, Triassic, Cretaceous and Palaeogene systems distribute in its vicinity.

The Triassic system, distributing in the uppermost stream of Tabia, forms a diapir consisting of slate, gypsum, dolomite, rock salt and so forth, and is unconformably overlain by the Cretaceous system.

The Cretaceous system is divided into the Cenomanian and Turonian formations. The Cenomanian formation, distributing in the upstream of Tabia, unconformably overlies the Triassic system and comprises 20 m thick limestone which is gray to yellow-gray in color, massive and compact, and is often associated with calcite networks. The Turonian formation, conformably overlying the Cenomanian, distributes also in the upstream of Tabia and can be divided into the upper and lower units. The lower unit consists of gray to gray-white limestone of the Bahloul facies with thickness of 25 m, while the upper unit is 110 m thick and composed of gray to yellow-gray limestone interbedded with marl.

The Palaeogene system, distributing in the middle stream of Tabia, is an Eocene formation which unconformably overlies the upper Turonian and comprises argillaceous limestone often interbedded with argillite. The argillaceous limestone is brown to dark brown in color and massive, containing fossils of planktonic foraminifers.

The ore deposit occurs in the upper Turonian limestone and forms a vein with thickness ranging from 0.5 to 1.5 m. The vein strikes in N 30° E and dips 80° to east, which approximately coincides with the attitude of the contact between the Triassic and Cretaceous systems as observed on an outcrop about 150 m to the northwest. Its continuity has been traced for distances of about 500m and 100 m in its strike and dip directions respectively, although its thickness considerably fluctuates from place to place. Ore minerals include galena, sphalerite, barite and so forth. A sample, collected at the abandoned portal, was submitted for chemical analysis. The result is shown in Table 40.

Table 40 Analytical Result of Ore Samples (Kef Lasfar)

Sample No.	Cu (ppm)	Pb (%)	Zn (%)	Fe (%)	Mn (ppm)	Cd (ppm)	Mg (%)	Ca (%)	Sr (ppm)	Ba (ppm)	Ag (ppm)
OJB05C	62.21	11.8	12.1	1.16	486.02	427.6	1965	12.80	1043.2	101.05	11.02

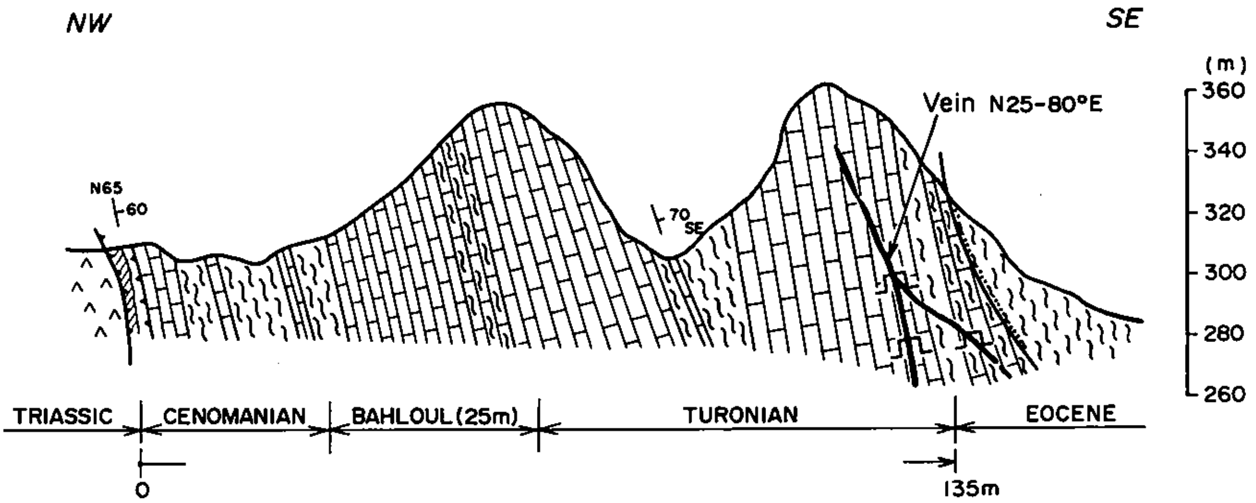


Figure 138 Geological section in Kef Lasfar

Chapter 7 Comprehensive Interpretation

(1) Grade-Tonnage Model

The grade-tonnage model for the carbonate hosted Pb-Zn deposits (D. L. Mosier and J. A. Briskey, 1985) is shown in Figure 139. According to Figure 139, ore deposits of this type with tonnage in excess of 2.2 million tons account for 90 %, those with tonnage in excess of 35 million tons account for 50 % and those with tonnage in excess of 540 million tons account for 10 % in number. Assuming that resources with similar tonnage and grade can be expected for this type of ore deposits under similar geological environment, it might be possible that half of ore deposits in the Republic of Tunisia as a whole would exceed 35 million tons in tonnage. The ore deposits that have been discovered to date are Bougrine (8000 kt, possible), Dal N'Hal (3800 kt, possible), Bou Khil (1200kt, possible), Koudiat Safra (230 kt, possible), El Akhouat (55 kt, possible) and Koudiat Soda (230 kt, possible). None of these reaches the order of tens of million tons, with the maximum being 8 million tons of Bougrine. This implies that ore deposits of such order remain undiscovered or that exploration of known deposits to depth is insufficient.

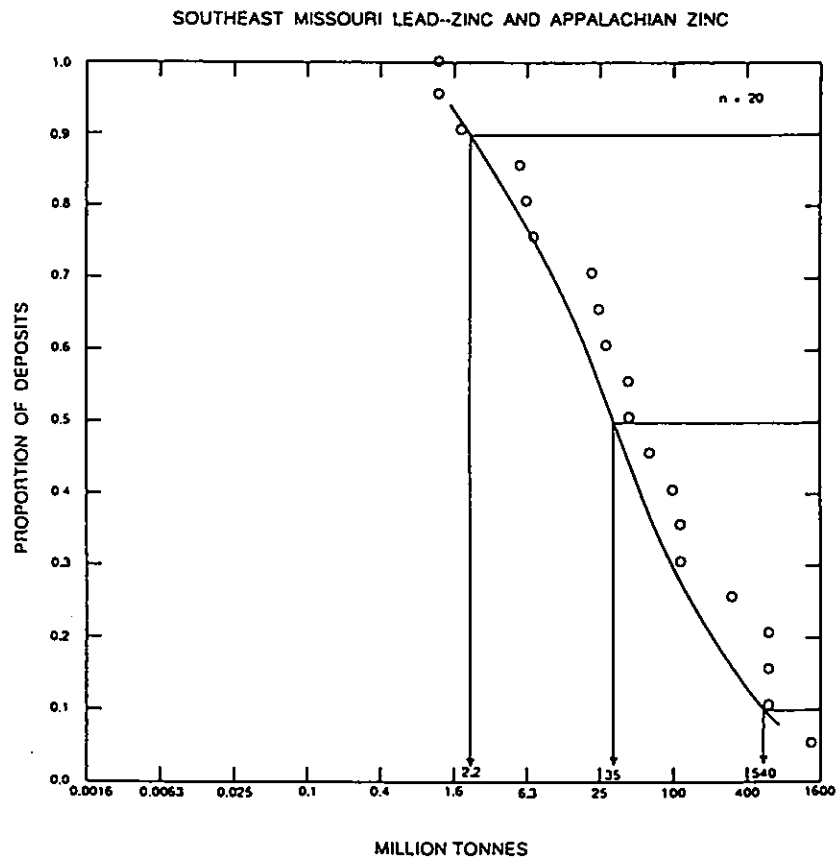


Figure 139 Correlation model between ore grade and ore quantity

(2) Regional Gravity and Geology-Mineralization

Figure 140 is the composite plan incorporating Triassic diapir distribution, mineral occurrences, Pb-Zn geochemical anomalies and the Bouguer Gravity Anomaly (Correction Density = 2.33 g/cm^3) Map by Jean Claude, G (1999). According to the Bouguer Anomaly Map, the regional gravity in the Project Area as a whole is high in the central-northeastern and the southwestern parts, and low in the central-southwestern part, indicating the general trend of the Bouguer anomaly in the NW-SE direction. This trend of NW-SE direction conflicts with that of the structural trend in the NE-SW direction that represents the most prevailing structures in this region affected by the Alpine diastrophism.

The sedimentary basin in the region started subsiding in Cretaceous, which resulted in deposition of thick sedimentary sequences of Cretaceous to Eocene. In the early half of Cretaceous, block movement of the basement prevailed and triggered diapirism towards middle Cretaceous. The block-movement, together with the diapirism, caused repetition of uplift and subsidence of the sedimentary basin, which resulted in deposition of conglomerate interbedded with the Cretaceous sedimentary sequences. As the Alpine diastrophism emerged in late Cretaceous, the sedimentary basin became progressively shallower towards early Tertiary. The Tertiary sedimentary sequences of Oligocene and afterwards, mostly of terrestrial nature, were extensively developed, overlying the Cretaceous and Eocene sequences.

The Alpine diastrophism, with its peak stage in Oligocene, brought about intense deformation of rocks in the region by folding, faulting and thrusting during the period of Neogene. These structures were developed under the prevailing stress field during the diastrophism, represented by NE-SW trending thrust faults particularly well demonstrated in the 'Nappe' zone and by NW-SE trending grabens and horsts commonly observed in the general area. It is quite conceivable that the basement is subsided in the zones of graben and is uplifted in the zones of horst. The regional gravity lows and highs, as above mentioned, may correspond respectively to subsided and uplifted zones of the basement.

Comparing Figure 140 to the geological map at a scale of 1 to 50,000, the Cretaceous system distributes centering regional gravity highs. Therefore, the Bouguer gravity distribution possibly indicates the depth of Cretaceous base. More in detail, minor gravity highs are observed in association with the Jebel Ech Cheid diapir and are aligned in the NE-SW direction. It is observed in the field that thin Neogene sequences distribute abutting on the diapir in places. Therefore, these gravity highs can be correlated to the Neogene sequences, reflecting the shallow base of the Neogene sequences.

Assuming that the Bouguer gravity distribution is related to the depths of the Cretaceous and Neogene bases, its characteristics with respect to the geology are summarized as follows;

- Neogene terrain: gravity highs and lows are correlated respectively to thin and thick Neogene sequences.
- Cretaceous terrain: gravity highs are correlated to thick sequences of the Cretaceous system, while lows indicate either thin sequences of the Cretaceous system or Triassic diapirs.
- Triassic terrain: gravity highs indicate diapirs without roots such as 'transition' or 'umbrella' zones, while lows suggest diapir centers or those continuing to depth.

A number of Pb-Zn mineral occurrences of the Mississippi Valley or the carbonate hosted type are located in this region, mostly in the steep gradient zones of the Bouguer gravity distribution. This implies that circulation of hydrothermal fluids, which brought about the mineralization, were controlled by the structure of sedimentary basin at that time. Besides, Pb-Zn geochemical anomalies distribute in the vicinity of diapir bodies.

(3) Gravity Basement-Apparent Resistivity Structure and Geology-Mineralization

(a) Bou Khil Prospect

The subsurface structure of the Bou Khil prospect differs from that of the El Akhouat-Argoub Adama. The Cretaceous system, contacting the Triassic system, comprises steeply dipping thin sedimentary layers. The Cretaceous system, forming the gravity basement in the prospect, is overlain by the Tertiary sedimentary rocks. The Tertiary sedimentary rocks are generally high in porosity and, therefore, low in apparent resistivity, which makes it difficult to discriminate low apparent resistivity due to mineralization from that due to conductive Tertiary sedimentary rocks. Another feature of the apparent resistivity in the prospect is that its structure tends to be laterally discontinuous. This discontinuity in apparent resistivity structure may be caused by variable degrees of fracture development and by variable water contents in fractured rocks (Figure 141).

Figure 142 is the composite plan produced by synthesizing residual gravity, apparent resistivity and chargeability distributions. The apparent resistivity distribution is expressed by the 50 and 10 Ωm contours on the level at an elevation of 300 m, while the chargeability highs are outlined by the 5 mV/V contour on the level at an elevation of 400 m. A zone indicating low apparent resistivity less than 10Ωm, including low apparent resistivity anomalies, is located along the Line B 0, that is, the contact between the Cretaceous and Tertiary systems. Minor high apparent resistivity

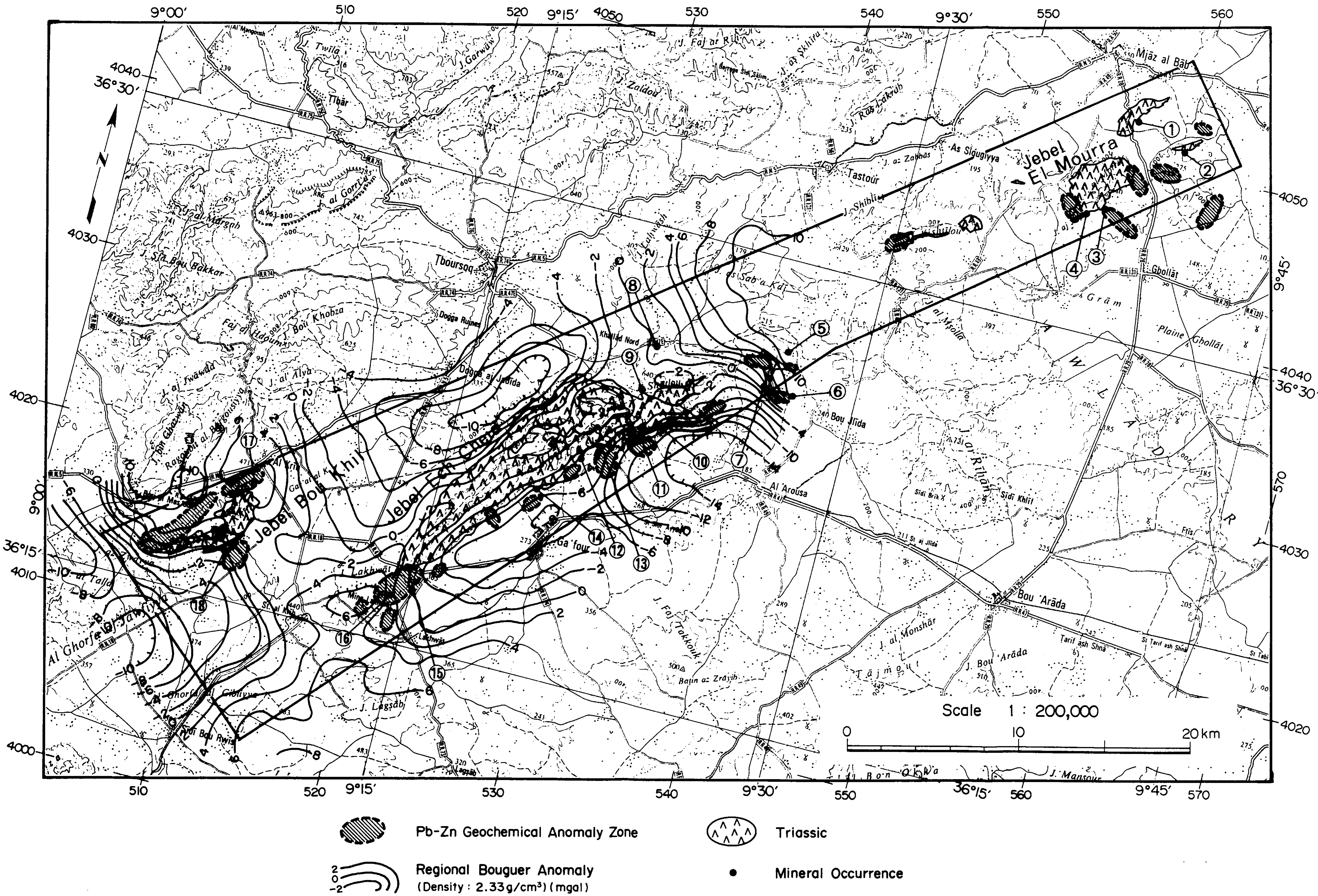


Figure 140 Summarized map of the existing data

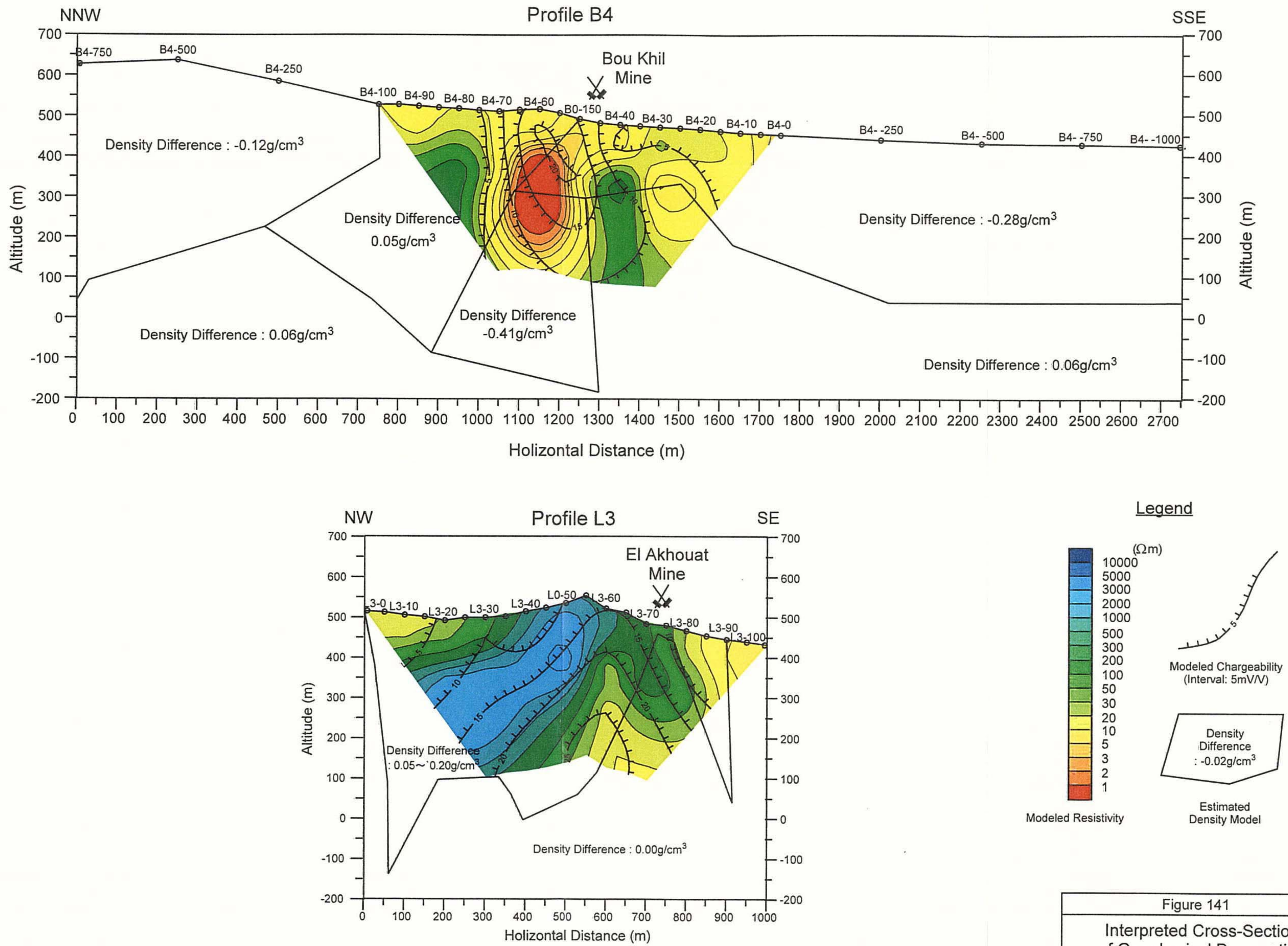
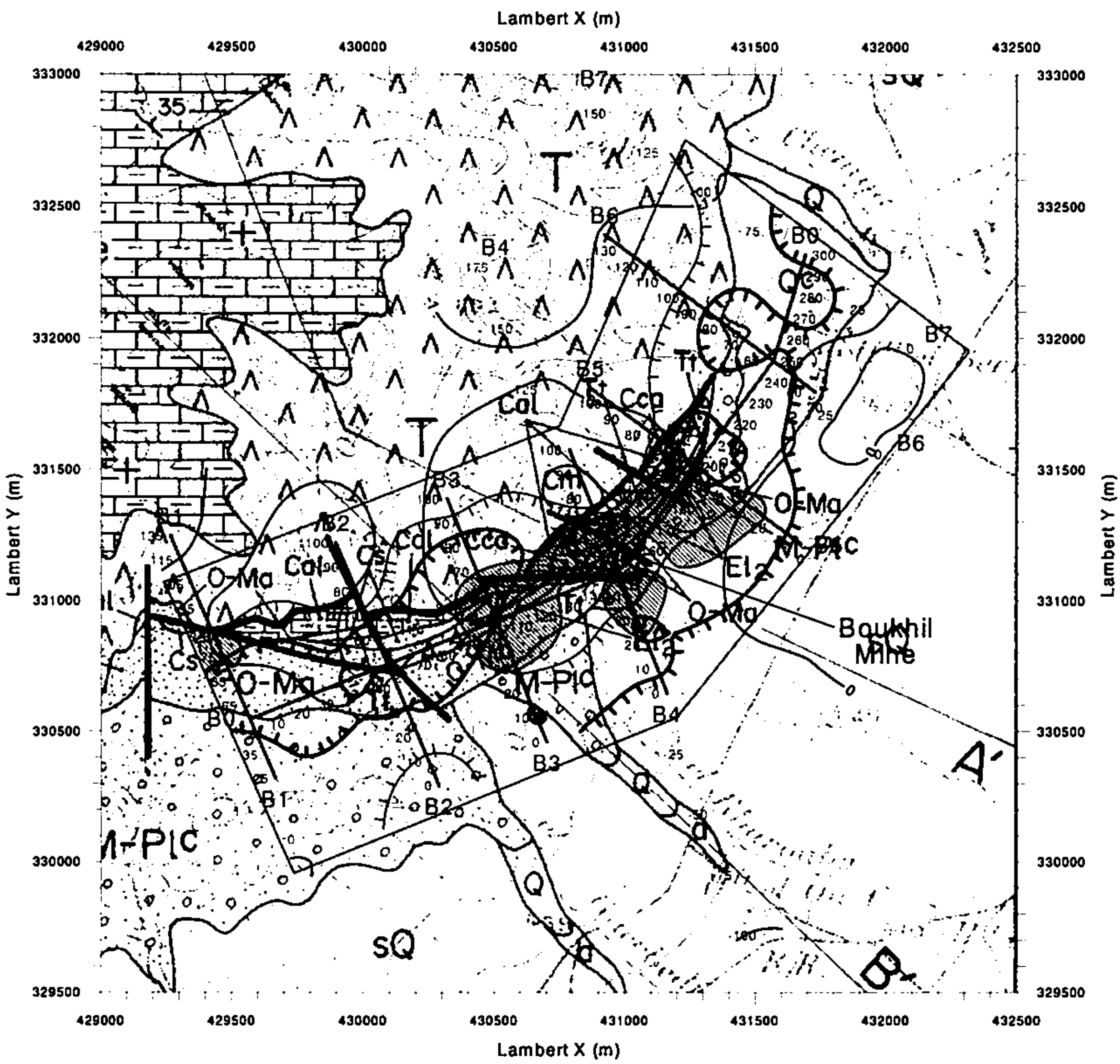


Figure 141

Interpreted Cross-Section of Geophysical Prospecting

Scale : 10,000

March, 2000



Legend

—— : IP survey Line

□ : Survey Area

: Closed Mine

Resistive zone > 50 Ωm (Altitude: 300m SL)

Conductive zone < 10 Ωm (Altitude: 300m SL)

High Chargeability > 5 mV/V (Altitude: 400m SL)

Contour : Residual Gravity (0.2 mgal interval)

Figure 142

Interpretation Map of Geophysical Prospectings in Bou Khil area

1 : 25,000

March, 2000

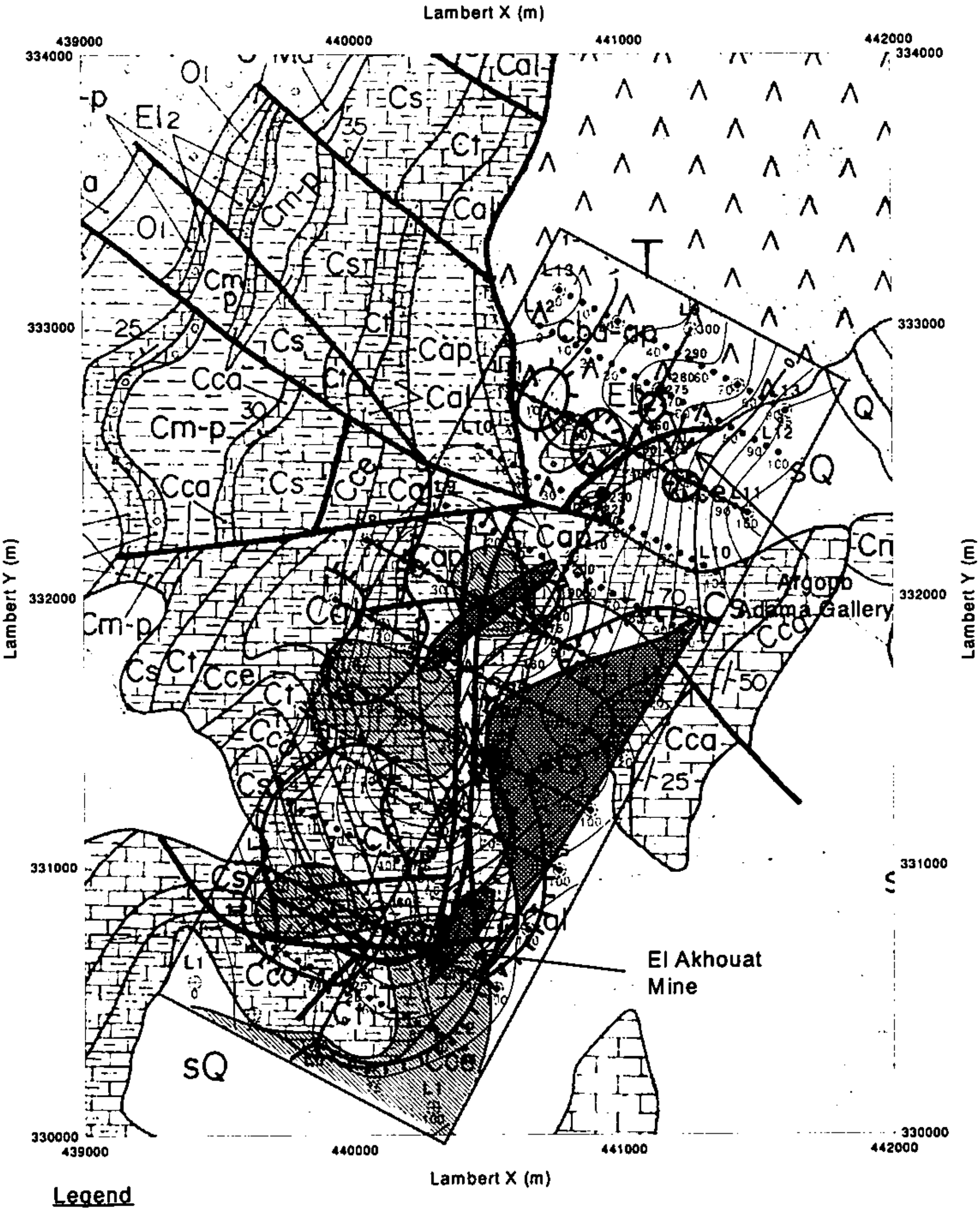
anomalies are identified in the neighbors of the Bou Khil workings (the station B 0-150) and of the celestite alteration (the station B 0-100) within the high apparent resistivity zone. Two chargeability anomalies are limited in the proximity of these high apparent resistivity anomalies and are situated in the steep gradient zone of residual gravity to the southeast of the triangular residual gravity high. It is interpreted that the low apparent resistivity zone corresponds to a highly fractured zone filled with electrolytic pore waters within the Cretaceous limestone that has high density and resistivity. High chargeability is associated only with part of the fractured zone where mineralization has taken place.

(b) El Akhouat-Argoub Adama Prospect

Figure 141 is the composite cross section produced by synthesizing the gravity, apparent resistivity and chargeability distributions along the line L 3 of the El Akhouat-Argoub Adama prospect. This composite cross section, along which the El Akhouat ore deposit is located, well demonstrates relationship between the ore deposit and the gravity basement-apparent resistivity structure. The ore deposit is situated in the Cretaceous system along its contact with the underlying Triassic system.

Apparent resistivity of rocks becomes higher with decreasing their porosity in general. The rocks of Cretaceous system are generally low in porosity and, therefore, indicate high apparent resistivity. Referring Figure 143, the gravity basement is harmonious in its trend with the base of the high apparent resistivity zone to the northwest of the station L 3-60. These two trends, however, become discordant to each other to the southeast of the station, with the base of high apparent resistivity zone being higher in its position than the gravity basement between the stations L 3-60 and –70. This discordance may be caused by the Cretaceous system with abnormally low resistivity either due to mineralization or electrolytic pore water, such as saline water, in highly fractured rocks. This part of the Cretaceous system is also characterized by high chargeability and constitutes a part of the El Akhouat ore deposit. Therefore, the low apparent resistivity and the high chargeability can be attributed to the Pb-Zn mineralization. The base of high apparent resistivity zone is lower than the gravity basement in the vicinity of the station L 3-80. Since dolomitization and silicification make rocks resistive in general, the Triassic rocks are probably dolomitized around this location, showing high apparent resistivity.

Figure 143 is the composite plan produced by superimposing residual gravity, apparent resistivity and chargeability distributions, together with gravity basement contours, over the geological map of the El Akhouat-Argoub Adama district. The apparent resistivity distribution is expressed by the 50 and 10 Ωm contours on the



<u>Legend</u>

⊕ : Gravimetric Survey Station

—— : IP survey Line

• : Magnetic Survey Station

▭ : Survey Area

⚒ : Closed Mine

Resistive zone > 100 Ωm (Altitude: 300m SL)

Conductive zone < 10 Ωm (Altitude: 300m SL)

High Chargeability > 10 mV/V (Altitude: 200m SL)

Contour : Residual Gravity (0.2 mgal interval)

Shallow Magnetic Basement

Figure 143

Interpretation Map of Geophysical Prospectings in El Akhouat - Argoub Adama area

Scale 1 : 25,000

March, 2000

level at an elevation of 300 m, while the chargeability highs are outlined by the 10 mV/V contour on the level at an elevation of 200 m. Distinct differences in geophysical characteristics are observed between El Akhouat, the northern part of the prospect, and Argoub Adama, the central to southern part.

The residual gravity in Argoub Adama is high in the western half and descends eastwards with steep gradient in the eastern half. The old Argoub Adama mine is located in the steep gradient zone of residual gravity near its western limit. The western limit of steep gradient zone, running meridionally, appears to be shifted to west to the north of the old mine, which suggests a fault running roughly in the E-W direction. A low apparent resistivity anomaly is identified near surface at the Triassic-Cretaceous contact to the west of the old Argoub Adama mine. However, neither anomalous chargeability nor sign of elevated magnetic basement is associated with this low resistivity anomaly.

In El Akhouat, a high residual gravity zone extends form the center-west limit of the prospect southwards. The old El Akhouat mine is located at the south end of the high gravity zone. This zone of high residual gravity can be correlated to the Cretaceous terrain, although its axis is shifted to the east from the center of the Cretaceous terrain that forms a hill running in the NNW-SSE direction. A sizable high apparent resistivity zone is outlined on the level at an elevation of 300 m in the southern part of the high residual gravity zone. This zone of high apparent resistivity presents a contracted form in its eastern part, which suggests that the zone includes local resistivity lows. Chargeability highs are also outlined in the vicinity of the contracted part of the high resistivity zone, surrounding elevated gravity and magnetic basements. It is, therefore, expected that open fractures are highly developed in the Cretaceous rocks in the neighbor of this location and are filled with electrolytic pore water or sulfides causing low resistivity and high chargeability. Chargeability anomalies are discontinued between the lines 4 and 5 and in the vicinity of the line 7, along which local lows in the high residual gravity zone are observed. This suggests that faults, controlling loci of mineralization, are developed in association with the chargeability discontinuity.

PART Ⅲ

PART III Conclusion of the First Year Investigation

Chapter 1 Conclusion

The first Year's programme included collection of existing documents, satellite image analysis, photogeologic interpretation of air photos, geological prospecting and geophysical surveys. The collection of existing documents and the satellite image analysis were carried out for the entire Krib- Mejez el Bab Area, the photogeologic interpretation of air photos and the geological prospecting, for the selected 4 prospects, namely, the Bou Khil, El Akhouat- Argoub Adama, Bazina Kebira and Oued Jebes. The geophysical surveys were applied to a limited area in the Bou Khil prospect with the gravity and IP methods and in the El Akhouat- Argoub Adama prospect with the gravity, IP and magnetic methods.

The Krib- Mejez el Bab Area is situated within the Dome zone, to the southwest of Tunis. The Dome zone is about 50 km wide and some 200 km long in the NE-SW direction, bounded by the Mediterranean Coast to the northwest, and continues southwestward across the international border to Algeria. A number of Triassic diapirs are discontinuously aligned in the NE-SW direction within the Dome zone, forming 3 or 4 major diapir alignments. The Project Area is located in the middle part of the southeastern-most alignment.

There are three sizable diapir bodies in the Project Area and called Mourrha, Jebel ech Cheid and Bou Khil respectively from northeast to southwest. Several smaller diapir bodies are also known around these major diapirs and are mostly elongated in the NE-SW direction. A number of Pb-Zn ore deposits or mineral occurrences are located in association with these diapirs. They indicate specific spatial relationship with the diapirs, being mostly positioned at either edge of elongated diapirs or along their southeastern flanks.

(1) Bou Khil Prospect

The Bou Khil Pb-Zn ore deposit is situated in the Campanian limestone of late Cretaceous at the contact with the bottom of 'umbrella' (transition zone) of the Triassic diapir. The ore deposit is categorized into the Mississippi Valley type, occurring to the proximity of the Triassic diapir in the Dome zone of northern Tunisia. The mineralization is mostly limited in the Cretaceous limestone contacting with the Triassic transition zone, although the Triassic is also mineralized in part.

The low residual anomaly is a part of gravity low surrounding the high residual anomaly and extends from southwest to northeast along the southeastern margin of the high residual anomaly. Based on the cross section analysis, the cause of the high residual anomaly can be attributed to Cretaceous limestone, while the low residual anomaly is possibly caused by the Triassic system. The steep residual gravity gradient such as above explained is a characteristic feature at this location and is not observed anywhere else in the course of the current gravity survey. Therefore, it is considered that this gravity feature is probably related to the Bou Khil ore deposit and/or the celestite alteration. The belt of steep gravity gradient is discontinued to the southwest beyond the line B 3 and to the northeast beyond the line B 5, being possibly faulted off.

The mine locates around the narrow Triassic system between the Cretaceous system and the Tertiary one. The Cretaceous system is represented by resistive limestone. The Tertiary system consists of porous sedimentary rocks indicating low resistivity. The Triassic system between the Cretaceous system and the Tertiary system is extremely conductive and thrusts down into the resistive Cretaceous system towards the northwestern sides. These conductive anomalies are distributed along the base line BO. In the southeastern side of known mineralization zones of the Bou Khil ore deposit and the celestite alteration around the crossing point between the line B3 and BO, the resistive basement become partly shallower towards the upper conductive layer correlated the Tertiary system. These characteristics in resistivity are consistent with the results of cross section analysis from the residual gravity.

The valid Chargeability zones concentrate around the Bou Khil ore deposit and the celestite alteration. The highest chargeability is indicated in the vicinity of the old Bou Khil working. It is supposed that galena is responsible for high chargeability around the mine.

(2) El Akhouat- Argoub Adama Prospect

The El Akhouat deposit is located in the west side of N-S striking faults running from the south end of the Jebel Ech Cheid diapir body. The deposit is hosted in the Cretaceous Albian limestone in contact with the Triassic system of which distribution is long and narrow along the N-S striking faults. The E-W striking fault, controlling the distribution of the Triassic system, exists at the south end of the Triassic system. No ore deposit is discovered in the southern side of this E-W striking fault. The occurrence of the deposit is veins to veinlets along the limestone bedding and cracks. The Argoub Adama deposit is located in the southeast side of the south end of the Jebel Ech Cheid diapir body. The deposit is hosted in the Cretaceous Cenomanian limestone and marl filling the cracks and along the bedding.

The old mine sites of the El Akhouat and the Argoub-Adama are located in and around the narrow zone of steep gravity gradient, where the high gravity residual exceeding 1mgal decreases rapidly to low gravity residual in the eastern parts of the survey area. It is considered that the anomaly of this high gravity residual is caused by the Cretaceous limestone layer with high density and the low density layer in the eastern side are caused by the Tertiary sediments. A constricted part of the local gravity residual low is observed in the eastern parts within high gravity residual and constricted parts are correlated with distribution of the Triassic. That is, the same as Bou Khil prospect, the high gravity lies regionally in and around the diapir, however the diapir itself is considered to be rock bodies with low density which give rise to low gravity anomaly. Such characteristics are also observed in the first vertical derivative plan. A contour line of 0 mgal/km indicates the boundary between the Cretaceous and Triassic systems and distributions of the Triassic are outlined as an arrangement of low anomalies with extremely small scale.

The Cretaceous limestone is grasped as the high resistivity layer with high density. The high resistivity layer distributed thick at shallow parts is considered to correlate with such Cretaceous limestone. The low resistivity anomalies extend from the lower parts towards the high resistivity layer at shallow parts in the line L3, running through the old mine site of El Akhouat and the lines L5, L6, L8. Those are considered to correlate the Triassic. This low resistivity anomaly is corresponding to the rising up structure of the gravity basement with low density and the chargeability anomalies are distributed around the vicinity of the rising structure. The chargeability anomalies appear from the shallow parts in the lines L0, L3, L5 and L6 but the chargeability anomalies are distributed at lower parts around the point, where line L0 intersect the line L8 in the central parts of the survey area.

Notwithstanding that the chargeability of zinc ore samples is less than 10 mV/V, high chargeability anomalies are widely distributed extending from the central to northern parts of the survey area. On the other hand, the lead sulfides are considered to give high chargeabilities and a little pyrite, which exhibit high chargeability, are also recognized in this prospect area.

Many magnetic anomalies higher than 2,000 nT are distributed from the central part to the south part involved the El Akhouat mine. Although it is suggested that high magnetic zones are related to the classification of Cretaceous limestone, it is difficult to prove the fact clearly. Magnetic characteristics are little correlation to that resulted from gravity and IP survey. It is supposed that distribution of magnetic total intensity is affected the difference of contents of magnetic minerals like as hematite and goethite.

(3) Bazina Kebira Prospect

The Triassic system is in contact with the Cretaceous and Tertiary systems to the southeast bounded by a fault or unconformity. A number of north-south running faults can be assumed to the northeast of Koudiat Safra, where alignments of dolomite and limestone strata are laterally offset step-by-step in the north-south direction. Faults are categorized into the N-S trending and the NE-SW or ENE-WSW trending systems, with the former crosscutting the latter. In addition, a number of small scale folds are commonly formed by intrusion of the diapir.

The Koudiat Safra deposit is located at the southeast flank of the Jebel Ech Cheid diapir body. The ore deposit occurs in the Barremian-Aptian sandstone, presenting a stratiform mode of mineralization along the side of diapir. Its lateral continuation can be traced for some 450 m westwards from its east end where the ore deposit is terminated by a crosscutting fault.

The Koudiat Soda deposit is located approximately 1.5 km to the northeast of the Koudiat Safra. The ore deposit occurs in the Lutetian sandstone in contact with the Triassic system. The mineralization forms discontinuous veins or tabular bodies filling fractures in the host sandstone. Minor lea mineralization is also observed in association with limestone of the Cenomanian- Turonian and the Campanian-Maastrichtian of Cretaceous.

(4) Oued Jebes Prospect

The Cretaceous System, adjacent to the southeast of the diapir, indicates a monoclinal structure striking in the NE-SW direction and dipping 50 to 70° to southeast. The Tertiary System forms a gentle syncline with its axis running in the NE-SW direction. The bedding of Tertiary System strikes in the NE-SW direction, and dips 35 to 50° to the northwest and 40° to the southeast respectively in the southeastern and northwestern flanks of the syncline. NW-SE trending faults are developed with intervals of 250 to 750 m within the Triassic through Tertiary Systems. These faults have been formed in association with the ascending diapir. The Cretaceous and Palaeogene formations change their thickness laterally across each of these faults. Two E-W trending faults are identified, crosscutting the NW-SE trending faults.

The Oued Jebes ore deposit is situated about 9 km south of Mejez el Bab, near a peak of hill. Pb-Zn mineralization occurs mainly in the contact zone between the Triassic and Cretaceous systems and occasionally within the Cretaceous system. The ore deposit, which was mined in the past, is formed in the contact zone composed of limestone breccia. The mineralization comprises sulfides and oxides filling matrices between angular limestone fragments and forms a single tabular ore body, striking in N 40° E and dipping about 70° to southeast. Veins and vein networks of lead and zinc minerals are also observed in association with the lower Turonian limestone.

The Kef Lasfar ore deposit is located about 9 km south southeast of Mejez el Bab, in the upstream of Tabia. The ore deposit was ever mined for lead and zinc, with its portal of abandoned adit remaining in the upstream of Tabia, The ore deposit occurs in the upper Turonian limestone and forms a vein. The vein strikes in N 30° E and dips 80° to east, which approximately coincides with the attitude of the contact between the Triassic and Cretaceous systems as observed on an outcrop about 150 m to the northwest.

Chapter 2 Recommendation for the Second Year Investigation

A number of Pb-Zn ore deposits and mineral occurrences of the Mississippi Valley type have been located in the Republic of Tunisia including the Project Area. The number of ore deposits of this type in excess of 35 million tons accounts for some 50 % of those in the type mineral provinces in North America according to the grade-tonnage model. In Tunisia, however, none comes even close to this order, with the Bougrine being by far the largest with its possible reserves of 8 million tons.

It is necessary to verify favourable geological, geophysical and other conditions for this particular type of ore deposits in order to substantially increase reserves by locating new resources or by revitalizing known ore deposits. Therefore, the 1999-2000 programme of this Project adopted two or more geophysical approaches in addition to the fundamental geological survey, aiming at establishing an adequate exploration procedure specified for ore deposits of the Mississippi Valley type.

The current year study constructed a detailed model of subsurface structure accounting for the geology, geological structures, gravity basements and resistivity features interpreted from the geological and geophysical data obtained in the course of the field observation and laboratory tests. The result led to a working hypothesis that mineralization would be associated with a zone of high chargeability superimposing that of low resistivity where the basement of resistivity becomes inharmonious with that of gravity.

Exploration principles are set up on the basis of the hypothesis as follows;

① Structural highs, such as domes and horsts, are regionally regarded as primary targets, because they play a role of traps for hydrocarbons generating reducing environment favourable for precipitation of sulfides. Such structural highs are demonstrated as areas of gravity high in the regional gravity map.

② Steep gradient zones in the regional gravity highs may indicate extensive development of fractures that have provided conduits for ascending hydrothermal solutions.

③ It is necessary to specify targets based on detailed subsurface structures constructed by adequate interpretation of geology and geological, gravity and resistivity structures.

Figure 140 is the comprehensive composite map produced by incorporating all the available existing data including the result of the current programme. Referring to this map as well as the above principles, a primary regional target for the second Year Programme will be the area of gravity high located in the central-northeast of the Project Area. Steep gravity gradient zones associated with this gravity high are appreciated for mineral potential, since known mineral occurrences, such as Assioud, Siliana and Mahjoubia, are included. It will become possible by carrying out detailed geological and geophysical surveys for selected targets to estimate precise subsurface structures, locations and sizes of mineralization and geological circumstances.

The outcomes of the current year programme are, however, still hypothetical, without elaborated examination on the processes of geological evolution and of ore genesis, and should be proved by further investigations in the second year onward. In order to prove the hypothesis, it is also recommended to explore by drilling the target identified as the result of the geophysical work in the El Akhouat- Argoub Adama prospect.

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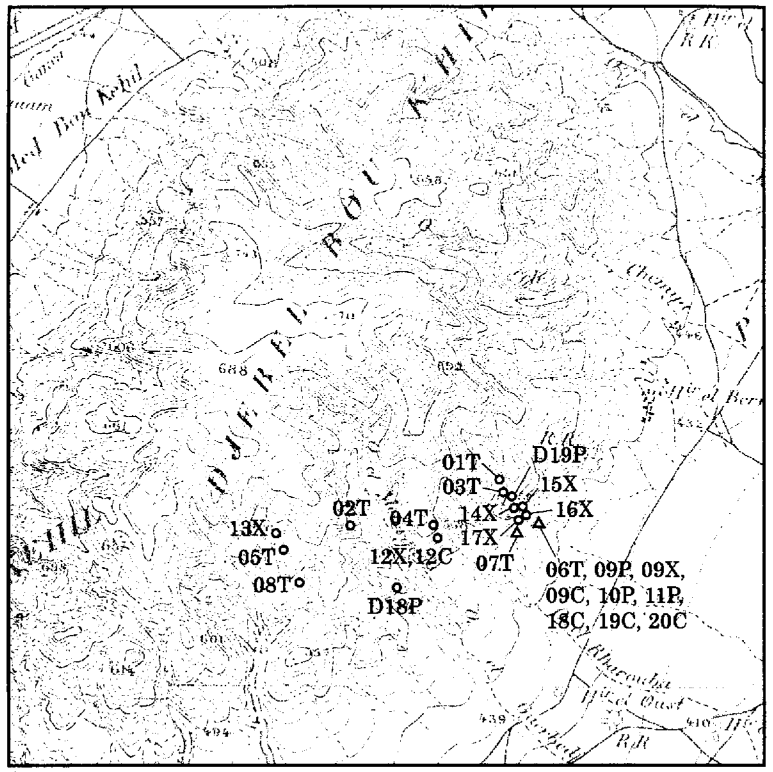
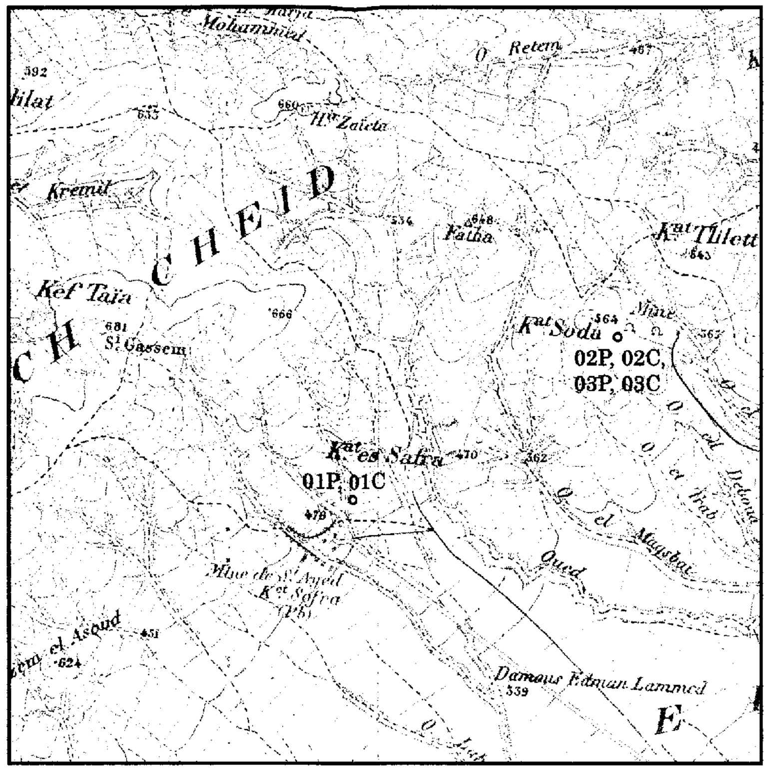
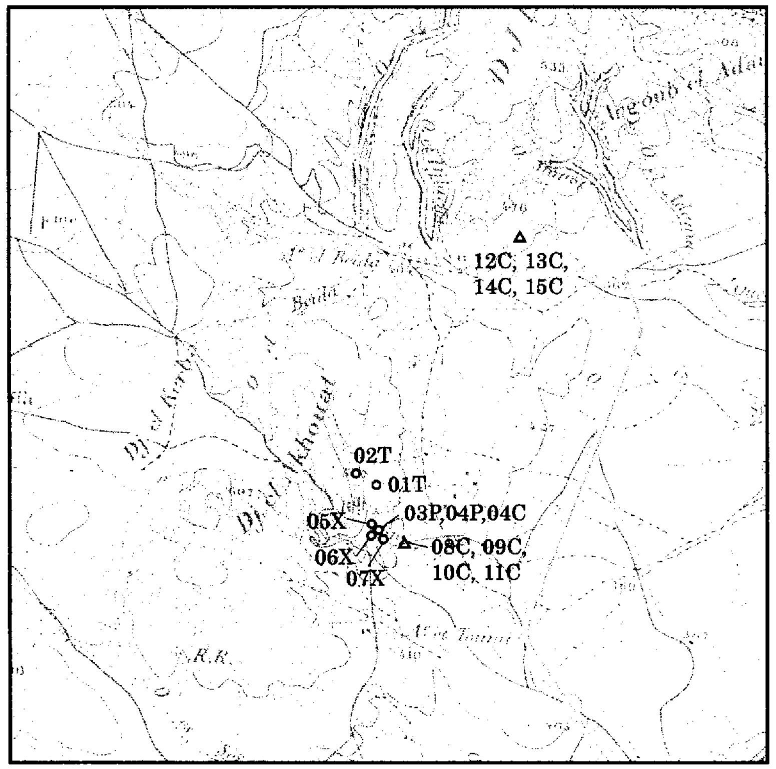
APPENDIXES



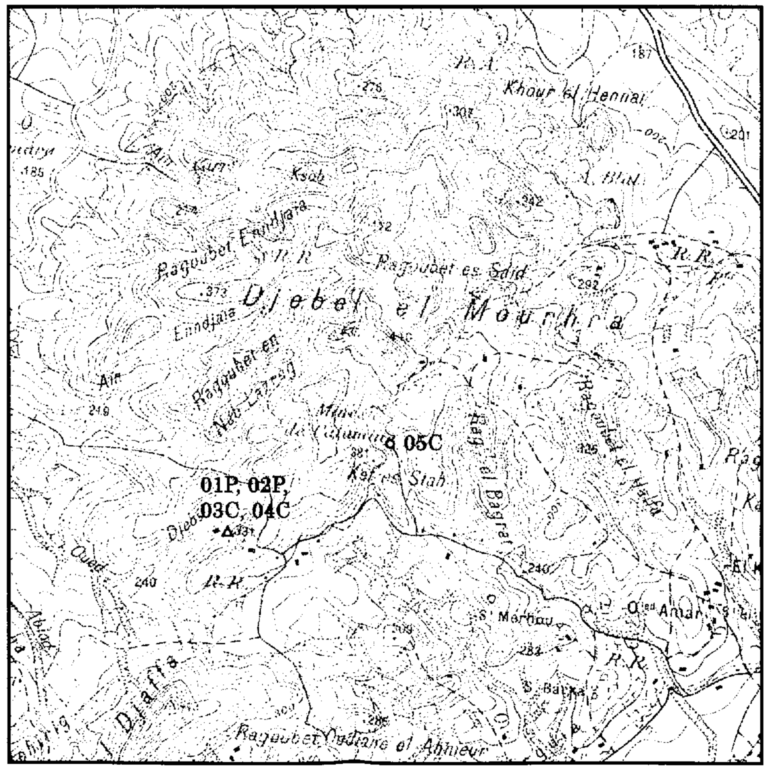
Bou Khil



Bazina Kebira



El Akhouat



Oued Jebes

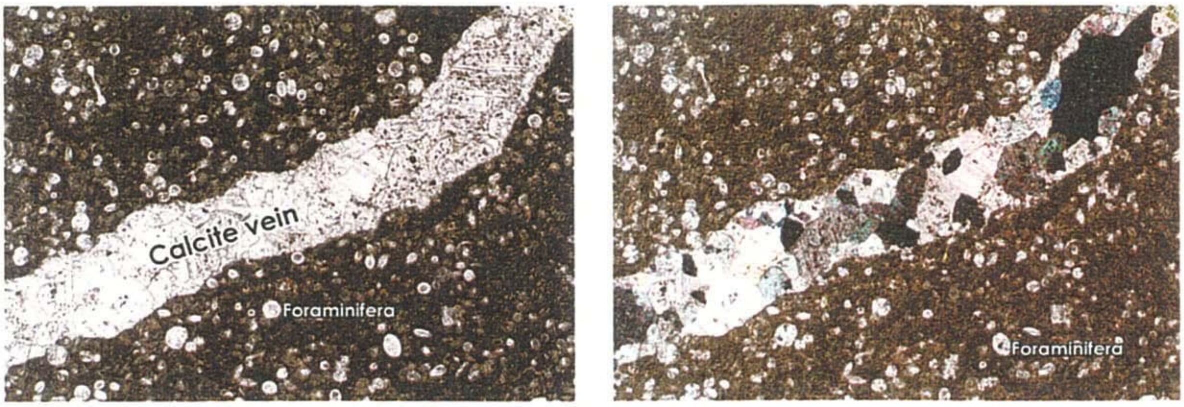
Scale 1:50,000

0 1 2 km

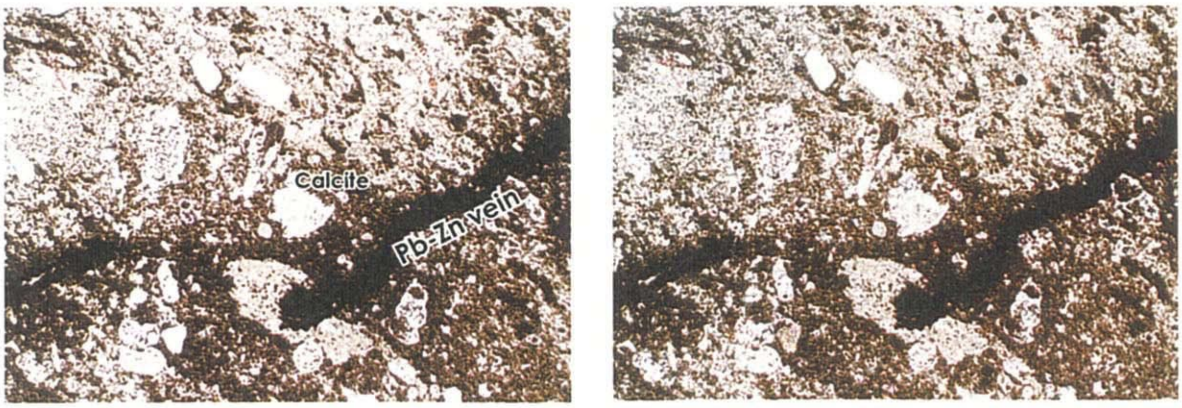
Sample number list of laboratory tests

Prospect	Area code of sample No.	Sample No. in figure left			
		Thin section	Polish	X-ray analysis	Chemical analysis
Bou Khil	BKH	01T			
		02T			
		03T			
		04T			
		05T			
		06T			
		07T			
		08T			
			09P	09X	09C
			10P		
			11P		
				12X	12C
				13X	
				14X	
				15X	
				16X	
				17X	
					18C
					19C
					20C
			D18P		
			D19P		
El Akhouat	EAK	01T			
		02T			
			03P		
			04P		04C
				05X	
				06X	
				07X	
					08C
					09C
					10C
					11C
					12C
					13C
					14C
					15C
Bazina Kebira	BKB		01P		01C
			02P		02C
			03P		03C
Oued Jebes	OJB		01P		
			02P		
					03C
					04C
					05C

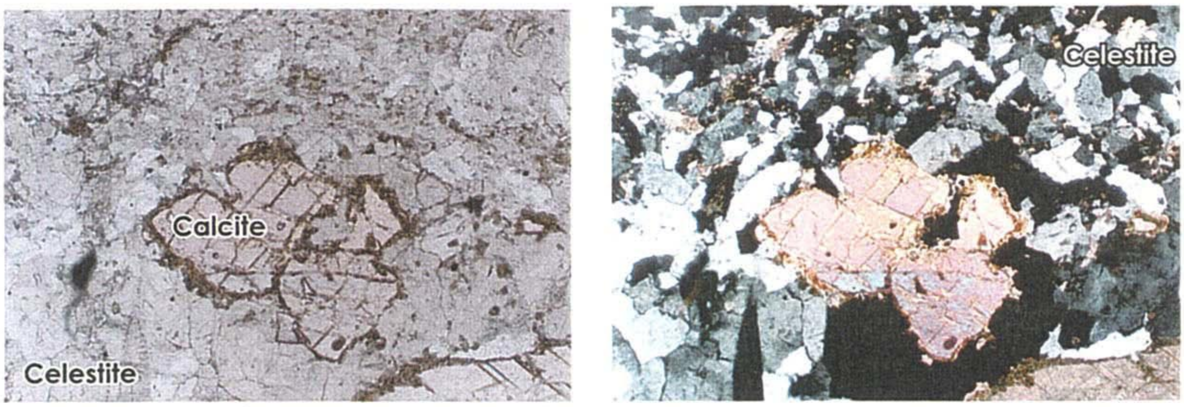
Appendix 1 Sample location map for laboratory tests



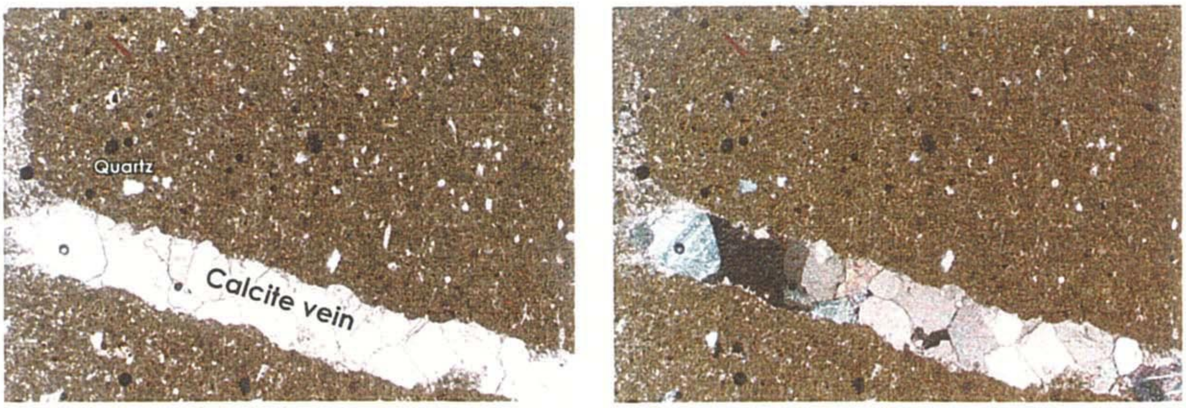
BKH04T: foraminiferal limestone (Santonian) with calcite vein



BKH06T: limestone (Campanian) with Pb-Zn veinlet



BKH07T: celestite (Triassic, transition zone)

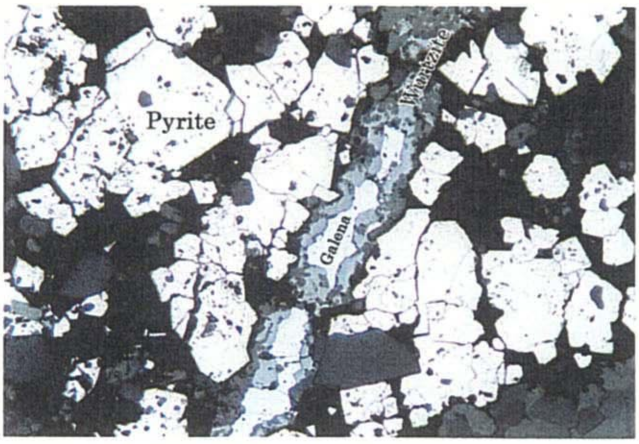


EAK01T: marl (Albian) with calcite vein

0 0.5 1.0mm

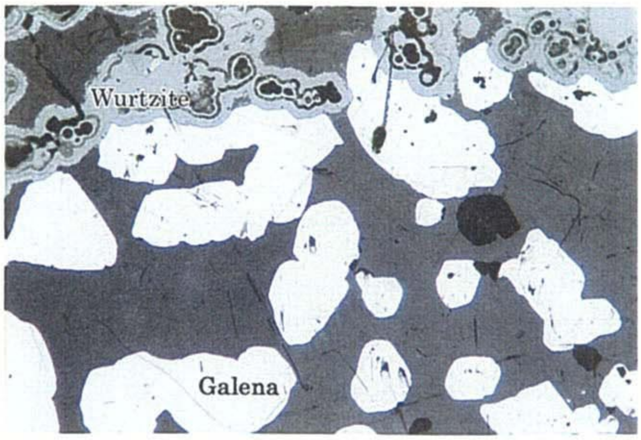
Note: Left side photos are under open nicol and right side under crossed nicols.

Appendix 2 Microphotographs of thin sections



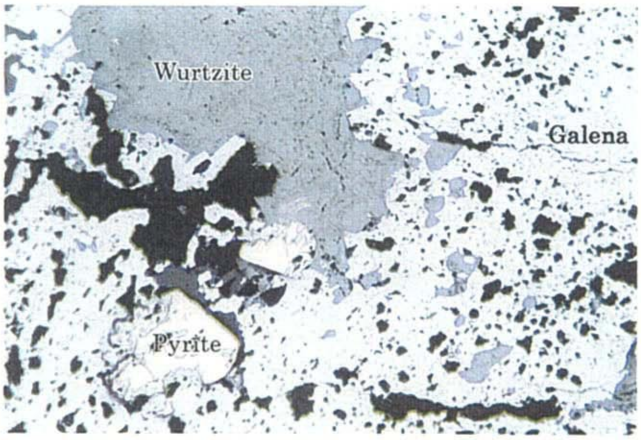
BKB03P:
from the pit of Koudiat Soda

Galena occurs as anhedral grains in the central part of wurtzite vein.
Wurtzite occurs as aggregates of anhedral grains.
Pyrite is subhedral to euhedral and occurred before the formation of galena and wurtzite.



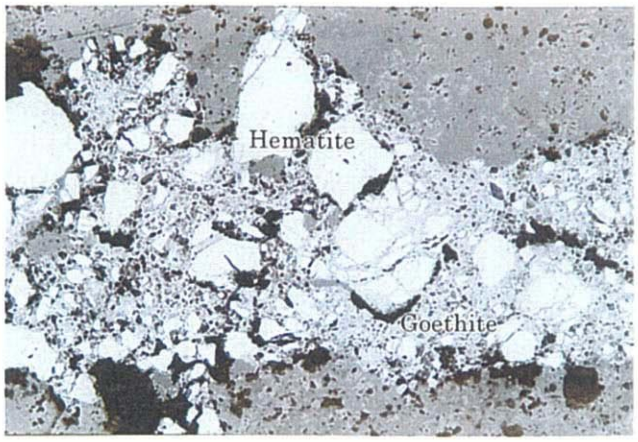
BKHD19P:
from the drilling core of BK19 in the north of Bou Khil mine

Galena occurs as anhedral to subhedral grains among wurtzite grains.
Wurtzite occurs as aggregates of framboidal grains with rhythmic bands and as euhedral to subhedral grains in the open space.
Pyrite occurs as framboidal grains.



BKH09P:
from the old strage of Bou Khil mine

Galena, wurtzite and pyrite are anhedral to euhedral and form thin veins.
Framboidal pyrite occurs in galena grains.
Marcasite occurs as anhedral grains in the aggregates of pyrite grains.



EAK03P:
from the large pit of El Akhouat

Hematite occurs as anhedral grains in the brecciated zone.
Goethite occurs at the rim and along the crack of hematite.
Pyrite may altered to hematite and rarely occurs as euhedral to subhedral grains.

Note: Square photos are micoroscopic photos and circular ones show the surface of polishes.
The scale of circle photo is a full size.

0 0.5mm
common scale of microphoto

Appendix 3 Microphotographs of ore polishes

Appendix 4 Result of microscopic obseravation for rock thin section

No.	Sample No.	Rock name	Primary minerals								Secondary minerals			
			Quartz	Calcite	Dolomite	Celestite	K-feldspar	Plagioclase	Biotite	Muscovite	Quartz	Chlorite	Calcite	Opaque
1	BKH01T	Psammite	◎				+	+	△	△		+		
2	BKH02T	Dolomite	△	△	◎						+		+	
3	BKH03T	Limestone		◎									+	
4	BKH04T	Limestone		◎									+	
5	BKH05T	Dolomite	△	△	◎								+	
6	BKH06T	Limestone		◎										○
7	BKH07T	Celestite		◎		◎								
8	BKH08T	Sandstone	◎	◎			△						+	
9	EAK01T	Dolomite	+	◎	◎								+	
10	EAK02T	Dolomite	+	◎	◎									

Legend ◎ : abundant, ○ : moderate, △ : a few, + : few

Appendix 5 Result of X-ray diffraction analysis

No.	Sample No.	Rock name	Minerals								
			Quartz	Feldspar	Mica	Kaolinite	Calcite	Dolomite	Celestite	Gypsum	Sphalerite
1	BKH09X	Ore					◎	+			△
2	BKH12X	Celestite	△				△	+	◎		
3	BKH13X	Dolomite	+					+	◎	+	
4	BKH14X	Dolomite						◎			
5	BKH15X	Limestone	+	+			◎				
6	BKH16X	Dolomite	+	+			◎	+			
7	BKH17X	Sandstone	△	△	+		◎	+			
8	EAK05X	Limestone	△			+	◎	+			△
9	EAK06X	Calcite vein	+			+	◎				
10	EAK07X	Limestone	+			+	◎				

Legend ◎ : abundant, ○ : moderate, △ : a few, + : few

Appendix 6 Result of microscopic obseravation for polish

No.	Sample No.	Rock name	Ore minerals						
			Galena	Sphalerite	Wurtzite	Pyrite	Marcasite	Hematite	Goethite
1	BKH09P	Veinlet	○		○	+	+		
2	BKH10P	Disseminated	+		◎	+	+		
3	BKH11P	Oxidized	△		◎	+			
4	BKHD18P	Thin vein	○		○	+			
5	BKHD19P	Disseminated	△		◎	+			
6	EAK03P	Disseminated				+		◎	△
7	EAK04P	Oxidized				+			◎
8	BKB01P	Veinlet	◎	+		+	+	+	+
9	BKB02P	Thin vein	◎	+		+			+
10	BKB03P	Thin vein	○	○		△			
11	OJB01P	Veinlet	◎			+			
12	OJB02P	Disseminated	◎						

Legend ◎ : abundant, ○ : moderate, △ : a few, + : few

(Quantity shows a relative amount among ore minerals.)

Appendix 7 Result of chemical analysis

		Cu (ppm)	Pb (%)	Zn (%)	Fe (%)	Mn (ppm)	Cd (ppm)	Mg (ppm)	Ca (%)	Sr (ppm)	Ba (ppm)	Ag (ppm)
1	BKH09C	2.4	1.78	26.00	1.97	790	394	708	18.99	450	56	<0.3
2	BKH18C	36.1	3.50	12.60	1.05	1016	1218	2.30%	21.99	418	115	38.9
3	BKH19C	1.5	0.77	7.60	9.17	1084	105	2.25%	21.59	264	35	<0.3
4	BKH20C	11.2	0.87	8.30	1.51	314	4	1.88%	30.79	586	140	<0.3
5	BKH12C	93.6	0.01	0.06	3.67	1668	<2	1.56%	3.30	4.8%	121	<0.3
6	EAK04C	29.3	0.24	17.00	2.68	1440	374	4.70%	16.79	1525	110	1.68
7	EAK08C	41.5	0.15	3.20	6.41	1241	47	1290	29.19	500	81	<0.3
8	EAK09C	1.9	0.26	12.70	7.96	3831	407	742	22.00	2269	1514	<0.3
9	EAK10C	4.8	10.40	2.25	0.74	607	163	2089	27.19	4766	270	3.86
10	EAK11C	9.1	33.00	2.70	0.70	1783	151	1657	18.24	305	43	90.07
11	EAK12C	10.9	4.84	0.52	0.88	1633	31	1437	28.58	4144	754	11.9
12	EAK13C	15.5	2.74	0.72	1.60	1985	29	4565	29.78	2569	3814	54.4
13	EAK14C	5.5	2.90	0.59	1.79	1457	19	2.90%	27.99	5236	306	16.2
14	EAK15C	32.8	9.20	8.30	1.69	1155	829	2.10%	22.99	1611	815	50.1
15	BKB01C	33.9	9.00	2.60	1.73	1221	364	1186	17.19	1179	123	31.9
16	BKB02C	19.5	10.60	1.1	0.99	1118	99	988	12.08	337	101	0.61
17	BKB03C	207.4	17.20	26.0	0.62	631	1472	647	8.32	248	51	0.76
18	OJB03C	38.2	3.30	0.7	2.66	949	44	673	4.79	2.41%	1.52%	4.11
19	OJB04C	12.3	10.00	10.0	0.89	584	189	926	8.00	4.32%	3.60%	4.04
20	OJB05C	62.2	11.80	12.1	1.16	486	427	1965	12.80	1043	101	11.02