CHAPTER 3 GEOLOGICAL SURVEY

3-1 Methods of survey

Items of the survey and survey method are shown in Table II-3-1.

3-2 Geological survey in tunnel

3-2-1 Underground geology

The geological map at level 1930 m and geological sections are shown in Fig. I-2-2 and Figs. I-2-4 (3) and (4), respectively. The geological sketch and geological map of the tunnel are shown in Plates 1 and 2.

The geology of the tunnel is composed of granodiorite porphyry dykes, lamprophyre dykes, skarnized dykes, and skarn and limestone (marble) of the Kumbel Formation of Devonian age.

(1) Granodiorite porphyry dyke

Granodiorite porphyry dykes appeared at two places, 33 m and 123 m from the 0 m point in the crosscut tunnel I. The former (dyke I) strikes NW-SE and dips steeply south and the latter (dyke II) strikes NE-SW and dips south. Both are accompanied with skarn and mineralization.

A. Dyke I

According to underground observation, dyke I is connected to the main body of Altyn Jylga intrusives without interruption. This dyke strikes N55°W and dips 60°S. The dyke is derived from the main intrusive body, which is elongated NNE-SSW toward the southeast. The dyke is 13-m wide (at the switch I of the underground rail) and accompanied with a mineralized skarn zone of 5-m width in the hanging wall side. The dyke is gray and composed of plagioclase and potash feldspar of less than 3 mm in diameter, and hornblende, biotite, clinopyroxene and quartz of less than 1 mm in diameter. (thin section 1930Cb-23Fa, result of identification; Appendixes 2 & 3).

B. Dyke II

This dyke is 2-m thick and strikes N48°E and dips 50°S. In the hanging wall side of the dyke, a 5-m thick body of pyroxene-garnet skarn is observed in contact with a fault that strikes N50°E and dips 70°S. A zone of chalcopyrite and bornite concentration having a thickness of 20-30 cm is often observed at the contact of the skarn body and marble of the hanging wall side of the skarn. Rock facies of this dyke is the same as that of Dyke I.

(2) Lamprophyre dyke

Lamprophyre dykes appeared at two places, 57 m and 121 m in the crosscut 1 tunnel. The former strikes N34°E and dips 55°S with a width of 1.2 m. The latter strikes N48°E and dips 50°S with a width of 1.5 m. Two directions of the joint, parallel and perpendicular to the dyke, were developed in the dykes. Very thin chalcopyrite-arsenopyrite quartz veinlets were recognized along the contact of the dyke and joints. The rock is dark gray to greenish gray and composed of fine grained (less than 1 mm) plagioclase, clinopyroxene, hornblende and biotite.

(3) Skarnized dyke

The skarnized dykes appeared at two places, 80 m and 139 m in the crosscut tunnel I. They are 1-m thick, and their strikes and dips are N42°E, 40°S and N60°E, 30°S. Chalcopyrite and bornite rich skarn with a width less than 15 cm occur along the contact of the dyke. The rock is grayish green to dark reddish brown and composed of clinopyroxene and plagioclase. The original can not be identified due to intense skarnization.

(4) Skarn

Skarns of this area occur in association with granodiorite porphyry and skarnized dykes. They are classified into endoskarn and exoskarn.
Skarns related with skarnized dyke belong to endoskarn.

- The skarns in a bedded form having a width of 5 m are associated with a granodiorite porphyry dyke and occur along the hanging wall of the dyke. Two meters from the dyke is endoskarn composed of fine-grained (less than 1 mm) pyroxenes and 3 m outside the dyke (marble side) is exoskarn mainly formed of garnet (thin section: 193005-15, 5F, 16Fa, 16Fb, 17F, 17.6FL, result of identification: Appendixes 4 & 5).
- Endoskarn is grayish green and composed pyroxene, feldspar, and quartz. Skarn minerals are distributed equally. Garnet skarn occurs along fractures and impregnates ore minerals such as chalcopyrite and arsenopyrite.
- Exoskarn is brown to dark green and composed of garnet and clinopyroxene of medium to coarse grain (1 mm to few cm). Garnet and clinopyroxene are distributed in irregular form of concentration respectively.
- Boundary surface between endoskarn and exoskarn is parallel to the granodiorite porphyry dike. Exoskarn grades into endoskarn in narrow zone. The exoskarn / marble boundary is irregular uneven shape.
- Skarns are mainly comprised of clinopyroxene and garnet, and sometimes contain quartz, plagioclase, potash feldspar, hornblende and biotite. Under the microscope, skarns show granoblastic texture. EPMA analysis revealed that

Table II-3-1 Method of the Geological Survey

Method		Location/Sample (quantity)	Procedure	Results
Tunnel sketch (side walls and roof)		The 1930 m level tunnel of phase III (161.5 m)	Scale 1/200, detailed sketch of important outcrops and faces, photography	Plates 1~3
Drillcore logging		MJKA-14 to 18 (5 drillholes, 828.9 m)	Scale 1/200, detailed sketch of important part, photography	Appendix 22
Sampling	Assay	Mineralization zones (tunnel 135+ drillcore 388)	**Tunnel:** Dimension of channel samples : principally 1 m (l) × 10 cm (w) × 5 cm (d) at 1m in height from the floor, taken from both sidewalls of cross-cut or each face of drift, and from side walls and faces in the part where the direction of ore zone was unidentified **Drillcore:** Principally 1 m length, splitting core longitudinally and taking a half for assay, another half for specimen	Appendix 6 (tunnel) Appendix 7 (drillcore)
	Thin sections	Fresh rocks and altered rocks, mainly unmineralized rocks (6 + 25)		Appendices 2 and 3
	Polished thin section and EPMA	Ore and mineralized rocks (8 + 18) EPMA was done to identify minerals and determine Au-Ag ratio of electrum (36 + 26)		Appendices 4 and 5 Appendix 11 (EPMA)
	X-ray diffraction analysis	Clay and altered or cryptocrystalline minerals of the thin section and polished thin section samples (5 + 8)		Appendix 8
	Homogenization temperature of fluid inclusions	Quartz, calcite and garnet accompanied with ore minerals (6 + 17)		Appendices 9 and 10
	Mineral separation test	No. 3 ore body in the 1850 m level tunnel (1)	Taken 8 ore samples of various Au grades, and mixed these samlples to make one representative ore sample of No.3 ore body	Appendices 12 ~ 21

the clinopyroxene is identified as hedenbergite, garnets are andradite and grossularite, and hornblendes are ferro-actinolite and ferroselite.

(5) Limestone

Limestone is white and massive and composed of calcite crystals of 1-2 mm in diameter.

(6) Fracture system

Two systems of fractures, trending NE-SW and NW-SE, were developed in the area (Table II-3-2).

Table II-3-2 Classification of Fracture System

Direction	Dip	Nature(width)	Mineralization
NE-SW	35° ～ 70° S	fault(<1m) dike(2m, <1m dominant) shear joint	mainly chalcopyrite, bornite and arseno-pyrite with Au
NW-SE	60° N～ 90°	fault(<1cm) dike(<13m) shear joint	mainly chalcopyrite, bornite and arseno-pyrite with Au

3-2-2 Mineralization

Major mineralized zones (average Au grade is over 3 g/t for a width over 1 m) determined to date are shown in Table II-3-3. Distribution of the gold grade is shown in Plate 3, and all assay results are shown in Appendix 6.

- Gold mineralization is observed both in skarns and dykes, and more intense in skarns.
- Gold mineralization in skarn is confined to the fractures in endoskarns whereas it is spread over the skarns in case of exoskarns.
  Mineralization in dykes is confined to the fractures.
- The highest grade of gold for a 1-m width was 116.2 g/t in endoskarn and 150.8 g/t in exoskarn. Including two types of skarns, the highest average grade of gold was 21.2 g/t for a width of 6.5 m.

3-3 Core logging

3-3-1 Core geology of each drill hole

Geological columns of all diamond drill holes are shown in Fig. II-3-1, and detail geological columns of each drill hole are shown in Appendix 22.

(1) MJKA-14

Geology of this drill hole is composed of limestone, lamprophyre dykes, skarns (exoskarns), skarnized gabbro (endoskarns), skarnized granodiorite (endoskarns) and granodiorite.

Limestone that appeared from the collar of the hole to 102.4 m is white and massive. Skarns from 102.4 to 105.4 m is dark green consisting of mainly pyroxene and garnet, less than 1 mm in diameter, with dissemination of magnetite (thin section: MJKA-14104.2, result of identification: Appendixes 4 & 5). Skarns at a depth of 103.5-104.5 m are formed of siderite, magnetite and pyrite. An alteration zone was formed at the contact of skarns and limestone. Skarnized gabbro, which appeared continuously from 109.1 to 131.2 m is dark green and mainly formed of clino-pyroxene, plagioclase and hornblende (thin section MJKA-14125.5). Arsenopyrite-quartz veins of 1 cm thick are frequently observed in the skarnized gabbro. A lamprophyre dyke intruded the boundary of skarns and skarnized gabbro. Skarnized granodiorite porphyry that appeared continuously from 131.2 to 134.2 m is grayish green and mainly formed of clino-pyroxene, feldspar and quartz. Arsenopyrite-quartz veinlets of about 1 cm thick frequently occur in the skarnized granodiorite and skarnized gabbro are intergradational. Granodiorite, which appeared from 134.2 to 181.0 m (bottom of the hole) is gray and partially shows porphyritic texture (thin section MJKA-14179.7). Contact of skarnized granodiorite and granodiorite is intergradational. Dykes of lamprophyre appeared at 15.2-18.9 m, 37.1-40.0 m and 87.9-88.2 m in limestone, and 105.4-109.1 m in skarns and skarnized gabbro. Dyke of lamprophyre is fine grained, gray and composed of plagioclase, clino-pyroxene, hornblende and biotite (thin section: MJKA-14107.8). A seam of skarns, consist of clino-pyroxene and disseminated chalcopyrite, was formed at the contact plane of lamprophyre dyke and limestone (thin section MJKA-1417.6-18.7).

(2) MJKA-15

Geology of this drill hole is composed of limestone, lamprophyre dykes, skarns (exoskarns), skarnized granodiorite (endoskarns) and granodiorite.

Limestone, which appeared from the collar of the hole to 72.0 m, is white and massive. Skarns, appeared from 72.0 to 100.4 m, is dark green and formed of mainly pyroxene of less than 1 mm in diameter with irregular shaped garnet concentration (thin section: MJKA-15105.8-109999.0). The skarns contain abundant magnetite and minor amount of disseminated chalcopyrite. An

Table II-3-3 Major Mineralization Zones in the 1930 m Level Tunnel and Drillcore

Location		Distance(m)	Length(m)	Host rock	Content		
					Au(g/t)	Ag(g/t)	Cu(ppm)
Tunnel	Side track I 1.8 m face	1.0 ～ 2.8	1.8	skarnized granodiorite	16.8	0.6	172
	Side track I 3.0 m face	0.8 ～ 2.1	1.3	skarnized granodiorite	6.3	0.7	129
	Side track I East wall	12.1 ～ 18.6	6.5	Garnte-Pyroxene skarn	21.1	51.2	8985
	Cross cut I North wall	130.0 ～ 131.5	1.5	Garnte-Pyroxene skarn	6.9	33.3	25166
Drillcore	MJKA-14	120.0 ～ 127.0	7.0	skarnized gabbroid	3.8	0.3	31
	MJKA-15	67.8 ～ 103.0	35.2	Garnte-Pyroxene skarn	3.0	1.0	432
	MJKA-16	144.0 ～ 148.0	4.0	silicified granodiorite	3.4	0.6	135
	MJKA-17	66.8 ～ 69.4	2.6	Garnte-Pyroxene skarn	7.9	0.15	106
	MJKA-18	117.6 ～ 120.00	2.4	Garnte-Pyroxene skarn	3.6	11.6	1450

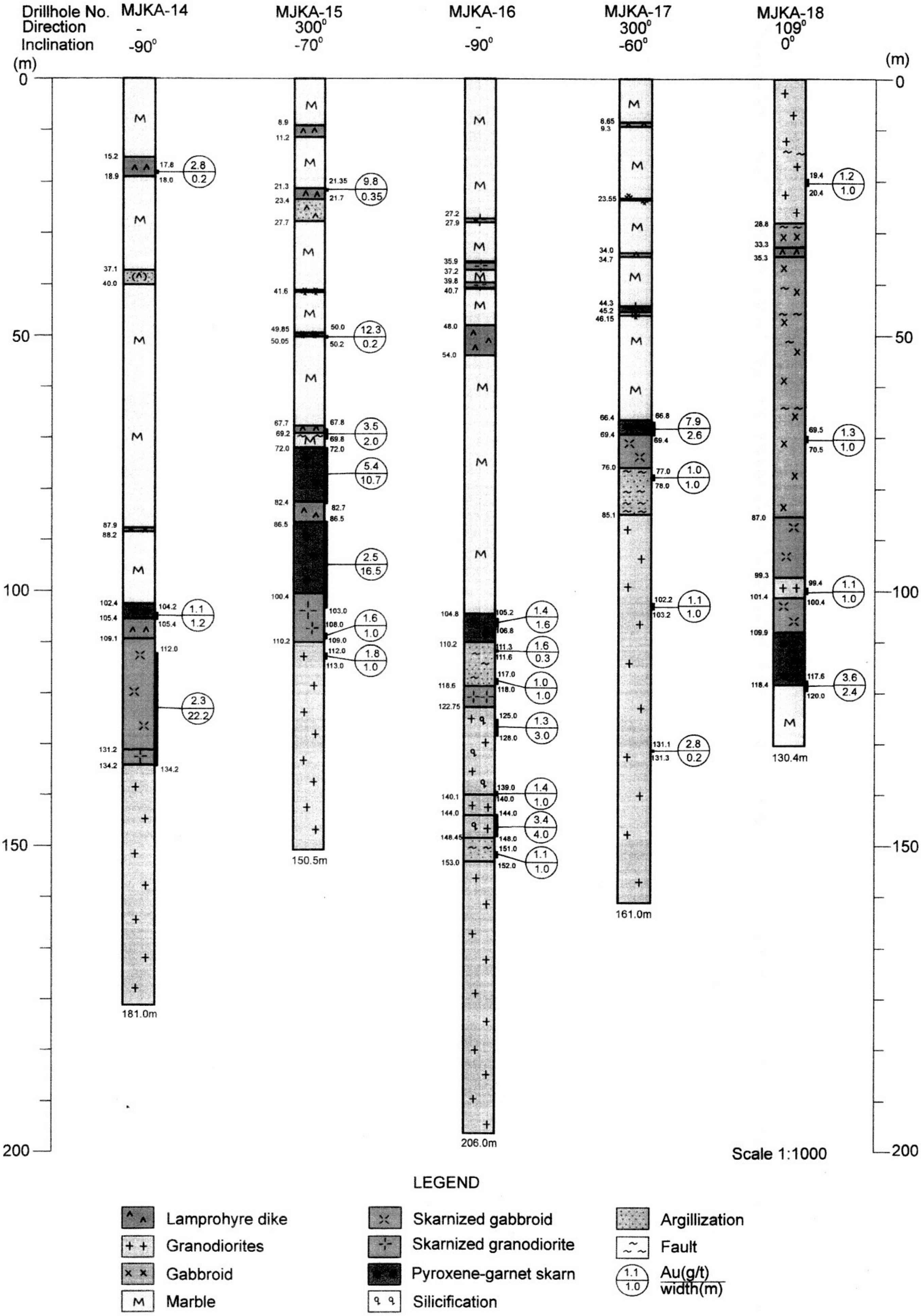

Fig. II-3-1 Summary of Core Logs (MJKA - 14~18) alteration zone was formed at the contact of skarns and limestone. Skarnized granodiorite (gabbro?), which continuously appeared from 100.4 to 110.2 m, is grayish green, mainly consists of plagioclase and clino-pyroxene (thin section MJKA-15105.8-109.0). A number of arsenopyrite-quartz veinlets with a thickness of 1-5 mm are observed in the skarnized granodiorite. Contact of the skarns and skarnized granodiorite is intergradational. Granodiorite, which appeared from 110.2 to 150.5 m, the bottom of the hole, is gray and partly shows porphyritic texture. A number of arsenopyrite-quartz veinlets with a thickness of 1 mm to 1 cm are observed from 111.0 to 123.0 m in the granodiorite. The skarnized granodiorite and granodiorite boundary is intergradational. Dykes of lamprophyre appeared at 8.9-11.2 m, 21.3-27.7 m and 67.7-69.2 m in limestone and 82.4-86.5 m in skarns. The lamprophyre is fine grained, gray and composed of plagioclase, clino-pyroxene, hornblende and biotite. A seam of skarns, consisting of clino-pyroxene, garnet and disseminated chalcopyrite, was formed at the contact plane of lamprophyre dyke and limestone (thin section: MJKA-1510.2-68.8).

(3) MJKA-16

Geology of this drill hole is composed of limestone, lamprophyre dyke, skarnized dyke, skarns (exoskarns), skarnized granodiorite (endoskarns) and granodiorite.

Limestone that appeared from the collar of the hole to 104.8 m is white and massive. The skarn that appeared from 104.8 to 110.2 m is dark greenish brown and mainly composed of garnet with subordinate amount of magnetite in form of irregular mass or dissemination (thin section MJKA-16105.0-109.0). Lumps of calcite containing chalcopyrite often occur in the skarn. An alteration zone was formed at the contact of skarns and limestone. Skarnized granodiorite, which appeared continuously from 118.64 to 122.75 m, is grayish green, mainly consisting of plagioclase and clino-pyroxene. A zone of fault breccia was developed between the skarns and skarnized granodiorite. The rocks along the fault zone were intensely silicified and argillized forming grayish white altered rock consisting of calcite and quartz. Original rock of the altered rock is unknown. The altered rock of 111.3-111.55 m is brecciated containing breccia with chalcopyrite impregnation. The fault plane crosses the drill hole at an angle of 40-45° (thin section MJKA 16117.3). Granodiorite, continuously appeared from 122.75 to 206.0 m (bottom of the hole), is gray and partly shows porphyritic texture. Granodiorite of 122.75-148.45 m is weakly silicified along the joints and chalcopyrite-arsenopyrite quartz veinlets are often observed in the joints. Dyke of lamprophyre, appeared from 48.0-54.0 m in limestone, is fine grained, gray consisting of plagioclase, clino-pyroxene, hornblende and biotite. Three skarnized dykes appeared from 27.2 to 40.7 m in limestone. The skarnized dykes are fine grained, greenish gray consisting of plagioclase, potash feldspar, clino-pyroxene and garnet (thin section: MJKA-1627.2). Impregnated chalcopyrite is often observed in joint and contact plane of skarnized dyke.

(4) MJKA-17

Geology of this drill hole is composed of limestone, lamprophyre dykes, skarnized dyke, skarns (exoskarns), skarnized gabbro (endoskarns) and granodiorite.

Limestone appeared from the collar of the hole to 66.4 m, is white and massive. Skarns appeared from 66.4 to 69.4 m, is dark greenish brown mainly consisting of garnet, which contains impregnated or veinlets of magnetite and chalcopyrite. Aggregates of quartz, hornblende and magnetite of 2 cm in diameter were observed in the skarn. An alteration zone was formed at the contact of skarns and limestone. Skarnized gabbro continuously appeared from 69.4 to 76.0 m, is grayish green mainly consisting of plagioclase and clino-pyroxene (thin section MJKA-1771.1). A zone of alteration was formed at the contact of skarns and skarnized gabbro. Granodiorite, appeared from 85.1 to 161.0 (bottom of the hole), is gray and partly shows porphyritic texture. A number of arsenopyrite quartz veinlets of about 1 mm in thickness were observed throughout the granodiorite. A zone of fault breccia was developed between skarnized gabbro and granodiorite. The rocks in the fault zone were intensely silicified and argillized forming light gray altered rock consisting of calcite and quartz. The original rock of the altered rock is unknown. The fault intersects the drill hole at an angle of 30-70° . A dyke of lamprophyre, which appeared from 8.65 to 9.3 m in limestone, is fine grained and gray consisting of plagioclase, clino-pyroxene, hornblende and biotite. These skarnized dykes of less than 30 cm in width penetrate limestone from 23.55 to 46.15 m. The skarnized dyke is fine grained, porphyritic, grayish green consisting of plagioclase, potash feldspar, clino-pyroxene and garnet. Impregnation of chalcopyrite is observed at the boundary of both lamprophyre and skarnized dykes.

(5) MJKA-18

Geology of this drill hole is composed of granodiorite porphyry, gabbro, skarnized gabbro (endoskarn), skarn (exoskarn), limestone and lamprophyre dyke.

Granodiorite porphyry, appeared continuously from the collar of the hole to 28.8 m. The rock is gray composed of plagioclase, potash feldspar, quartz, biotite and hornblende (thin section MJKA-188.8). A number of arsenopyrite quartz veinlets of 1 mm in thickness are recognized. Gabbro, which appears from 28.8 to 87.0 m, is dark gray comprised of hornblende, olivine, clino-pyroxene, biotite and plagioclase (thin section MJKA-1829.8-41.4-57.5). Arsenopyrite quartz veinlets of about 1 mm thick were rarely observed in gabbro. Boundary of the granodiorite porphyry and gabbro is intergradational. Skarnized gabbro, which appeared from 87.0 to 109.9 m, is grayish green consisting of plagioclase and clino-pyroxene. An alteration zone was formed at the boundary of gabbro and skarnized gabbro. Four silicified veins of less than 3 mm in thickness were observed in granodiorite porphyry dyke from 100.2 to 100.7 m. Skarns, appeared from 109.9 to 118.4 m without interruption, is dark green formed of mainly pyroxene. Dissemination of fine-grained chalcopyrite is observed in the skarn. An alteration zone was formed at the boundary of skarnized gabbro and skarn. Limestone, which continuously appeared from 118.4 to 130.4 m (bottom of the hole), is a white to brown massive that is partly skarnized. Lamprophyre dyke appeared from 33.3 to 35.3 m. The lamprophyre is fine grained, gray consisting of plagioclase, clino-pyroxene, hornblende and biotite.

3-3-2 Mineralization

Major mineralized zones (average Au grade is over 3 g/t for the width of over 1 m) proved to date are shown in Table II-3-3. Major gold mineralized zones are also shown in the section of diamond drilling Fig. 1-4-4(1)-(2). Assay results are shown in Appendix 7.

- Gold mineralization was recognized in those rock of skarns, lamprophyre dyke, skarnized dyke and granodiorite, which is more intense in the skarns.
- Gold mineralization in skarns took place along fractures in the case of endoskarns, whereas it is spread over the skarns in the case of exoskarns. Mineralization in dykes and granodiorite intrusives is confined to fractures.
- The highest gold grade for a 1 m width was 9.9 g/t in endoskarn, which was obtained from 66.8 to 67.8 m of MJKA-15, and it was 5.9 g/t in exoskarn

obtained from 124.0 to 125.0 m of MJKA-14.

3-4 Occurrence of ore minerals

Main ore minerals are chalcopyrite and bornite. They are associated with arsenopyrite, pyrite, magnetite, marcasite, tetrahedrite, chalcocite, galena, sphalerite, electrum, argentite, native bismuth, clausthalite, gersdorffite and hauchecornite as accessory minerals (identification result of polished sections Appendixes 4,5,15,16).

- Gold occurs in electrum. Ratio of gold and silver in electrum is 59% Au and 36% Ag (EPMA result, Appendix 11).
- Size of electrum is 1③m-200③m in diameter and larger grain of electrum tends to occur in higher-grade ore.
- Electrum is round or irregular, and occur as an inclusion of bornite and chalcopyrite (sulphides copper minerals), middling of sulphide copper minerals, or a separate mineral. Sometimes electrum occurs as an inclusion or middling of garnet and clino-pyroxene. Very small grains of electrum were found in association with small crystals of native bismuth, clausthalite, tetrahedrite and gersdorffite.
- From the above-described mineral assemblage, crystallization of electrum is presumed to have taken place at least three times.
  - Crystallization of skarns such as garnet and pyroxene.
  - Crystallization of sulphide copper minerals.
  - Later than the crystallization of sulphide copper minerals (crack in the sulphide copper mineral is filled with electrum)

3-5 Homogenization t emperature of fluid inclusions

Homogenization temperature measurement of liquid inclusion was carried out on the quartz and calcite, which are associated with ore minerals such as chalcopyrite, pyrite and arsenopyrite. Histogram of all measured data, table of measured data and histograms of measured data of each sample are shown in Fig.II-3-2, Appendixes 9 and 10, respectively.

- Four peaks were recognized in the histogram of all temperature measurements; 125° C, 160° , 200° C, and 260° C. Similar result was obtained in the histogram of each measured sample. The maximum temperature was 304° C.
- Distribution of homogenization temperature indicates that the crystallization of quartz and calcite was commenced at the temperature of about 300° C and intense hydrothermal activities took place four times at

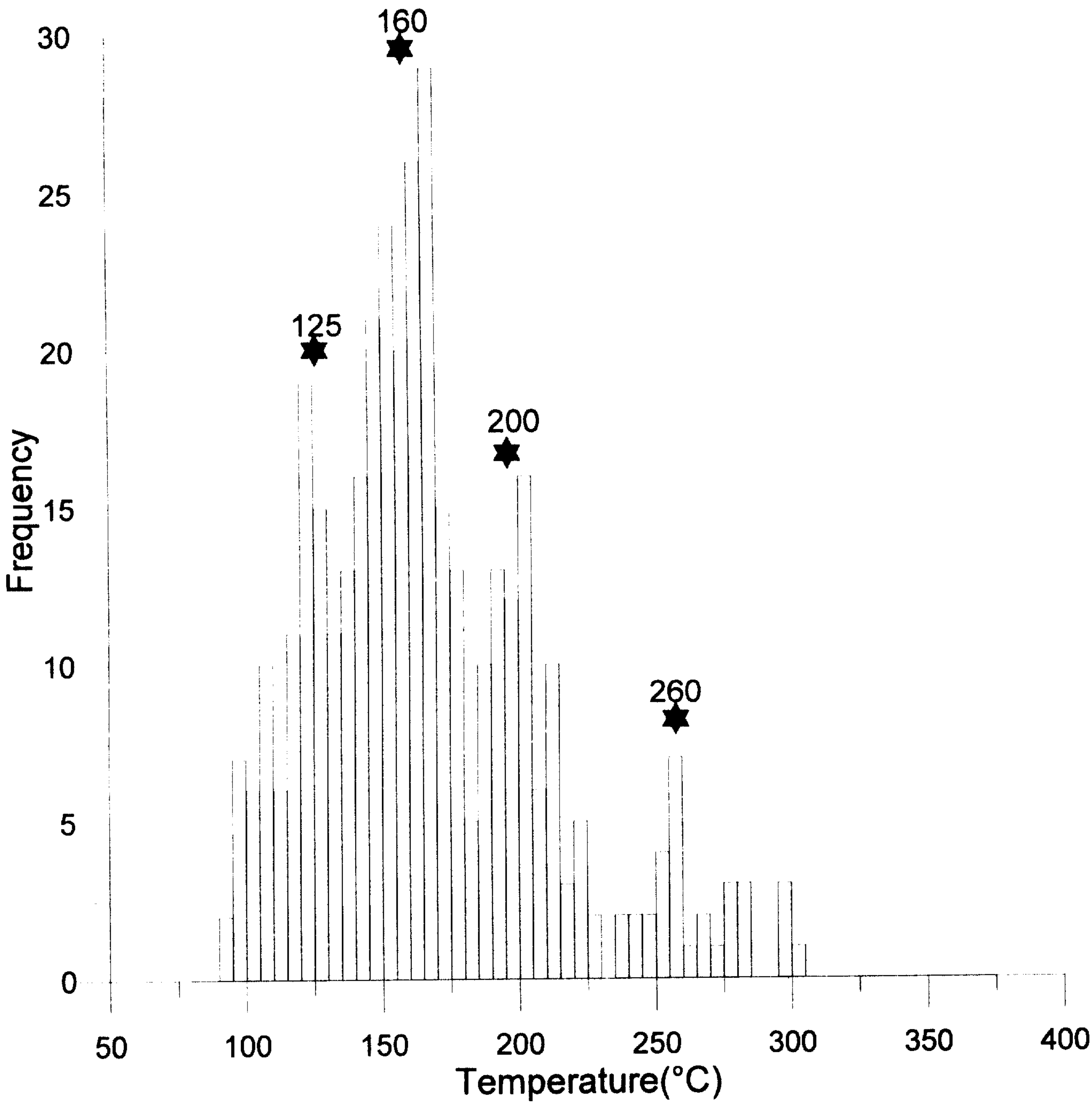

Fig. II-3-2 Histogram of Homogenization Temperatures of Fluid Inclusions temperatures of 125° C, 160° C, 200° C and 260° C.

3-6 Result of Mineral Dressing Test

In order to obtain basic information on the character of the ore and judge the degree of difficulty of mineral dressing, a preliminary mineral processing test was carried out on a sample representing skarn ore. The flow of the test is shown in Appendixes 12 and 13. As a result of the test, the recoveries of gold, silver, and copper are shown in Appendix 14.

● Samples for test

The below eight skarn ore samples were collected from the tunnel at the 1850-m level. The samples were mixed to make one sample for the test in order to make the grade of the sample close to the average grade of the high-grade ore body.

① T2-182L: chalcopyrite ore (fine grained pyroxene-quartz skarn) 1.05 kg
② T3-63.7R: chalcopyrite ore (garnet-pyroxene skarn) 0.5 kg
③ T3-64.5L: magnetite ore (pyroxene-garnet skarn) 1.08 kg
④ T3-87.5: chalcopyrite-bornite ore (garnet skarn) 0.4 kg
⑤ T3-111L: chalcopyrite ore (garnet skarn) 1.0 kg
⑥ C1-15R: equigranular pyroxene skarn 0.98 kg
⑦ C2-19.5L: bornite-chalcopyrite ore (pyroxene-garnet skarn) 0.9 kg
⑧ C2-19.8R: chalcopyrite ore (pyroxene-garnet skarn) 0.3 kg

● Flow of test

Crushing & grinding- separating of minerals by shaking table-chemical analysis- further grinding for medium to light minerals- two stage flotation tests for sulphide minerals-chemical analysis of float and tailings

● Results of test

- Grade of the test sample was Au 20.3 g/t, Ag 16 g/t, Cu 0.98%
- Products of the shaking table were 12% heavy minerals, 13% medium minerals, 63% light minerals and 11% slime.
- Recovery of gold was 60% in heavy minerals, 11% in medium minerals and 26% in light minerals. Recovery of silver was 55% in heavy minerals, 10% in medium minerals and 30% in light minerals. Recovery of copper was 56% in heavy minerals, 13% in medium minerals and 22% in light minerals.
- Result of flotation test showed that the recovery of gold, silver and copper was 33%, 37% and 43%, respectively. The grade of the tailings was Au 1.1 g/t,

Ag 2 g/t and Cu 0.01%.

- Combining the results of the shaking table and two stage flotation, as the final recovery, 94% for gold, 92% for silver and 99% for copper was obtained.