2-2 I Area (Ighcrm Arca)

2-2-1 Geology

(1) Pre-Cambrian System

Pre-Cambrian System in this area consists of PII, PII-III, and PIII formations, in which PII formation consists of, in ascending order, quartzite, schistose mudstone, green rocks, and dolomite, PII-III formation consists mainly of tuffaceous conglomerate, containing the partings of sandstone and shale, and PIII formation consists of tuffaceous conglomerate, sandstone, shale, rhyolite, rhyolitic tuffs, and dolomite. PII and PII-III formations are in remarkable relation of unconformity, while PII-III and PIII formations are in a relation of gently inclined unconformity.

PIII formation is distributed mostly around Tagragra in the southeastern part of this area, between Tizirt and Tifelsine in the western central part, and near Tadenst in the eastern part, though small as it is, being exposed like an isolated island. This formation consists of quartzite, schists, green rocks, and dolomite.

Quartzite is widely distributed over the surroundings of Tifelsine and Tizirt as well as near Tadenst. Moreover, the quartzite is a single constituent of PII formation in these localities. The quartzite is also exposed in a small scale near Tagragra in the southeastern part, but it is associated with other kinds of rocks of PII formation. This rock has white, light pink, and gray colors, and is coarse to medium grained quartzose sandstone. The quartzite in this area is generally clearly stratified, in which cross laminae are often recognized, and ripple marks are also recognized occasionally. The one in the south of Tizirt has very changeable strikes and dips, forming an irregular folding. Near the contact with PII-III, it is often brecciated.

Green rocks occur in the schists, intercalated in a few layers, within the distribution of PII formation near Tagragra. The green rocks in this area consist of dark green, massive intrusive rocks and green schist of light green color.

Schists are principal constituents of PII formation near Tagragra in the southeast. Being gray or dark gray in color, the schists consist of pelitic schist and psammitic schist. Schistose structure is well developed in both of them.

Dolomite can be seen only near Tagragra, occurring as partings in the schists above mentioned or alternated with them. This is light purplish or gray rock with distinct stratification.

PII-III formation is distributed mainly in the northeastern part, eastern central part, and near Tizirt in the western part. Other than them, small exposures like isolated islands in same scale are recognized in the east from Tizirt and in the south from Tikhfakt. This formation in this area consists of tuffaceous conglomerate having the partings of sandstone, shale, and siltstone, which can be divided into comparatively continuous formation consisting of sandstone, shale, and silstone and the rest of conglomeratic formation.

Conglomerate is light greenish gray or dark gray, containing various pebbles of quartzites, andesites, granites, and gneisses, and the pebbles of quartzite is overwhelmingly increase near the quartzite bodies. Matrix is tuffaceous, though chloritized. Sizes and roundness varies by locality, and range of variation is from nearly 1 meter to less than 1 cm in sizes and from nearly rounded pebbles to angular breccias.

Sandstone, shale, and siltsone are intercalated in the conglomerate and thickness of each of them is not so much but a few meters only. They are mostly greenish gray, and tuffaceous of andesitic nature, but some are dacitic, with remarkable quartz fragments.

PIII formation is distributed most widely in this area, occupying most of the central part. The lower part of this formation consists of rhyolitic lavas, rhyolitic tuffs, tuffaceous sandstone, the middle part is a thick andesite lava, and the upper part is conglomerate containing the partings of rhyolite, sandstone, shale, and siltstone. Thin layers of dolomite are intercalated in the lowermost and uppermost parts of this formation.

The main constituents of PIII formation are those clastic rocks as sandstone and conglomerate, but rhyolitic lavas and rhyolitic tuffs are often intercalated. These rhyolitic rocks are treated into one. In these rocks, there is very few of the one treated as rhyolite lava, but most of it are pyroclastic rocks as rhyolitic tuffs, rhyolitic lapilli tuffs, rhyolitic tuff breccias, and rhyolitic welded tuffs. The color of the pyroclastics varies as gray, creamy, pinkish gray, purplish gray, etc., but collectively they are siliceous rocks containing phenocrysts of quartz and K-feldspar or fragments of them abundantly.

Andesitic lava is distributed as long as more than 12 km from Talilit at the southern extremity of the area to the north of Aniloul, with its maximum thickness of 500 m. This rock mass was treated as a dyke in the survey of second year phase, but the present survey has revealed it as lava in its occurrence. Copper mineralization is recognized often in this rock, of which details will be stated in the paragraph of ore deposits. Small exposures of this rock can also be observed in the east of Tikhfakt and in the northeast of Talilit.

Dolomite occurs as thin partings at the uppermost and lowermost parts of PIII formation.

As for the shale, sandstone, and conglomerate of the PIII, as is clear from the geological column (PL. I-4-2), those underlying the thick andesite above mentioned, consist mainly of sandstone, while those overlying it, consist mainly of conglomerate, but they are tuffaceous either. The lower sandstone is very distinctly stratified, well sorted, and coarse to medium grained arkose sandstone with light purple or light purplish gray color. It can be easily distinguished from the sandstone of PII-III formation by such characteristic color. The upper conglomerate, having light purplish or grayish color, contains the pebbles mostly of quartzite and rhyolite, and of granite, greenschist, and andesite locally. Boulders are few, and most of the pebbles are sub-rounded or rounded pebbles with more or less 3 cm diameter. The material of matrix is tuffaceous arkose snadstone with gray color. Shale occurs commonly in both of them as partings, but is dark gray or dark purplish gray rock with less continuity.

(2) Infra-Cambrian System

Infra-Cambrian System in this area consists of Basal Series in the lower part and Lower Calcareous Series in the upper part, and is distributed in the northwestern and southwestern parts of the area. The system is in a relation of clino-unconformity with the underlying Pre-Cambrian formations.

Basal Series in this area consists of dolomite, conglomerate, sandstone, and shale, of which lower part consists of conglomerate or dolomite, while upper part consists of alternation of sandstone and shale, locally intercalating thin layers of dolomite.

The dolomite is the gray and massive rock exposed in the north of Tizirt, northwestern part of the area, being seated as the lowermost layer of Basal Series.

The conglomerate is exposed near Tasurem in the southwestern part, being seated as the lowermost layer of Basal Series. Among the pebbles contained, pebbles of quartzite is most and those of rhyolite and chert are contained, too. The matrix is tuffaceous, containing abundant muscovite.

Sandstone and shale are exposed either in the north of Tizirt of northwestern part or near Tasurem of southwestern part with similar rock facies in both of the localities. That is, they are tuffaceous with purplish gray or greenish gray color, containing abundant muscovite and forming alternation of sandstone and shale.

Lower Calcareous Series is distributed only in the northwestern and southwestern extremities. Similarly to the case of H Area, this series consists principally of dolomite with rare intercalation of thin layers of siltstone, shale, and chert. The lowermost part of this formation overlies Basal Series almost with constant thickness as poorly stratified Tamjout dolomite. Repeated folding in small scale is recognized in this Tamjout dolomite.

2-2-2 Intrusive Rocks

Intrusive rocks are very few except for a few rhyolite dykes penetrating PII-III formation.

A rhyolite dyke of less than 10 m wide is exposed in the north of Tadenst of northeastern part of the area. Being characterized by the phenocrysts of quartz and K-feldspar, the appearance of the rock has a close resemblance to the rhyolites in the PIII. It may be so interpreted that the rhyolite penetrated the PII-III as a dyke during the igneous activity of PIII period, while the effusive rhyolite were brought out in the PIII.

2-2-3 Geological Structure

A fault called Igherm Fault runs with its splits in the direction of N - S or NNE-SSW from Aït Ya'zza in the northwestern part towards Tifelsine. With wide distribution of PII and PII-III formations, both sides of this fault are considered elevated blocks. On the eastern block of the fault, PII-III formation forms an elevated block with anticlinal and dome structures, being exposed in the surroundings of Ouislane and Tadenst in the northeastern part, as well as near Immi and at 2 km south of Tikhfakt in the eastern central part of the area. Similarly around Tagragra of the southeastern part, and elevated block is formed with semidome structure over the kernel of PII formation. In contrast to this, the PIII widely distributed as if it were filling up the relatively depressed parts. Its structure differs between east and west sides of a slender zone of andesite lavas along Tifelsine-Aniloul-Lala Aïcna-Talilit in the central part. Nearer to the PII and PII-III, PIII formation of the east side has its strikes and dips in harmony with them, being affected by the anticlinal or dome structures of them, while apart from them, the PIII forms folding of small scale with varying strikes and dips. On the contrary, the PII of the west side forms an orderly structure of west dipping, with dominant direction of its extension parallelly to the andesite lavas.

2-2-4 Ore Deposits

The ore deposits and mineralized zones in this area are shown by the columns of mineralization in the attached Schematic Colomnar Section of Each Area (Fig. I-5) and List of Ore Deposits in Surveyed Area (Table I-10). And the details will be mentioned in the paragraphs of 2-5-3 and 2-6-3 about L and M Areas where detailed survey on geology and ore deposits were made in the present survey.

Minerlization observed in this area is principally of copper, which will be roughly classified as the followings;

Malachite dissemination in the PII-III conglomerate (e.g., Amsengarf, Assoulai, Tadenst),

Malachite and chalcopyrite dissemination emplaced in the andesite of PIII formation (e.g., Aniloul-S, Igherm-2),

Malachite and hematite dissemination in the sandstone and shale of Basal Series and in Tamjout dolomite (e.g., A t Ya'zza, Igherm-1).

Aside from them, a feeble dissemination of malachite and chalcopyrite is recognized in association with the PII quartzite or PIII rhyolites. Among the ore deposits above mentioned, the two types of them emplaced in the PIII andesite and emplaced in the dolomites of Basal Series and Tamjout dolomite have a tendency to continue on more or less definite horizon, but the rest are poor in continuity, scattered around, and small scaled.

In the present area, the mineralization associated with the andesitic activity of PIII period the mineralization can only be recognized scatteredly in the andesite formation distributed in a zone from the central part to the southern part, and its relation with the fault can hardly be disclosed directly. Although the mineralization can be recognized widely throughout the distribution of andesite including M Area, the deposits, instead of being localized in the specific locations in the andesite lavas, are not well concentrated in this area, and questions are left for them to be developed into sizable ore deposits.

The disseminated deposits emplaced in the sandstone and shale of Basal Series and in Tamjout dolomite are distributed intermittently in accordance with the extension of the hosting formation. They are the disseminated deposits developed in a shape of bedded form, but there seems to be locally concentrated, controlled by minor fractures derived by the folding movements took place after the sedimentation of Lower Calcareous Series. The mineralized zone in Aït Ya'zza is taken as an extension of the Tizirt Mine on the opposite side, but as this type of deposits lacks unity in their distribution areas and are so low graded by less concentrative mineralization, possibility can hardly be found for them to be developed considerably within this area some day in the future.

2-3 J Area (Talat-n-Sous Area)

This area is located in the west annex to H area and the present survey performed detailed survey on ore deposits in this area. This area has ever been prospected by trenches by B.R.P.M. Detailed geological survey was made in a scale of 1 : 5,000, which was made along the survey lines spaced at 150 m interval layed out beforehand for the purpose of IP survey by the geophysical survey team. The geological survey was made along 26 survey lines in north-south direction with the length of 3,000 m - 3,400 m each. Along with the geological survey, geochemical survey was also performed.

2-3-1 Geology

Formations of PII-III, PIII, Basal Series and Lower Calcareous Series are distributed in this area. PII-III formation consists principally of rhyolitic tuffs and intercalates thin layers of andesite. The rhyolitic tuffs have light bluish white or gray color, containing breccias of rhyolite with 2 or 3 cm diameter. Copper mineralization is recognized hither and thither, which is manifested by occurrence of bluish malachite. This formation is distributed about in a direction of ENE - WSW, with gentle dip of 10° - 30° towards south. Having the thickness of about 2,000 m, PIII formation consists principally of conglomerate, intercalating thin layers of sandstone and rhyolitic tuffs. The conglomerate is reddish brown, and contains the pebbles of granite, rhyolite, and quartzite of 5 - 10 cm. Matrix is either sandy or tuffaceous. The matrix and pebbles are separated easily as the conglomerate is not well solidified. The sandstone is reddish brown and contains andesitic volcanic ashes. The sandstone corresponds to the sandy parts of lenticular forms intercalated in the conglomerate, which is about 1 m thick and are poor in continuity. The PIII is distributed generally in a east-west trend and dips to the south. PII-III and PIII formations are regarded in a relation of unconformity, but exact relation can not be recognized satisfactorily.

Basal Series has an anticlinal structure of whic axis is plunging to the west, being distributed in a way of U shape facing its convex to the west. This formation consists of dolomite, sandstone, and shale. Dolomite is gray in color and projected on the surface to display a characteristic topography because of its resistant nature against weathering. As it is continuous, it serves as key bed. The boundary between

Pre-Cambrian and Infra-Cambrian Systems has been estimated at the base of the dolomite formation, because the dolomite formation in this area is considered to overlie the Pre-Cambrian formations unconformably. But the dolomite sometimes is underlain by basal conglomerate. The dolomite formation is well stratified and locally intercalated with thin layers of chert. Stratification in the part of alternation of sandstone and shale is distinct, especially distinct in the layers of shale. The shale has gray or light bluish color and muscovite is formed along the plane of stratification by which the rock is made cleavable along these planes. Sometimes pyrite is contained in this rock, too. Compared to the shale, the sandstone is less in quantity and mostly occurs as thick as about 1 m. The sandstone is fine grained and light brown, containing muscovite similarly to the shale. This part of alternation is estimated about 100 m thick with fair continuity.

Lower Calcareous Series can be classified into Tamjout Dolomite and Dolomie formations. This series is distributed in a way to surround the inlier at its periphery. Within the present area, this series distributed to occupy the topographic highs in the northern, western, and southern parts.

Tamjout dolomite formation is distributed near the summits of hills forming steep cliffs in the southern part of the area. The formation, having a thickness of about 30 m, is characterized by gray or grayish white, and nonstratified massive dolomite with fair continuity. Tamjout dolomite formation overlies Basal Series and dips gently, forming a dome structure in general.

The Dolomite formation overlies the Tamjout with distinct stratification. Being intercalated with chert, this formation sometimes shows intense intra-formational folding.

2-3-2 Geological Structure

Geology of this area is constructed by the Pre-Cambrian and Infra-Cambrian formations. The Pre-Cambrian formation consists of conglomerate, rhyolitic tuffs, and andesitic tuffs. The formation generally strikes in north-south and dips gently to the south. This Pre-Cambrian formation is overlain by Infra-Cambrian formation. The overlying Infra-Cambrian formation shows a gentle folding, forming a domy anticlinal structure in this area. The anticlinal axis corresponds to the west end of major axis of dome structure to form Azerbalou inlier. The Infra-Cambrian

formation is folded and is in contact with Pre-Cambians of the inlier by clino-unconformity, but the south dipping Pre-Cambrians and Infra-Cambrians apparently possess the folding axes of similar direction.

2-3-3 Ore Deposits

As shown by Table I-10, 5 ore deposits and mineralized zones are recognized in this area, but except for the Talat-n-Sous mineralized zone, the rest are nothing but small mineralized zones of copper.

The Talat-n-Sous mineralized zone is located in the central part of this area, which is near the survey stations of 17 and 18 on the geophysical survey lines of J, A, and K. Being facilitated by fair condition of transportation, the place can be accessed from the Amadouz Ore Deposit along car road passing through the central part of II Area. Altitude around the mineralized zone is about 1,370 - 1,390 m S.L., with gentle topography.

This has ever been prospected by B.R.P.M. with 9 trenches (270 m), 6 test pits (60 m), and 8 drill holes (560 m), and in the present project, too, general geological survey has been performed in the first and second year phases. The detailed geological survey of present year was carried out in combination with simplified land survey with pocket compass in an area of about 0.08 km^2 (about 0.2 x 0.4 km), centering around the trenches above mentioned, to trace up the surface outcrops.

Geology of this area is built up with the PII-III rhyolite, andesite and their cognate pyroclastics, and with Basal Series, and its situation in geological structure corresponds to the western end of Azerbalou inlier surveyed in the second year phase.

The PII-III volcanic and pyroclastic rocks around this mineralized zone strike in ENE - WSW generally, forming a monoclinal structure of southward dip, on which dolomite of Basal Series lies unconformably with its strike of NE - SW and dip of NW.

This mineralized zone is a net-work disseminate deposit principally of copper in the host rocks of rhyolite and its pyroclastics, and andesite locally, of PII-III formation, of which ore consists mainly of secondary minerals such as malachite, covellite, and chalcocite with rare association of chalcopyrite and chrysocolla.

The center of mineralization is within a patche of maximum 50 m x 130 m (6,500 m^2) surrounding the trenches No. 1 and No. 2, in which the copper minerals occur as films along joint planes and fractures developed in the rhyolite and as dissemination in the host rock. Major fractures are extended in N20° - 40° W which corresponds to the major direction of trenches. Strong mineralization is recognized along these fractures, as well as along other ones intersecting diagonally in N - S system the mineralization is recognized commonly. The followings are the average grades of each trench;

No. of Trench	Ag g/t	Cu %
1	58	3.16
2	415	5.21
3	12	1.24
4	<1	0.02
5	24	2.78
6	53	1.30
7	3	0.73
8	192	4.24
9	245	6.43

All the trenches from No. 1 to No. 9 can be treated as one ore body, but the detailed survey on the surface has divided into 3, namely the west ore body (10 m x 30 m x 100 m) around the trenches Nos. 3, 4, 5, and 7, the central ore body (25 m x 50 m x 130 m) around the trenches Nos. 1, 2, 8, and 9, and the east ore body near the trench No. 6. The trenches No. 1 and No. 2 of the central ore body are specially fair graded, showing the maximum of 850 g/t Ag and 11.20 % Cu, while overall average of the two trenches shows 137 g/t Ag and 3.08 % Cu. The average grades are 11 g/t Ag and 1.27 % Cu in the west ore body, 221 g/t and 4.44 % Cu in the central ore body, and 53 g/t Ag and 1.30 % Cu in the east ore body. The east ore body is in a small scale. It has been estimated through the results of boring by B.R.P.M. that the thickness of ore bodies does not exceed 10 m.

Rhyolite and its pyroclastics, the main host rocks of ore deposits, have been affected by several kinds of alteration centering around the deposits; the rhyolite has produced quartz and sericite by intense silicification, while in the pyroclastics, hornblende, chlorite, and epidote are often recognized.

Other than the deposit of Talat-n-Sous, 2 or 3 feeble mineralizations are recognized in the rhyolite of PII-III formation in this area, and they are all characteristically limited to be emplaced near the boundary with Infra-Cambrian System. Formation of these deposits may be interpreted that the origin had been initiated by the rhyolitic activity in the PII-III period, and later on, ore forming components were remobilized and reconcentrated by tectonic movements and circulation of meteoric water. Because the dissemination is recognized in the dolomite of Basal Series too, the process of mineralization and concentration may have continued for long period. Copper anomalies have been detected by the present geochemical survey either in the rhyolitic and andesitic rocks as well as near the boundary between the said formations and Infra-Cambrian System.

According to the results of geophysical prospecting which will be mentioned later, anomalous zone, where similar kinds of ore deposits will be expected, has been detected in the north of this mineralized zone (betw. surv. sta. 20 & 21, on line J), and considering from geological structure, the PII-III rhyolite is expected to extend in shallower ground from the spot to the central part of the survey line (i.g. west of this mineralized zone). As this mineralized zone, even if the grade is permitted, still contains problems about its dimension and downward persistency, it is desireble to prospect the similar kind of deposit in the area covered by the dolomite of Basal Series.

2-4 K Area (Assif Imider Area)

Covering a range of 1.5 km x 2.0 km, this area is located in the northern central part of the G-3 Area (Alous Area) in the survey of second year phase, in which the Assif Imider Ore Deposit is included. Detailed geological survey, geochemical survey, and electrical prospecting were performed during present survey.

2-4-1 Geology

This area corresponds to the northern margin of Ouaonfenerha inlier. Most of the area is covered by Infra-Cambrian Basal Series, while Pre-Cambrian PIII formation is exposed along the valleys in the central and southern parts of this area. Relation between Basal Series and PIII formation is unconformable.

(1) Pre-Cambrian System

Pre-Cambrian formation in this area consists of PIII formation, in which andesitic lavas and andesitic pyroclastics are thickly accumulated, while non-volcanic clastic rocks are deposited in the uppermost part.

The andesite is dark green or dark gray, mostly microcrystalline, and generally affected by chloritization and epidotization, and veinlets of quartz, epidote, and calcite are often recognized (cf. microscopic examination, C87, Y 38).

The andesitic pyroclastics consist of dark green or light green fine grained tuffs and light purple lapilli tuffs. The fine grained tuffs near the Assif Imider deposit are affected by chloritization and epidotization, and the lapilli tuffs in the eastern part of the area contain exotic pebbles of rhyolite.

The non-volcanic clastic rocks in the uppermost of PIII formation in this area consist of well stratified dark reddish purple shale, fine grained sandstone, and dark voilet or dark gray fine conglomerate, and they are tuffaceous as a whole (cf. microscopic examination, C 88).

There exists a fractured zone extending in N 20° E in these rocks of PIII formation, and copper dissemination and secondary enrichment is recognized along the fractured zone (Assif Imider Ore Deposit).

(2) Infra-Cambrian System

Infra-Cambrian System consists of the middle and lower formations of Basal Series in this area, overlying the Pre-Cambrians unconformably.
In the south from the surveyed area, conformable succession of the upper formation of Basal Series, Tamjout dolomite, and Lower Calcareous Series is observed. The middle and lower formations of Basal Series consist of, in ascending order, alternation of dolomite and shale, massive dolomite, alternation of conglomerate, sandstone and siltstone, and massive dolomite, of which total thickness exceeds 300 m.

The alternation of dolomite and shale which forms the basement of Basal Series is the alternation of dark gray or light gray dolomite and grayish purple shale, and minor foldings are often recognized in it. The formation is

partly fractuated near the Assif Imider Ore Deposit, in which copper mineralization is recognized together with stringers of quartz and sericite (cf. microscopic examination, Y 43).

The massive dolomite in the middle and upper formations are dark gray and well stratified, intercalating lenticular or bedded chert and shale of 3 - 5 cm thick.

The alternation of conglomerate, sandstone, and shale, inserted between the upper and lower massive dolomites, has a thickness of 15 - 25 m and is distributed fairly continuously. This formation is characterized by fine conglomerate consisting of angular or subangular pebbles of quartzite, but its facies is so variable that dark gray or light gray shale and fine grained sandstone become dominant in the northern part of the surveyed area. Minute grains of pyrite are contained in this formation, and according to the results of geochemical survey, it contains a little more copper or zinc compared to the massive dolomites.

2-4-2 Geological Structure

Geological structure of the Pre-Cambrian PIII formation in this area still contains not a few questionable points due to the lack of exposures, but weak folding structure has been reported by the survey of second year phase. A fractured zone in a direction of NNE - SSW and nearly vertical (80° E) is recognized in the central part of this area, which derived the dissemination and secondary enrichment of the Assif Imider Ore Deposit.

Basal Series is stratified and forms a monoclinal structure dipping 10° - 20° towards NNE, and at the same time, it forms a faint anticlinal structure (or dome structure) with axis of NNE - SSW direction in the southern part of this area.

At the central part of this anticlinal structure, PIII formation hosting the Assif Imider Deposit is peeping out through an eroded patch of overlying formation. This anticlinal axis nearly coincides to the fractured zone which derived the dissemination and secondary enrichment of the Assif Imider Ore Deposit, therefore this structural line is considered to have worked for some extent after the deposition of Basal Series.

2-4-3 Ore Deposits

Dissemination of malachite, covellite, bornite, chalcocite, chalcopyrite, etc. associated with franctured zone in the PIII andesite and its pyroclastics (Assif Imider Ore Deposit), dissemination of malachite, covellite, bornite, etc., in the alternation of dolomite and shale at the base of Basal Series, and a feeble dissemination of chalcopyrite in the alternation of conglomerate, sandstone and shale, the middle formation of Basal Series, are the types of mineralization observed in this area.

The Assif Imider Mine is now under operation by B.R.P.M. The deposit is emplaced, as stated before, in a fractured zone in the PII extended in a direction of NNE - SSW, of which known dimension is 5 or 6 m in width, 250 m in horizontal extension, 80° in dip, 50 m - 85 m in dipwise downward extension. According to the report of B.R.P.M. (Les minèralization Cuprifèros d'Assif Imider, 10, 1973), the ore reserves and grades of the Assif Imider deposit are said to be 230,000 tons with 3.65 % Cu and 76.16 g/t Ag. Moreover, a few localities of mineral indication by malachite, covellite, and bornite are observed in the PIII andesite and in the alternation of dolomite and shale at the base of Basal Series, scattered on the extension of the fractured zone for 800 m.

It has been interpreted about the genesis of this ore deposit that copper minerals contained in the PIII andesite and rhyolite in minor amounts were concentrated for some extent into the fractured zone along with the formation of the fractured zone and quartz veinlets, and that owing to so long a period of erosion as the topography had been denudated to peneplain during the period from PIII to Basal Series, these copper minerals were exposed for intense oxidation in the fractured zone which caused for the copper components to migrate downwards to be reconcentrated into copper minerals (cf. report of the second year phase). But, as the copper dissemination is recognized also in the alternation of dolomite and shale at the base of Basal Series, the secondary enrichment above mentioned is considered to have worked upon successively in the early part of the period of Basal Series.

2-5 L Area (Tizirt Area)

Covering a terrain of 2 km x 3 km, this area is located between Tizirt and Tadenst villages, 12 km north of Igherm. This area is also in the north of the I Area of present survey. Detailed geological survey and geochemical survey were performed in this area during the present survey.

2-5-1 Geology

This area occupies the northern side of Igherm inlier and is on the eastern side of the Igherm Fault. Geology is mainly built up with Pre-Cambrian PII, PII-III, and PIII formations, but in a part of northwestern extremity, the west of Igherm Fault, Infra-Cambrian Basal Series and Tamjout dolomite are distributed.

(1) Pre-Cambrian System

The lowermost formation in this area is PII formation, which is represented by small patches of quartzite scattered like isolated islands at the north and south extremities of the surveyed area.

The quartzite is grayish white or light purple, distinctly stratified, and is considered to have been metamorphosed from sandstone, as ripple marks and crossed laminae are recognized in the same formation in I Area.

PII-III formation is widely distributed in the eastern side of this area, overlying the PII unconformably. In addition, it is exposed often along faults in the western side of the area, being distributed in a belt extended in north-south. This formation consists mainly of conglomerates of volcanic nature, and locally (especially in the north of surveyed area) intercalates thin layers of coarse grained sandstone, shale, rhyolitic tuffs, and lapilli tuffs, of which thickness is estimated about 600 m at maximum.

In the conglomerates, ill-sorted, either rounded or subrounden pebbles of 1 - 15 cm in diameter are cemented by the andesitic matrix, and sortings and beddings are scarcely found. Rock types of the pebbles are mostly those of PII formation as quartzites, green rocks, granites, andesites, schists, dolomites, and limestones, in which the pebbles of quartzites and green rocks are generally predominant.

PII formation in this area, covering PII-III and partly PII formations unconformably, is distributed in the west side of the area and consists of conglomerate, sandstone, rhyolite, and rhyolitic pyroclastics, locally intercalating thin layers of andesite, shale, and dolomite. Comparatively lower part of PIII formation is distributed in this area, and the thickness is more than 300 m.

The conglomerate is dark purple in color, well sorted more or less, and alternated with sandstone. The coglomerate becomes predominant in the upper part of the PIII. Pebbles are quartzite, rhyolite, and andesite of 1 - 5 cm, and the matrix is sandy.

The sandstone is mostly coarse grained, often containing fine pebbles. But it is rather well stratified. Most of the PIII sandstone is reddish purple or dark violet, but in the lower part of PII formation, a characteristic sandstone of dark bluish gray or dark green in color is distributed, which becomes thicker in the southern part of this area.

The andesite is distributed at the lowermost part of PIII formation in a small scale. It has dark bluish gray or dark green color, and is affected by chloritization and epidotization.

The rhyolite and its pyroclastic rocks are interbedded with the conglomerate and sandstone above mentioned, in which a few layers of rhyolitic rocks were recognized varying from the layers having a fair continuity to others of small scaled lenticular layers. The rhyolite mostly occurs as lavas except for some dykes, being seated mostly in the lower part of the PII in the south of this area. The rock is light gray or dark gray, slightly porphyritic, and containing quartz and feldspar phenocrysts (cf. microscopic examination, C 56, C 76, D 13).

The rhyolitic pyroclastics consist of tuffs or essential lapilli tuffs with light gray or light purple color.

The dolomite is dark gray and occurs in small scale as lenticular masses in a part of the lowermost part of PIII formation.

(2) Infra-Cambrian System

The system in this area consists of Basal Series and Tamjout Dolomite, which are distributed in the northwestern corner of the area and in the west side of the Igherm Fault.

Basal Series is in contact with PIII formation with fault in this area, but their essential relation is unconformity, as it has been found in the west of the surveyed area that Basal Series directly overlies the PII-III conglomerate unconformably. Basal Series consists of alternation of light greenish gray, fine grained sandstone and dark purplish shale, with very marked stratification.

Tamjout Dolomite formation overlies the Basal Series conformably, which is dark gray, mostly massive but well stratified by intercalating thin layers of fine grained sandstone and shale at the lower part of the formation in this area.

2-5-2 Geological Structure

All the structural trends in this area are characterized by the direction of NNE - SSW, which are represented by the distributional trends of PII, PII-III, and PIII formations, folding structures in PII formation, the Igherm Fault passing through the western margin of the surveyd area, and split faults from it.

Judging from the mode of distribution of PII formation in the surrounding areas, the basement ground for the PII-III seems to have been formed as a graben around this area in a direction of NNE - SSW by tectonic movement. Consequently, the structure of PII-III formation may be considered to have been controlled by the structure of the basement to form the repeated foldings in the direction of NNE - SSW, although the geological structure of PII-III formation can not be determined with full accuracy because the formation mostly consists of worstly sorted conglomerates. Fractures of N - S or NNE - SSW direction are developed in PII-III formation, which also coincides to the major direction above stated. PIII formation strikes in N 40° W - N 50° E and dips to the east or west at 15° - 60°, in which folded structure with its axis in the direction of NNE - SSW can be recognized, though considerably disturbed it is.

The Igherm Fault has given its influence to the basement topography for the deposition of PII-III formation, for the distribution of PIII formation, and for the distribution of the lower Cambrian formations, which may suggest that the fault is a tectonic line having been active for a long period. The split faults from the Igherm Fault are formed collectively on the anticlinal part of the PII, which may suggest the formation of these faults was closely related to the folding movement of the PIII period.

2-5-3 Ore Deposits

Dissemination of malachite, chalcocite, and chalopyrite in the PII-III conglomerates, dissemination of malachite, covellite, chalcocite, and chalcopyrite in the PIII rhyolites and sandstones, and malachite dissemination observed from the lower part of Tamjout Dolomite formation to the upper part of Basal Series, are the examples of mineralization in this area.

Mineral indications found in the conglomerates of PII-III formation are widely scattered over the area. Most of the minerals are films of malachite, but spotty chalococite and chalcopyrite are often contained, too. A chalcopyrite bearing quartz vein in a direction of N 65 W was recognized at one locality. The spotty chalcocite and chalcopyrite are more in the south of the area.

The affected range of each mineralization is about 2 m x 5 m on plane. Each showings are controlled by the fractures in the direction of N 10° W - N 35° E, but generally speaking, they are lacked in continuity or regularity. Most of the copper contents obtained through the geochemical survey are less than 0.1 %, although local maximum showed 0.8 % and local higher parts were 0.12 % - 0.16 %. Intrusive body of rhyolite considered to have derived the copper mineralization exists in the PII-III formation of western part of the surveyed area, and mineralization in the PIII is also estimated to have been caused by the rhyolite activity. It may be considered therefore, that the dissemination had been initiated selectively along the fractures by hydrothermal solution, either derived from the rhyolite intrusion into PII-III formation or from the rhyolite activity during the PII period, and they were enriched secondarily by the later supergene process.

Mineral indications in PII formation are scattered more collectively in the southern part of this area. They are represented by filmy or spotty malachite,

spotty chalocite and chalcopyrite found in the rhyolite, filmy malachite and covellite, and spotty chalcocite and chalcopyrite though very minor in amount, found in the sandstone, and filmy malachite, spotty chalcocite found in the basal dolomite of PIII formation. The affected range of mineralization is mostly within a few meters to 4 or 5 meters, though occasionally amounting to 10 m x 30 m on plane. Especially those in the sandstone are used to be extended along the fractures in the directions of N 30° E - N 60° E. Grades of copper in the PIII mineralized zone obtained through the geochemical survey showed local maximum of 3.4 % - 3.9 % with considerable parts of more than 0.1 %. Geologically speaking, these mineral indications are limited to exist in the rhyolite lava near the base of the PIII, in the dark bluish gray sandstones situated either upper or lower than this rhyolite, and in the intrusive bodies of rhyolite. In view of this, it may be interpreted that the mineralization in PIII formation had been initiated by the igneous activity of rhyolite in the early part of the PIII period, and the minerals were reconcentrated in enriched state along with the later formation of fault fractured zones or fissures.

Mineral indications observed in Basal Series are emplaced near the contact with Tamjout Dolomite formation, consisting of filmy malachite disseminated along the bedding planes or fractures, with affected range of 10 m x 50 m. Copper grade obtained through the geochemical survey showed 0.8 % at the most predominant part of the mineralization. As these indications exist in such a special environment of sedimentation that Tamjout Dolomite had deposited in unusual thickness, as well as exist near the Igherm Fault, they are considered that the copper minerals initially deposited near the base of Tamjout Dolomite had been enriched secondarily along the Igherm Fault.

As stated above, mineralization is recognized widely in this area as well as recognized in every formation, and even high grade parts are found in PIII formation. But they are all so small scaled and lacked in continuity that there seems to be scarce chance to expect the existence of sizable deposits to be worked out.

2-6 M Area (Aniloul Area)

Covering a terrain of 1.5 km x 3 km, this surveyed area is located 100 m east of Tifelsine and 100 m north of Aniloul, which corresponds to the central part of I Area in the present survey.

Detailed geological survey and geochemical survey were performed in the present survey.

2-6-1 Geology

This area is an eastern center of Igherm inlier and located on the east side of the Igherm Fault, where the Pre-Cambrian formations are distributed.

(1) Pre-Cambrian System

The Pre-Cambrian geology of this area is divided into two by a fault of NW - SE system passing across the northern part of the area; in the north-eastern side of the fault are distributed PII-III and PIII formations, while in the southwestern block, faulted down block, PIII formation is exposed.

PII-III formation in this area consists of dark gray or dark greenish gray conglomerate, partly intercalating thin layers of coarse grained sand-stone.

This conglomerate consists of andesitic matrix and rounded or sub-rounded pebbles of 1 - 20 cm in diameter, and the rocks of pebbles are quartzite, andesite, limestone, rhyolite, schists, and granite, etc. Sorting is not clear in this conglomerate, but startification is a little developed near the intercalation of thin layers of sandstone.

PIII formation in this area overlies PII-III unconformably, and is dis-tributed in most of the surveyed area, in which a few layers of volcanic rocks such as andesite and its pyroclastics, and rhyolite and its pyroclastics, are interbedded with conglomerate or sandstone, amounting to the thickness of more than 560 m. The rhyolite is predominant in the middle or lower part of this formation, while the andesite in the upper part.

The andesitic rocks are consisted of lavas and tuffs or tuff breccias, which can be classified into 3 layers according to the periods of activity. The lower andesitic rocks are distributed in small scale in the lowermost part of PIII formation and consisted mostly of reddish purple or dark reddish purple lavas, in which some are characterized by long prismatic phenocrysts of feldspar (cf. microscopoic examination Y 17).

The middle andesitic rocks are a little thicker in the south while extinct in the north of the area. This formation is dark bluish gray or dark green, consisted mostly of tuffs and tuff breccias, partly containing autobrecciated lavas in which epidotization is recognized (cf. microscopic examination, C 34).

The upper andesitic formation is fairly continuous with its maximum thickness of 150 m. This formation is dark blue or dark green, varies from porphyritic to microcrystalline, and is generally chloritized, partly containing epidote and quartz veinlets. Dissemination of malachite and chalcocite is recognized in this formation.

The rhyolitic rocks consists mostly of pyroclastic rocks and lavas are recognized in a part of the lowermost part. This formation, with light gray or light purple color, is composed of pyroclastic rocks accumulated by several times of effusions and the interbedded sandstone or conglomerate. The pyroclastics graduate from tuff to tuff breccia. Phenocrystic quartz and feldspar are often contained in the matrix of this formation (cf. microscopic examination, C 45, C 50).

The alternation of sandstone and shale is dark gray or dark reddish purple, and well stratified. The conglomerate is predominant in the upper part of PIII formation, while the lower part is dominated by sandstone. Rocks of pebbles are mostly quartzite, andesite, and rhyolite with 1 - 5 cm in diameter, partly containing boulders of rhyolite of 10 - 50 cm in diameter.

2-6-2 Geological Structure

Similarly to the structural features of the surroundings, the geological structure in this area is characterized by the trend of NNE - SSW direction. In the northern part of the surveyed area, a fault in a direction of NW - SE has been recognized, which intersects perpendicularly to the direction afore mentioned.

PII-III formation of this area strikes in N 10° W - N 50° E, and dips 30° - 45° to the west, showing a monoclinal structure.

PII formation also shows a monoclinal structure with its strike of N 0° - 40° E and dip of 20° - 40° W, although an irregular anticlinal structure is locally

recognized. Bur even this monoclinal structure is considered to correspond to the west wing of a gentle but large scaled anticlinal structure with its axis in the direction of NNE - SSW.

The volcanic rocks of PIII formation show notable lateral variation of rock facies. The sedimentary environment of PIII formation is considered neritic or terrestrial with its basement paleotopography full of changes. During the PIII period there were pauses of volcanic activity for a few times which caused the deposition of non-volcanic clastic sediments in some area. But on the contrary, in others especially like in the central part of this area, the enormously thick formation of pyroclastic rocks is considered to have been cause by the lack of deposition of non-volcanic sediments which allowed almost exclusive accumulation of pyroclastic materials repeatedly for several times.

A fault in a direction of NW - SE passing through the north of Tifelsine is a normal fault, by which the south block was thrown down for about 250 m.

2-6-3 Ore Deposits

Major mineralization in this area is the dissemination of malachite, chalcocite, and chalcopyrite found in the andesite in the uppermost part of PIII formation. Other than this, only the one is specularite associated with a quartz vein in the direction of NNE - SSW found in the andesite, and none of mineralization has been recognized in other horizons.

This mineral indication in the andesitic formation consists of filmy malachite and minute grains of chalcocite, rarely containing minute grains of chalcopyrite, and is widely distributed. The concentrated parts are used to be extended along the fractures of NNE - SSW direction within the spread area as wide as about 2 m x 4 m on plane, but they are never extended continuously. Copper grades obtained through the geochemical survey mostly shows less than 0.1 % and even local maximum is only between 0.1 % and 0.2 %. In addition, this andesite formation contains more zinc than other rocks.

Such mineral indications are considered to have been formed by reconcentration of copper components derived from the copper minerals initially contained in the andesite formation, at the later period of formation of fractures or quartz veins.

In any case, these mineral indications are so much deficient in their copper contents as well as in scales, that workable ore deposits can hardly be expected in M Area.

2-7 Correlation between Each Area

Present survey of the third year phase was performed in the 3 separate districts which consist of the 6 extracted areas through the survey of second year phase. The first district of H and J Areas is located near Talat-n-Sous, the second district of I, L, and M Areas is near Igherm, and the third, K Area is near Alous. The 3 districts are included in the different inliers each other: H and J Areas are in Azerbalou inlier, I, L, and M Areas in Igherm inlier, and K Area in Ouaonfenerha inlier. On account of this, the correlation will be made between the 3 districts.

PIII formation consists of quartzite alone in I Area, which is an elongated area in almost north - south in Igherm inlier. Quartzite is contained in the layers of conglomerate in the formations after its overlying PII-III formation as the principal constituent pebbles. Such is entirely similar in all other areas, and a tendency is recognized that the proportion of quartzite pebbles to these of other rock types is generally increased as approached towards the areas of quartzite exposures. PII-III formation is distributed throughout entire areas, but its facies is different locally. This formation consists principally of andesitic ot rhyolitic lavas and their pyroclastics in H Area, while in I Area it consists of conglomerate, in which intercalation of sandstone layers and intrusion of rhyolite are observed.

PIII formation consists principally of conglomerate in H Area, often intercalating sandstone layers and rhyolitic lavas in its lower horizon. In I Area, it consists principally of sandstone layers and contains rhyolitic tuffs abundantly. K Area consists of PIII formation alone which is mostly andesite. Copper mineralization is recognized in each area in the rhyolitic and andesitic rocks but mineralization is generally weak.

Basal Series shows almost constant thickness and rock facies. Its thickness is about 200 m and it consists of alternation of dolomite, sandstone, and shale with occasional intercalation of conglomerate. In H Area, mineralization is recognized

in the basal conglomerate of Basal Series. Lower Calcareous Series is distributed in all the areas except K Area, showing well stratified stable facies together with the underlaying Tamjout Dolomite formation of characteristic massive dolomite. Tamjout Dolomite is generally as thick as 30 m - 50 m, but is exceptionally as thick as 100 m in the eastern part of I Area. Mineralization is not recognized in these formations.

Mineral indications are recognized more or less in these formations of PII-III, PIII and Basal Series in every area as stated above. Among them, however, in H and J Areas, mineralization is recognized only along the surface of unconformity between Basal Series and underlying formation, and prominent mineral indications do not always exist in PII-III and PIII formations. Mineral indications are recognized in the volcanic matters of PII-III and PIII formations throughout the entire areas. Especially in the andesitic rocks and cognate tuffs of K and I Areas, mineral indications are recognized abundantly. In other wards, it has been made clear that the mineral indications are well developed in the areas where the formations derived from intermediate to acidic volcanic activities are distributed, but they are poor in the stable sediments and quartzite.

2-8 Field Geological Summary of Mineralization

Present survey was performed in the 3 district containing the extracted areas through the survey of second year phase, where many ore deposits and mineral indications were gathered. It has been pointed out by the results of the survey of second year phase, that mineralized zones of copper dissemination in the PII-III rhyolite and that of copper dissemination in the fractured zones in the conglomerate are the most important.

In the present survey too, it has been found that PII-III formation accompanies rhyolite and rhyolitic tuffs, and many occurrences of copper mineralization are contained in the rhyolitic rocks. But, as many of them are observed in the fractures, it has been interpreted that they are the disseminations as the results of secondary precipitation into the fractures by copper components initially contained in the rhyolite. Copper dissemination is also recognized in the andesitic and rhyolitic lavas, and their pyroclastics. A greater part of PIII formation is occupied by conglomerate and sandstone but andesite and rhyolite are also associated. Copper

mineralization is recognized in these effusive rocks too. Especially in the andesite of K and M Areas is recognized distinct mineralization.

Bedded copper deposits are recognized in the conglomerate, sandstone and shale of Basal Series. Especially in Basal Series in H Area, distinct ore deposit is found, part of which has been prospected by tunneling. According to the results of detailed survey of ore deposits, existence of mineral indications was recognized acculately near the unconformity between PIII formation and Basal Series. They are considered to be the residual deposits by the weathering at the time of formation of the unconformity surface. In other words, non-existence of ore deposits on the unconformity surface may be interpreted to be due to the lack of concentration mechanism of useful minerals, in spite of intense erosion worked upon before the deposition of Basal Series.

Followings are brief summary of present survey specially on mineralization:

1. PII-III formation contains rhyolitic and andesitic volcanic rocks abundantly in H and J Areas and copper mineralization is recognized in these volcanic materials.

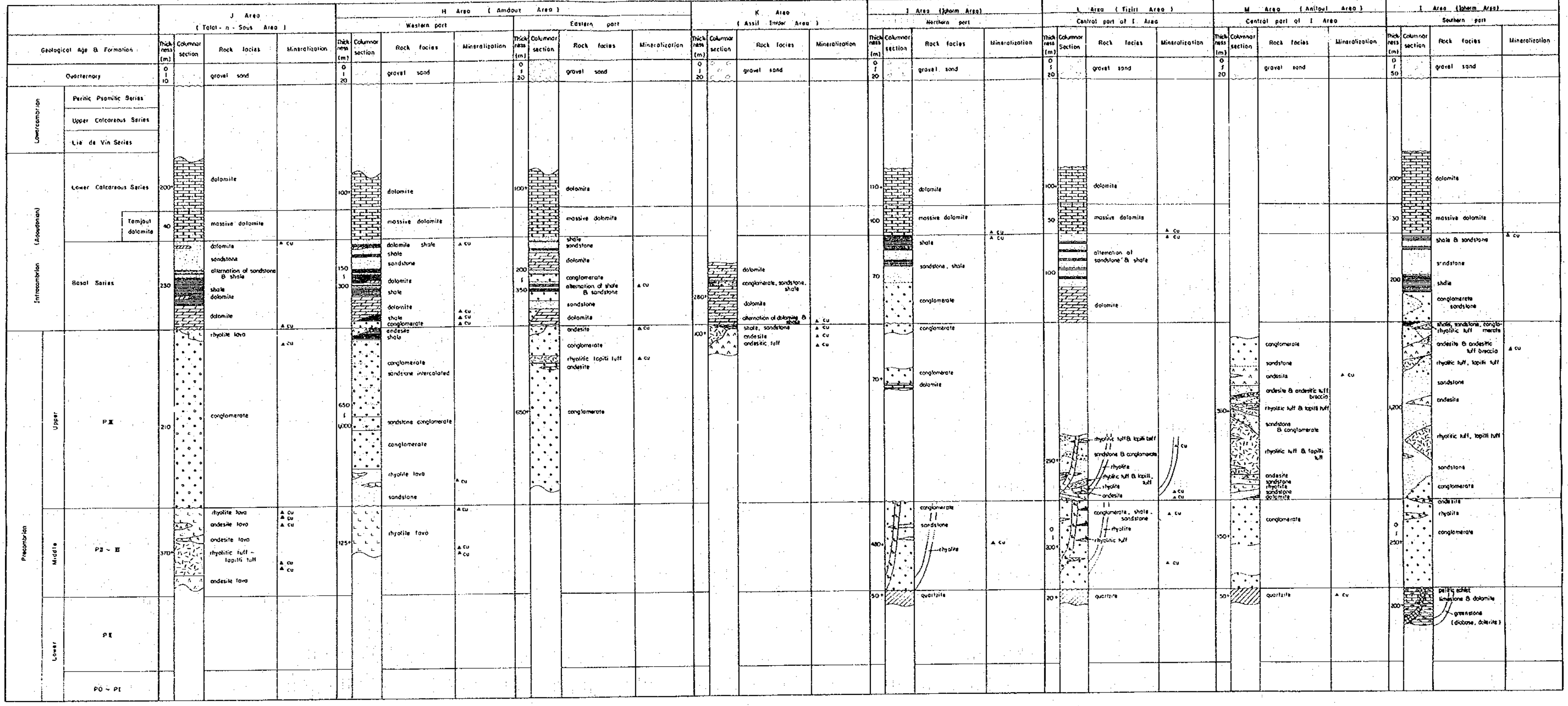
2. PII formation consists principally of conglomerate and sandstone, intercalating andesitic and rhyolitic lavas, and mineralization is found in the andesite and rhyolite.

3. Copper mineralization is observed in the fractured zone of PIII formation in K Area.

4. Basal Series consists of conglomerate, sandstone, and shale, and mineralization is recognized in every layer of conglomerate, sandstone, and shale. In spite of thick development of the basal conglomerate in the northern part of I Area, no mineralization is recognized.

5. Being consisted principally of dolomite layers, Lower Calcareous Series does not contain any distinct mineralization.

Fig. I-5 Schematic Columnar Section of Each Area.



Chapter 3 Geochemical Survey

3-1 Prospecting Procedures

Procedures of collecting geochemical samples from stream sediments and making data analysis on the assay data of them were adopted in the geochemical survey of first and second year phases, and the relationship of the stream desiments with geology and mineral indications were enabled to prospect. In order to obtain the local relationship specially between geology and mineral indications, the geochemical survey in the present survey adopted a procedure of collecting geochemical samples from exposed rocks. Based upon the assay data of these samples, efforts were made to determine the background values of each formation, to find out the original sources of the mineral indications from the detected anomalies, and to establish the relationship between indicator elements and geological formations.

3-1-1 Sampling

This survey was performed along with geological survey. In H and I Areas, survey routes were spaced at 300 m, on which samples were collected at every 250 m, or at every 50 m - 100 m in thickness of a layer, while in J, K, L and M areas, the routes were spaced at 150 m, on which samples were collected at every 200 m. Size of the collected samples were as big as fists.

3-2 Results of Data Analysis

Total samples of 2,913 were assayed on the 3 elements of Cu, Pb, and Zn. The numbers of samples collected in each area are as follows;

H Area (area of detailed geological survey in Amdouz)	780
I Area (area of detailed geological survey in Igherm)	1,222
J Area (area of detailed survey of ore deposit in Talat-n-Sous)	401
K Area (area of detailed survey of ore deposit in Assif Imider)	112
L Area (area of detailed survey of ore deposit in Tizirt)	264
M Area (area of detailed survey of ore deposit in Aniloul)	134

In the works of data analysis, H and J Areas were treated together as they were annex each other, so with I, M, and L Areas, and K Area was treated alone. Analysis of the entire areas was also made.

Computor was used for statistical calculation and drafting. The input data for the computor were sample numbers, geological ages, rock types, and assay values of Cu, Pb, and Zn. In this analytical works, the assay values by each element was studied on the items of each geological unit, each geological age, and of non-classified.

3-2-1 Local Analysis by Areas

The geological units were defined according to their ages as follows;

Group 1: Lower Calcareous Series

Group 2: Basal Series

Group 3: Conglomerate, shale, sandstone, mudstone, siltstone, and slate of PII formation

Group 4: Rhyolitic rocks of PIII formation

Group 5: Andesitic rocks of PIII formation

Group 6: Dolomite and limestone of PIII formation

Group 7: Conglomerate, shale, sandstone, mudstone, siltstone, and slate of PII-III formation

Group 8: Rhyolitic rocks of PII-III formation

Group 9: Andesitic rocks in PII-III formation

Group 10: Quartzite of PII formation

Group 11: Green stone and schist of PII formation

Statistical examination of the assay values after logarithmic conversion was made by geological units, of which results are shown by Tables from I-7-8 to I-7-15.

(1) H and J Areas (cf. Tables I-7-8 & I-7-12)

According to the results of statistical treatment of assay values in these areas, the medium value of Cu is highest in Basal Series as 13 ppm, which is followed by 12 ppm in the andesitic rocks of PII-III formation. They are lowest in the conglomerate and sandstone of PIII and PII-III formations. As the medium value for the entire rock types is 6 ppm, Basal Series and the andesitic rocks of PII-III formation show higher medium values than other formations.

The medium value of Pb is 11 ppm for the entire rock types, and higher values than this are 22 ppm in Lower Calcareous Series, 13 ppm in Basal Series, and 10 ppm in the andesitic rocks of PII-III formation. Dolomite in Lower Calcareous Series shows comparatively high contents.

The medium value of Zn is 22 ppm for the entire rock types. The andesitic rocks of PIII formation show 42 ppm which is the highest among all the geological units. In other rock types, the medium value is more or less 22 ppm and can be accepted equal.

In the variation of medium values, Cu shows the highest value of 13 ppm in Basal Series, while equally lower values are shown by other formations, by which is understood a tendency for Cu to be accumulated in Basal Series. The medium value of Pb is highest in Lower Calcareous Series as 22 ppm, and a tendency of Pb is perceived to be accumulated in the dolomite of the said formation. Specially high Zn is not recognized.

Assuming the medium value as the background value of respective formation, the geological units showing the highest backgrounds of Cu, Pb, and Zn, are Basal Series, Lower Calcareous Series, and the andesitic rocks of PIII formation.

(2) I, L, and M Areas (cf. Tables I-7-9 & I-7-13)

High medium values of Cu in I, L, and M Areas are recognized in the dolomite of PIII formation and in the andesite of PII-III formation, but uncertain factors are contained yet, because of scarcity of samples. Lower Calcareous Series shows comparatively higher values, in these areas and is getting low in order of green stones, and Basal Series. Excluding the green stones because of scarcity of samples, Lower Calcareous Series and Basal Series are the formations with high medium values. On the medium values of Pb, rock types of fewer samples are taken out of consideration. Lower Calcareous Series shows the highest medium value of Pb as 27 ppm, which is followed by 10 ppm of Basal Series. High medium values are found in the rock types with fewer samples, but others generally show low values. That of Zn as high as 57 ppm is recognized in PII-III formation. That of the conglomerate of PII-III formation is 60 ppm. The andesitic rocks of PIII for-

mation also shows as high as 83 ppm. Lower Calcareous Series and Basal Series which show high medium values of Cu and Pb, show very low medium values of Zn.

Correlation is recognized in these areas between Cu and Pb, but Zn shows different distribution pattern from other two elements and there can be recognized no correlation between Pb and the other 2. Basal Series and Lower Calcareous Series show high medium values in Cu and Pb, but PIII, PII-III, and PII formations show lower medium values each other. This fact indicates that the backgrounds of Cu and Pb are higher in Lower Calcareous Series and Basal Series, but lower in PIII, PII-III, and PII formations. The andesitic rocks of PIII formation show the highest background of Zn.

(3) K Area (cf. Tables I-7-10 & I-7-14)

The distributed formations are limited to Basal Series and the andesite of PIII formation in K Area, which makes it unable to make comparison with other rock types. On account of this, comparison will be made with the same rock types in other areas. The medium values of Cu and Pb of Basal Series are highest in the 3 districts, but that of Zn is low. The andesitic rocks of PIII formation has shown the medium value of Zn as 13 ppm, which is the highest among the 3 districts. Pb shows similar value as other areas and Zn shows higher value than other rock types, but the andesite of PIII formation shows similar value of other areas. This Area, therefore, can be said the area of high Cu background.

3-2-2 Relation between Elements and Formations

In order to find out the characteristics between elements by geological formations from the samples collected in each area, Table I-7-15 has been prepared.

(1) Cu

Comparison of medium values of Cu by geological units tells that the dolomite of PIII formation shows the highest of 50 ppm, which is followed by 21 ppm of green stones and schists of PII formation and further by 17 ppm of the andesitic rocks of PII-III formation, but as they are the geological units with fewer samples, the values obtained seem to be short of generality. In the geological units with more than 100 samples, higher medium values are

14 ppm of Basal Series and the next is 14 ppm of the PII-III sediments. The lowest values by geological units are almost constant, being within a range of 1 ppm - 3 ppm. The highest values are 39,000 ppm of the PIII sediments and 36,000 ppm of Basal Series, which are followed by 1,6250 ppm of the PII-III sediments, 10,750 ppm of Lower Calcareous Series, 9,500 ppm of the rhyolitic rocks of PIII formation, 3,400 ppm of the rhyolitic rocks of PII-III formation, and 2,150 ppm of the andesitic rocks of PIII formation.

The PIII sediments have shown the lowest medium value of 4 ppm among all the geological units, while the value of 39,000 ppm is the highest among all of them. Therefore, this formation is the one having lower background but containing high contents of Cu. Basal Series has the medium value of 14 ppm with the highest of 36,000 ppm. This formation is the one having high values in the higher background.

(2) Pb

Considering the medium values of Pb by geological units, 24 ppm of the PIII dolomite is the highest, which is followed by 23 ppm of Lower Calcareous Series, 14 ppm of Basal Series, and the rest shows low medium values less than 11 ppm. The lowest values by geological units fall within a range of 2 ppm - 4 ppm. The highests are 1,400 ppm in Basal Series, and 1,120 ppm in Lower Calcareous Series, while the others fall within a range of 40 ppm - 370 ppm, generally low graded.

(3) Zn

The medium Zn values are 73 ppm in the andesitic rocks of PIII formation, which is follows by 59 ppm of the PIII sediments, 51 ppm of the metamorphic rocks of PII formation, and the other units show a range of 5 ppm - 29 ppm. The lowest values by geological units fall into a range of 1 ppm - 12 ppm. The highest values are 1,100 ppm of the PII-III sediments, 580 ppm of Basal Series, 440 ppm of the PIII andesite, and 430 ppm of Lower Calcareous Series, and the other geological units have their highest values within a range of 50 ppm - 240 ppm. Zn contents are said to be generally low in each of the geological units.

3-2-3 Anomalies (cf. Fig. I-6)

For the purpose to find out the distribution patterns of quantities of each element, cumulative frequency diagrams and histograms are prepared. Fig. I-6 is what shows the distribution of each element from the lumped data of all the samples collected from the entire areas surveyed in the forms of cumulative frequency diagrams and histograms. In the cumulative frequency diagrams, bending points are observed on Cu at 30 ppm and 100 ppm. As difference of populations are recognized, they are defined as the first threshold value and the second threshold value respectively. Similar bending are also recognized on Pb at 15 ppm and 100 ppm, and the difference of populations are also recognized. Therefore, they are defined as the first and second threshold values. Zn shows almost straight lined distribution, the logarithmic normal distribution. Therefore, the threshold value of Zn has been obtained by adding standard deviation to the medium value of Zn. Consequently, the threshold values obtained from the logarithmic frequency diagrams for all the rock types lumped together have been defined as follows;

	First Threshold	Second Threshold
Cu	30 ppm	100 ppm
Pb	15 ppm	100 ppm
Zn	80 ppm	240 ppm

Since the geochemical samples were collected from the exposed rocks, their assay values indicate the absolute amounts of contained elements in the rocks. Consequently, geochemical maps will enable to extract the areas of high contents as well as to distinguish certain rock types with certain values.

(a) H and J Areas (cf. PLs. I-6-1, I-6-2, I-6-3)

High anomalies of Cu are recognized in Talat-n-Sous along the surface of unconformity, and are recognized specially distinctly in the lower part of Basal Series. In Basal Series slightly high anomalies are recognized. Anomalies continuously scattered to the east from Talat-n-Sous are those contained in Basal Series as well as along the surface of unconformity between Basal Series and PII formation.

Pb values above the first threshold value are recognized in dolomite. Especially in Basal Series of Talat-n-Sous, anomalies are recognized. In Lower Calcareous Series too, values between the first and second threshold values are found. No anomaly is detected in the conglomerate of PIII formation.

Zn anomaly is not accumulated in definite area or in definite rock. But weak anomalies are observed in Basal Series.

(b) I, L, and M Areas (cf. PLs. I-6-7, I-6-8, & I-6-9)

Accumulation of Cu anomalies is recognized in the northern half of I Area. The detailed survey of ore deposits was performed in a part of the accumulated area, where the geochemical samples were collected at every 200 m along the survey routes spaced at 150 m interval.

Geology of the accumulated area of anomalies is composed of sandstone and rhyolite of PIII formation and conglomerate of PII-III formation. There is no tendency for the anomalies specially concentrated in certain formation.

Cu anomalies distributed in M Area, southern part of I Area, are found in the andesitic lavas of PIII formation. This is considered due to the enrichment in the andesite itself, as there is no anomalies found in the sedimentary rocks in the surroundings.

Accumulation of anomalies are also recognized in Basal Series in the southern part of the area. Especially they are found in the layer of shale too, but not found in the formations except Basal Series. On account of this, the anomalies are considered to be derived by the sedimentological mineralization.

Contents of Pb is generally poor and areas of accumulation of Pb anomalies can not be found. Accumulation of slightly higher anomalies is found in dolomite, but this is due to the generally higher contents of Pb in dolomite. Sporadical high anomalies are found in rhyolite somewhere.

Accumulation of Zn anomalies is found in the northern part of I Area. Here, the rock types are conglomerate of PII-III formation and rhyolite and sandstone of PIII formation. A few rhyolite dykes are observed here and there, and the said anomalies may have been effected by these dykes.

Accumulation of anomalies is also found in the andesitic lavas, which may be due to the enrichment by the andesite itself. Slightly loose accumulation of anomalies are recognized in the sandstone of PIII formation in the southern part of I Area.

(c) K Area (cf. PLs. I-6-4, I-6-5 & I-6-6)

Cu anomalies are accumulated in the andesite of PIII formation and in other rocks of its surroundings. As this andesite contains the mineralized fractured zones, these mineralized zones may be represented by the accumulation of anomalies. The anomalies often appear in the conglomerate of Basal Series, in which dissemination of pyrite has been recognized by field observation.

Pb anomalies are found in the dolomite layers of Basal Series, which have the feature of higher Pb contents than other rock types.

Zn anomalies are quite spodadic in these areas. Accumulation of anomalies are observed in the PIII andesite, which are considered to be related to the mineralization in the fractured zones like Cu anomalies. A feeble accumulation of Zn anomalies are also found in the conglomerate of Basal Series.

3-3 Summary

3-3-1 Existing Amounts of Each Element

The medium value of Cu for the entire rock types is 8 ppm. Comparison will be made with the examples of mineralized zoned by the value in which standard deviation (σ) is added to the medium value. In the present surveyed areas, medium value + standard deviation (σ) equals to 36, and medium value + 2 σ equals to 177. For example, medium value + σ = 360 ppm, medium value + 2 σ = 660 ppm in Yauri district, Peru. Thus, the copper assays are rather lower in the present areas and its existing amount seems less.

The similar medium value of Pb is 8 ppm, medium value + σ = 21 ppm, and medium value + 2 σ = 54 ppm, which are rather lower assays compared with other mineralized zones.

In the case of Zn, the medium value is 25 ppm. Accumulation of high assays can not be recognized, as medium value + σ is 80 ppm and medium value + 2σ is 240 ppm.

3-3-2 Interrelation of Elements

Comparing the distribution patterns of each element of Cu, Pb, and Zn, the parts showing similar pattern of distribution are often recognized, and such tendency of similar pattern of distribution is found especially in these volcanic rocks such as rhyolitic and andesitic rocks. Cu sometimes shows anomalies in the locations quite indifferent to the other elements.

Pb is more contained in dolomite, showing independent behavior.

3-3-3 Relation with Geology

As the geochemical samples in the present survey are collected directly from the exposed rocks, assays reflect directly the geology of collected locations. Therefore, each assay value is estimated to indicate directly the content in each rock type, and further that of each formation. Tables from I-7-8 to I-7-10 are shown the medium values and the values of standard deviation which are proper to each area surveyed and to each formation. The tendency of metallic content in each formation is shown by the histograms by formations on PLs. from I-6-10 to I-6-12.

3-3-4 Summary

Many areas containing many anomalies are extracted by the data analysis of geochemical survey, and many locations containing the anomalies to be investigated are extracted in each of the surveyed areas through correlation between assays and geology, correlation between assays and the concentrated locations of ore minerals, and examination of relationship between the assay values. These anomalous spots, however, are simply so relatively to the mean values, and should not be accepted as the values to indicate the hidden existence of large area of mineral indications.

4 areas of accumulation of important anomalies have been revealed, which are the mineral indications of Talat-n-Sous in H Area, northern half of I Area, the area of andesite lavas in M Area, and the area of andesitic lavas in K Area.

The mineral indications of Talat-n-Sous in H Area is the area of accumulation of principally Cu anomalies. Anomalies are concentrated on the surface of unconformity between Basal Series and the underlying formation, as well as in Basal Series.

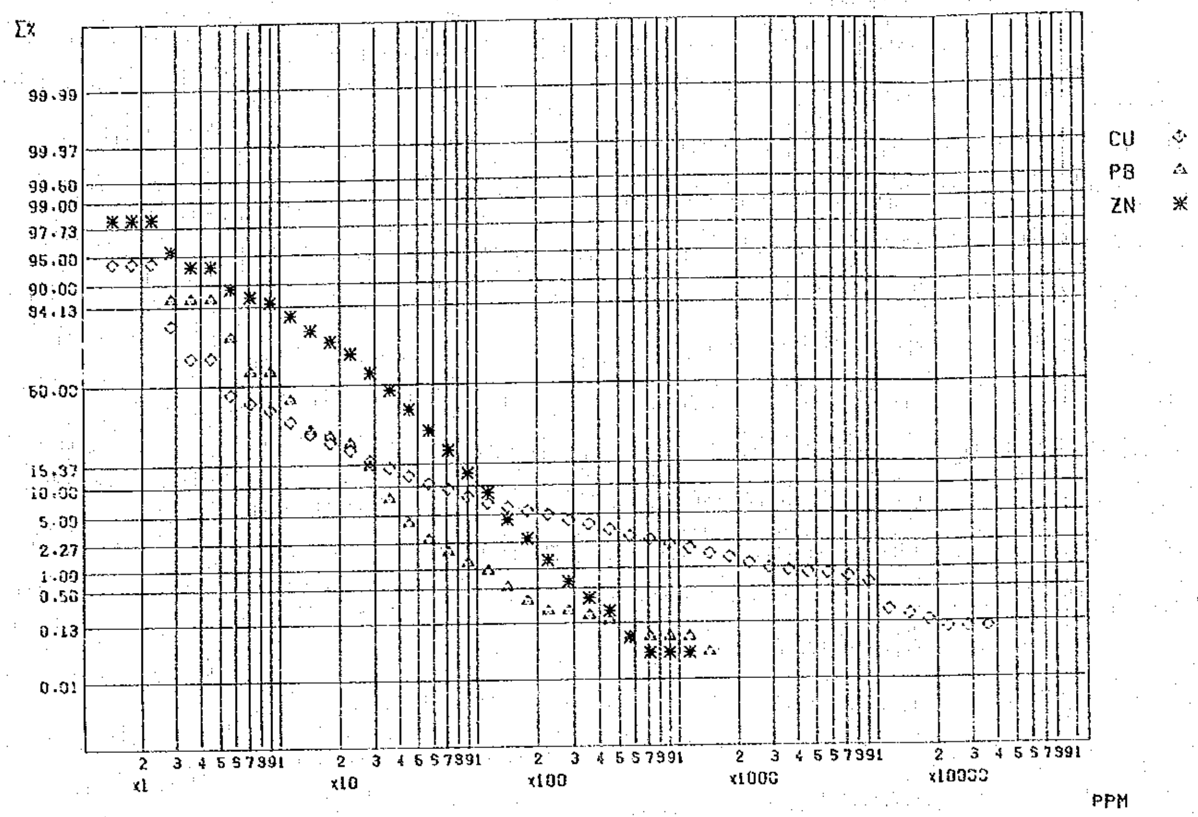
The northern part of I Area is the accumulated area of Cu anomalies. They are distributed in the conglomerate, sandstone, and rhyolitic tuffs without any characteristics by rock types.

Accumulation of Zn anomalies is recognized in the andesitic lavas in M Area.

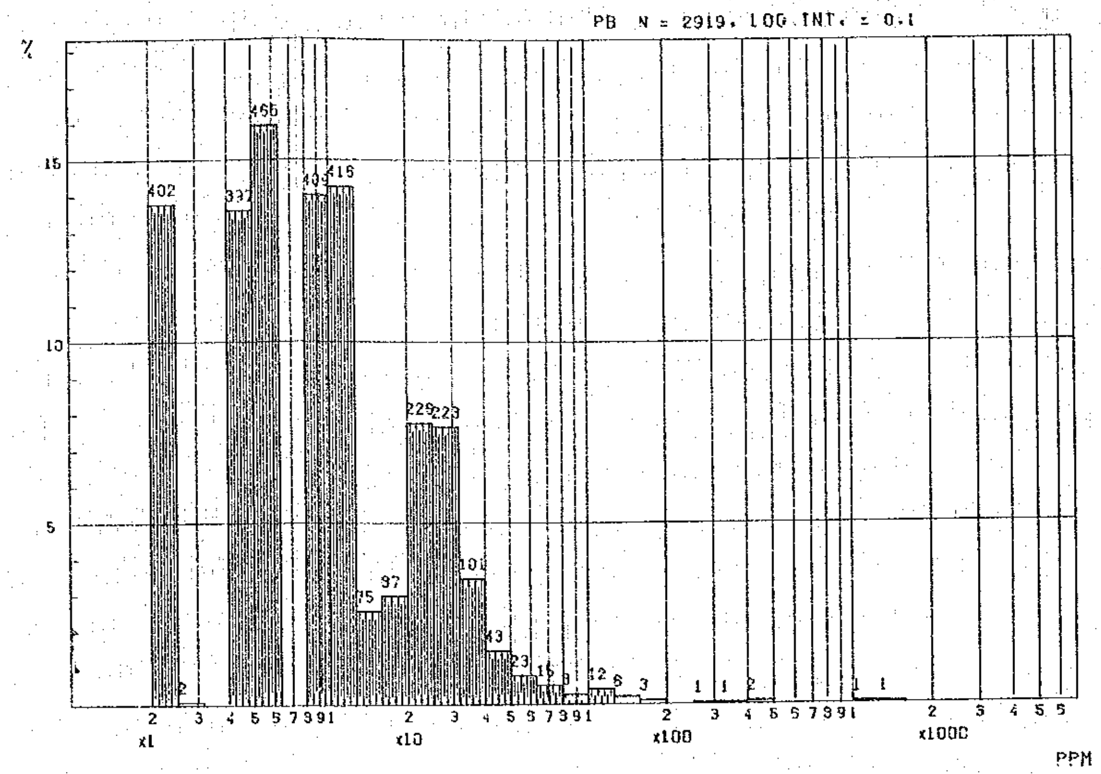
Accumulation of Cu and Zn anomalies is observed in the andesitic lavas in K Area, too.

Fig. I-6 Histogram of Geochemical Data by Elements in the Whole Area

CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN



HISTOGRAM FOR PB



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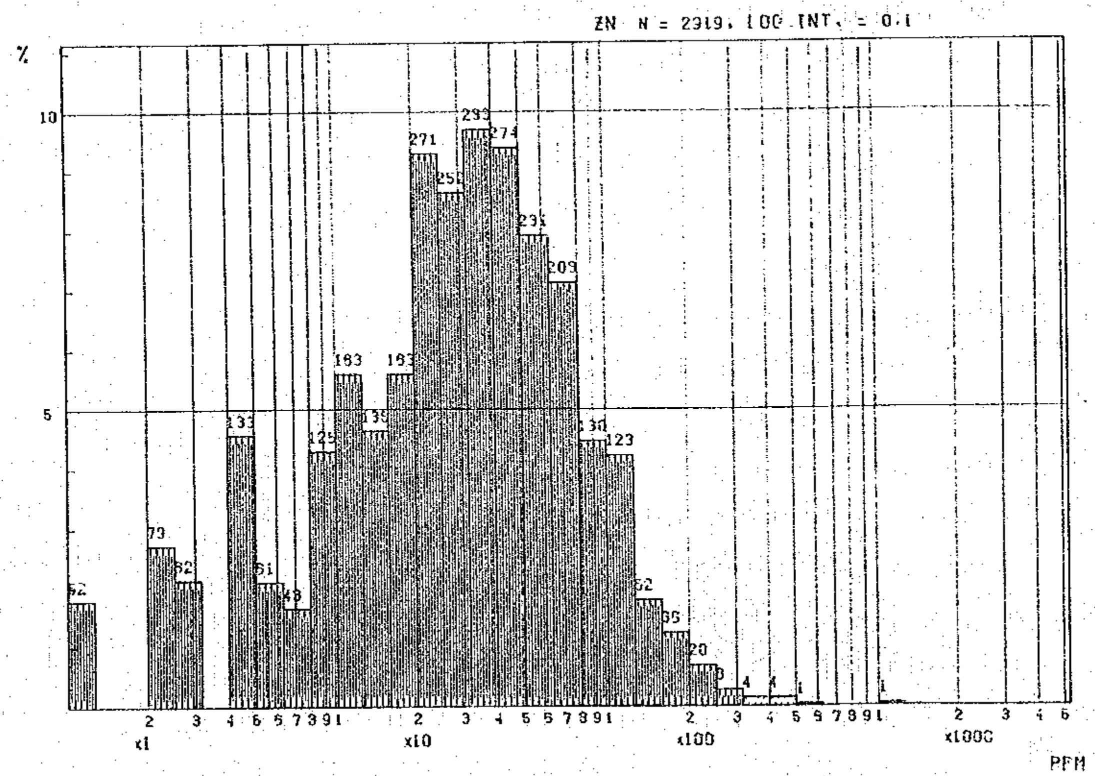
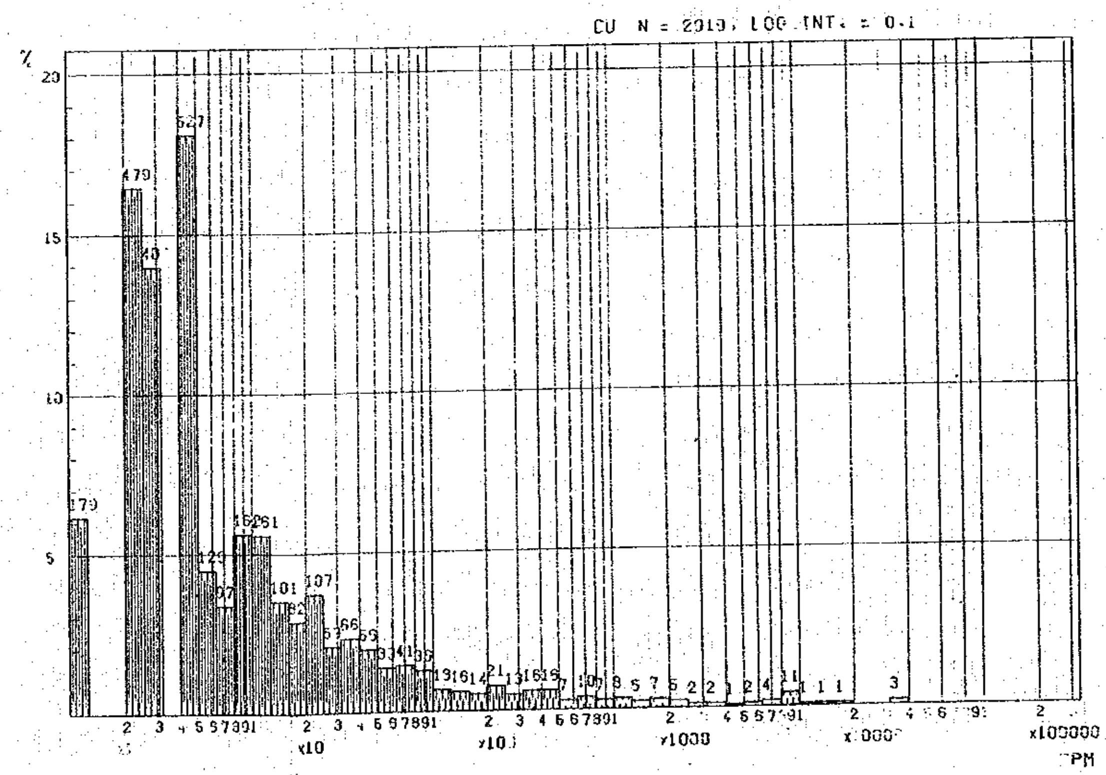


HISTOGRAM FOR CU



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PART 2

GEOPHYSICAL SURVEY

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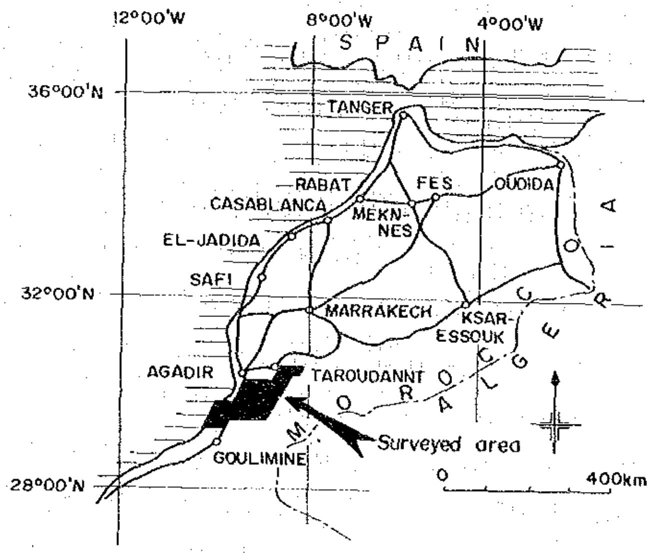
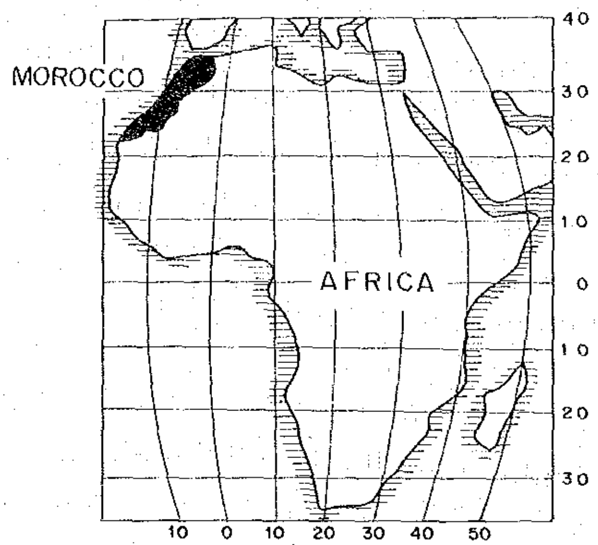
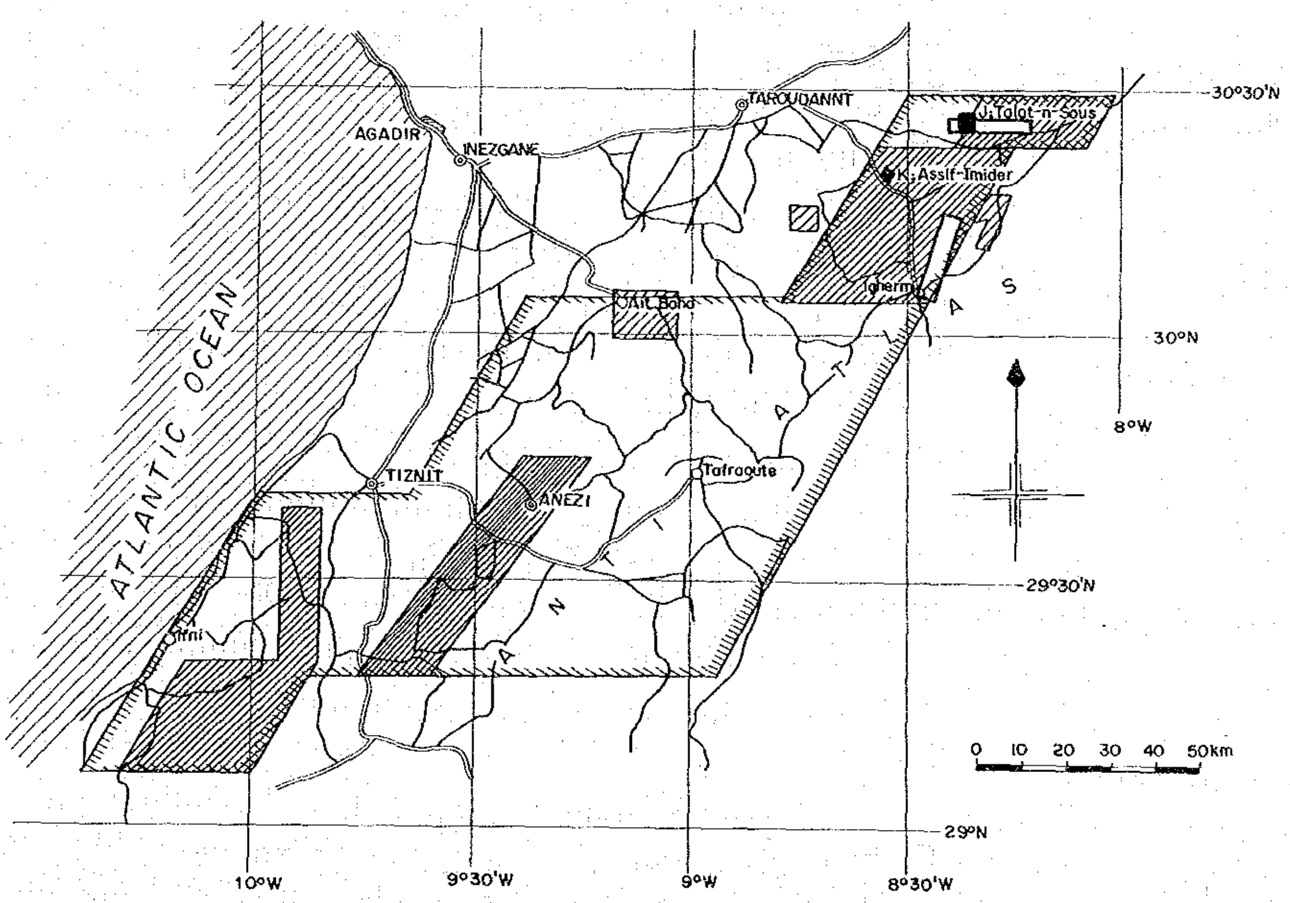
Fig. II-1-1 Location map of the Ip Surveyed Area







PHASE I surveyed area PHASE II surveyed area PHASE III surveyed area

Chapter 1 General Remarks

1-1 Purpose

This survey was performed as one of the survey operations of the third year phase in the Anti Atlas Area, the Kingdom of Morocco, for the purpose to obtain the informations regarding to the mineral resources in these areas of J: Talat-n-Sous and K: Assif Imider as shown by Fig. II-1-1.

They are the areas where the possibilities of hidden existence of mineralized zones were pointed out through the survey of the second year phase, in spite of the covering of younger formations and poor mineral indications on the surface.

The survey was practiced by the induced polarization method (IP method) of frequency domain system similarly to the geophysical survey of the second year phase, in order to detect the hidden mineralized zones.

The survey covered an area of 10.7 km^2 in the J Area: Talat-n-Sous and another 2.6 km^2 in the K Area: Assif Imider.

1-2 Location (Fig. II-1-1)

The surveyed areas are, as indicated by the A and B sections on Fig. II-1-1, located in the southwestern part of the Anti Atlas. From Agadir, a sight-seeing city, the J Area: Talat-n-Sous is located about 120 km east and the K area: Assif Imider is about 110 km east both in direct distances.

1-3 Transportation

To access to Talat-n-Sous in the J Area, one can follow a paved road that starts from Agadir and reaches to Aoulouz via Taroudant, and then an unpaved mountain road from Aoulouz to Talat-n-Sous. Transportation is more facilitated in the K Area: Assif Imider, as a paved road is available from Taroudant to Alous. It takes about 5 hours by car from Agadir to Talat-n-Sous and about 3 hours by car from Agadir to Assif Imider.

1-4 Topography

The J Area: Talat-n-Sous has gentle topography as a whole, being located at an altitude of 1,300 - 1,600 m S.L. But steep cliffs are developed near the survey lines in the west of the district as well as in the north and south extremities of it, where Tamjout dolomite of Infra-Cambrian System is distributed.

The K Area: Assif Imider is a mountenous land with scarce vegetation with an altitude of 800 - 1,100 m S.L. The land has very steeply dissceted topography with frequently repeating topographic ups and downs of great relative hights, where the andesite in the central part of the area is exposed at the bottom of valleys, while the sediments of Basal Series covering the andesite is deeply eroded.

1-5 Geology

1-5-1 J Area: Talat-n-Sous (Plate II-1)

Rocks of the area consist of Pre-Cambrian andesitic tuffs, rhyolitic tuffs and conglomerates that form the lowermost part, and a succession of Infra-Cambrian rocks, overlying the former unconformably, such as dolomites and alternation of siltstone and sandstone of Basal Series, and dolomites of Lower Calcareous Series including Tamjout dolomite.

Pre-Cambrian andesitic and rhyolitic tuffs are distributed from the central part to the eastern part of the area, of which southern adjacent is overlain by the conglomerate of Pre-Cambrian PIII formation. The Pre-Cambrian terrain is surrounded by Basal Series, consisting of dolomites and alternation of siltstone and sandstone and overlying the Pre-Cambrians unconformably. The Tamjount dolomite, overlying the alternation of siltstone and sandstone, is distributed around the north and south extremities of the area and in the western part, of which distribution is terminated with steep cliffs.

As for mineral indications, copper dissemination in the rhyolitic tuffs is recognized near the central part of the area as well as those to be seen at some parts around the unconformity with Basal Series. No mineral indication has ever been recognized in the dolomites of Tamjout and Lower Calcareous Series.

1-5-2 K Area: Assif Imider (Plate II-2)

Constituent rocks of the area, in ascending order, are Pre-Cambrian andesitic lavas and alternation of tuffaceous sandstone and shale, and dolomites, conglomerates, and alternation of sandstone and shale of the Infra-Cambrian Basal Series. No distribution of the Tamjout dolomite is in the area.

Copper mineralizations in the andesitic lavas are remarkable as mineral indications, some of which are now under operation as copper mines.

Chapter 2 Method of Prospecting

2-1 Equipments

The main specifications of the equipments used in the present survey are listed hereafter.

(1) Transmitter

A Model L-5106 A, B: manufactured by Yokohama Electronic Laboratory

Weight:	50 kg
Output Voltage:	800 V, max.
Output Current:	0.20 A - 2 A
Frequency Range:	0.1 Hz, 0.3 Hz, 1.25 Hz, 2.5 Hz, 5 Hz
Input Source:	60 Hz or 400 Hz, 100 V, single phase

B Model FT-4: manufactured by Geotronics

Weight:	21.7 kg
Output Voltage:	800 V, max.
Output Current:	0.4 A - 4 A
Frequency Range:	0.01 Hz - 100 Hz, DC
Input Source:	400 Hz, 115 V, three phase

(2) Receiver

A Model YI-804: manufactured by Yokohama Electronic Laboratory

Weight:	approx. 7.5 kg
Sensitivity:	10 μV
Frequency Range:	0.1 Hz, 0.3 Hz, 1.25 Hz, 2.5 Hz, 5 Hz
Input Impedance:	10 MΩ

B Model P-660: manufactured by McPhar

Weight:	approx. 2.5 kg
Sensitivity:	10 μV
Frequency Range:	0.1 Hz, 0.3 Hz, 1.25 Hz, 2.5 Hz, 5 Hz
Input Impedance:	2 MΩ

(3) Engine Generator

A-1 Model 421: manufactured by Geotronics

Weight:	Approx. 37 kg
Voltage:	115 V
Frequency:	400 Hz, single phase
Output Power:	2 KW

A-2 Model EG-2400: manufactured by Shin-Yamato Kogyo Co.

Weight:	approx. 56 kg
Voltage:	100 V, single phase
Frequency:	60 Hz
Output Power:	2.4 KW

B Model B-2: manufactured by Geotronics

Weight:	approx. 50 kg
Voltage:	115 V, three phase
Frequency:	400 Hz
Output Power:	3 KW

2-2 Measuring Procedures

Apparent resistivity of the earth is a function of frequency. Measured values of apparent resistivity of the rocks in general usually come higher when they are measured by lower frequency than when measured by higher frequency. Difference between the measured apparent resistivities by higher and lower frequency will become bigger especially when the ground contains sulphides or so. The electrical prospecting method to make use of this phenomenon is the IP method of frequency domain system adopted in the present survey; that is, two kinds of alternative current of different frequency, $AC_L = 0.3$ Hz and $AC_H = 2.5$ Hz, were used in the present survey.

Among several ways of earthing electrodes in the field operation of IP survey by frequency domain system, the Dipole-Dipole configuration (Fig. II-2-1) was adopted in the present survey, as this configuration is widely used and causes less coupling between electric wires.

In the Dipole-Dipole configuration, distance between current electrode and potential electrode is expressed by a product of electrode spacing (a) and separation factor of electrodes (n), i.e., na. Under the varying conditions of separation factor of electrodes (n) by 1, 2, 3, 4, and 5, the calculated values of apparent resistivity and FE from potential differences, measured to each condition, will become to contain the informations about the electrical natures of the ground wider horizontally and deeper vertically in accordance to increase of n. In the present survey, the informations, both horizontal and vertical, of the ground were ascertained.

2-3 Field Procedures

(1) Land Survey of IP Survey Lines

Land survey was made along the IP survey line with pocket compass and ethlone tape. The measuring stations were spaced at 100 m in horizontal distance and each station was marked by piled stones, on which the station number was painted. Land survey was also made between the survey lines and main roads or between the lines and tunnels and portals, in order to make clear the relation of survey lines with topography and ground installations. Topographic maps in the scales of 1 : 15,000 and 1 : 5,000 were referred to in laying out and determining locations of the survey lines, too. Elevation of measuring station was obtained through the contour lines of these maps, for instance, 1,375 m was taken as the elevation of measuring station No. 13 on survey line H in the Talat-n-Sous district, and 932 m as that of No. 8 on survey line No. 1 in the Assif Imider district.

Names and lengths of the survey lines in each district are shown by Table II-2-1.

(2) Layout of Survey Lines (cf. Plate II-1, Plate II-2, Table II-2-1)

A J Area: Talat-n-Sous

Bearing of survey lines was set at O10° (N10°E) in view of east-westerly general trend in the strike of Basal Series, and 15 survey lines from B to N and another Q and S were layed out. Two additional lines, P and X, were layed out at 100° (S80°E) and perpendicularly to

the above lines to detect further the IP anomaly which had been obtained through field operation. Length of each survey line varies from 2.6 km to 3.4 km.

B K Area: *Assif Imider*

In order to obtain the informations of mineralization and geological structure in and around the area of Assif Imider Mine now under operation, a survey line was layed out across the mine at 300° (N60°W), nearly perpendicular to the strike of the ore deposit. An IP anomaly reflecting the said ore deposit was detected by the previous IP survey along this line. Further, in order to detect the continuity of the deposit, additional survey lines of No.2, No.4, and No.6 (2 km long each) were layed out to the north from survey line No. 1 at 300 m spacing, and another No. 8 and No. 9 (1.5 km each) were layed out to the south of No. 1.

(3) Installation of Electrodes, Wiring, and Location of Transmitter and Receiver

A sheet of copper plate of about 30 cm x 30 cm was used for a current electrode, which was laid in a pit of about 50 cm deep and was covered by fine soils to keep better contact with the ground, and an effort was taken to take down contact resistance to the earth by spraying salt water over it. In case of bigger contact resistance to the earth, arrangement was made to take down the resistance by adding the copper plates. This current electode was connected to receiver by vinyl-insulated wire.

A non-polarized electrode was used as a potential electrode, which is a system of satulated solution of $CuSO_4$ - metallic copper. In order to reduce contact resistance between a potential electrode and the ground, water was poured where the potential electode was earthed.

In order to avoid the measurement errors caused by electromagnetic coupling between electric wires and leakage of current, efforts were taken so that insulation resistance between the wires would be kept maximum and the coupling might be kept minimum by avoiding intersection or approach of the potential and current wires.

Field measurement was carried out by dividing each survey line into sections of 1 or 2 km long in consideration of efficiency of the works. Transmitter was located nearly on the center of each divided section, while receiver was moved along the line in progress of the works. Current was transmitted to appointed current electrode whenever instruction arrived from the receiver side, while the receiver side made measurement of potential difference between necessary potential electrodes.

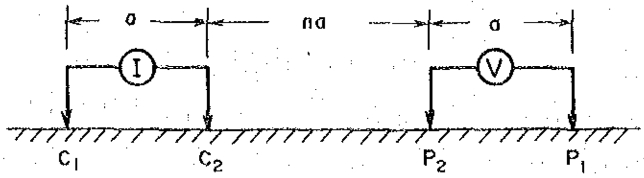


Fig II - 2 - 1 Dipole - Dipole Configulation

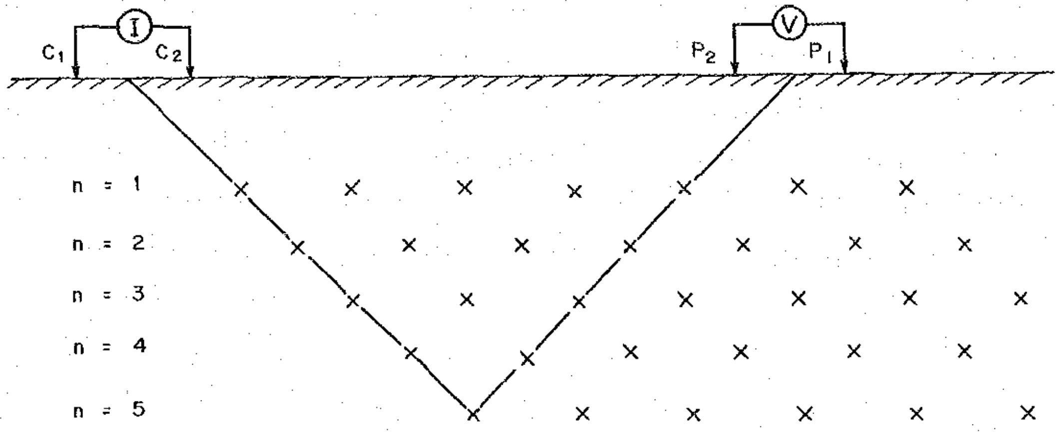


Fig. II - 3 - 1 Example of Plotting

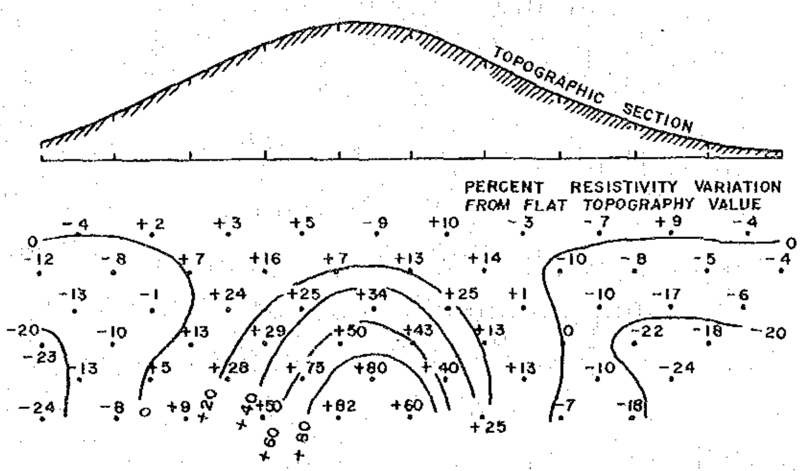


Fig. II - 3 - 2 Influence due to Topography on the Apparent Resistivity

Chapter 3 Data Analysis

3-1 Handling of Measured Data

An apparent resistivity ρ_a (to be called AR hereafter) was calculated from the measured value by the following formula;

$$\rho a = K. \frac{V}{A} \quad \Omega\text{-m}$$

in which K: geometric constant

V: received potential between P_1 and P_2 (V)

I: transmitted current between C_1 and C_2 (A)

V and I were obtained by AC_H (signals by 2.5 Hz).

Frequency effect (to be called FE hereafter) was used as a mean to indicate the degree of electric polarization, which is used as a common mean to indicate the IP value by frequency domain system. The FE was defined as shown by the following formula;

$$FE = \frac{\rho aL - \rho aH}{\rho aH} \times 100 \%$$

in which ρaH: AR measured by lower frequency (0.3 Hz here) (Ω-m)

ρaH: AR measured by higher frequency (2.5 Hz here) (Ω-m).

The ratio between FE and AR is called metal conduction factor or metal factor (to be called MF hereafter). Although the MF has been defined in several ways, it was defined here as

$$MF = \frac{FE(\%)}{\rho aH\ (\Omega\text{-m})} \times 10^3$$

As many of metallic sulphides generally have lower AR and higher FE, their MF values usually come out in bigger figures. Therefore, MF can be used as a parameter to prospect metallic minerals.

3-2 Plotting of Measured Results

In plotting these values as AR, FE and MF calculated from measured data, a widely used method of plotting was adopted, in which any value is plotted at an apex of a right-angled isosceles triangle with its base connecting the middle point of current electrodes (C_1, C_2) and that of potential electrodes (P_1, P_2).

3-3 Topographic Adjustment

The AR value obtained through the measurement in the Dipole-Dipole electrode configuration contains not only the informations from underground structure but also the effects of topography. For instance, even if the underground structure seems uniform in terms of AR, distribution of AR may show as if the underground structure were not uniform in the case when the ground surface is uneven. Fig. II-3-2 shows AR distribution when the underground structure is uniform but the ground surface is uneven.

Therefore, it is necessary to make topographic adjustment against AR to eliminate the topographic influence in analysing structure of a terrain with much rugged topography.

In data analysis of the present survey, the analysis was proceeded in such a way to make topographic adjustment by putting two dimensional topographic models in an electronic computor so that it would convert the topographic influence into numerical expression.

3-4 Examination of Physical Properties of Rocks by In-situ and Laboratory Measurements

In case to infer the underground structure from the measured data of IP prospecting, it is useful to acquire the values of FE and AR on the rocks distributed in the terrain to be surveyed. There are two ways of measuring the values of FE and AR; the one is measurement on the spot where the objective rock is exposed, that is, in-situ measurement, and the other is laboratory measurement on the piece samples of rocks. It is difficult to discuss the merit and demerit of these procedures, as such has its own advantage and disadvantage. In the present survey, both procedures were applied to facilitate the data analysis.

In-situ measurement is the one to examine the physical properties of the specified rocks to be measured by setting the current and potential electrodes on them. Advantage of the in-situ measurement, therefore, is that the specified rocks can be measured as they are in natural state. Disadvantage of this method, however, is that the physical properties of the adjacent rocks will also be measured together, and the effects of surface soils and weathering can not be avoided. Such effects,

therefore, has to be taken into consideration in the interpretation of the physical properties obtained through the in-situ method.

In the present survey, the in-situ measurement was carried out in the J Area: Talat-n-Sous as shown by Fig. II-3-3. The results are shown by Table II-3-1, Table II-3-2, and Fig. II-3-4. To summarize the physical properties of rocks to be considered through the results of in-situ measurement, dolomite is high in AR (more than 1,000 Ω-m) and low in FE (less than 1 %), rhyolitic tuffs show high AR (more or less 1,000 Ω-m) and low FE, conglomerates show intermediate AR (200 - 400 Ω-m), andesite shows slightly low AR (200 Ω-m or so), and both are low in FE, sandstone and siltstone show low AR (more or less 100 Ω-m - less than 500 Ω-m) but they have a range of variation in FE from the lower to the higher.

Results of measurement in a terrain of mineralized rhyolitic tuffs are shown by Table II-3-2 and Fig. II-3-4. A tendency is observed that FE is higher a little around the pits and trenches (more than 1 %), but FE values are low as a whole. Such is interpreted to have been caused by the existence of secondary copper minerals such as carbonates and oxides in the targetted rocks of measurement in the mineralized zone. It may also be attributed to a very thin mineralized zone.

Results of laboratory measurement are shown by Table II-3-3 and relation between AR and FE measurements are shown diagrammatically by rock types in Fig. II-3-C. Aside from the measurements on the rocks in Assif Imider and Talat-n-Sous, examination was made on the drill cores of DH-No. 1 located near the station 62 on survey line E surveyed in Alous in the second year phase and results are also shown by the figure.

Characteristics obtained through the laboratory measurement of the core samples is that those showing FE values as strong as 5 - 22 % are mostly noticed in andesite as well as in some of sandstone. A strong FE anomaly detected in the survey of second year phase around station 62 on survey line E is considered to have been caused by the iron oxide rather richly contained in the andesite and pyrite contained in the sandstone. This is one of the data to warn careful interpretation in the electrical prospecting and full consideration of geological environments, because this fact shows a strong anomaly of FE does not always indicate useful minerals. Among the rock samples collected on the surface, only the sample of shale collected

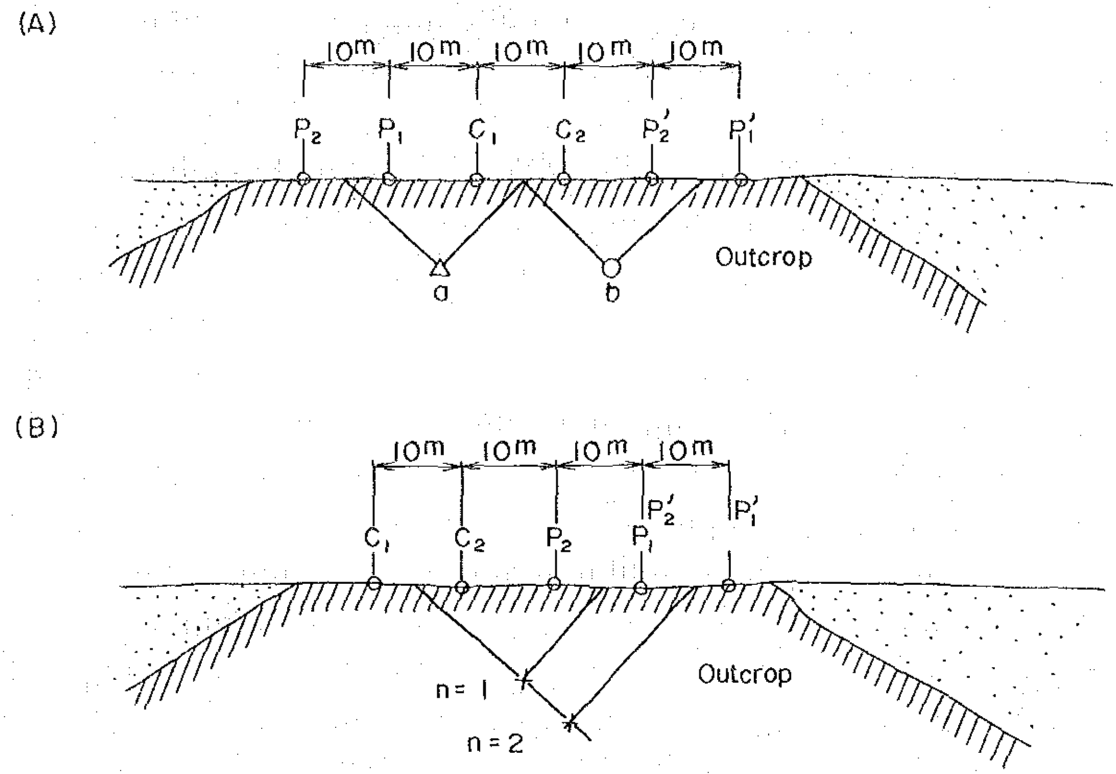


Fig II-3-3 Electrode Coufigulations of In-situ Measurement

between stations 8 and 9 on survey line H in Talat-n-Sous area only showed a little stronger FE, but the rest of all did not show any strong FE. Most of dolomite samples showed FE values of less than 1 %, but high AR values.

3-5 Standardization of Data Measured by Different Equipments

Operation of the present survey was performed by two parties of A and B (with two sets of equipments A & B, and two parties of measuring engineers). Since the apparent resistivity of the ground is a function of frequency as stated in paragraph 2-2, Measuring Procedures, frequency effect FE is also a function of frequency. Therefore, there may not exist any essential errors in the measured values, because frequencies of AC_L = 0.3 Hz and AC_H = 2.5 Hz were commonly used by both of the parties. However, in order to examine the personal errors and those to be caused by different equipments, comparison was made between the measured values by the two parties.

Table II-2-2, Examination of the Reciprocity, is a summary of measurements repeatedly done by the B party on 23 stations picked up from the measuring lines H, J, and N. It is noticed that the maximum variation of apparent resistivity, $(AR_1 - AR_2)/AR_1$, is 6.5 % and the maximum difference of FE is 1.1 %.

Table II-2-3, Comparison of Data between Party A and Party B, is a summary of measured results done by both of the parties commonly on the same 19 stations for comparison of difference by parties. It is noticed in the difference of measured values by A and B parties that the maximum variation of AR, $(AR_{party\ A} - AR_{party\ B})/AR_{party\ A}$ is 6.3 % and the maximum difference of FE is 0.7 %.

Since no bias is noticed in the measured values of AR and FE between A and B parties and so in the difference of dispersion, the measured values by the two parties have been treated equal.

3-6 Simulation

Simulation was made by electronic computor on the selected data among those

obtained through the present IP survey according to the flow chart shown by Fig. II-3-5. The items studied were in the order cited below.

(1) Topographic adjustment of the measured data (on the apparent resistivities whenever required).

(2) Plotting of the adjusted apparent resistivities.

(3) Preliminary modeling of the underground structure from the values of AR and FE with their distribution. In this procedure, reference was made to those data enabling to assume the physical properties of underground structure such as geological information from the field observations and the results of in-situ and laboratory measurements on rocks, and to the calculated values of IP models. In the IP model calculation, numerously accumulated examples are used to be referred to. Examples of model calculation on a fault-like structure and inclined slab structure are shown on Figs. from II-3-6 to II-3-9.

(4) Calculation of AR and FE values on modesl.

(5) Correlation between the calculated and measured values.

(6) Improvement of models by repeated trials whenever the correlation did not show fair coincidence.

(7) Acceptance of the model as finally estimated underground structure.

The results of simulation will be mentioned in Chapter 5.

Fig. II - 3 a. Correlation Between A R and F E in In-situ Measuremant (Talat - n - Sous)

Fig. II - 3 b.

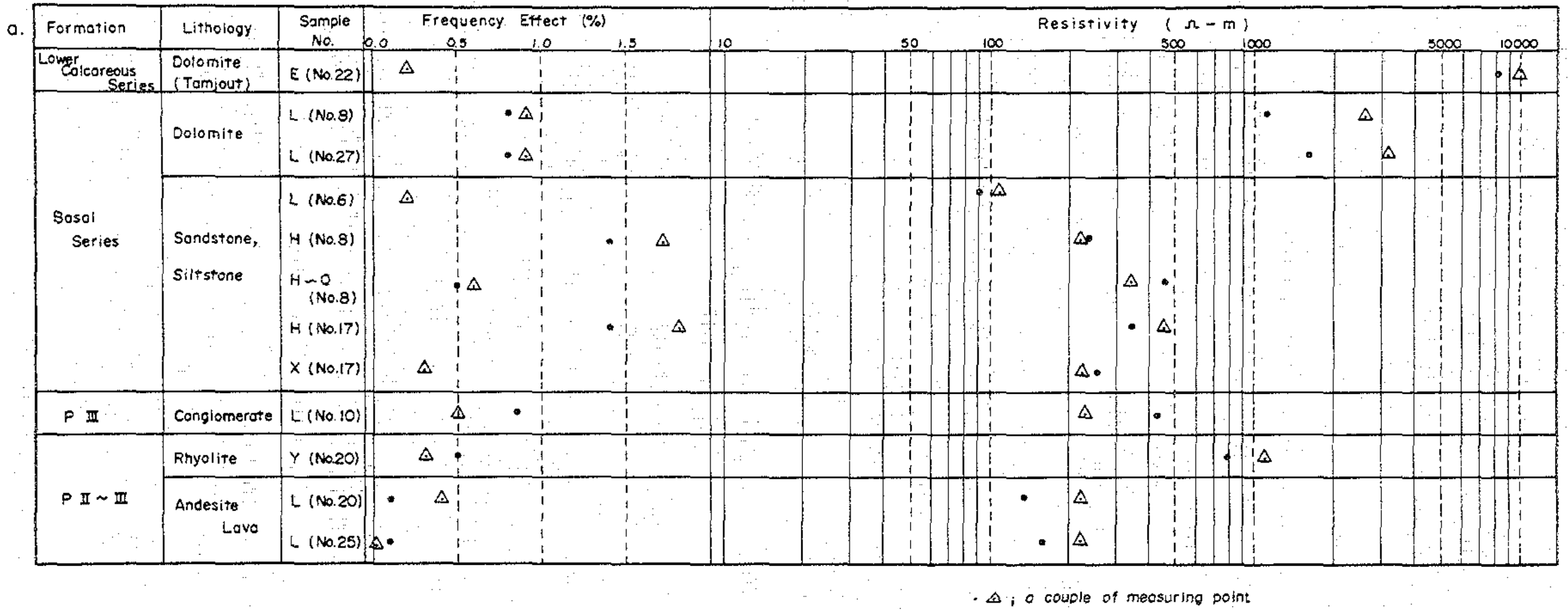


Fig II-3-C Correlation Between AR and FE in Laboratory Measurement

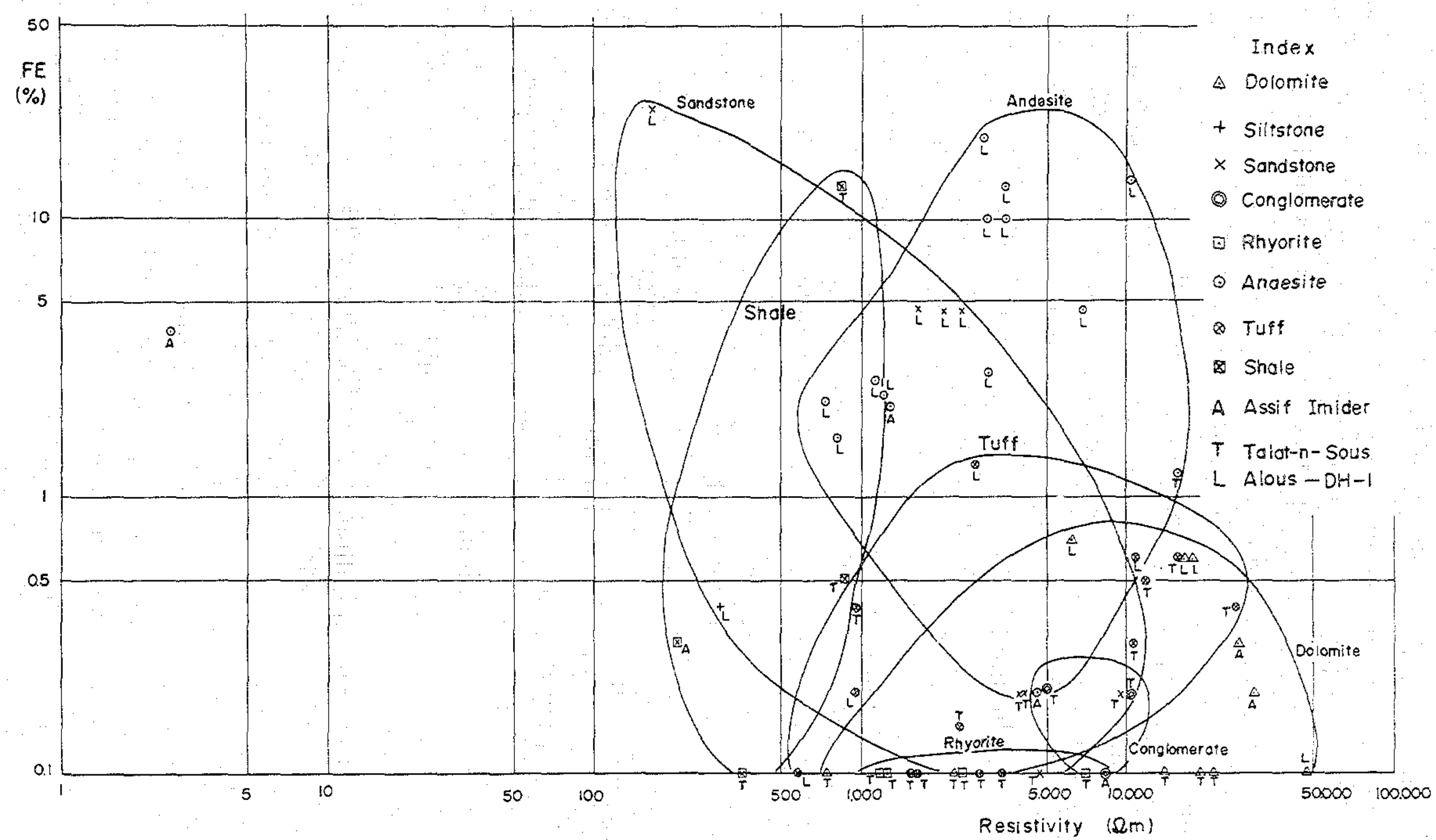


Fig. II-3-4 In-situ Measure entmin Talat-n-Sous
(by Electrode configlation of B)

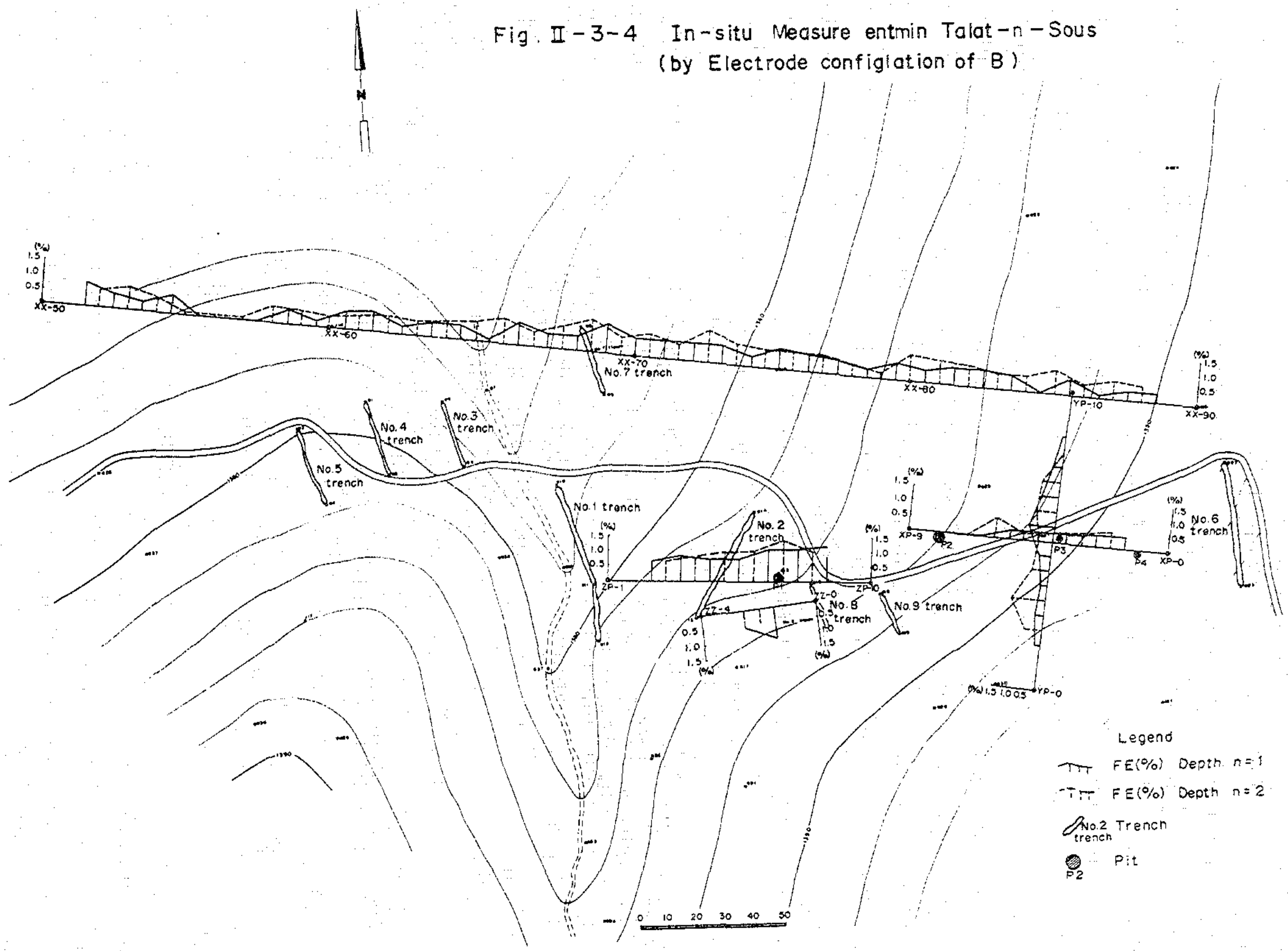
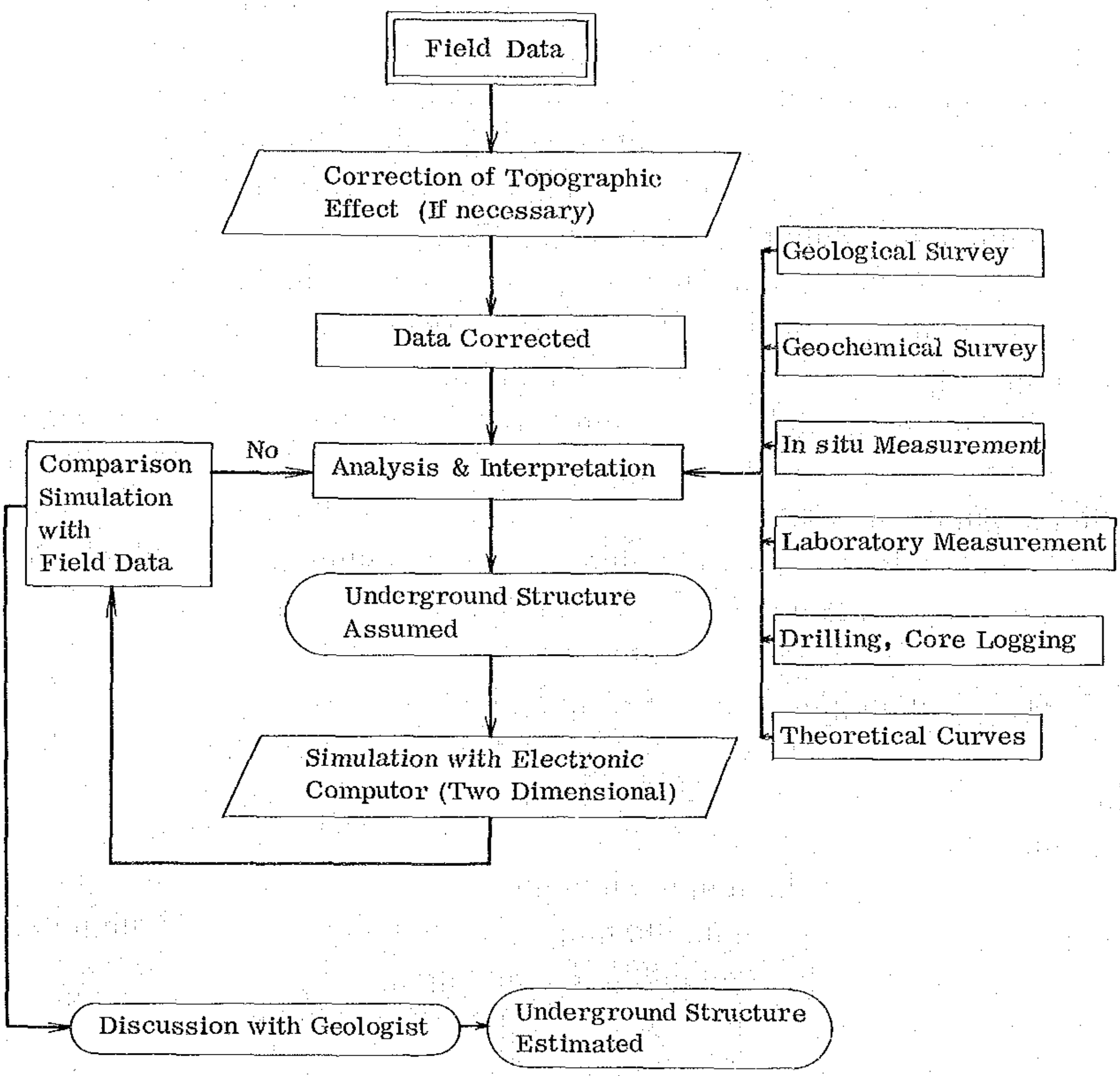


Fig. II-3-5 Flow Chart of Simulation



Index

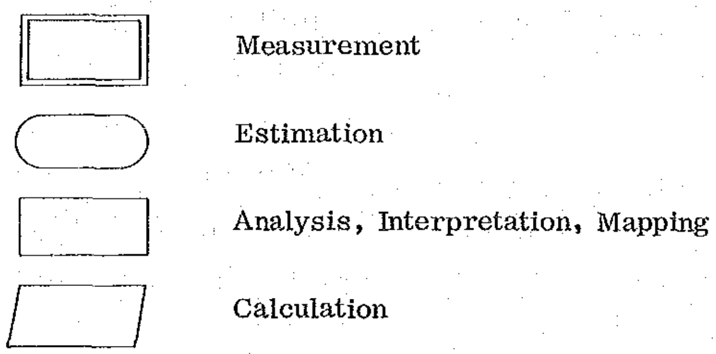
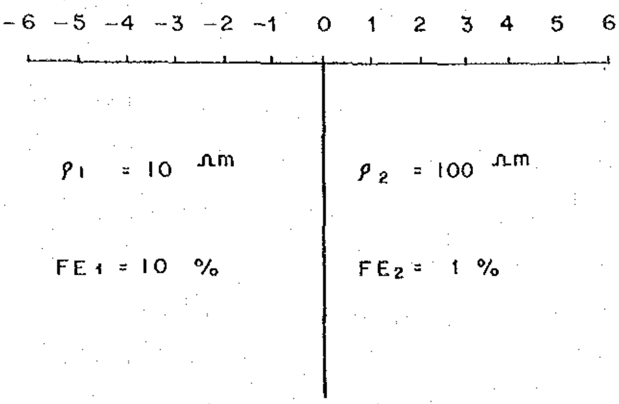
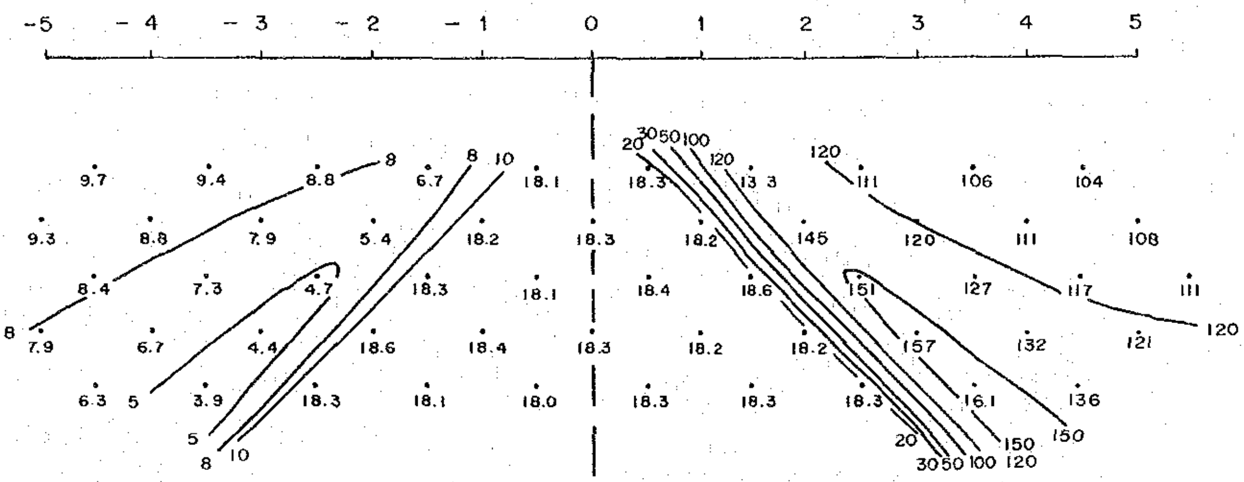


Fig. II - 3 - 6.   Calculation by Model (Fault)



Apparent Resistivity of Dipole - Dipole Coupling



Apparent Percent Freq. Effect of Dipole - Dipole Coupling

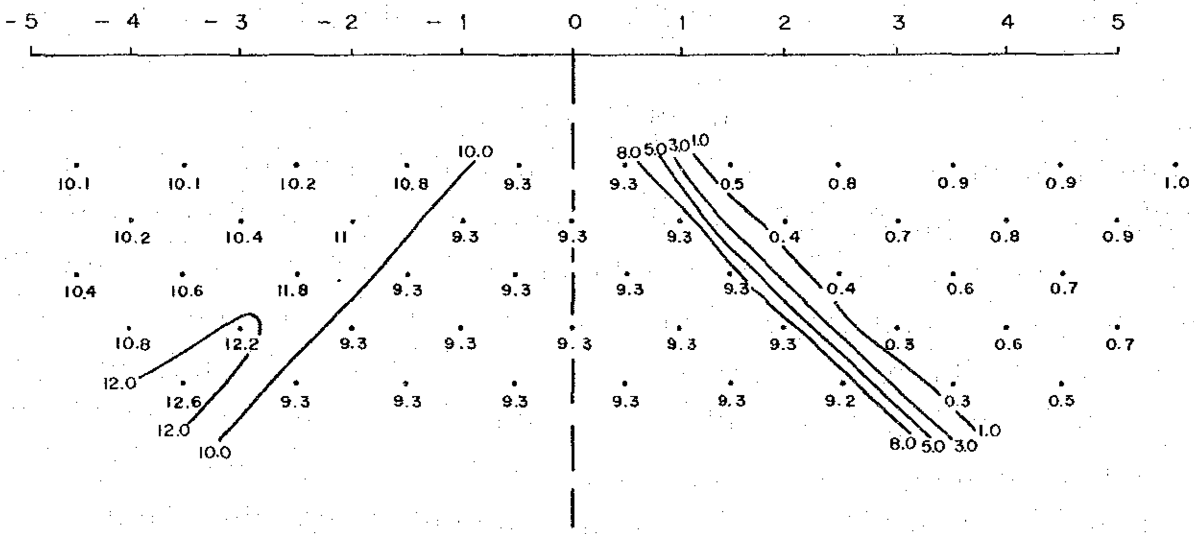
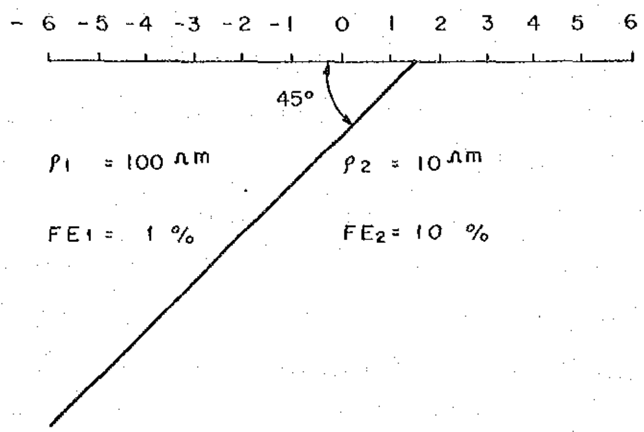
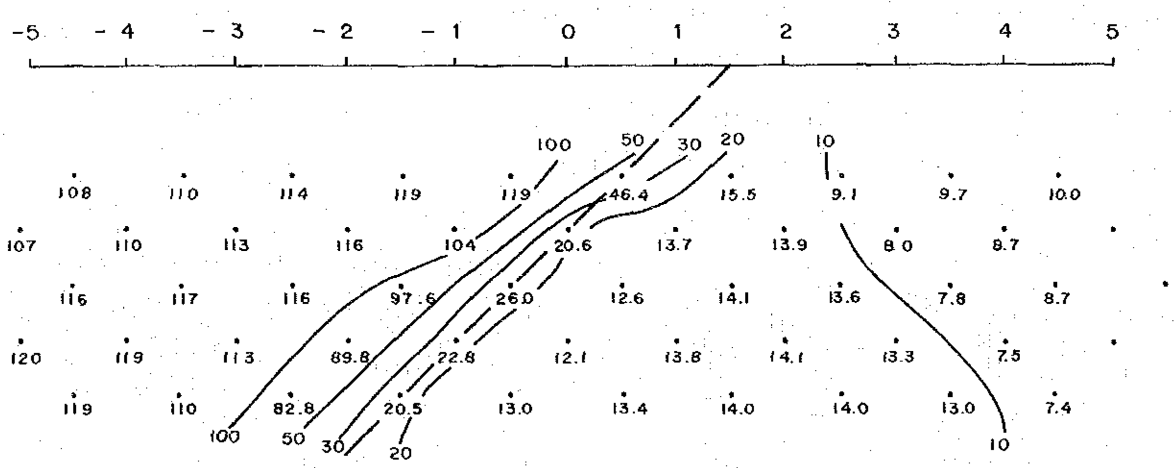


Fig. II - 3 - 7 Calculation by Model (Fault)



Apparent Resistivity of Dipole - Dipole Coupling



Apparent Percent Freq. Effect of Dipole - Dipole Coupling

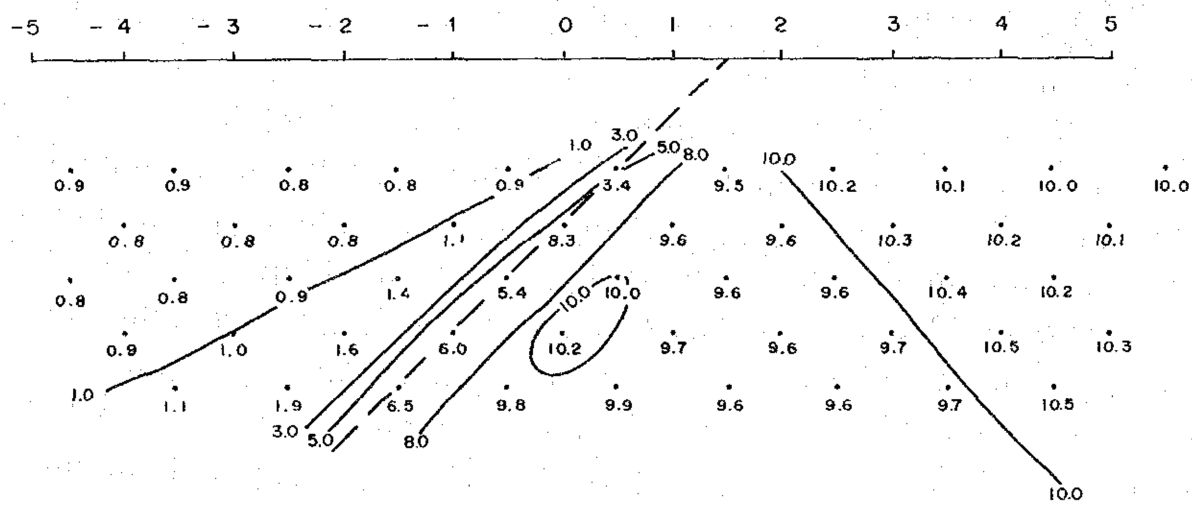
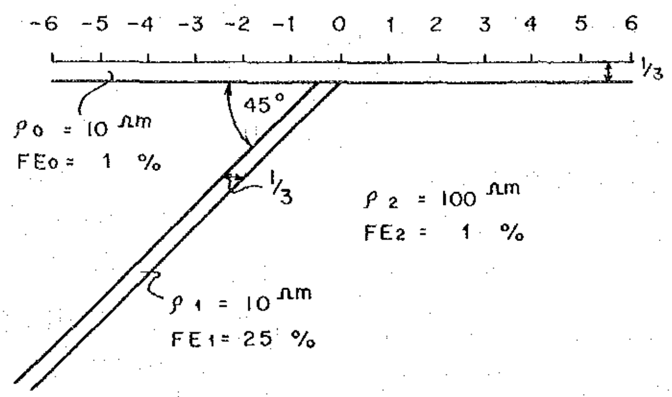
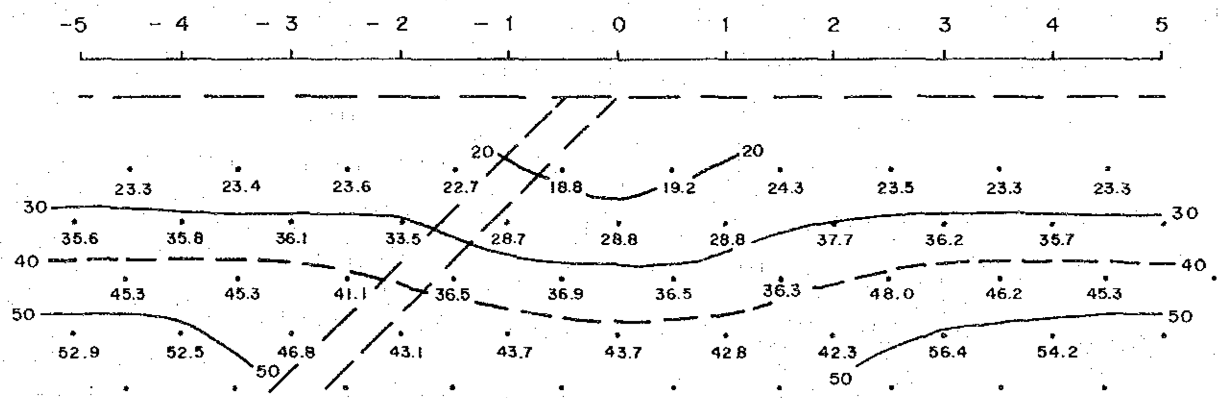


Fig. II - 3 - 8 Calculation by Model (Inclined Slab)



Apparent Resistivity of Dipole - Dipole Coupling



Apparent Percent Freq. Effect of Dipole - Dipole Coupling

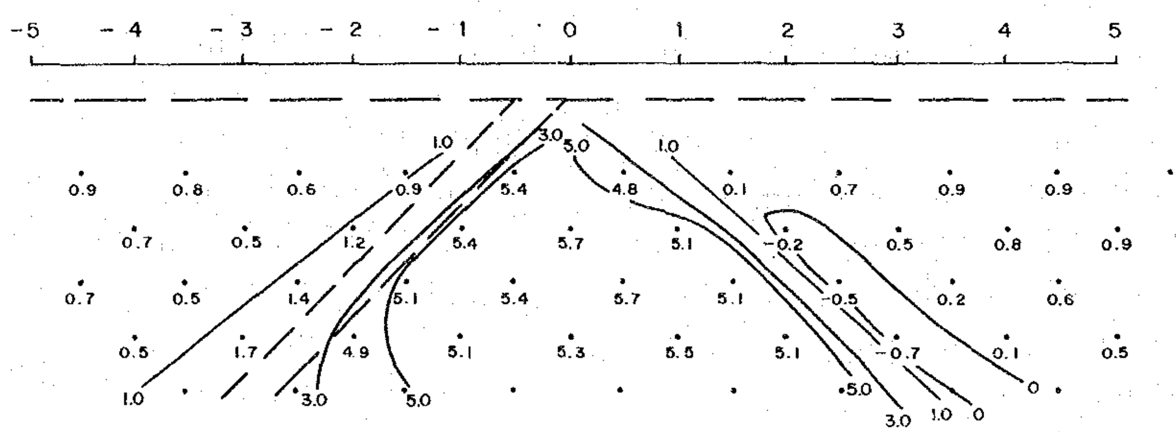
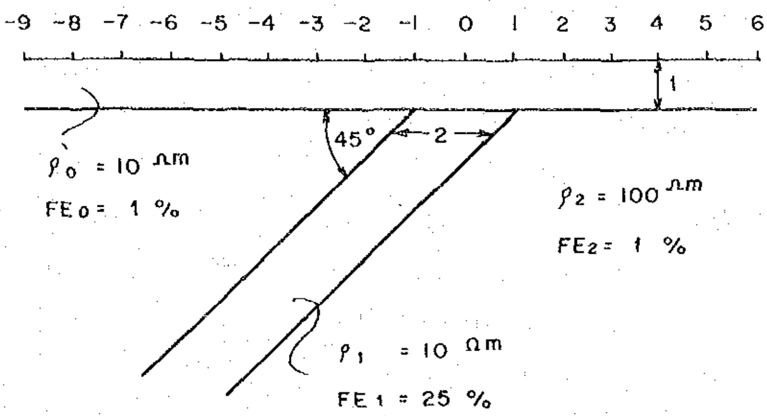
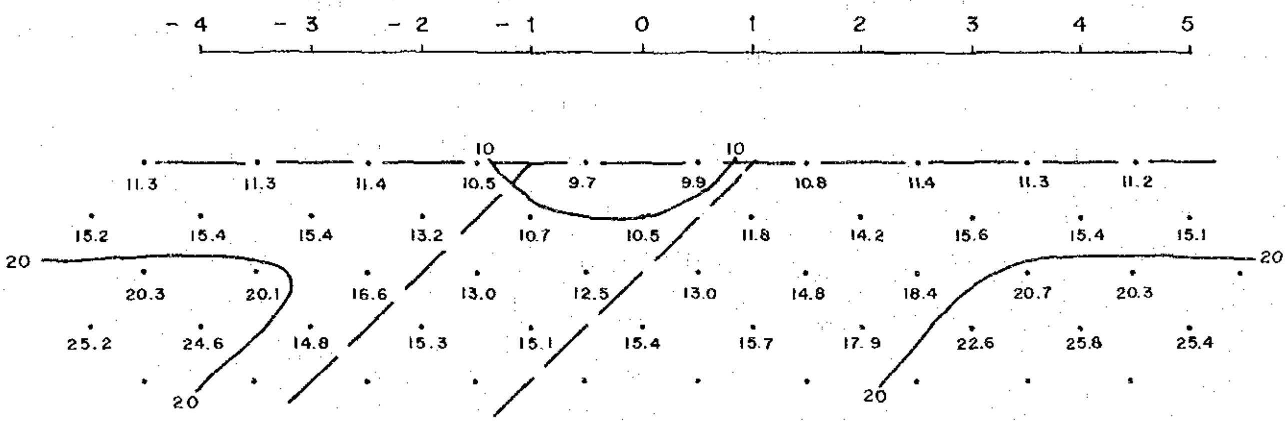


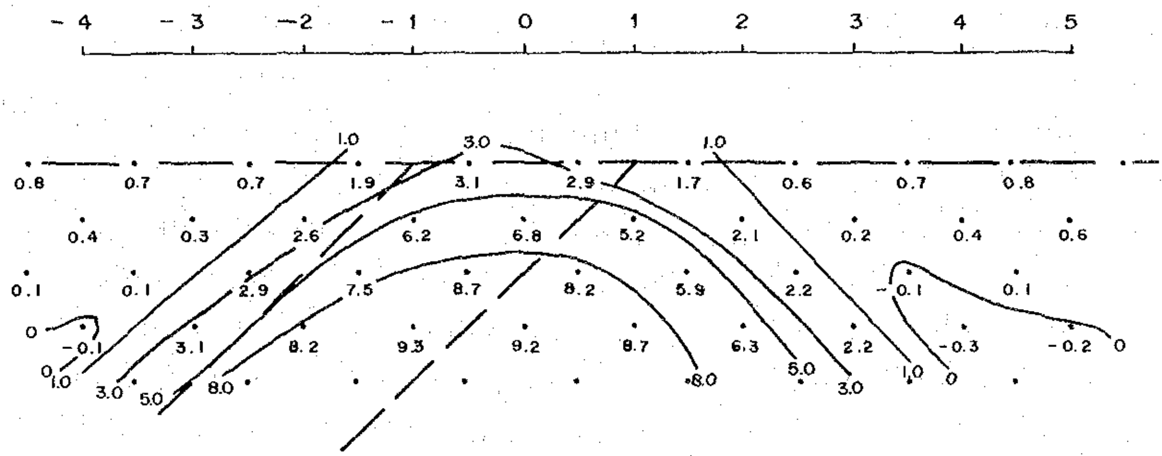
Fig. II - 3 - 9. Calculation by Model (Inclined Slab)



Apparent Resistivity of Dipole - Dipole Coupling



Apparent Percent Freq. Effect of Dipole - Dipole Coupling



Chapter 4 Results of IP Survey

4-1 J Area: Talat-n-Sous

4-1-1 Distribution of AR

Results of IP survey were plotted on profiles along survey lines, and plan maps of AR were compiled from the profiles; these drawings are attached as Plates from II-3-1 to II-3-17 and Plates from II-4-1 to II-4-9. Distribution of AR has shown a wide range of variation from 2 Ω -m at minimum to 30,000 Ω -m at maximum. For discussing distribution, the data of AR have been roughly divided into 4 classes; those above 1,000 Ω -m has been classified as high AR, those between 200 and 1,000 Ω -m as intermediate, those between 200 and 100 Ω -m as low AR, and those less than 100 Ω -m as ultra low AR. Followings are general tendencies in AR distribution perceived from the profiles and plans:

(1) Distribution of high AR more than 1,000 Ω -m corresponds to the distribution of dolomite and rhyolitic tuff on the surface.

(2) Distribution of low AR less than 200 Ω -m corresponds to that of sandstone and siltstone.

(3) No distinct correlation can be made with the surface geology in the distribution of intermediate AR between 200 and 100 Ω -m.

Characteristics shown by each profile along each survey line are:

(1) Along the survey lines from B to E, high AR zones were detected at northern and southern ends of the lines, and those of intermediate and low ARs were in the central parts of the lines. Among the zones of high AR, the one detected on the northern ends of the lines is distributed in the north from around the stations of 20 and 21 on each line, and, moreover, along F - J lines, the high AR is found to be shifted to the north, which is in accordance with dolomite distribution shifted to the north.

(2) The high AR appeared in the south of survey lines B, C, and D has been detected in the south from around stations of 12 and 13. Distribution of this high AR comes up shallower to the surface from survey line B to that of D, while intermediate AR is developed in the deep. Distribution of this high AR

is limited only in a part of the ground surface on line E. In the east from survey line F, distribution of this high AR disappears, which is in accordance to the dolomite shifted away from the survey lines.

(3) Near the middle of the survey lines from B to D, intermediate AR has been detected, and low ARs on both sides of the intermediate. The low AR in the south side occupies nearly between stations 13 and 16, while the southern one occupies nearly between stations 18 and 21. An ultra low AR of less than 100Ω-m has been detected nearly between stations 18 and 21 in the northern low AR except along survey line C. Distribution of southern low AR is widened between stations 9 and 13 on survey line E. Distribtuion of these intermediate AR and low AR changes the pattern towards east as from survey line F to G, S, and H. In other words, the low ARs are dispersed in the distribution of intermediate AR along survey line F, while along survey lines from G to H, the low ARs have been detected rather collectively either in the shallow or deep zone.

(4) A high AR of more than 1,000Ω-m has been detected nearly between stations 11 and 17 along survey line I, which appears in the shallow zone from the surface. Its distribution is widened between stations 10 and 19 on Q line as well as reaches deeper. But it is dispersed in the deep zone on survey line K. It is collective in the deep zone nearly between stations 8 and 12 on L line. On survey lines M and N, its pattern of distribution starts from the surface nearly between stations 6 and 8 and reaches to the deeper zone.

(5) In the south side of the high AR stated in the last paragraph (4), intermediate and low ARs have been detected intermixed; in the south from nearby station 8 on survey lines Q and J, and in the south from nearby station 6 on survey lines K, L, and M. An ultra low AR less than 100Ω-m has been detected in the low AR zone on survey lines M and N.

4-1-2 Distribution of FE

FE values in this district vary from less than 1 % to more than 9 %. They have been roughly divided into 4 classes; those less than 2 % have been classified as background, those between 2 and 3 % as weak anomaly, those between 3 and 5 % as intermediate anomaly, and those above 5 % as strong anomaly.

(1) Weak and intermediate anomalies have been detected in the deeper zone nearly below the center of survey lines from B to F. Depth of the anomalies increases from survey line B eastwards to the line F. Strong anomaly more than 5 % is contained in the anomaly along survey lines B and C. Weak anomaly of about 2 % has been detected in the deeper zone nearly below stations from 9 to 11 on survey line D, which has been found inclined to the south.

(2) Along survey lines G, S, and H, anomalies from weak to strong have been detected all over; that is, in shallow part nearly below stations 12 - 17 on survey line G, in shallow part nearly below stations 11 - 22 on survey line S, and both in shallow and deep parts nearly below stations 5 - 23 on survey line H. Among the anomalies detected on all the survey lines, line H has indicated most strong values of anomaly.

(3) FE anomalies have been detected in the middle and in the southern end of survey line I. The central anomaly is smaller than that of lines G, S, and H, and is inclined to the south in the shallow part nearly below stations 20 - 21 and in the deeper part nearly below stations 17 - 19. The anomaly detected on the southern end is an intermediate anomaly of more than 3 %, which spreads from the shallow part nearly below stations 6 - 7 to the deeper part nearly below stations 3 - 8 and contains strong anomaly of more than 5 %.

(4) On survey lines Q, J, K, L, M and N, anomaly has been detected continuously, which has similar pattern as that detected on the southern end of survey line I. On J line, weak anomaly about 2 % predominates, but on survey lines M and N, strong anomaly more than 5 % is distributed from nearby stations 4 - 5 to the deeper zone, being inclined towards north. A weak anomaly has been detected on line Q in the deeper part nearly below stations 20 - 21.

(5) Concentrated FE values of about 1 %, though below background, has been detected in the shallow part nearly below stations 27 - 29 in the northern part of survey lines L, M, and N.

(6) Distribution of FE anomalies along survey lines P and X have been detected by east-westerly survey lines and correspond to the already detected