CONCLUSION AND RECOMMENDATION FOR THE THIRD PHASE SURVRY PROGRAM

CHAPTER 1 CONCLUSION

The purpose of the second phase survey in the Haute Atlas Occidental Area of the Kingdom of Morocco was to extract highly favorable areas for the emplacement of ore deposits and to confirm the continuity of known ore deposits by the geological reconnaissance survey and geochemical survey (stream sediments) in the southern area in succession of the survey carried out during the first phase, and by the geochemical survey (soils) and the geophysical exploration applying CSAMT Method in Erdouz Sector, in which emplacements of ore deposit were found promising during the first phase, and by the geophysical exploration applying SIP Method and drilling operations in Azegour Sector.

The new informations and the conclusion obtained from the results of the second phase investigation are as follows:

1-1 Southern Area

This area is overlain by the Pre-Cambrian Group, the Paleozoic Groups, the Mesozoic Groups and the Cenozoic Groups, and associated with the intrusive rocks of the Hercynian age. The Pre-Cambrian Group is the basement of this area, and is distributed in the eastern part of the area. This formation is mainly composed of andesite and andesitic pyroclastics, and forms a monoclinic structure that dips westward. The Paleozoic Groups, which is considered to be of Ordovician or Cambrian age, is widely distributed in the whole of the area. In this survey, this Paleozoic Groups was classified into CI Formation, C II Formation, C III Formation, and CIV Formation in ascending order according to differences of constituent rocks and geological structure.

The CI Formation is composed of the alternation of dolomite, siltstone and andesites, and is distributed in the eastern part of the area. This formation is characterized by the monoclinic structure that dips about 30° westward, and by the weak metamorphism. The C II Formation is mainly distributed in the central southern part of the area that trends northeast, is composed of psammitic schist, pelitic schist, and thin limestone, and is characterized by the monoclinic structure that dips about 60° northwestward. The C III Formation is distributed from northwestern part to southwestern part of the area, and is composed of limestone, psammitic schist, pelitic schist, calcareous schist, and green schist. This formation corresponds to the limestone predominant formation described in the report of the first phase survey. This formation is characterized by the anticlinorium structure having the northeast trending axis. The CIV Formation is widely distributed in the central part of this area, is composed mainly of thick layer of pelitic schist, and is characterized by the folded structure of which axis trend northeast. Judging from these facts, it is considered that this Paleozoic Groups is accumilated by the geosynclinic sediments under the environments repeating transgression and regression accompanied with volcanic activities during initial and middle periods of Paleozoic age. Furthermore, from the facts that the metamorphism becomes stronger and developments of folding structures become more remarkable in assending order in this area.

It is considered that the upper formation is undergone the stronger lateral pressure than the lower formation, which caused by relative subsidence in the central part of the sedimentary basin during the Hercynian orogenic movement period in the latest Paleozoic age.

Intrusive rocks of Hercynian age are composed of granite stocks represented by Tichika Granites in further western area of the southwestern part of this area, and of granites and porphyrites dykes. All of those rocks are characterized by the existence of alkali feldspar and their intrusion forms are inharmonious to the folded structures of the Paleozoic Groups. Especially, the skarn ore deposits replacing limestone are observed beside the strong thermal metamorphysm observed in the circumference of the Tichika Granite. These facts suggest that these intrusive rocks were intruded in the end of Hercynian orogenic movement, especially after the completion of the folded structures of the Paleozoic Groups.

The Mesozoic Groups are composed of Triassic system and Cretaceous system. The Triassic system consists of red sandstone and conglomerate, and is distributed northeastward in the central part of the area. This system unconformably covers up on the peneplane of the Paleozoic Groups at its northwestern margine. The Cretaceous system is composed of red sandstone and dolomite, and is distributed in the southern edge of the area, showing the slender form placed between the east-west faults. Both of the system show the monoclinic structure dips less than 30° southward. These facts indicate that the Paleozoic Groups including intrusive rocks was formed the peneplane before the sedimentation of Triassic system, and then, transgressions and regression repeatedly occurred during the Mesozoic age, furthermore, fault-block movements and the epeirogenic movements took place during the Alpine orogenic movement period.

It is considered that faults in this area were formed during the folding period of Paleozoic Groups of Hercynian age, and during the fault-block and epeirogenic movements period of Alpine orogenic movement. Especially, it is considered that high mountainous topographical structures of nearly present conditions were formed by the upheavals of Haut Atlas mountains at the end of the Alpine orogenic movement.

Mineralizations in this area are composed of ore deposits of copper, lead, zinc, molybdenum, tungsten, iron, barite, etc. Although almost all of them are vein-type ore deposits, some of them are skarn-type ore deposits and disseminated ore deposits. The mineralization in this area classified by the constituent minerals and the host rocks are characterized as follows:

(1) Vein-type copper-quartz deposits and barite deposits in Pre-Cambrian Group (eastern area)

(2) Vein-type copper-lead-zinc-quartz deposits in Paleozoic CI Formation (eastern and southeastern areas)

(3) Stockwork disseminated copper deposit in dolomite in Paleozoic CI Formation (northeastern area)

(4) Vein-type copper-quartz deposits in Paleozoic CIII Formation (western area)

(5) Skarn-type copper-tungsten-iron deposits replacing limestone in CIII Formation in the circumference of Tichika Granite (southwestern area)

(6) Vein-type molybdenum-quartz deposits in granite (southwestern area)

Thus, all of the mineralizations in this area are limited in the formations and intrusive rocks of Pre-Mesozoic formations, and none of them are observed in Post-Paleozoic formation. In addition, since the skarn-type ore deposits are formed in the circumference of granite of the Hercynian age, and most of the mineralizations is accompanied with the micro-granite and porphyrite dykes seems to of the same age, it is assumed that these mineralizations in the area occurred during the Hercynian orogenic movement at the end of Paleozoic.

According to the results of geochemical survey by the samples of stream sediments, it was revealed that strong anomalous zones of copper, lead, and zinc were distributed in northeastern, southeastern, northwestern, and southwestern areas, and they almost corresponded to the locations of the above-mentioned mineralization. Strong anomalous zones of molybdenum were found in southwestern area (Agadir area) and southern part of the central area, and the strong anomalous zones of tungsten were detected in southwestern area (Agadir area). These facts, such results of geochemical survey corresponded to the locations of known indication of mineralization, show that the geochemical survey method applied in this phase were effective to detect the mineralization. It is, therefore, necessary to carry out detailed surface survey on the areas where no mineral indications are recognized despite of the strong anomalous zone.

Existences of copper, lead, and zinc ore deposits and barite ore deposits, such as the Gundaha mine which was mined in full scale in the past and l'Ounein mine which small scaled explorations are being made, etc., are known in this area. According to the results of this survey, strong mineralizations were observed in three areas except the above-mentioned ore deposits. Further explorations should be carried out in following three areas as promising mineralized areas in future.

(1) Agadir Area in southwestern part: This area is at the eastern margine of Tachika Granite. Three ore deposits, Agadir deposit and Maouass deposit, which are the skarn-type ore deposits of copper, tungsten, and iron formed by replacing limestone of the C III Formation, and Ikissane deposit, which is molybdenum quartz veins in granite, are recognized in this area. Its mineralized area reaches more than 2 km x 2 km.

o Agadir Deposit is in limestone layer of which width is about 100 m and of which strike is running from south to north. Skarnized zone, mainly consists of garnet of 10 m - 30 m width, is formed at the hanging and foot walls of limestone and at the contact zone of limestone with granite, and it is confirmed the continuity more than 500 m in length along the limestone layer. Ore minerals are composed of pyrrohtite, chalcopyrite, pyrite, scheelite, etc. and their grades were obtained at Cu: 0.06% - 1.60%, and W: 0.01% - 0.41% according to the analysis results on the samples taken from the outcrops.

o Maouass Deposit is skarn-type ore deposit of garnet replaced limestone of about 5 m width in conglomerate of the P III Formation. The outcrop was confirmed about 40 m length there. It is said that similar outcrop exists at about 500 m south of this outcrop. Ore minerals are composed of chalcopyrite, pyrite, pyrrohtite, hematite, etc., and the outcrop is undergone the strong oxidation. The analysis results by the samples taken from the outcrop shows grades at Cu: 0.02% - 0.70%, Mo: 0.01%, and W: 0.01% - 0.02%. Improvements of grades are expected in deeper zone since this deposit is severely oxidized.

o Ikissan Deposit is composed of 5 - 7 parallel veins that trends west-northwest in granite. The veins are about 30 cm width, and they are traceable from several meters to several hundreds meters. Ore minerals are composed of molybdenite, chalcopyrite, pyrite, etc. Grades of samples were obtained at Cu: 0.01% - 0.07%, and Mo: 0.03% - 0.46%.

(2) Iguidi Area in northeastern part: This area is in the circumference of Iguidi village in the northeastern part of the surveyed area. This area mainly consisted of the CI Formation. There is a fault trending northeast in the west of the deposit, and exposure of andesite of Pre-Cambrian is observed at the west side of the fault. The dolomite bed of the CI Formation, which is the host rock of the deposit, is running toward ENE-WSW and dips about 40° northward, and its thickness is about 15 m. The mineralization accompanied with stockwork quartz veinlets are observed along the hanging wall, about 5 meters thick, of the dolomite layer. Horizontal extension of more than 500 m and vertical extension of more than 50 m of the deposit were confirmed, and the mineralized boulders were also observed about 2 km further of this ore deposit. Ore minerals of this deposit consists of chalocopyrite, pyrite, malachite, azurite, etc. Grades examined on the samples taken from the stock pile near the pit were obtained at Cu: 0.82% - 3.80%.

(3) Taddart Area in northwestern part: This area is near the Taddart village in the northwestern part of the survey area. The deposit consists of copper-quartz veins are developed in conglomerate of the C III Formation. Strikes of those veins are shown 3 directions, north-south, northeast-southwest and west-northwest-east-southeast. Although their widths vary from 150 cm maximum to 10 cm minimum, they are about 30 cm in general. Ore minerals are mainly composed of chalcopyrite, pyrite and malachite. Grades on the samples taken at the outcrop were obtained at Cu: 0.15% - 5.20%. Although the mineralized area confirmed during this survey was over 60 m x 60 m, continuity of the mineralization toward north is possible because the grade of the stock pile in the old mine in about 1 km north of this area was obtained at Cu: 8.02%.

As mentioned above, geology and geological structure of southern area were clarified by the survey work in this phase, and the geological structure and igneous rocks, controlled and retated the mineralization, were elucidated as well. Especially, it is assumable that the above three areas are promised the strong posibilities of favorable emplacement of mineralization. However, it can not necessarily be said that tracing of continuities of mineral deposits and confirmations of details of mineralizations and locations of ore shoots were made satisfactorily during this survey. In this connection, it is desirable that understandings of actual conditions of mineral deposits by carrying out detailed geological surveys, geochemical survey by the rock samples and soil samples, magnetic prospecting, electrical prospecting such as IP method in the further survey.

1-2 Erdouz Sector

This sector is composed of limestone, pelitic schist, psammitic schist, calcareous schist, and green schist of the C III Formation in which tight foldings are developed. Geological structure of this area is characterized by the northeast trending anticlinal structure observed in the central part, by the fault-blocked structure caused by the northeast trending faults which are represented by Erdouz fault, and by the faults trends from south to north and from east to west, and by the intrusion of micro granite of same direction. Especially, it is noteworthy that each block formed by the block movements are different each other in the constituent rocks and in the geological structure.

It was clarified by the survey made in the first phase that mineralizations in this area were composed of vein-type deposits of copper, lead, and zinc. Moderately concentrated mineralizations were observed in the circumferential aras of the north deposit in the northern slope and south deposit in the southern slope, and weak mineralizations were observed at the extension of those deposits and at the southeastern part of the area. The north deposit is located at the folding axis of the limestone and its mineralization extended over the area of 100 m x 100 m. The deposit is consists of several northeast trending veins. The south deposit is in a limestone layer running from south to north in which tight foldings are observed. Its mineralization extended over the area of 150 m x 200 m, and mineral deposit is emplaced in the faults or along the bedding plane of limestone.

(1) Geochemical survey by the soil samples in this phase were carried out in the area including the above two ore deposits. The soil samples taken in this phase on the grid-patterned points and the samples taken in the circumferential areas of those deposits in the first phase, were tested for studying possible continuity of mineralizations between the two ore deposits.

According to the results of geochemical survey, it was revealed that all of the three elements, Cu, Pb, and Zn, indicated clear correlations each other, and showed similar distribution. That is to say, strong anomalous zones of those elements were concentrated in the areas of north deposit and south deposit as if suggesting the strikes of the veins. Weak anomalous zones were distributed in the outer zone of strong anomalous zones as if indicating extensions of those ore deposits. At the same time, very slight mineralizations were detected by this survey. However, some of weak anomalous zones of Cu indicated the micro granite dykes and the faults. Distribution forms of anomalous zones including weak anomalous zones corresponded to the distribution of folding axis of limestone in the north area, and to the distribution of limestone layers cut by northeast trending faults in the south area, and no continuity of anomalous zone connecting these two deposits was observed.

Therefore, it is considered that north deposit and south deposit are independent each other being in the different host rocks of the limestones of different horizons, and there is little possibility that these two deposits are continued each other taking the results of geochemical survey into consideration.

(2) As geophysical explorations, CSAMT method were carried out in the northern half of this area including the north deposit. According to the results of the survey, this area was divided into 3 areas, east side area and west side area of Erdouz fault and circumference area of the north deposit, by the characteristics of resistivity structures. The characteristics of resistivity structure of these areas are as follows:

o West side of Erdouz Fault: Resistivity vs frequency curves were analysed as 4 layer structure at almost all of the observation stations. The first layer is to the depth of about 1,000 m from the ground surface with high resistivities of around 10 KΩm. The second layer is of about 100 m thick existing beneath the first layer, and with extremely low resistivities (assumed to be 20 Ωm). The third layer is of about 2,000 m thick existing beneath the second layer, and with comparatively high resistivities (assumed to be 800 Ωm). The fourth layer is the bottom in this area from which low resistivities (assumed to be 10 Ωm) were obtained.

o East side of Erdouz Fault: Resistivity vs frequency curves were analyzed as 3 layer structure at almost all of the observation stations. The first layer occupies to the depth of 300 m - 1,000 m beneath the ground surface, and is with resistivities higher than 1 KΩm - 10 KΩm. The second layer is of several hundreds meters thick existing beneath the first layer, and with resistivities of 1 - 4 KΩm. The third layer is the bottom in this area, and with resistivities of several hundreds Ωm.

o Circumference of North Deposit: Resistivity vs frequency curves were analysed as 2 layers structure at all of the observation points in this area (about 1 kim wide in NE-SW direction, and several hundreds meters long in NW-SE direction). Thickness of the first layer is 200 m - 400 m, and resistivities are obtained in the range of 200 Ωm - 300 Ωm. The second layer is beneath the first layer, and resistivities are about 15 Ωm.

These differences of resistivity structures, especially big difference between east side and west side of Erdouz fault, should be due to difference of constituent rocks in the deep underground of respective areas. It is considered that these facts should support the existence of block movement caused by the Erdouz fault. Furthermore, circumference of north deposit was grasped as large scaled low resistivity zone. However, it is better to understand such phenomena as the evidence of the axis area of folding or complicated folding structures of limestone and calcareous schist which easily became as the host rock of the deposit, rather than relating the existence of such low resistivity zone to the mineral deposits and altered zones. It should be noted that no tendency of the southward continuity of such low resistivity zone, existence of the favorable host rocks of ore deposit emplacement in other words, to suggest the continuity from the north ore deposit to south ore deposit passing under Mt. Erdouz was not recognized by the survey work.

(3) From the results of above geochemical survey and geophysical explorations applying CSAMT method, no positive data indicating the continuity between the north ore deposit and the south ore deposit was available, and strong possibility is that independent ore deposits were formed in the north ore deposit and in the south ore deposit respectively through different mineralizations. It is, therefore, desired that future explorations should be made toward lower layers of respective deposits separately.

1-3 Azegour Sector

This sector is composed of schists of the C III Formation distributed from south to north inserting limestone layer of 80 m - 150 m thick, and the granite dikes of same direction. Intrusion of granite is observed in the west of the area. Geological structure of this area is characterized by the monoclynic structure which strikes from south to north and dip 40° - 70° eastward, and by the east-northeast trending faults. The mineralization is this area are copper, molybdenum, and tungsten ore deposits in Azegour mine, and disseminated molybdenum ore deposit in the garnet skarn along the above limestone layer running northward from the Azegour mine. It is considered that the above intrusive granite brought the mineralization.

In this phase, as SIP method, as geophysical method and drillings (by B.R.P.M.) were carried out in the circumferential area of Tizgui village which was about 3.5 km north of Azegour mine, in which comparative strong mobibdenum mineralization was observed, to examined the continuity of mineralization at the deep zone and existence of enriched ore deposit.

(1) According to the geophysical exploration applying SIP method (on 4 traverse lines), it was revealed that resistivities of the north-south trending limestone layer, which is the host rocks of the ore deposit, are low and indicating 1/2 to 1/5 (200 Ωm - 300 Ωm) of those obtainable in other rock layers. However, the resistivities in the east side of several granite dykes in the eastern part of the area are high over 1 KΩm.

The formation having the IP effect widely distributed as a whole in this area. Especially, remarkable IP effect is observed at the west side of the above granite veins. This indicates the conformity to the results of geological surveys reporting that slight pyrite dissemination was observed in the formation widely distributed in this area. This suggests that the formation of west side of granite dyke are stronger pyritized than east side, formation.

It is considered that strata of high PFE value, those which indicate high IP effect in other words, should be limestone which is the host rock of the deposits in this area. 1 - 2% higher PFE values than those obtained in the peripheral area are obtained in the distribution area of limestone in this survey area. Especially, high PFE values are obtained in the line A and in the line B (northern part).

Since comparatively high resistivities were obtained in this area (all of the apparent resistivities are higher than 200 Ωm), almost the same tendencies were observed in all phase pseudo sections (especially in those of below 1 Hz) and in PFE pseude sections. Furthermore, it was impossible to obtain characteristic tendency for identifying kinds of minerals by spectral classification in Cole-Cole curve.

According to the results of SIP survey carried out in this area, it is revealed that tracing existence of limestone layers and surveying distribution of mineralization or iron pyrite in this area are possible. However, it is found impossible to clarify locations of skarnized zone and mineralization of molybdenum. Especially, it is still unknown if detailed information regarding mineralization could be obtained by carrying out spectral measurements.

(2) Drillings were carried out by B.R.P.M. at ATE-1 hole and ATE-2 hole on the traverse line A and at ATE-3 hole and ATE-4 hole on the traverse line B of the SIP survey. It was recognized that skarnization and mineralization of molybdenum tended to become stronger downward in the ATE-1 hole and ATE-2 hole. Especially, Mo grade of 0.46% was obtained in ATE-2 hole at between the depth of 143.50 m - 144.10 m (thickness: 0.6 m) at the hanging wall side of skarn zone, and Mo grade of 0.12% was obtained in the same hole at between the depth of 144.10 m - 144.85 m (thickness: 0.75 m). Copper mineralization accompanied with quartz vein indicating Cu grade of 3.50% was recognized in the same hole at between the depth of 217.00 m - 217.60 m (thickness: 0.60 m).

However, such tendency, that skarnization and mineralization of molybdenum became stronger as going downward, was observed neither in ATE-3 hole nor ATE-4 hole beside silicification and pyritiration were observed in the limestone.

(3) As the results of geophysical exploration applying SIP method and

drilling survey, it was revealed that the existence of limestone layers and pyritization is vaguely traceable by the former exploration method.

According to the results of drilling surveys, it was revealed that conditions of mineralization were different each other at the south side and at the north side of the east-northeast trending fault. It tended that skarnization and mineralization of molybdenum became stronger as going downward in the former side, but such tendency was not remarkable in the latter side except the pyritization.

Therefore, the such south side of the north-northeast trending faults are thought as the promising area of the predominant skarnization and the molybdenum mineralization in the depth.

The first attention to be paid on further explorations in this area should be for confirming if such predominance of mineralization exists at the south side of the same fault.

CHAPTER 2 RECOMMENDATION FOR THE THIRD PHASE SURVEY PROGRAM

Based on the conclusion obtained from the results of this phase survey and the consideration on the results, the surveys in the following area are recommended as the third phase investigation program.(Fig. I-10)

(1) Agadir Sector : investigation area 10 km^2
(2.5 km x 4 km)

In this area, the skarn-type copper, tungsten and iron (pyrrhotite) ore deposits and the vein-type molbdenum ore deposits have been emplaced.

It is considered that the area of 2.5 km x 4 km including above ore deposits is the favorable area for the emplacement of ore deposit as the target area of further exploration.

The following methods are desirable for the further exploration.

① Detailed geological survey; geochemical survey (rocks) : to confirm the sizes and grades of the ore deposits, and to estimate the continuity of the ore deposits.

② Geophysical exploration : Execution of the IP method, etc., and the magnet survey to elucide the continuity of the ore deposits to the depth.

(2) Iguidi Sector : investigation area 3 km^2

In this area, the copper stockwork ore deposits have been emplaced.

It is considered that the area of 1 km x 3 km including the Iguidi ore deposit is the favorable area for the emplacement of ore deposit as the target area of further exploration.

The following method are desirable for the further exploration.

① Detailed geological survey, Geochemical survey (rocks) : to confirm the sizes and grades of the ore deposits and to grasp the continuity of the ore deposits.

(3) Taddart Sector : investigation area 3 km^2

In this area, the vein-type copper deposits have been emplaced.

It is considered that the area of 1 km x 3 km including the Taddart ore deposit is the favorable area for the emplacement of the ore deposit as the target area for the further exploration.

The following method are desirable for the further exploration.

① Detailed geological survey, Geochemical survey (rocks) : to confirm the size and grade of the ore deposits and grasp the continuity of the ore deposit.

Besides, in case of the B.R.P.M. execucute continuously the exploration in the Erdouz Sector and in the Azegour Sector, the following enforcement of surveys are recommendable.

o Erdouz Sector : As the results of the survey in this sector, it is considered that the continuity between the north ore deposit and the south ore deposit is rarely possible, and that the ore deposits forms the isolated ore body independently. Therefore, though the lateral disparsion of the ore embeded formation is not expected, the emplacement for ore deposit warranting further exploration remains in their depth.

From the above reasons, the execution of diamond drillings are desirable to grasp the state of each ore deposits in the depth.

o Azegour Sector : As the results of the survey in this sector, though the feeble molybdenum mineralizations have been confirmed, the high grade, large-scaled ore deposits have not been grasped. However, since the molybdenum mineralization at the depth in this sector are presumable the tendency to become stronger at the south side of the east-northeast trending faults, the same geological conditioned area remains still as the favorable area for the emplacement of molybdenum ore deposit. Therefore, the execution of continuous explorations (Diamond drilling) at the south side of the east-northeast trending fault are desirable to confirm the states of the mineralization in the depth as the further exploration.

Fig. I-10 Recommended Area for Third Phase

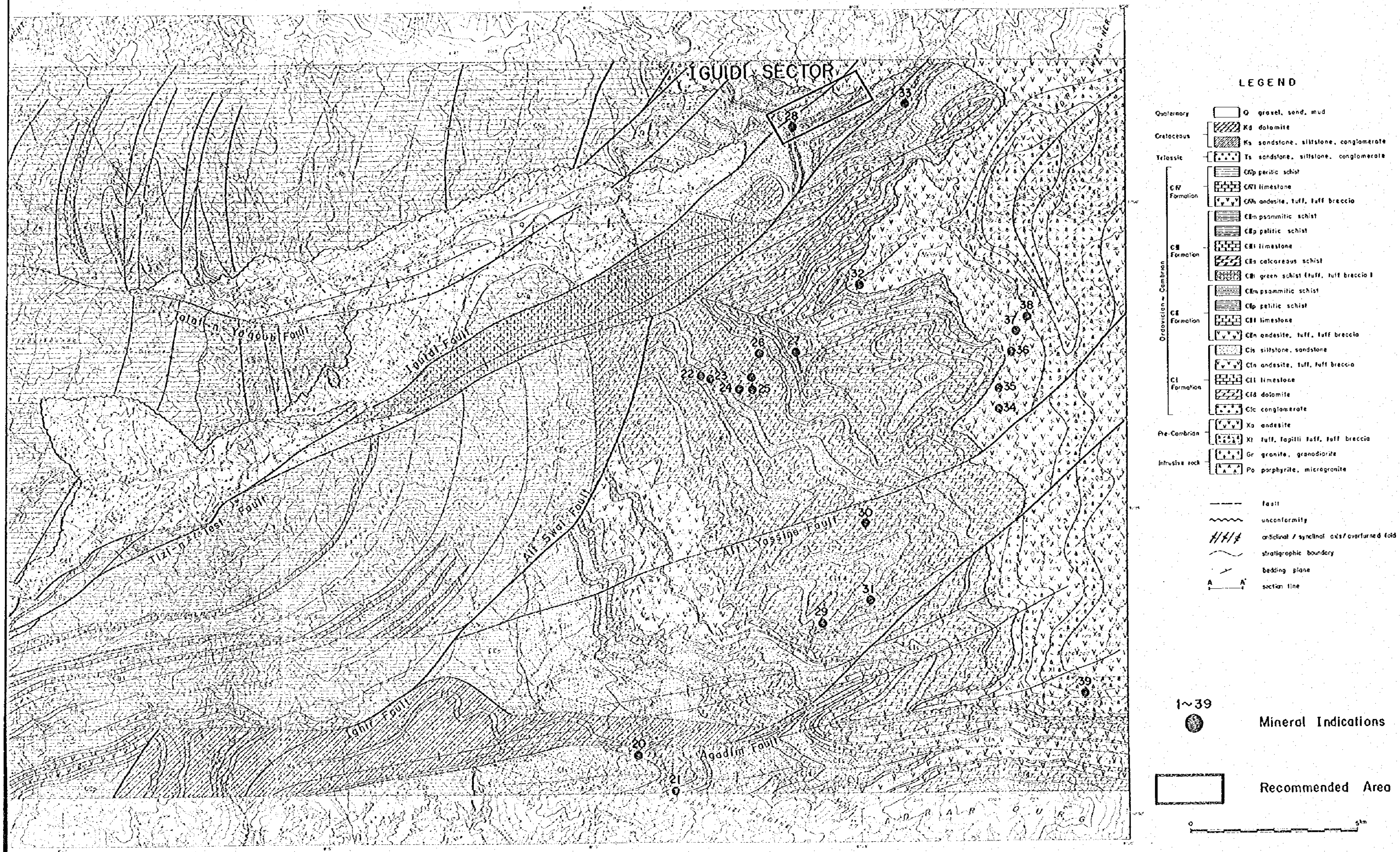


Fig. I-10 Recommended Area for Third Phase

APPENDICES

Table A-1 List of Rock and Ore Samples

No.	Sample No.	Geological unit	Location	Rock and Ore Name	Thin Section	Polished Section	X-ray Analysis	Whole Rock Analysis	Mineral Analysis					
									Cu	Pb	Zn	Ag	Mo	W
1	WR1	Ig (stock)	Ikissane Mine	Granite	O			O						
2	WR2	CⅢm	"	Porphyrite	O									
3	WR3	CⅢl	Agadir Mine	Actinolite garnet skarn	O									
4	WR4	CⅢl	"	Clinopyroxene garnet skarn	O									
5	WR6	PIs	Agdim, NW 1.0 km	Carbonate rock	O									
6	WR8	PⅢ	Ankasdam SE 0.3 km	Lapilli tuff	O			O						
7	WR9	PⅢ	Ankasdam W 1.3 km	Tuff breccia	O									
8	WR13	PⅢ	Taghorghist	Pyroxene andesite	O									
9	WR14	CⅠt	Tijghicht	Calcareous silt-sandstone	O									
10	WR16	PⅢ	Tijghicht NE 2.0 km	Andesite	O			O						
11	WM2	CⅢt	Taddart A Mine	Cu ore					O	O	O	O		
12	WM3	CⅢt	"	"					O	O	O	O		
13	WM4	CⅢt	"	pyrite, galena ore		O			O	O	O	O		
14	WM5	CⅢt	"	Cu ore					O	O	O	O		
15	WM6	CⅢt	"	"					O	O	O	O		
16	WM7	CⅢt	"	"					O	O	O	O		
17	WM8	CⅢt	"	"					O	O	O	O		
18	WM9	CⅢt	"	"					O	O	O	O		
19	WM10	CⅢt	"	"					O	O	O	O		
20	WM11	CⅢt	"	Chalcopyrite, pyrite ore		O	O		O	O	O	O		
21	WM12	CⅢt	Taddart A Mine	Cu ore					O	O	O	O		
22	WM13	CⅢm	Amsfouh SEE 1.8 km	"					O	O	O	O		
23	WM14	CⅢl	Arg, W 1.5 km	Chalcopyrite, pyrite ore					O	O	O	O		
24	WM15	Ig (stock)	Ikissane Mine	Molybdenite, pyrite ore		O	O		O				O	O
25	WM16	Ig (stock)	"	"					O				O	O
26	WM17	Ig (stock)	"	Molybdenite ore		O	O		O				O	O
27	WM18	Ig (stock)	"	"					O				O	O
28	WM19	Ig (stock)	"	"					O				O	O
29	WM20	Ig (stock)	"	"					O				O	O
30	WM21	Ig (stock)	"	Pyrrhotite, molybdenite ore		O			O				O	O
31	WM22	Ig (stock)	"	"		O	O		O				O	O
32	WM23	Ig (stock)	"	Pyrrhotite, Native bismuth ore		O	O							
33	WM24	CⅣp	Zawyat Askar, S 0.3 km	Chalcopyrite, sphalerite ore					O	O	O	O		
34	WM25	CⅢt	Maouass Indication	Pyrite garnet skarn			O		O				O	O
35	WM26	CⅢt	"	Hematite ore			O		O				O	O
36	WM27	CⅢt	"	"		O			O				O	O
37	WM28	CⅢt	"	"			O		O				O	O
38	WM29	CⅢt	"	"					O				O	O
39	WM30	CⅢt	"	"					O				O	O
40	WM31	CⅢt	"	Hematite, magnetite ore		O	O		O				O	O

No.	Sample No.	Geological Unit	Location	Rock and Ore Name	Thin Section	Polished Section	X-ray Analysis	Whole Rock Analysis	Mineral Analysis					
									Cu	Pb	Zn	Ag	Mo	W
41	WM32	CIIIl	Agadir Mine	Garnet skarn			O		O				O	O
42	WM33	CIIIl	"	Pyrrhotite chalcopyrite ore		O	O		O				O	O
43	WM34	CIIIl	"	"					O				O	O
44	WM35	CIIIt	"	Tetradymite, Native bismuth ore		O	O		O				O	O
45	WM62	CId	Tawrirt SE 2.0 km	Bornite, chalcocite ore		O	O		O	O	O	O		
46	WM63	CId	Tawrirt S 0.6 km	Malachite ore		O	O		O	O	O	O		
47	SR8	Ig (stock)	Tamsoult, SE 0.7 km	Quartzdiorite	O			O						
48	SR11	CIIIm	Outakhri, S 0.5 km	Siltstone	O									
49	SR13	CIn'	Ait Yassine	Pyroxene andesite	O									
50	SR18	Ig (stock)	Tawrirt, W 2.5 km	Granodiorite	O			O						
51	SR37	CIn	Taksucht, SEE 3.5 km	Pyroxene andesite	O			O						
52	SR45	Ig (dyke)	Tizirt, NWW 2.3 km	Granite porphyry	O			O						
53	SR46	Ig (dyke)	Tizirt, NWW 2.0 km	Hornblende porphyrite	O			O						
54	SM1	CIIIt	Taddart, NE 2.5 km	Pyrite ore			O		O	O	O	O		
55	SM2	CIIIt	Maouass Indication	Magnetite, hematite ore		O	O		O				O	O
56	SM3	CIIIt	"	Hematite ore					O				O	O
57	SM4	CIIIt	"	"					O				O	O
58	SM5	Ig (stock)	Tamsoult, SE 0.7 km	Arsenopyrite ore		O	O		O	O	O	O		
59	SM9	CId	Achdirt Mine	Azurite ore		O	O		O	O	O	O		
60	SM14	CId	Iguidi Mine	Chalcopyrite, hematite ore		O			O	O	O	O		
61	SM15	CId	Iguidi Mine	Chalcopyrite, hematite ore		O	O		O	O	O	O		
62	NR6	CId	Gundafa Mine	Dolomite	O									
63	NR9	CIIIl	Igherm, SSE 0.5 km	Limestone	O									
64	NR11	Ig (dyke)	Arg, SW 2.5 km	Andesitic porphyrite	O			O						
65	NR22	PIII	Assakka NNW 1.5 km	Andesite	O			O						
66	NR30	Ig (dyke)	Gundafa Mine	Quartz porphyrite	O			O						
67	NM3	CIIIt	Tizi-n-Oumzro	Cu ore					O	O	O	O		
68	NM5	CId	Gundafa Mine	Cu, Pb, Zn ore					O	O	O	O		
69	NM6	CId	"	"					O	O	O	O		
70	NM7	CId	"	"					O	O	O	O		
71	NM8	CId	"	"					O	O	O	O		
72	NM9	CId	"	Galena covellite ore		O	O		O				O	O
73	NM11	CIIIl	Igherm, SSE 1.7 km	Cu ore					O	O	O	O		
74	NM12	CIIIl	Igherm, S 1.6 km	"					O	O	O	O		
75	NM13	CIIIm	Tirmouza W 0.5 km	"					O	O	O	O		
76	NM14	CIIIm	Tirmouza NW 1.6 km	"					O	O	O	O		
77	NM15	CIIIm	Analghi N 2.5 km	"					O	O	O	O		
78	NM17	CIIIm	Analghi N 2.0 km	"					O	O	O	O		
79	NM18	CIVp	Tirmouza NE 0.5 km	"					O	O	O	O		
80	NM20	CId	Imi-n-Tislit, NE 0.1 km	"					O	O	O	O		

No.	Sample No.	Geological Unit	Location	Rock and Ore Name	Thin Section	Polished Section	X-ray Analysis	Whole Rock Analysis	Mineral Analysis					
									Cu	Pb	Zn	Ag	Mo	W
81	NM22	CId	Agadirane, NW 2.0 km	Chalcopyrite ore		O	O							
82	NM30	PIII	Anammer SSE 0.5 km	Cu ore					O	O	O	O		
83	NM31	PIII	Anammer S 1.0 km	"					O	O	O	O		
84	NM32	PIII	Anammer S 2.0 km	"					O	O	O	O		
85	NM33	PIII	Anammer S 3.0 km	"					O	O	O	O		
86	NM34	PIII	Anammer S 3.5 km	"					O	O	O	O		
87	NM36	CIII	Igherm SE 1.7 km	Galena, sphalerite ore		O								
88	MM1	CIII	Agadir Mine	Skarn ore					O				O	O
89	MM2	CIII	"	"					O				O	O
90	MM3	CIII	"	"					O				O	O
91	MM4	CIII	"	"					O				O	O
92	MM5	CIII	"	"					O				O	O
93	MM6	CIII	"	"					O				O	O
94	MM7	CIII	"	"					O				O	O
95	MM8	CIII	"	"					O				O	O

Index

Palaeozoic

Formation	Rock Name		
CI	p ...... Pelitic schist	PIII	...... Pre-Cambrian III
CII	m ...... Psammitic schist		
CIII	l ...... Limestone		
CIV	t ...... Green schist	Ig	...... Igneous rock
	d ...... Dolomite		
	n ...... Andesite		

Table A-2-1 Microscopic Observations (Thin Section)

No.	Sample No.	Location	Rock Name	Texture	Primary Minerals																	Secondary Minerals																
																	Others																	Opaque minerals				
					Quartz	Plagioclase	K-feldspar	Biotite	Hornblende, Amphibole	Clinopyroxene	Orthopyroxene	Sphene	Zircon	Sericite	Clay minerals	Rock fragments	Apatite	Calcite	Dolomite	Carbonaceous matter	Tourmaline	Quartz	Carbonate	Calcite	Clinopyroxene	Epidote	Chlorite	Garnet	Sericite	Biotite	Amphibole	TiO_2 minerals	Albite	Opaque minerals	Hematite	Magnetite	Chalcopyrite, Pyrite	Others Nontronite
1	WR-1	Ikissane Mine	Granite	Equigranular Holocrystalline	◎	◎	◎	△					•				•										△		△			•		•				
2	WR-2	Ikissane Mine	Porphyrite	Porphyritic		◎						△																	△	◎	◎			△				
3	WR-3	Agadir Mine	Actinolite garnet skarn																			○		◎			•	○			○						•	•
4	WR-4	Agadir Mine	Clinopyroxene garnet skarn																			△		○	◎	•		◎			•			•				•
5	WR-6	Agdim NW 1.0 km	Carbonate rock	Clastic	△	•		•						•	○								◎															
6	WR-8	Ankasdam SE 0.3 km	Lapilli tuff	Pyroclastic		△							•		△	△											△		•				△					
7	WR-9	Ankasdam W 1.3 km	Tuff breccia	Pyroclastic	•	△										◎						△	○				○		○			•						
8	WR-13	Taghorghist	Pyroxene andesite	Porphyritic		◎				△																•	△								○			
9	WR-14	Tijghicht	Calcareous silt-sandstone	Clastic	◎	◎	○?							△	△					•				◎					•?									
10	WR-16	Tijghicht NE 2.0 km	Andesite	Porphyritic		◎											•					◎		△			◎					△						
11	SR-8	Tamsoult SE 0.7 km	Quartz diorite	Holocrystalline	△	◎			△	○														•		△	◎		○		○							
12	SR-11	Outakhri S 0.5 km	Siltstone	Clastic	◎	○	•?							○	◎												◎					△						
13	SR-13	Ait Yasane	Pyroxene andesite	Porphyritic		◎				○											•						◎					△				△		
14	SR-18	Tawrirt W 2.5 km	Granodiorite	Granular Holocrystalline	○	◎	○	○	○			•					•									•			△					•				
15	SR-37	Takaucht SEE 3.5 km	Pyroxene andesite	Porphyritic		◎																△	△				○		△			•			◎			
16	SR-45	Tizirt NWW 2.3 km	Granite porphyry	Porphyritic Microgranitic	◎	◎	◎		△	•		•												•		•			△		•							
17	SR-46	Tizirt NWW 2.0 km	Hornblend porphyrite	Porphyritic		◎			△													○		•						○	○				•			
18	NR-6	Gundafa Mine	Dolomite		•										•				◎			•		•														
19	NR-9	Igherm SSE 0.5 km	Limestone		△									△				◎																•				
20	NR-11	Arg SW 2.5 km	Andesitic porphyrite	Porphyritic		◎		△	△								•					△		•			△					△				△		
21	NR-22	Assaka NNW 1.5 km	Andesite	Porphyritic		◎																○		○		•	◎		△			△					•	
22	NR-30	Gundafa Mine	Quartz porphyrite	Porphyritic Micrographic	○	◎											•															△						

◎ Abundant ○ Common △ Little • Rare

(1) WR-1

Weakly altered granular granite.
The rock is composed mainly of quartz, plagioclase, kali feldspar and small amount of biotite. Apatite and zircon are present in accessory amounts.
Plagioclase, probably oligoclase with albite twinning, has weakly been replaced by flaky ∿ columnar muscovite.
Kali feldspar occurs as microcline with grating structure and as orthoclase with perthite texture. No alteration is seen in this feldspar.
Biotite is replaced mostly by chlorite with small amount of opaque minerals, some showing pseudo-morphous form.

(2) WR-2

Dark gray andesitic porphyrite, altered at hydro-thermal condition.
The rock consists chiefly of plagioclase. No relic of mafic minerals can be seen and porphyritic texture is still remained.
Sphene is accessory minerals.
Lath-shaped plagioclase, with twinning and up to 3 mm in length has been changed into albite with minor amount of sericite, biotite and actinolitic amphibole.
The groundmass is occupied mostly by secondary minerals of brown biotite, green actinolite, granular albite and minute opaque minerals.
Primary plagioclase 0.3 mm ∿ 0.9 mm in size, is also observed.
Opaque minerals are presumably of ilmenite that partially altered into TiO_2 minerals.

(3) WR-3

Actinolite-garnet skarn, affected by pyrite-chalcopyrite mineralization.
The rock is made up mostly of garnet, actinolite, quartz and calcite. Garnet and actinolite are weakly layered.
Actinolite appears as tabular ∿ prismatic, euhedral ∿ subhedral grains, party showing deeply corroded form, where rich in quartz and calcite.
Optically isotropic garnet accurs as granular grains and clusters, that has been strongly replaced by quartz and calcite, showing pseudomorphous texture.
Interstitial chlorite and nontronite are observed in a small amount.
Quartz and calcite also occur as large tabular crystals enclosing many crystals of garnet, epidote and actinolite poikilitically.
Opaque minerals are mainly of chalcopyrite and pyrite.

(4) WR-4

Clinopyroxene and garnet skarn.
The main constituents are clinopyroxene (diopside-hedenbergite) and garnet. Calcite and quartz are present in accessory amount.
Epidote and actinolite are not common.
Anhedral to subhedral clinopyroxene and garnet, optically

anisotropic, are seen to be crowded together.
Quartz occurs interstitial of garnet crystals.
Calcite, as irregular coarser tabular crystal, appears widespreadly, partly enclosing garnet and clinopyroxene grains.

(5) WR-6

Yellowish brown carbonate rock came from silt stone.
The rock is composed mainly of carbonate minerals, probably dolomite, with subordinate amounts of clay minerals and quartz.
Carbonates, 0.02 mm ~ 0.04 mm in average size, show granular to rhombic form.
The constituent minerals are weakly oriented and interstitial clay minerals and clastic quartz are also layered being accompanied by tiny flakes of sericite and biotite in small amounts.

(6) WR-8

Dark grey lapilli tuff, strongly altered at hydrothermal condition.
Clastics are plagioclase and rock fragments.
Plagioclase, 1.5 mm in max. size, has been converted into dusty albite with a small amount of flaky sericite.
Rock fragments, 4.5 mm in max. size of essential dacite and andesite, are strongly silicified and argillized.
A trace amount of mafic minerals, perfectly replaced by chlorite and leucoxene, shows pseudomorphou texture.
Matrix consists mainly of secondary quartz, albite and chlorite.
The trace of arcuate shards of glass is still remained.

Irregular vesicles, filled with granular quartz and albite grains are scattered widely.
Sericits veinlet, sericite-chlorite veinlet and albite-chlorite veinlet are observed.

(7) WR-9

Altered dacitic tuff breccia.
Clastics are composed chiefly of rock fragments with a small amount of plagioclase and a trace amount of quartz.
Fragmental rocks, up to over 10 mm in size, consist mainly of andesite, next in abundance is basaltic rock, then andesitic tuff. Pumice fragment is also present. All rock fragments have been strongly suffered the alteration.
Sericite, carbonate, chlorite and quartz are hydrothermal products.
Plagioclase shows sub-rounded to sub-angular grains.
Sub-angular fragmental quartz sometime shows corroded form indicating dacitic andesite origin.
Constituents of matrix are fine-grained albite, sericite, quartz and chlorite.
Chlorite and sericite are alteration products after mafic minerals, accompanied by TiO_2 minerals (presumably of sphene)
Shards of glass have been completely replaced by minute crystal of chlorite.

(8) WR-13

Very strongly oxidized, chloritized reddish brown pyroxene andesite. Phenocrysts are plagioclase and clinopyroxene. Plagioclase (oligoclase) has been totally replaced by sericite and hematite. Clinopyroxene has also converted into chlorite and smaller crystals show pseudomorphous. Orthopyroxene is not observed. Weakly oriented lath-shaped plagioclase of 0.1 ∿ 0.2 mm in average size are observed in a groundmass, associated with hematite after ex-magnetite up to 0.3 mm in size. Epidote occurs granular ∿ slender prismatic clusters that are scattered as spot in a groundmass.

(9) WR-14

Very fine-grained calcareous sandstone (feldspathic arenite) or coarse-grained silt. The rock is composed mainly of plagioclase, quartz, kali feldspar and clay minerals with subordinate amount of sericite and carbonaceous matters. Zircon and Apatite are present but in a minor amount. Clastics of quartz, plagioclase and kali feldspar occur as sub-angular grains of 0.05 mm in average size. Some plagioclase reaches 0.9 mm. Plagioclase is more abundant than quartz. Kali feldspar is not clear in amount. The rock has been affected by strong carbonatization and calcite fills both interstitial and innerpart of clastic grains. Plagioclase has also been replaced by minute sericite flakes. Carbonaceous matters show layered texture.

(10) WR-16

Dark grey andesite, strongly altered at hydrothermal condition. Only zoned plagioclase (labradorite) is present as phenocryst, showing randomly oriented, prismatic idiomorph and being affected by very weak sericitization and carbonatization. Chlorite and/or quartz occur as tabular ∿ lath-shaped pseudo-morphs after essential pyroxene. Originally the groundmass was glassy and numerous lath-shaped plagioclase crystale were present and now owing to strong alter-ation, glassy materials have replaced by quartz and chlorite enclosing plagioclase laths. Granular grains and clusters of TiO_2 minerals, probably of anatase, are observed widespreadly. Apatite is seen in accessory amounts.

(11) SR-8

Strongly altered quartz-diorite. The constituents are plagioclase, hornblende, clinopyroxene and quartz. Brown hornblende has been retrogressively altered with the following process:

hornblende → pale green actinolite → chlorite, TiO_2 (sphene?)

Augite is still remained as hypidiomorphic and partly corroded

grains within the crystals of hornblende.
Plagioclase has strongly replaced inner part of the crystal by dusty albite, epidote, chlorite, sericite and calcite.
Small amounts of quartz appears filling interspaces of plagioclase.

(12) SR-11

Strongly chloritized pale green siltstone.
The constituent minerals are quartz, plagioclase, kali feldspar, muscovite and clay minerals (mainly of illite).
Minute flakes of white mica is strongly altered into chlorite.
Other clastics appear randomly oriented, sub-angular to sub-rounded and well sorted (0.05 mm in average size) in a felsitic and clayey matrix.
Leucoxenes are dispersed throughout in a matrix.

(13) SR-13

Strongly chloritized pyroxene andesite.
Phenocryst : Plagioclase and Clinopyroxene are present.
Prismatic idiomorphic plagioclases of 2.0 m in max. size have been perfectly altered into albite-muscovite assemblage.
Mafic minerals, probably orthopyroxene and/or hornblende, show perfect alteration to pale green chlorite with the liberation of secondary sphene.
Only clinopyroxene is remained unaltered.

The groundmass is composed mainly of plagioclase with subordinate amounts of clinopyroxene.
TiO_2 minerals and chlorite are alteration products.
Opaque minerals, probably of magnetite, occur widely in accessory amount.
Plagioclase, showing lath-shaped grains of 0.3 mm ~ 0.4 mm in average size, has changed perfectly into albite-sericite or albite-chlorite assemblage.
Chlorite is also observed enclosing plagioclase and clinopyroxene grains.

(14) SR-18

Weakly chloritized, saussuritized medium-grained granodiorite.
The rock is composed chiefly of plagioclase, kali feldspar, quartz, brown biotite and green hornblende.
Sphene and apatite are accessory minerals.
Almost plagioclases have been affected by saussuritization and inner parts of the crystals changed into albite, epidote, sericite assemblage.
Micrographic texture is observed at the contact of plagioclase and kali feldspar, or plagioclase and quartz.
Hornblende and Biotite have been partly replaced by chlorite along cleavage.

(15) SR-37

Strongly oxidized and chloritized reddish brown pyroxene andesite.

Phenocrysts : Plagioclase and pseudomorphs of mafic minerals are present.

Plagioclase occurs mostly as euhedral prismatic crystals of 1 mm ∗ in average some as clastic grain.

Mafic minerals, presumably of pyroxene have changed perfectly into the assemblage of sericite-chlorite-cartonate or that of chlorite-carbonate-quartz.

Groundmass : Plagioclases occur as very fine lath-shaped clusters of 0.03 mm ∿ 0.05 mm in average and minute grains of hematite after ex-magnetite occupied interspaces of plagioclase crystals.

Secondary quartz and chlorite fill the small vesicles.

Quartz-calcite veinlet traverse a groundmass.

(16) SR-45

Weakly altered granite porphyry.

Phenocrysts are of plagioclase and subordinate amounts of hornblende and clinopyroxene.

Idiomorphic tabular to prismatic plagioclase, up to 4.5 mm in size, has been affected by saussuritization from the inner part of the crystal and changed into albite with sericite, epidote and calcite.

Prismatic brown hornblende has partially been altered into the assemblage of pale green actinolite-sphene.

Clinopyroxenes show mostly corroded form but partly been enclosed by hornblende.

The groundmass consists chiefly of quartz, kali feldspar and plagioclase.

(17) SR-46

Hornblende bearing porphyrite, strongly altered at hydrothermal condition.

The principal phenocrysts are of plagioclase with a small amount of hornblende.

Prismatic to tabular zoned plagioclase has partially altered into albite with sericite, chlorite and epidote.

Brown hornblende of 1 ∿ 2 mm in size also has changed into actinolite in part.

Mafic minerals, suffered the alteration into the assemblage of actinolite and biotite, show their pseudomorphs.

The main constituents of the groundmass are of plagioclase laths of 0.2 mm ∗ in average.

Secondary quartz, formed by hydrothermal alteration, occurs filling the interstitial part of plagioclase crystals.

Biotite occurs as dissemination of slender prism or irregular form.

The weak replacement of opaque minerals by hematite is observed.

(18) NR-6

Dark gray carbonate rock (dolomite?).

The rock is composed mainly of dolomite with a trace amount of quartz and clay minerals.

Dolomite? occurs as mosaic of 0.01 mm ~ 0.02 mm in average size.

Secondary quartz appears as aggregates and veinlets accompanied by calcite.

(19) NR-9

Light gray recrystalline limestone.

The rock consists chiefly of calcite with small amounts of minute granular quartz and flaky or needle-shaped sericite.

Calcite occurs as granular crystals of 0.02 mm to 1.5 mm in size.

All constituting minerals show parallel arrangement.

(20) NR-11

Weakly altered andesitic porphyrite.

The rock shows porphyritic texture.

Twinned plagioclase, presumably correspond to oligoclase-andesine in composition, occurs as tabular to prismatic crystal of 0.5 mm ± in average size and has partially altered into albite with sericite flakes.

Subhedral hornblende of 0.2 ~ 1.0 mm in size has been replaced by actinolite and chlorite.

Tabular biotite has been retrogressively replaced by chlorite with the separation of sphene in part.

Secondary quartz is observed interspaces of plagioclase crystals.

A trace amount of calcite is locally found.

Opaque minerals, probably of magnetite, are seen partly transformed into hematite.

(21) NR-22

Dark gray andesite, strongly altered at hydrothermal condition.

Phenocrysts : Plagioclase and mafic minerals are present.

Plagioclase, up to 3.5 mm in size, has been totally replaced by albite-sericite-calcite-epidote assemblage. (Saussuritic alteration)

Mafic minerals, essentially of pyroxene, are perfectly changed into chlorite or the assemblage of chlorite-calcite, chlorite-quartz and of chlorite-calcite-quartz.

Groundmass : Only plagioclase is found as a primary mineral, showing lath-shaped crystal of 0.1 mm ± in average size.

Some aggregate of minute chlorite grains shows pseudomorph after essential pyroxene.

Secondary quartz, chlorite, calcite are found filling some vesicles and interstitial of plagioclase grains.

Idiomorphic secondary pyrite, formed by hydrothermal alteration, is scattered throughout and original opaques have been completely transformed into limonite and leucoxene assemblage.

(22) NR-30

Reddish gray altered quartz porphyrite.

Phenocrysts : Plagioclase and mafic minerals are present.

Plagioclase (oligoclase) of 4 mm in max. size, has been replaced by dusty albite with sericite, epidote and calcite.

Mafic minerals, presumably of hornblende or biotite has been perfectly transformed into the assemblage of chlorite-calcite-sphene, epidote-calcite-(sphene), and epidote-chlorite-sphene, showing tabular ∿ prismatic pseudomorphs of 3 mm in max. size.

Groundmass : Constituents are composed mainly of prismatic plagioclase with a small amount of quartz and chlorite filled the interspaces of plagioclase grains.

Plagioclase occurs as prismatic idiomorph with stripe twinning of 0.2 ∿ 0.4 mm in size and has been affected by saussuritization.

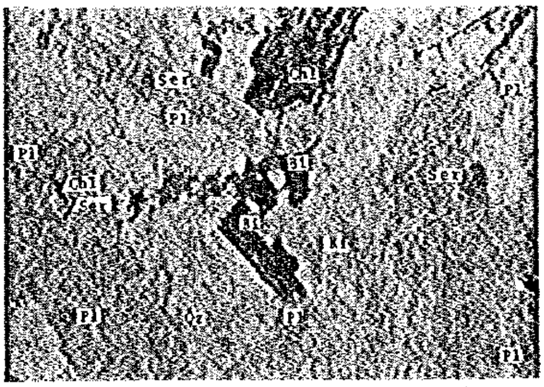
Micrographic texture is common at some contact between albite and quartz.

Apatite is present as accessory.

Photo A-2-1 Microphotograph of Thin Section

Abbreviation

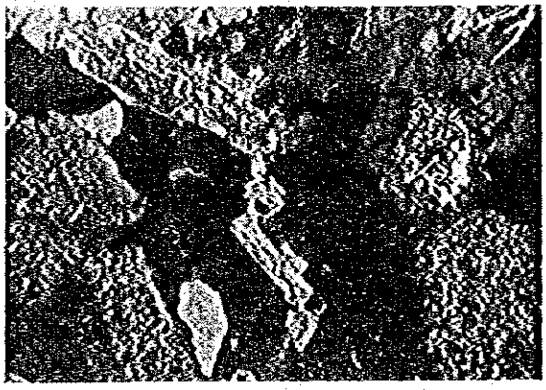
Qz	: Quartz	Carb	: Carbonate
Pl	: Plagioclase	Cal	: Calcite
Kf	: K-feldspar	Clay	: Clay minerals
Bi	: Biotite	Chl	: Chlorite
Hb	: Hornblende	Gar	: Garnet
Cpx	: Clinopyroxene	Ser	: Sericite
Opx	: Orthopyroxene	Mv	: Muscovite
Zr	: Zircon	Amp	: Amphibole
Sp	: Sphene	Act	: Actinolite
Ap	: Apatite	Ti	: TiO_2minerals
Ab	: Albite	Opq	: Opaque minerals
Ep	: Epidote	Hem	: Hematite
Tl	: Tourmaline	Rf	: Rock fragments



Sample No. : WR-1
Rock name : Granite
Location : Ikissane Mine
Texture : Equigranular
Holocrystalline

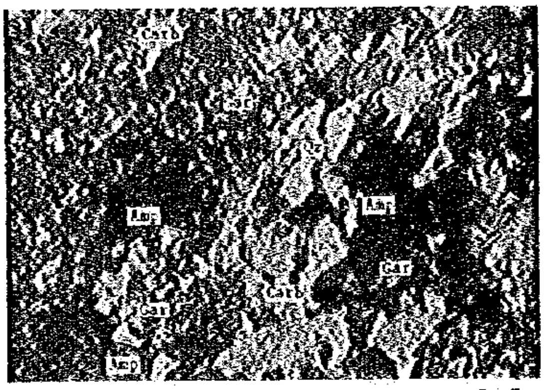
(open nicol)

0 0.5mm



(crossed nicols)

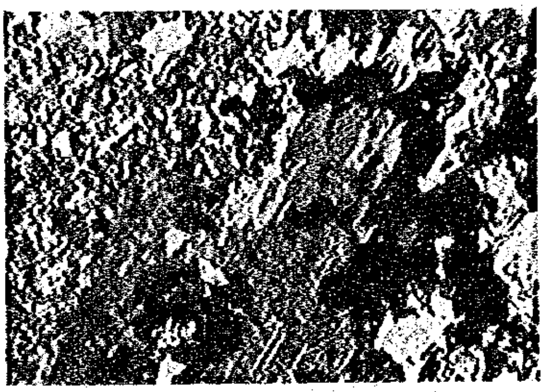
0 0.5mm



Sample No. : WR-3
Rock name : Actinolite garnet Skarn
Location : Agadir Mine

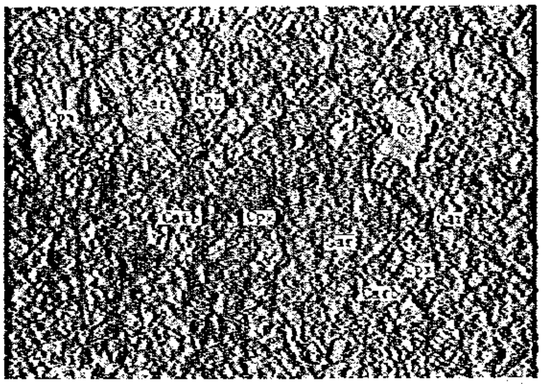
(open nicol)

0 0.5mm



(crossed nicols)

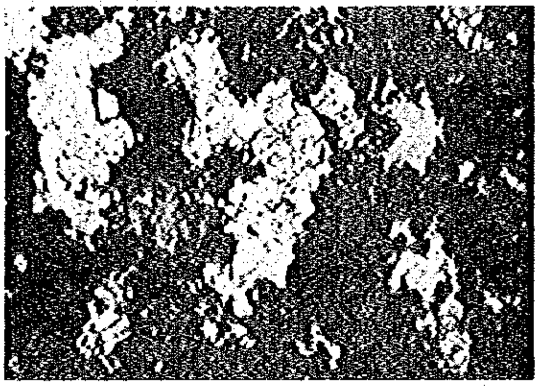
0 0.5mm



Sample No. : WR-4
Rock name : Clinopyroxene garnet Skarn
Location : Agadir Mine

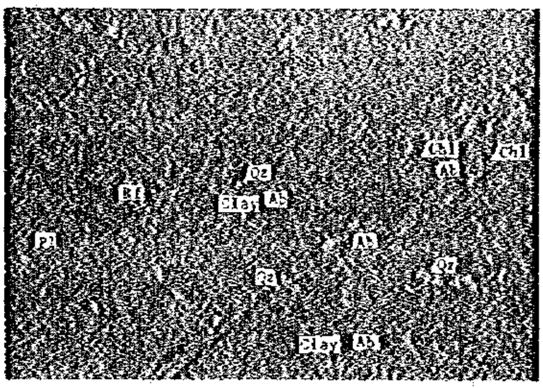
(open nicol)

0 0.5mm



(crossed nicols)

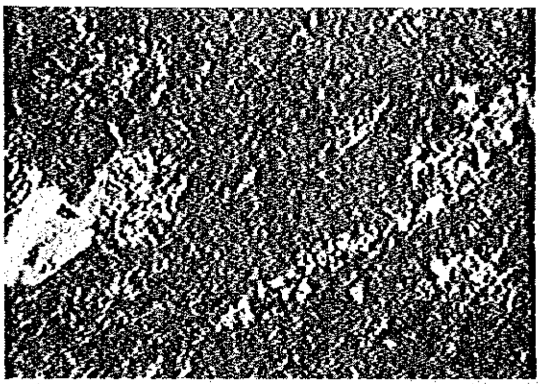
0 0.5mm



Sample No. : WR-8
Rock name : Lapilli tuff
Location : Ankasdam SE 0.3km
Texture : Pyroclastic

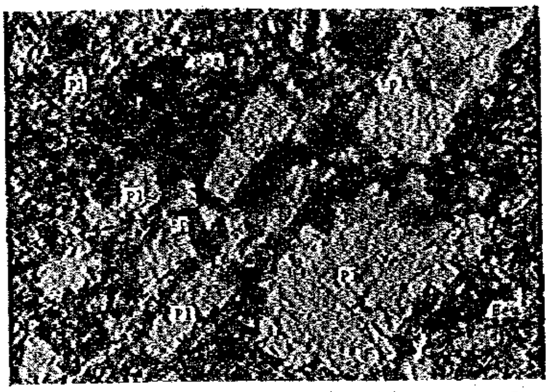
(open nicol)

0 0.5mm



(crossed nicols)

0 0.5mm



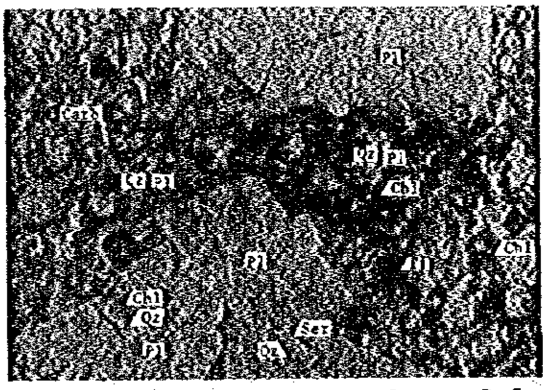
Sample No. : WR-13
Rock name : Pyroxene andesite
Location : Taghorghist
Texture : Porphyritic

(open nicol)

0 0.5mm

(crossed nicols)

0 0.5mm



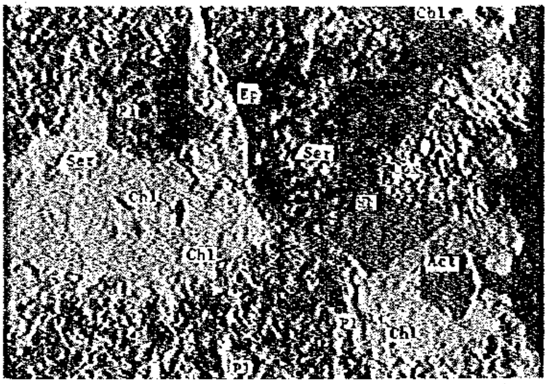
Sample No. : WR-16
Rock name : Altered andesite
Location : Tijdhicht NE 2.0km
Texture : Porphyritic

(open nicol)

0 0.5mm

(crossed nicols)

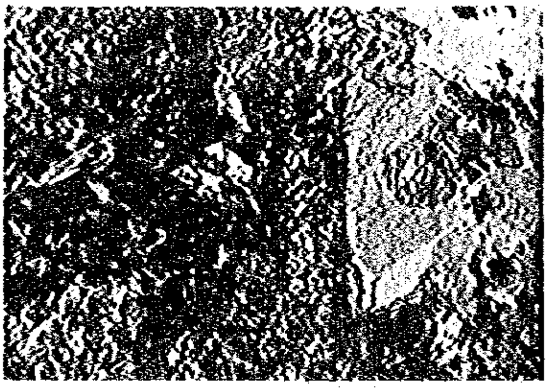
0 0.5mm



Sample No. : SR-8
Rock name : Quartz diorite
Location : Tamsoult SE 0.7km
Texture : Holocrystalline

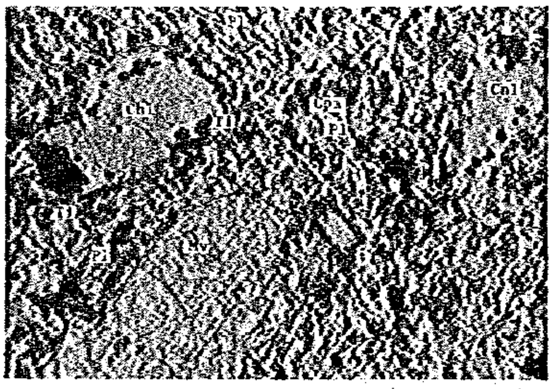
(open nicol)

0 0.5mm



(crossed nicols)

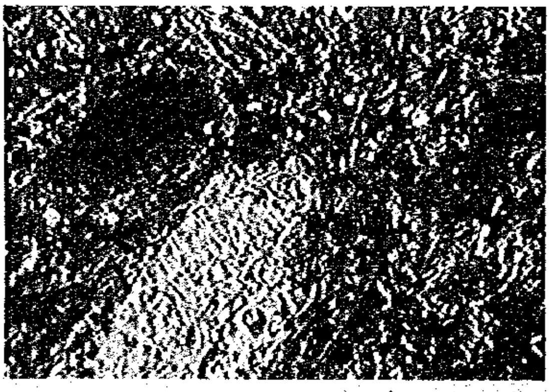
0 0.5mm



Sample No. : SR-13
Rock name : Altered pyroxene andesite
Location : Ait Yassine
Texture : Porphyritic

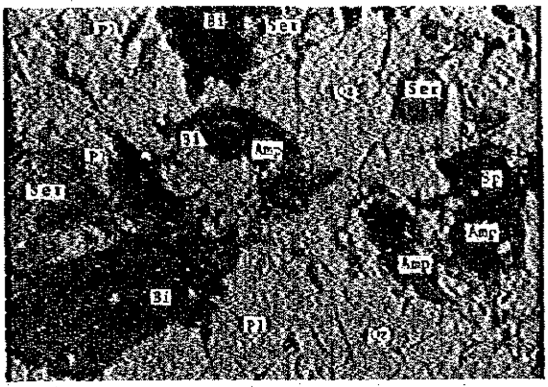
(open nicol)

0 0.5mm



(crossed nicols)

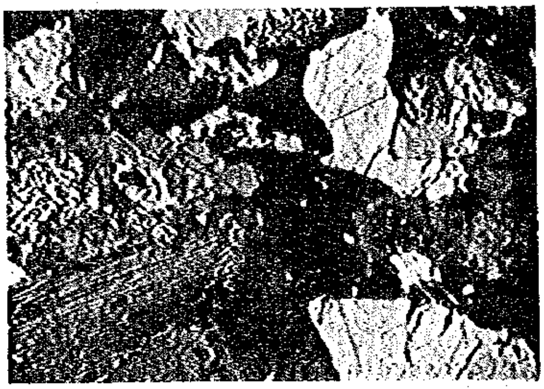
0 0.5mm



Sample No. : SR-18
Rock name : Granodiorite
Location : Tawrirt W 2.5km
Texture : Granular
Holocrystalline

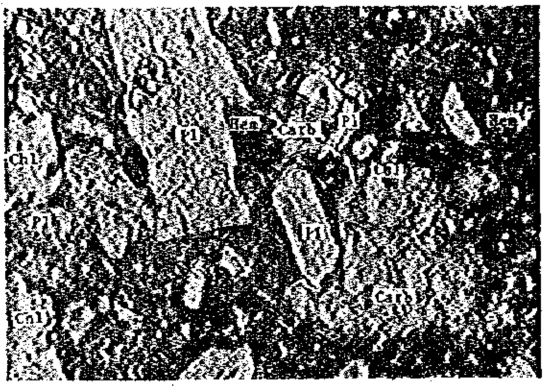
(open nicol)

0 0.5mm



(crossed nicols)

0 0.5mm



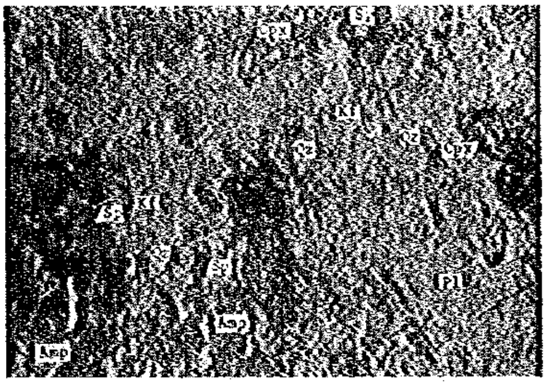
Sample No. : SR-37
Rock name : Altered pyroxene andesite
Location : Takaucht SEE 3.5km
Texture : Porphyritic

(open nicol)

0 0.5mm

(crossed nicols)

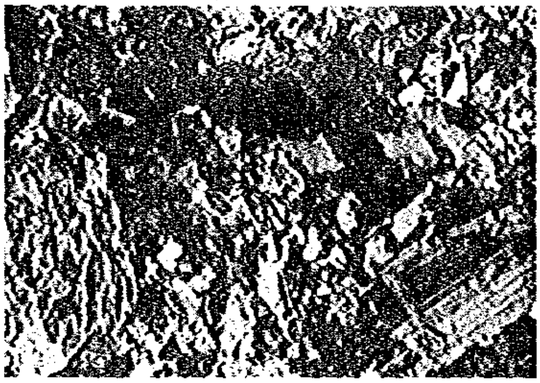
0 0.5mm



Sample No. : SR-45
Rock name : Granite porphyry
Location : Tizirt NWW 2.3km
Texture : Porphyritic
Microgranitic

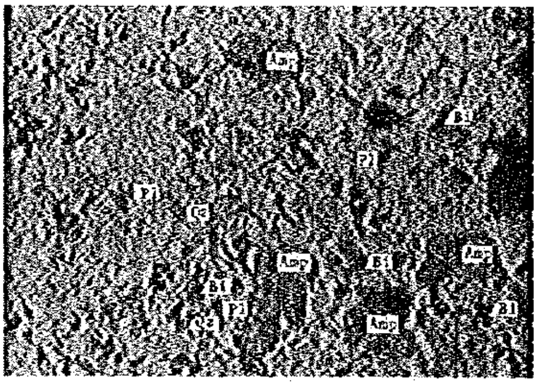
(open nicol)

0 0.5mm



(crossed nicols)

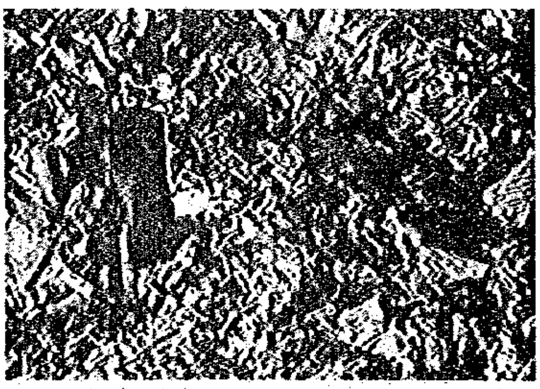
0 0.5mm



Sample No. : SR-46
Rock name : Hornblend porphyrite
Location : Tizirt NWW 2.0km
Texture : Porphyritic

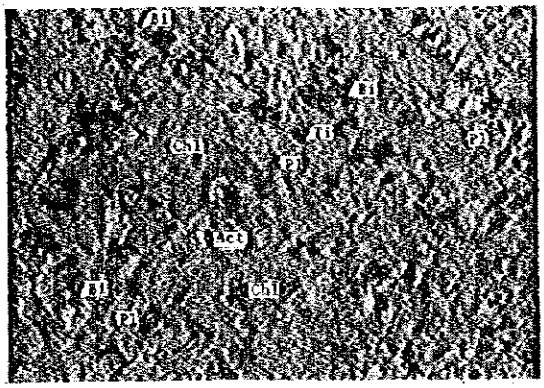
(open nicol)

0 0.5mm



(crossed nicols)

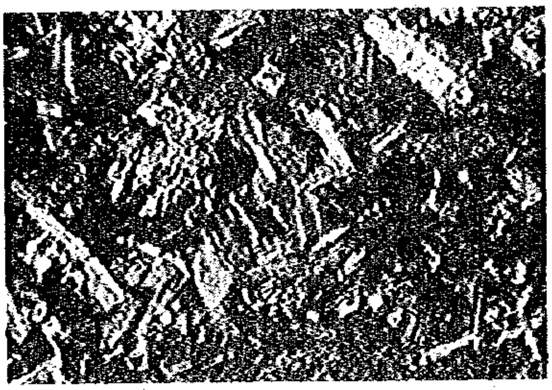
0 0.5mm



Sample No. : NR-11
Rock name : Andesitic porphyrite
Location : Arg SW 2.5km
Texture : Porphyritic

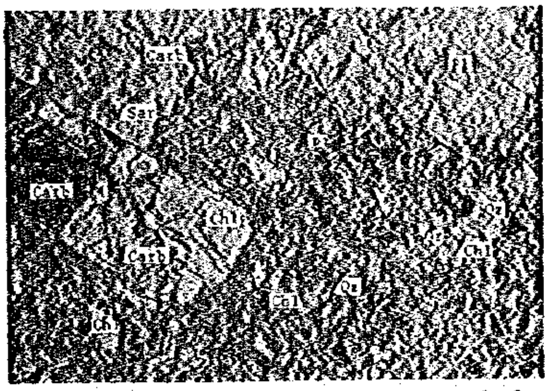
(open nicol)

0 0.5mm



(crossed nicols)

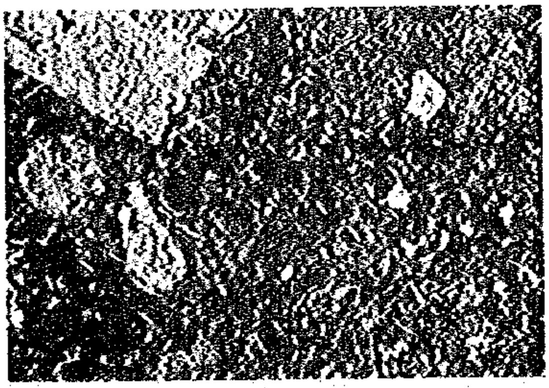
0 0.5mm



Sample No. : NR-22
Rock name : Altered andesite
Location : Assaka NNW 1.5km
Texture : Porphyritic

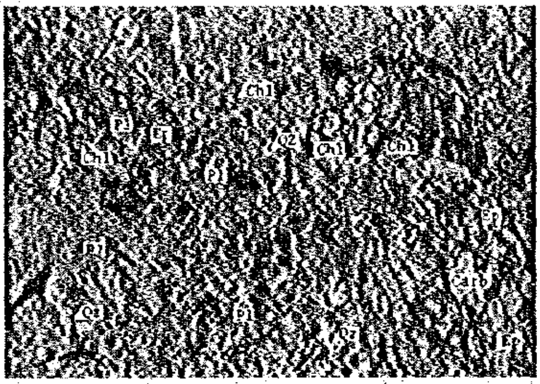
(open nicol)

0 0.5mm



(crossed nicols)

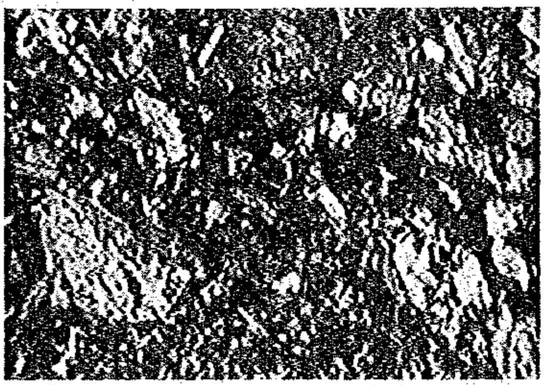
0 0.5mm



Sample No. : NR-30
Rock name : Quartz porphyrite
Location : Gundafa Mine
Texture : Porphyritic
Micrographic

(open nicol)

0 0.5mm



(crossed nicols)

0 0.5mm

Table A-3-1 Microscopic Observations (Polished Section)

No.	Sample No.	Location	Ore Name	Sphalerite	Galena	Chalcopyrite	Bornite	Chalcocite	Covellite	Azurite	Malachite	Molybdenite	Pyrite	Arsenopyrite	Pyrrhotite	Magnetite	Hematite	Limonite	Native bismuth	Tetradymite	Anglesite	Tetrahedrite
1	WM-4	Taddart A Mine	Pyrite, galena ore	•	•								△									
2	WM-11	"	Chalcopyrite, pyrite ore			△							△					△				
3	WM-15	Ikissan Mine	Molybdenite, pyrite ore			•			•			△	△					△				
4	WM-17	"	Molybdenite ore			•						△										
5	WM-21	"	Pyrrhotite, molybdenite ore	•		○						○	○		◎			△				
6	WM-22	"	•			△						△	○		○			△				
7	WM-23	"	Pyrrhotite, Native bismuth ore			△						△	○		○			△	•			
8	WM-27	Maouass Indication	Hematite ore			△		•					○			△	◎					
9	WM-31	"	Hematite, magnetite ore			•			•				○			○	○					
10	WM-33	Agadir Mine	Pyrrhotite chalcopyrite ore	•		△									◎			△				
11	WM-35	"	Tetradymite, Native bismuth ore			△							△		△			△	•	•		
12	WM-62	Tawrirt SE 2.0 km	Bornite, chalcocite ore			•	△	△	•	•	•		•					•				
13	WM-63	Tawrirt S 0.6 km	Malachite ore			•			•		○		•					△				
14	SM-2	Maouass Indication	Magnetite, hematite ore			△			•				○			○	○					
15	SM-5	Tamsoult SE 0.7 km	Arsenopyrite ore											◉								
16	SM-9	Achdirt Mine	Azurite ore			•	•	•	•	△			△					△				△
17	SM-14	Iguidi Mine	Chalcopyrite, hematite ore			○		△										○				
18	SM-15	"	"			△		•			△		△					○				
19	NM-9	Gundafa Mine	Galena, covellite ore	△	◉				△				△								△	○
20	NM-22	Agadirane NW 2.0 km	Chalcopyrite ore			◉							△									△
21	NM-36	Igherm SE 1.7 km	Galena, sphalerite ore	△		◉															△?	

◉ abundant ◎ more ○ common △ less • scarce

(1) WM-4

Ore minerals are composed of few amount of pyrite and scarece amount of galena and sphalerite.
Pyrite is found in crack of gangue as anhedral crystal.
Galena and sphalerite exist several ten micron in size within pyrite.

(2) WM-11

Ore minerals are composed of little amount of chalcopyrite, pyrite and limonite.
Chalcopyrite and pyrite are disseminated in the quartz.
Limonite is secondary minerals, surrounding chalcopyrite and pyrite crystals.

(3) WM-15

Ore minerals are composed of little amount of molybdenite, pyrite, limonite and few amount of chalcopyrite and covelline.
Anhedral pyrite is a vein form and its margin is replaced by limonite.
Molybdenite co-exists with limonite as a vein form and fills in cracks of gangue mineral.
Chalcopyrite is disseminated in gangue minerals and is small dots in pyrite.
Covelline is scattered in gangue mineral.

(4) WM-17

Ore minerals are composed of little amount of Molybdenite and few amounts of chalcopyrite.
Molybdenite and chalcopyrite fill the small cracks of gangue minerals.

(5) WM-21

Ore minerals are composed of lots of pyrrhotite, medium amount of molybdenite, pyrite, chalcopyrite and little amount limonite and sphalerite.
Pyrrhotite exists either in cracks or disseminated in gangue mineral which shows birds-eyes texture owing alteration and partly changes to pyrite.
Pyrite consists primary and secondary crystal altered from pyrrhotite.
Chalcopyrite is in a cracks and disseminated in gangue minerals.
Molybdenite exists either in crack of gangue minerals or fills the interstics of pyrrhotite, chalcopyrite.
Sphalerite is in primary pyrite crystals.
In view of above facts, it is assumed that mineralization of molybdenite accurs after mineralization pyrrhotite and chalcopyrite. And it is also considered that the alteration of pyrrhotite is an oxidation phenomena by weathering.

(6) WM-22

Ore minerals are composed of lots of pyrrhotite, pyrite, a few amount of molybdenite chalcopyrite and limonite.

Pyrrhotite exists either in a crack or in dissemination in gangue mineral, which often changes to pyrite.

Pyrite consists of primary and secondary mineral which changes from pyrrhotite.

Molybdenite exists either in a crack or in dissemination in gangue minerals.

Chalcopyrite disseminates in gangue minerals.

Limonite exists either surrounding pyrrhotite and pyrite or in crack of gangue minerals.

(7) WM-23

Ore minerals consists of lots pyrrhotite, pyrite, a few amount of molybdenite, chaocopyrite, limonite and few amount of native bismuth.

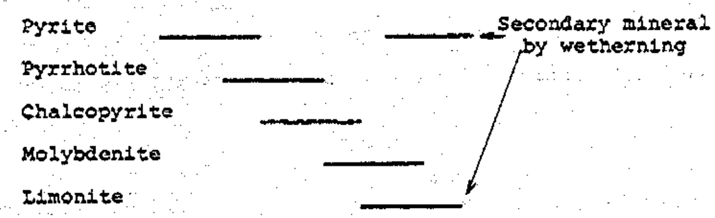
Pyrrhotite exists in a crack and in vein form and changes into secondary pyrite showing birds-eyes texture.

Most of pyrite is secondary crystal and rare pyrite is primary crystal.

Chalcopyrite occupies around the pyrrhotite cristal or in cracks.

A native bismuth coexisting pyrrhotite and chalcopyrite are observed 100 μm in size.

Order of mineral cristalization is assumed as follows.



(8) WM-27

Ore minerals consist of lots of hematite, a little amount of pyrite, a few amount of chalcopyrite, magnetite and few amount of chalcocite.

Pyrite is scattered and suffered strong alteration.

Hematite replaces gangue minerals. Chalcopyrite disseminated as dots form.

Secondary chalcocite is surrounding chalcopyrite crystals.

(9) WM-31

Ore minerals are composed of medium amount of pyrite hematite magnetite and few amount of chalcopyrite and covelline.

Pyrite exists in dissemination as anhedral.

Hematite and Magnetite exist interstics of pyrite or in gangue minerals. Chalcopyrite scatters in dissemination.

Covelline is surrounding chalcopyrite.

(10) WM-33

Ore minerals consist of lot of pyrrhotite, a little amount of chalcopyrite, limonite and few amount of sphalerite and grey ~ greyish brown indeterminable mineral.

Pyrrhotite exist either in cracks or in granular mass, which seems to hexagonal pyrrohotite caused by its non-magnetic character.

Chalcopyrite is surrounding pyrrhotite cristals.

A sphalerate coexisting chalcopyrite is observed.

Indeterminable arey mineral shows interreflection and anisotropy, so it may be rutile or cassiterite, and greyish-brown opaque mineral showing strong anisotropy might be stannite.

(11) WM-35

Ore minerals are composed of a little amount of pyrrhotite, pyrite, chalcopyrite, limonite and few amount of native bismuth and tetradymite.

Pyrrhotite exist in granular mass form and in dissemination form. Pyrites are primary crystal and secondary bird-eyes texture crystal.

Chalcopyrite is scattered in the surroundings pyrrhotite and in gangue minerals.

Native bismuth and tetradyminte is determined by XMA analysis. Some native bismuth contains few amount of iron. (Tetradymite occurs in middle - high temperature quartz vein and contact replaced ore deposit.)

(12) WM-62

Ore minerals consist of a little amount of bornite, chalcocite, few amount of azurite, covelline, malachite, chalcopyrite, pyrite and limonite.

Bornite is as spot inshape and replaced by chalcosite in its margin. Azurite, covelline and malachite exist in cracks and in gangue mineral as a spot.

Chalcopyrite scatters in gangue minerals and partly coexist bornite, therefore bornite and chalcopyrite are considered primary minerals.

Pyrite exists in bornite as fine grain.

(13) WM-63

Ore minerals are composed of medium amount of malachite, a little amount of limonite and few amount of chalcopyrite, pyrite and covelline.

Malachite exists in a crack or interstics gangue crystals.

Chalcopyrite and pyrite is in gangue minerals as a fine spot.

(14) SM-2

Ore minerals are composed of medium amount of hematite, magnetite, pyrite, a little amount of chalcopyrite and few amount of covelline.

Anhedral pyrite exists in a spot and in dissemination.

Magnetite is in a spot and interstics pyrites, hematite is in veinlet or in rim of magnetite and party replace gangue minerals.

Covelline is in a margin of chalcopyrite.

(15) SM-5

Ore mineral are entirely consist of pyrrhotite.

(16) SM-9

Ore mineral are composed of a little amount of tetrahedrite, azurite, pyrite, limonite, few amount of chalcopyrite, bornite, chalcocite and covelline.
Eu-anhedral pyrites are in dissemination and in aggregation and partly replaced by limonite.
Tetrahedrite exist either interstics pyrite of in gangue minerals as a spot.
Azurite occurs along a crack in gangue minerals. Chalcopyrite and bornite are interstics or in gangue minerals, and their borders are replaced by chalcocite and covellina.

(17) SM-14

Ore mineral are composed of medium amount of chalcopyrite, limonite, a little amount of chalcocite.
Chalcopyrite existe in a spot and in dissemination.
Their margines are replaces by chalcocite and surrounded by limonite. Chalcocite and limonite are secondary minerals.

(18) SM-15

Ore minerals are composed of medium amount of limonite, a little amount of chalcopyrite, malachaite, pyrite and few amount of chalcocite.
Chalcopyrite exists in dissemination, and its margine is frequently changed by limonite.
Most of pyrite is also replaced by limonite.
Malachite exists in a crack and in a space of gangue minerals.

(19) NM-9

Ore minerals are composed of lot of galena, medium amount of tetrahedrite, little amount of anglesite, sphalerite, covelline and pyrite.
Massive galena contains tetrahedrite, sphalerite and pyrite.
Other sphalerite is in gangue minerals as a spot.
Covelline exists in a crack or in a margine of tetrahedrite and coexists anglesite.
It is difficult to determinate anglesite under microscopic observation, but it seems to exist in margine of galena or in a crack.
(Anglesite is detected by X-ray reflection analysis).

(20) NM-22

Ore minerals consist of lot of chalcopyrite, a little amount of tetrahedrite and pyrite.
Chalcopyrite is massive, tetrahedrite is interstitial veinlet in chalcopyrite.
Eu-anhedral pyrite is either contained or in a veinlet in chalcopyrite, therefore, it is considered that pyrite has two stage of crystallization before and after crystallization of chalcopyrite.

(21) NM-36

Ore minerals are composed of lot of galena, a little amount of sphalerite and anglesite.

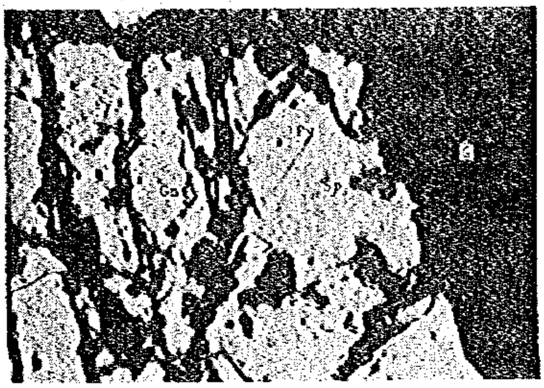
This specimen is a mass of galena which contains sphalerite 2mm - 3μm in size.

Replaced dark grey anglesite exists in a crack or in a rim of galena.

Photo A-3-1 Microphotograph of Polished Section

Abbreviation

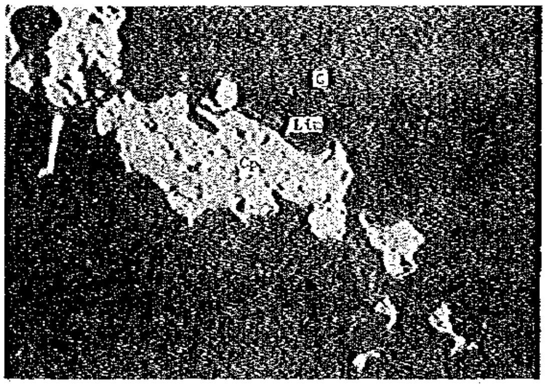
Sp	Sphalerite	ZnS
Gn	Galena	PbS
Cp	Chalcopyrite	$CuFeS_2$
Bn	Bornite	Cu_5FeS_4
Cc	Chalcocite	Cu_2S
Cv	Covellite	CuS
Az	Azurite	$Cu_3(OH)_2(CO_3)_2$
Mala	Malachite	$CuCO_3.Cu(OH)_2$
Mo	Molybdenite	MoS_2
Py	Pyrite	FeS_2
Asp	Arsenopyrite	$FeAsS$
Po	Pyrrhotite	Fe_1-xS
Mag	Magnetite	Fe_3O_4
Hem	Hematite	Fe_2O_3
Lim	Limonite	$Fe_2O_3.nH_2O$
Bi	Native bismuth	Bi
Ty	Tetradymite	$Bi_2(TeS)_3$
Ang	Anglesite	$PbSO_4$
Td	Tetrahedrite	$(CuFeZn)_{12}Sb_4S_{13}$



0 0.1mm

Sample No. : WM-4
Ore Name : Pyrite, galena ore
Location : Taddart A Mine

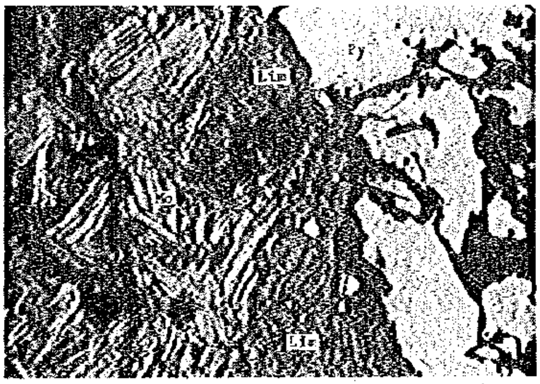
(open nicol)



0 0.1mm

Sample No. : WM-11
Ore Name : Chalcopyrite,pyrite ore
Location : Taddart A Mine

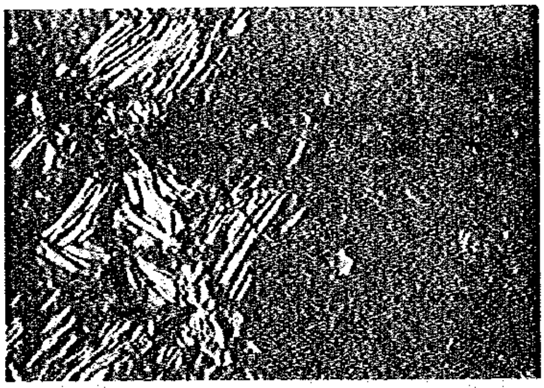
(open nicol)



0 0.2mm

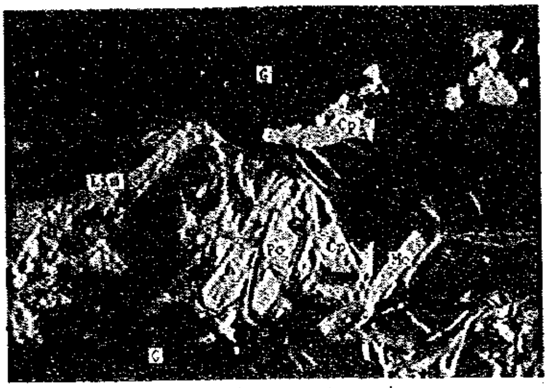
Sample No. : WM-15
Ore Name : Ikissan Mine
Location : Molybdenite, pyrite ore

(open nicol)



0 0.2mm

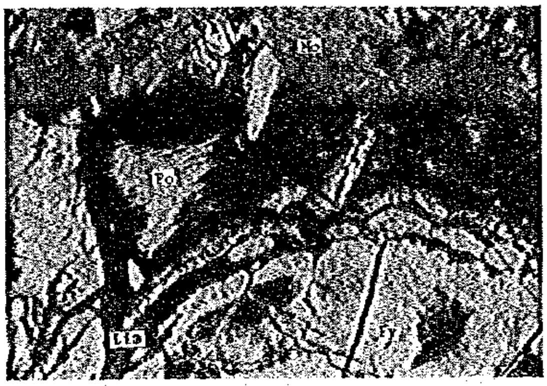
(crossed nicols)



Sample No. : WM-21
Ore Name : Pyrrhotite, molybdenite ore
Location : Ikissan Mine

(open nicol)

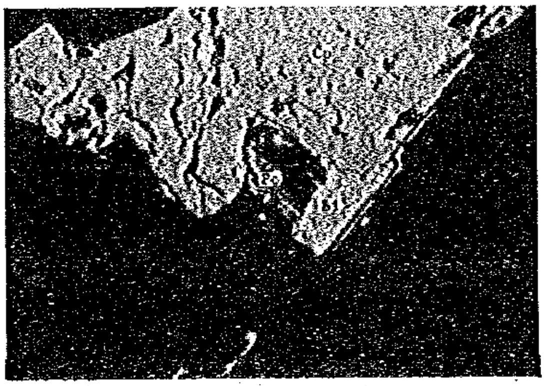
0 0.2mm



Sample No. : WM-21
Ore Name : Pyrrhotite, molybdenite ore
Location : Ikissan Mine

(open nicol)

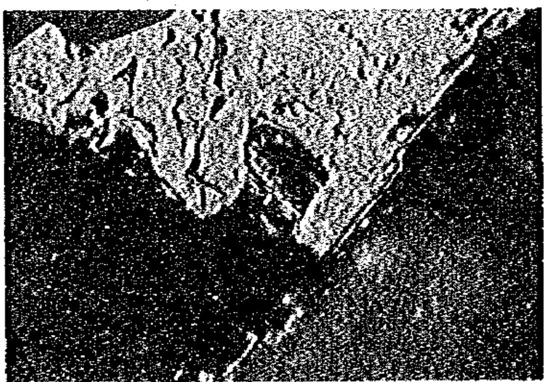
0 0.2mm



Sample No. : WM-23
Ore Name : chalcopyrite Native bismuth ore
Location : Ikissan Mine

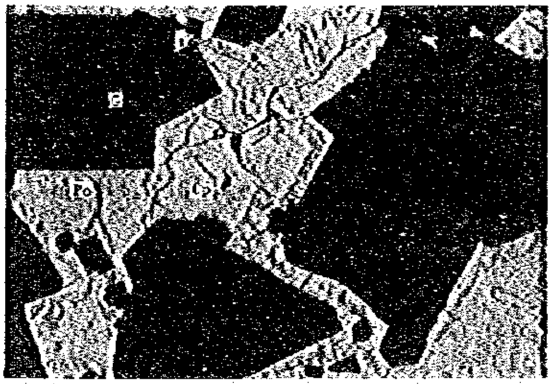
(open nicol)

0 0.1mm



(crossed nicols)

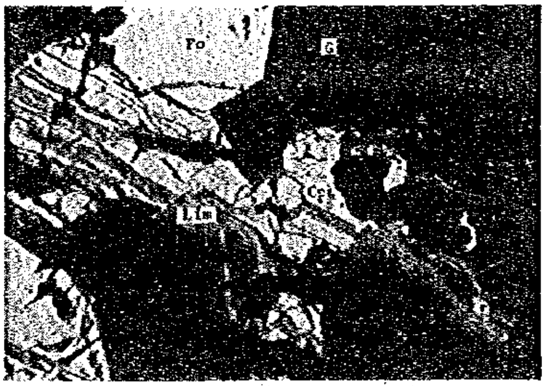
0 0.1mm



Sample No. : WM-33
Ore Name : Pyrrhotite, Chalcopyrite ore
Location : Agadir Mine

(open nicol)

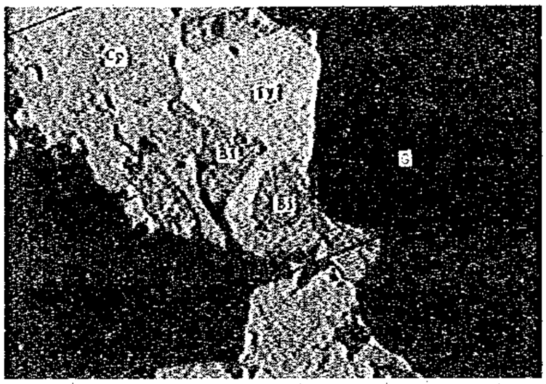
0 0.2mm



Sample No. : WM-33
Ore Name : Pyrrhotite, Chalcopyrite ore
Location : Agadir Mine

(open nicol)

0 0.2mm



Sample No. : WM-35
Ore Name : Tetradymite, Native Bismuth ore
Location : Agadir Mine

(open nicol)

0 0.05mm

(crossed nicols)

0 0.05mm