Quartzite is characterized by coarse-grain opaque minerals, which shows banding structure together with quartz and appears in medium quantity. Very small amount of sericite is dispersedly detected in quartz.

2-5-3 Survey results

Mineralization of MJZM-12

A dissemination of pyrite, pyrrhotite, and chalcopyrite was recognized in charnockite.

According to microscopic observation of polished sections(depth : 61.00 metres, 75.00 metres), the sulphide minerals in the hole are characterized by rather fluctuation of the mineral abundance depending on the portion. The kind of sulphide minerals(pyrite, pyrrhotite, sphalerite, and chalcopyrite), however, invariably appears independent of the portion of the hole.

These minerals tend often closely to associate with each other.

Assay results are as follows:

M J Z M - 1 2

SAMPLE NO.	D E P T H(m)	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	COMMENT
12-01	59.50- 61.50	0.02	0.05	0.01	<0.01	<0.01	
12-02	- 63.50	<0.01	0.49	0.01	<0.01	0.01	
12-03	- 65.50	<0.01	0.39	0.01	<0.01	<0.01	
12-04	- 67.50	0.01	<0.01	0.01	<0.01	<0.01	
12-05	- 69.50	0.01	0.05	0.01	<0.01	0.02	
12-06	- 71.50	0.01	<0.01	0.01	<0.01	0.16	
12-07	- 73.50	<0.01	<0.01	0.01	<0.01	0.01	
12-08	- 75.50	0.03	0.05	0.01	<0.01	0.01	
12-09	- 78.50	<0.01	<0.01	0.01	<0.01	0.01	
	TOTAL 19.00 m						

No encouraging assay results were obtained.

Mineralization of MJZM-13

A strong dissemination and banding or network of pyrite, pyrrhotite, and chalcopyrite was recognized in charnockite and quartzite.

According to microscopic observation of polished sections(depth : 74.00 metres, 93.00 metres, 104.00 metres, 143.00 metres), the sulphide minerals in the hole are characterized by rather fluctuation of the mineral abundance depending on the country rocks. No significant differences, however, in its kindness was recognized between in charnockite and quartzite.

Galena and arsenopyrite which are not found in other holes appear in the shallower part of charnockite and associate intimately with each other.

On the other hand, quantity of the sulphide minerals in quartzite is shown as follows: That is, it is pyrrhotite > pyrite > sphalerite > chalcopyrite in general.

Pyrrhotite appears as larger grains and comprises other sulphide minerals within the crystal.

Assay results are as follows:

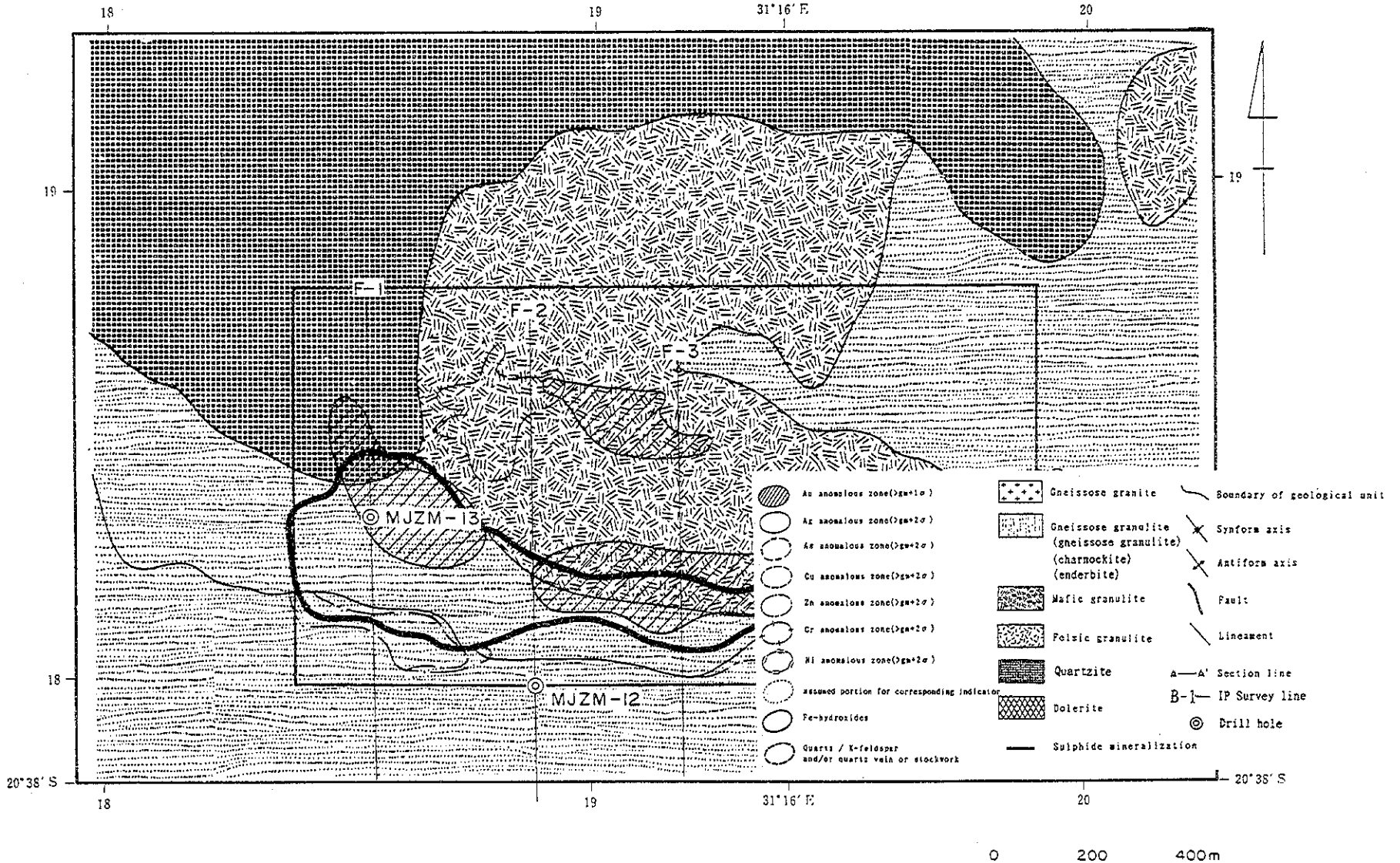

FIG. 2-2-16 Locality Map of Drill Holes(Fumure Area)

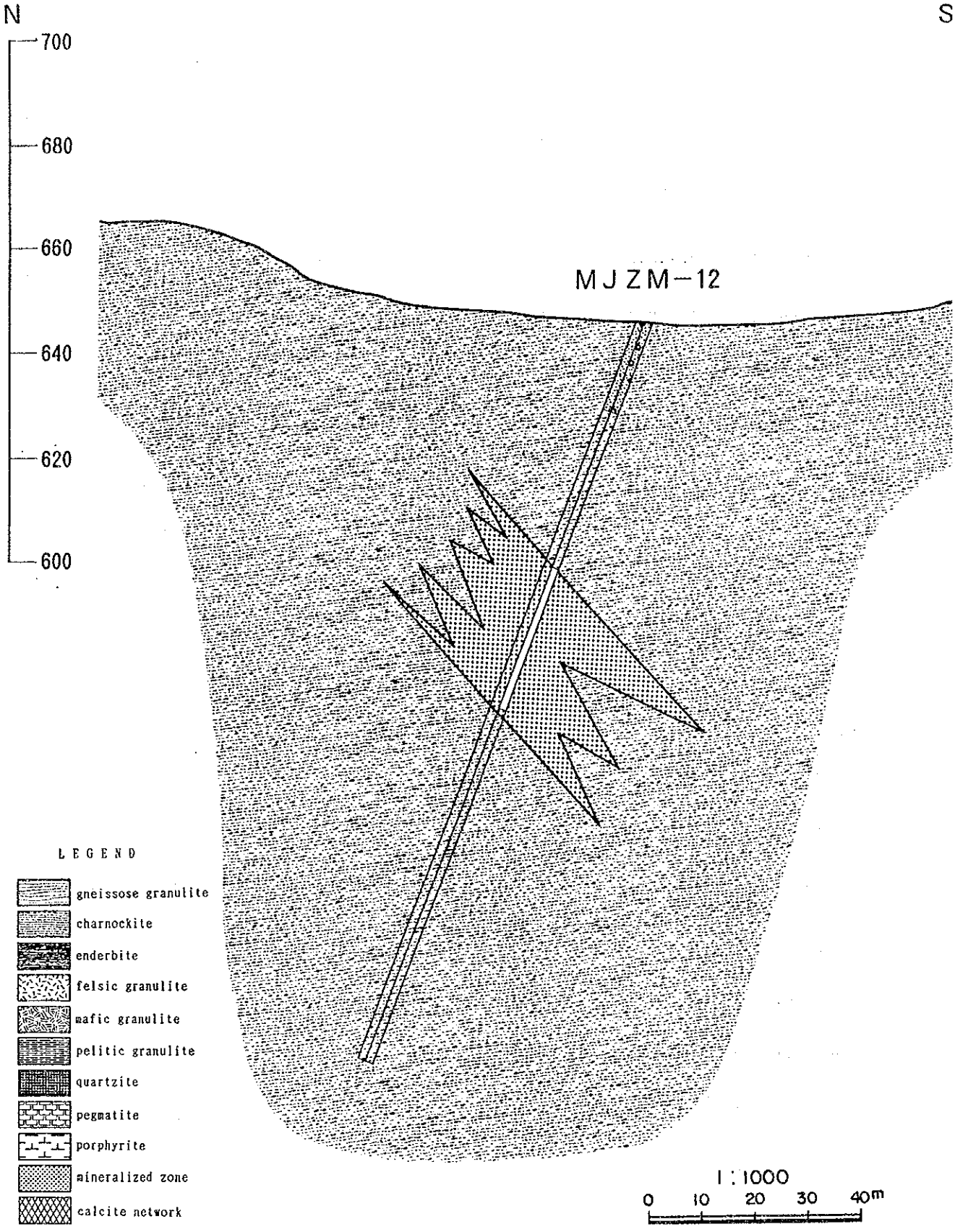

FIG. 2-2-17 Geological Section of Drill Hole MJZM-12(Fumure Area)

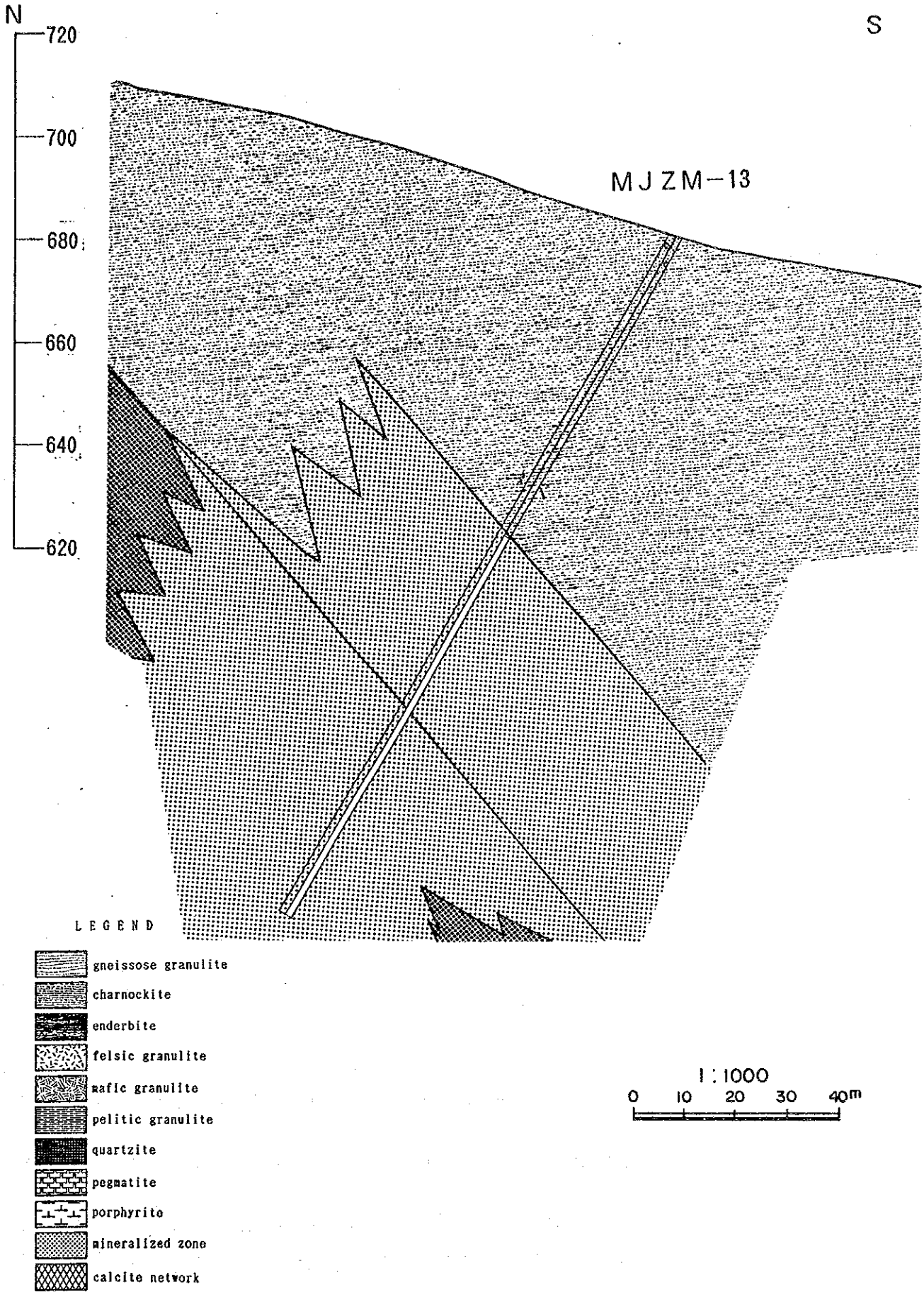

FIG. 2-2-18 Geological Section of Drill Hole MJZM-13(Fumure Area)

MJZM-13

SAMPLE NO.	DEPTH(m)	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	COMMENT
13-01	66.34- 68.34	0.03	0.10	0.01	<0.01	<0.01	
13-02	- 70.19	<0.01	0.39	0.01	<0.01	0.01	
13-03	70.19- 72.19	0.06	0.34	0.02	<0.01	<0.01	
13-04	- 74.19	<0.01	<0.88	0.02	<0.01	<0.01	
13-05	- 76.19	<0.01	0.05	0.03	<0.01	0.02	
13-06	- 78.19	0.01	0.20	0.06	<0.01	0.16	
13-07	- 80.19	<0.01	<0.01	0.02	<0.01	0.01	
13-08	- 82.19	0.03	0.10	0.02	<0.01	0.01	
13-09	- 84.19	<0.01	<0.01	0.01	<0.01	0.01	
13-10	- 86.19	0.02	<0.01	0.01	0.01	<0.01	
13-11	- 88.19	<0.01	<0.01	0.01	<0.01	0.01	
13-12	- 90.19	<0.01	<0.01	0.01	<0.01	<0.01	
13-13	- 92.19	0.01	<0.01	0.01	<0.01	<0.01	
13-14	- 94.19	0.01	0.15	0.02	<0.01	0.02	
13-15	- 96.19	0.01	0.29	0.03	<0.01	0.16	
13-16	- 98.19	<0.01	0.25	0.03	<0.01	0.01	
13-17	-100.19	0.03	0.29	0.01	<0.01	0.01	
13-18	-102.19	<0.01	0.39	0.01	<0.01	0.01	
13-19	-104.19	0.02	0.34	0.01	<0.01	<0.01	
13-20	-106.19	<0.01	0.15	0.01	<0.01	0.01	
13-21	-108.19	<0.01	0.59	0.02	<0.01	<0.01	
13-22	-110.19	0.01	0.39	0.02	<0.01	<0.01	
13-23	-112.19	0.01	2.02	0.03	<0.01	0.02	
13-24	-114.19	0.01	0.58	0.03	<0.01	0.16	
13-25	-116.19	<0.01	<0.01	<0.01	0.01	<0.01	
13-26	-118.19	0.03	0.24	0.01	<0.01	0.02	
13-27	-120.19	<0.01	<0.01	<0.01	<0.01	0.03	
13-28	-122.19	0.02	<0.01	0.01	<0.01	0.02	
13-29	-124.19	<0.01	0.05	0.02	<0.01	0.03	
13-30	-126.19	<0.01	<0.01	0.01	<0.01	<0.01	
13-31	-128.19	0.01	<0.01	<0.01	<0.01	<0.01	
13-32	-130.19	0.01	<0.01	<0.01	<0.01	<0.01	
13-33	-132.19	0.01	4.78	0.01	<0.01	<0.01	
13-34	-134.19	<0.01	0.34	0.01	<0.01	<0.01	
13-35	-136.19	0.03	0.54	0.01	<0.01	<0.01	
13-36	-138.19	<0.01	<0.01	0.01	<0.01	<0.01	
13-37	-140.19	0.01	<0.01	<0.01	<0.01	<0.01	
13-38	-142.19	0.01	<0.01	0.01	<0.01	<0.01	
13-39	-144.19	0.01	<0.01	0.01	<0.01	<0.01	
13-40	-146.19	<0.01	<0.01	<0.01	<0.01	<0.01	
13-41	-148.19	0.03	0.68	0.01	<0.01	<0.01	
13-42	-150.00	<0.01	0.24	0.01	<0.01	<0.01	
	TOTAL 83.66 m						

No significant assay results were obtained although intense sulphide mineralization was intersected.

2-5-4 Considerations

The following are combinations of sulphide minerals and features of alteration minerals of executed MJZM-12 and MJZM-13.

① Similarly to the case of Jegede zone, pyrrhotite is a main sulphide mineral in quantity. Very small amounts of pyrite and chalcopyrite are commonly present in this zone similarly to other zones. In addition, galena, sphalerite, and arsenopyrite are detected.

Therefore, this zone is slightly rich in sulphide minerals compared with other zones.

② For the mode of occurrence of sulphide minerals, the country rock consisting of charnockite shows dissemination structure but the country rock consisting of

quartzite shows more banding structure. It can be said that this case is also approximately concordant with foliation.

③ Alteration minerals are poorly formed.

From the above facts, the mineralization by sulphide minerals had been done before metamorphism and the mode of occurrence of sulphide minerals differs in types of country rocks. Therefore, the zone has a high possibility of *stratabound ore deposit similarly to Juwere and Jegede zones.*

2-6 DISCUSSION

Relation between Geological Structure and Mineralization

Juwere Zone

The geological unit constituting this zone mainly consists of mafic granulite, felsic granulite, and, in a wide sense, gneissose granulite (including gneissose granulite, charnockite, and enderbite). Especially, gneissose granulite (in a wide sense, the same is true for the following) is most widely distributed. Also in this zone, the geological unit is influenced by the foliation of ENE-WSW system.

Though no main tectonic line is found in this zone, it is estimated that there is a tectonic line of NNE-SSW system in the eastern part of this zone. However, it is considered that there is no or a little dislocation. In addition, the linear structure detected through a LANDSAT image and air photographs is restricted to lineaments free from dislocation. In the microfolding structure detected in this zone, it is found that deformation repeatedly occurred in different period.

For the mineralization characteristic, it is found from the results of three executed holes (MJZM-1, MJZM-2, and MJZM-3) that the mineralization of pyrrhotite, pyrite and chalcopyrite is found mainly in charnockite and local felsic granulite and their mode of occurrence is almost concordant with foliation.

This fact shows that mineralization occurred before metamorphism. Meanwhile, because mineralization inadequately occurs in mafic granulite, it is estimated that mineralization and country rock are syngenetic or mafic granulite was produced after mineralization.

Judging from selectivity and concordance of mineralization for the country rock, this zone has a large possibility of stratabound ore deposit.

Muchacha Zone

The geology and structure of this zone are basically same as those of Juwere zone. Also in this zone, geological structure of ENE-WSW system in the foliation

is predominantly detected. The main tectonic line in this zone is the tectonic line of NNE-SSW system detected in the west and east of this zone. It is assumed that a slight dislocation (dislocation sense includes right-lateral and left-lateral) is given to the geological unit by the tectonic line. In addition, the linear structure detected through the LANDSAT image and air photographs is classified into lineaments free from dislocation. Also in this zone, it is found the microfolding structure that metamorphism repeatedly occurred in different periods.

For the mineralization characteristic, it was impossible to obtain the genetic relation between geological structure and mineralization from the results of two executed drill holes (MJZM-4 and MJZM-5) because mineralization was weak. Especially for MJZM-4, it is found that the mineralized zone having intensely silisified zone detected on the ground surface is changed to a calcite network zone in a deep portion. The following two possibilities are considered for the above change:

① possible lower extension of mineralized zone in surface.
② possible presence of a fault.

Benzi Zone

The geology of this zone mainly consists of gneissose granulite (gneissose granulite and charnockite). For the geological structure, a tectonic line of NE-SW system is detected in the eastern part of this zone. However, no remarkable dislocation due to the tectonic line is detected in felsic granulite. However, a mylonite zone restricted by the tectonic line of E-W system is present and hydrothermal alteration is also detected in Benzi river at the center of this zone.

The following are features of the sulphide minerals (pyrite, pyrrhotite, and chalcopyrite) and the alteration minerals (especially, sericite) of MJZM-6 and MJZM-7.

① Pyrite is more than pyrrhotite compared with other zones.
② Because veinlets (width: 1 to 3 mm) diagonally intersecting with foliation are present in addition to sulphide minerals along foliation similarly to other zones, the mode of occurrence of this zone is different from that of other zones.
③ Alteration minerals appear more frequently than other zones.

There are not so many sulphide minerals in general in this zone. However, judging from the above facts, it is estimated that two stages of mineralization,

① mineralization before metamorphism and
② mineralization after metamorphism

occurred in this zone.

Moreover, for Item ②, it can be estimated that mylonite zone along Benzi river is

also related to the time of the mineralization.

Jegede Zone

This zone mainly consists of mafic granulite, felsic granulite, and gneissose granulite. Also for the geological structure of this zone, the foliation of ENE-WSW system is distinguished and no main tectonic line is found. However, a tectonic line of NNE-SSW system having right-lateral sense is detected at the east outside of the zone.

The following are combinations of sulphide minerals and features of alteration minerals of executed MJZM-8, MJZM-9, MJZM-10, and MJZM-11.

① Pyrrhotite is a predominant sulphide mineral. In addition, very small amounts of pyrite and chalcopyrite are commonly present in this zone similarly to other zones. However, it is different from other zones that a very small amount of sphalerite is commonly produced in this zone.

② The sulphide minerals show dissemination structure. However, some portions also show banding structure. It can be said that this case is approximately concordant with foliation.

③ The presence of mineralization zone (zone including sulphide minerals) is roughly concordant with the direction of foliation in this zone.

④ Alteration minerals (sericite and chlorite) are poorly formed.

⑤ The country rock of mineralized zone mainly consists of charnockite and enderbite. Mafic granulite does not have mineralization of sulphide minerals.

The above facts show that mineralization occurred before metamorphism similarly to the case of Juwere zone. Also judging from the selectivity and concordance of mineralization for the country rock, this zone has a large possibility of stratabound ore deposit.

Fumure Zone

The main geological unit of this zone consists of quartzite, mafic granulite, and gneissose granulite (in a wide sense). There are some types of gneissose granulite commonly having orthopyroxene and clinopyroxene but lacking in K-feldspar close to enderbite .

The geological structure does not include any remarkable tectonic line. However, it is considered that Mt. Fumure consists of quartzite and forms a synclinal part.

The following are combinations of sulphide minerals and features of alteration minerals of executed MJZM-12 and MJZM-13.

① Similarly to the case of Jegede zone, pyrrhotite is a main sulphide mineral in quantity. Very small amounts of pyrite and chalcopyrite are commonly present

in this zone similarly to other zones. In addition, galena, sphalerite, and arsenopyrite are detected.
Therefore, this zone is slightly rich in sulphide minerals compared with other zones.
② For the mode of occurrence of sulphide minerals, the country rock consisting of charnockite shows dissemination structure but the country rock consisting of quartzite shows more banding structure. It can be said that this case is also approximately concordant with foliation.
③ Alteration minerals are poorly formed.

From the above facts, the mineralization by sulphide minerals had been done before metamorphism and the mode of occurrence of sulphide minerals differs in types of country rocks. Therefore, the zone has a high possibility of stratabound ore deposit similarly to Juwere and Jegede zones.

It can be estimated that alteration minerals (e.g. sericite and chlorite) once had been formed by accompanying mineralization were poorly remained in all surveyed zones except Benzi zone. Major of alteration minerals formed concurrently with mineralization were changed to other minerals due to the following reaction in later metamorphism or retrogressive metamorphism.
That is:
* Biotite rarely appear in the granulite facies and the range of chemical composition is limited in general. However, these surveyed zones frequently contain medium amount of biotite(see Appendix A-3), which is characteristic. This may be because sericite (muscovite) which is an alteration product formed biotite according to the following reaction with amphibole(Miyashiro, 1965).

$$\underset{\text{muscovite}}{3KAl_3Si_3O_{10}(OH)_2} + \underset{\text{amphibole}}{Ca_4(Mg,Fe)_9AlSi_{15}AlO_4(OH)_4}$$

$$= \underset{\text{biotite}}{3K(Mg,Fe)_3AlSi_3O_{10}(OH)_2} + \underset{\text{Ca-feldspar}}{4CaAl_2Si_2O_8} + \underset{\text{quartz}}{7SiO_2} + 2H_2O$$

* It is also estimated that chlorite formed by alteration produced biotite according to the following reaction with sericite (muscovite)(Miyashiro, 1965).

$$\underset{\text{molecule of serpentine}}{5(Mg,Fe)_6Si_4O_{10}(OH)_8} + \underset{\text{muscovite}}{6KAl_3Si_3O_{10}(OH)_2} = \underset{\text{biotite}}{6K(Mg,Fe)_3AlSi_3O_{10}(OH)_2}$$

$$+ \underset{\text{molecule of amesite}}{3(Mg,Fe)_4Al_4Si_2O_{10}(OH)_8} + \underset{\text{quartz}}{14SiO_2} + 8H_2O$$

Mineral Potential on Survey Area

It has been estimated that mineralization by sulphide minerals rarely occur in the surveyed zones in general. However, a dominant mineralization by sulphide minerals which was hardly found through the field survey was detected in three

zones(Jegede zone, Juwere zone, and Fumure zone) from the results of the geophysical survey (IP method) and drilling survey in this year though no economical mineralized zone was found.

Meanwhile, it was confirmed that some sulphide minerals is also present in Juwere and Benzi zones. This shows that mineralization by sulphide minerals occurred in these zones too.

The gold mineralization in Zimbabwe is characterized by accompanying sulphide minerals. Especially, Renco deposit near the surveyed zones is a stratabound ore deposit hosted in charnockite and enderbite, which has mineralization similar to the mineralization found in the above three zones in view of the country rock and type of sulphide minerals.

Though expected encouraging assay results are not obtained from the results of these surveys, it is significant that dominant sulphide minerals were confirmed in the surveyed zones where it has been thought that mineralization rarely occurs.

Though it was impossible to find any gold deposit through a series of these surveys, it is concluded that presence of a deposit similar to Renco deposit can basically be expected in Limpopo Mobile Belt.

Relation between Geochemical Anomalies and Mineralization

A typical geochemical anomalous zone was found in the following three zones.

① Jegede zone
② Benzi zone
③ Fumure zone

The geochemical anomalous zone in these zones
① contains relatively high gold value, and
② forms well-continuous anomalous zones,
and also
③ the anomalous zones are distributed in topographic depressed portions (e.g. Jegede and Fumure zones) or located at inclined portion (e.g. Benzi zone).

Therefore, it can be estimated that these anomalous zones are a hydromorphic anomalies formed by transported indicators from a topographic high place where mineralized signs are found.

The mobility of Au is confirmed depending on oxidation or reduction state, pH, and Cl^- ions, which is not expected under the state of Au^0. The mobility mechanism is roughly shown by the following equation(Cloke & Kelly, 1964).

$$3H_2O + Au^0 = H_2AuO_3^- + 4H^+ + 3e^-$$
$$4Cl^- + Au^0 = AuCl_4^- + 3e^-$$

$$Au^{0} = Au^{+++} + 3e^{-}$$

These equations depend on one or two factors of Eh, pH, and Cl^{-} and the mobility of Au under natural environment is also confirmed through the results of experiments.

In reality, precipitation of Au occurs in a solution according to the following phenomena.

① lowering of Cl^{-} ionic concentration(dilution)

② increasing of pH

③ reduction of $AuCl_4^{-}$ (or $AuCl^{-}$)

For example, when the case of factor③ is assumed, Au is precipitated at a topographically low place through the mechanism shown by the following reaction formula when Fe^{+2} reduces $AuCl^{-}$.

$$AuCl^{-} + 3Fe^{+2} + 6H_2O = Au^{0} + 3FeOOH + 4Cl^{-} + 9H^{+}$$

When the above reaction continues, enrichment of Au is promoted and forms a hydromorphic anomalous zone.

From the survey results in this year that

① the geochemical anomalous zones are located at a topographically low land and,

② no any mineralized zone corresponding to the zones is found,

it is estimated that these are hydromorphic anomalous zones.

In the hydromorphic anomalous zone, more condensed to gold than the mineralized zone where gold was originated was probably formed.

PART III CONCLUSIONS AND RECOMMENDATIONS

PART Ⅲ CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 1 CONCLUSIONS

The following is the conclusions of the geophysical survey (IP method) and drilling survey in this year which is Phase Ⅲ of the mineral exploration programme in Zimbabwe.

Geophysical survey (IP method)

The geophysical survey (IP method) which is considered to be the most effective for detection of sulphide minerals was conducted in the following three zones selected as the result of Phase Ⅱ survey.

① Benzi zone
② Jegede zone
③ Fumure zone

As a result, dominant sulphide minerals were found through the drilling survey at a place where

① high PFE zone (10 to 19%) and,
② low resistivity zone (2 to 50 Ω·m)

were overlapped.

Therefore, it is concluded that the geophysical survey (IP method) is effective for the survey of the mineralized zone showing dissemination to banding structures in a high grade metamorphic rock zone like the surveyed zones.

Drilling Survey

The drilling survey with thirteen holes and the total length of 1,530.65 m (depth: 90 to 150.30 m/hole) in this year was conducted in five zones(Juwere zone, Muchacha zone, Benzi zone, Jegede zone and Fumure zone) having a large possibility of gold deposits as the results of the past surveys. The following are the reasons for selection of drilling holes.

① Mineralized zone confirmed through ground surface survey
② Places where a geochemical anomalous zone and mineralized signs(Fe-oxides and quartz/pegmatite) are found
③ High 'PFE' zone
④ Low resistivity zone

As the result of the drilling survey conducted according to these reasons, mineralized zones of sulphide minerals showing dissemination to banding structures concordant with the foliation of country rocks were detected though they differ in drill holes except MJZM-4. The country rock of these mineralized zones is frequently composed of charnockite similarly to that of Renco deposit. Therefore, it is estimated that main mineralization occurred before metamorphism judging from the mode of occurrence of the mineralized zones and the present condition of them in the fields.

For the intensity of mineralization, dominant sulphide minerals (mainly, pyrrhotite, pyrite, and chalcopyrite, and locally, sphalerite and galena) were detected at:

① MJZM-9 and MJZM-11 in Jegede zone

② MJZM-13 in Fumure zone

In addition, sericite and chlorite can be observed as alteration minerals. However, they are not strongly associated with sulphide minerals. Therefore, it is estimated that the alteration minerals (sericite and chlorite) formed together concurrently with sulphide minerals were changed to minerals such as biotite due to metamorphism after mineralization.

No encouraging results were obtained from the analysis of these mineralized zones in {Au(g/t), Ag(g/t), Cu(%), Pb(%), Zn(%)}. The highest Au assay obtained in this survey was less than 0.4 g/t Au and we have not got an assay of 10 g/t Au which is supposed to be an economical grade of gold deposit in Zimbabwe.

CHAPTER 2 RECOMMENDATIONS

According to the conclusions obtained through the survey results in Phase Ⅲ and the study of them, we would like to recommend the following for future.

Though expected results were not obtained from the analysis results of mineralized zones, it can be evaluated that the survey methods, that is:

① Phase Ⅰ :LANDSAT image interpretation, geological reconnaissance survey, geochemical survey by stream sediments,

②Phase Ⅱ:semi-detailed geological survey, soil geochemical survey, and

③Phase Ⅲ:geophysical survey(IP method), drilling survey

were to be effective. Because sulphide mineralized zones hardly found through geological survey in the zones were detected when considering the fact that main gold deposits in Zimbabwe are associated with sulphide minerals.

The climate and topographical factors in this country tends to produce a pseudo-soil geochemical anomaly in topographic depressed portion, sloped portion and a boundary between the alluvial and soil layers.

Therefore, a geophysical survey(e.g. IP method) must be carried out to confirm the existence of sulphide minerals in soil geochemical anomalous zones, and after the interpretation of the IP survey results, a planning of drilling survey should be conducted.

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