Chapter 4 Analyses of Survey Results

4 - 1 Characteristics and Structural Control of Mineralization

(1) Mineralization in the geological survey area

Gold-silver-copper-lead-zinc mineralization is observed in the geochemical exploration area of the second year. Manganese mineralization was also found, but in small scale. Gold-silver-copper-lead-zinc mineralization was mainly found in quartz veins accompanied by chalcopyrite, galena, and sphalerite. Also skarn minerals were found in the existing mining concessions and occurrence of associated base-metal mineralization is inferred. Gold, silver, copper, lead, zinc, and molybdenum anomalies were detected by geochemical work in these concessions. The following mineralization was found by the geological survey carried out during the present year.

・Tempursari District: Chalcopyrite dissemination was confirmed in green altered rocks in the Ngrawan River Basin. The maximum copper and gold grades are low at 0.11% Cu and 0.164g/t Au but copper (0.04~0.11%) and gold (0.043~0.164g/t) mineralization is confirmed along the strike direction of 12km. Malachite is observed with unaided eyes, and chalcopyrite with maximum grain size of 100 microns is observed microscopically together with an iron oxide mineral (hematite?). Veins of fine-grained magnetite was observed in an outcrop adjacent to this sample and thus potassium alteration characteristic to porphyry copper deposits was anticipated, but the altered rock was found to consist mainly of chlorite with associated sericite and potash feldspars and biotite could not be confirmed. But the size of the diorite exposure is only several tens of meters and there is a possibility that the shallow part of the mineralized zone is not exposed.

White argillized zones occur widely, but they are controlled largely by the NW-SE fault system. Alteration minerals are mainly sericite accompanied by smectite. Also green alteration zone consists mainly of chlorite and epidote, and is distributed widely in the Tempursari District from Gede River to Ngrawan River and it is difficult to distinguish regional alteration from that associated with mineralization. Pyrite dissemination occurs widely in both the white argillized zones and green alteration zones, particularly in the smectite-bearing white alteration zone along the Ngrawan River and green alteration Zone of the Gede River.

Sample T035 collected from the eastern part contain small 20-micron chalcopyrite within pyrite grains indicating formation of the copper mineral simultaneous with or earlier than pyrite.

・Purwoharjo District : Hypogene mineralization was not found by the survey. Quaternary conglomerate, which occur along the Coban River, contain Mandalika gravel and volcanic breccia and tuff of the Wuni Formation. They all contain 0.01~0.02% Cu which is higher than other unaltered rocks in the area. Thus the background Cu value of the soil in this area is believed to be high.

・Seweden District: Copper and gold mineralization was observed along the Putih River, Cekelan River, and Centung River in the western part of this district. The maximum copper contents of the samples collected at the Putih River this year are 0.81% Cu for silicified and argillized rocks and 0.57% for green altered rock with pyrite dissemination (floater). Copper contents of the quartz veins of the Centung River are low at <0.01% Cu, but although low at 0.064g/t Au, gold mineralization is observed. Chalcopyrite grains are detected microscopically from a sample collected at the Putih River. Also covelline was detected from these samples. In Centung quartz veins, association of sphalerite and galena is confirmed. White argillized zone is widely distributed in this district and sericite is found in many samples from the vicinity of the Putih River. On the other hand, clay consisting mainly of kaolin is being mined on a small scale in this district. At this site, there are kaolin accompanied by pyrite and kaolin without pyrite, and soft clay containing iron oxide and smectite are mined as pottery clay. Other mineral combinations of altered rocks found in this district by PIMA measurement during the second year are:

A: Kaolin
B: Dickite・ (kaolin・alunite, gypsum)
C: Sericite・smectite
D: Pyrophyllite (dickite・alunite)
E: Mixed-layer clay minerals・(ankerite)
F: Sericite・(chlorite)
G: Sericite・ankerite・(gypsum).

Of the above, A and parts of C are of supergene origin. E, F, and G are believed to be of hypogene origin. A occurs in shallow subsurface zones and along faults and thus are considered to be the product of alteration overlapping E, F, and G.

・Prambon District: Occurrence of gold-silver-copper-lead-zinc bearing quartz veins have been confirmed during the second-year survey. Continuation of the mainly gold mineralization at the Suren River in the north and of silver-copper-lead-zinc quartz veins at the Sumurup and Beloran

Rivers in the central part was inferred at that time, but it could not be confirmed by surface survey of the third year. Therefore, emphasis was laid on detailed survey of the northern gold-bearing quartz veins this year. The results show that 71 samples, of the 72 quartz vein and altered rock samples analyzed, contained gold in excess of the detection limit, and 11 contained more than 1g/t Au. The maximum value is not high at 3.03g/t Au, but native gold with 50-micron diameter was found to occur in pyrite together with acanthite microscopically in one sample (V107). Acanthite was also found in 2 other samples (T124, U066). Chalcopyrite was confirmed in 3 samples, sphalerite in 10 samples, and galena in 9 samples. Regarding alteration minerals, sericite is developed adjacent to the veins, and volcanic and volocanilastic rocks are widely affected by green alteration.

(2) Host rocks and stratigraphic horizon affected by mineralization

The geology of the four surveyed districts consists mainly of Oligocene to Miocene volcanic and volocanilastic rocks and Pliocene limestone. Quaternary volcanic rocks also occur in the northern part. The volcanic rocks of the Tempursari, Seweden, and Prambon Districts mainly belong to the Mandalika Formation and are basalt, andesite, and dacite. The volocanilastic rocks are dominantly coarse-grained. In the Purwoharjo District, the Miocene Wuni Formation and Quaternary volcanic and volocanilastic rocks are dominant. Many of the volcanic rocks are strongly altered and the original rock cannot be determined, but both tholeiitic and calc-alkaline series possibly occur in the basalt and andesite of the Tempursari District, but the diorite of the Ngrawan Basin belong to the calc-alkaline series. Also in the Seweden District, both tholeiitic and calc-alkaline basalt and andesite possibly occur, but the weakly altered dacite in the Putih Basin is most probably calk-alkaline (T079, X057).

Mineralized units are mostly volcanic and volocanilastic rocks of the Mandalika Formation and gold-silver-copper-lead-zinc mineralization-alteration has not been confirmed in the Miocene Wuni Formation and Quaternary System. Also various types of intrusive rocks, such as diorite, quartz diorite, basalt, and dacite occur in the four survey districts. In the Tempursari District, the vicinity of the dioritic intrusion is widely altered by hydrothermal activity. In the Seweden District, dacite occurs closely associated with hydrothermally altered zones. The ages of the intrusive activity are 16.5 ± 1.7Ma for andesite in Tempursari is, and 10.1 ± 0.5Ma for quartz porphyry to the east of Seweden, and the intrusive bodies exposed nearby also show Miocene age. It is noted, however, that quartz porphyry occurring to the south of Malang outside of the present survey area show somewhat younger age of 10Ma.

(3) Results of soil geochemical survey and mineralization

Soil geochemical survey was carried out in three districts, namely Tempursari, Seweden, and Prambon Districts. Clear gold anomaly was detected at one site in Tempursari and Prambon Districts. Also Au values are higher in the Prambon District than in the other two districts, and it is inferred that this fact reflects the exposure of Au mineralized parts at the surface in this district. On the other hand regarding Cu, the Cu values are low in all three districts, and large-scale copper mineralization is considered not to be exposed on the surface. The Cu values of the soil in the Tempursari District are higher than those of the other two districts.

The high Au values in the Tempursari District are concentrated in two zones. One zone extends in the NNE-SSW direction on the ridge of the central part and Cu and Zn values are rather low. The other zone occurs in the Ngrawan Basin in the southwestern part of the sampled range and high As values are concentrated together with some high Cu and Mo values. Therefore it is anticipated that there could be blind Cu mineralization in this district which has not reached the surface. There is a possibility that the existence of alteration zones, hydrothermal mineralization, igneous activities such as intrusion, and geologic structure are manifestations of subsurface blind porphyry copper deposits.

In the Seweden District, high values of Pb, Zn, As, Mo, and Cu are concentrated in three zones, namely Putih River and vicinity, southeastern part (Kuning River), and northwestern part. Concentration of these elements indicates epithermal to mesothermal mineralization. From the study of surface silicified zones and quartz veins, it is believed that the indicated epithermal mineralization is of low sulfidation type because of the lack of As sulfides which often occur in high sulfidation system, but at the same time high sulfidation characteristics are inferred from strong pyrite dissemination, occurrence of pyrophyllite as an altered mineral.

In the Prambon District, high As, Hg, Sb, Cu, Zn, Pb values occur widely together with Au. The occurrence of these high values was confirmed by surface survey to generally coincide with the distribution of the outcrops of silicified rocks and quartz veins. Parts of the epithermal mineralization are exposed on the surface in this district, and it seems that erosion here is more advanced than in the Tempursari and Prambon Districts.

(4) Related igneous rocks

In all districts, aside from equigranular holocrystalline quartz diorite-diorite, basalt and andesite (diorite porphyry) and dacite intrusive rocks are exposed. The nature of these rocks is as follows.

(a) Diorite bodies exposed in the Tempursari District contain quartz veinlets and are strongly

disseminated by pyrite. Radiometric dating has not been carried out, but andesite to the south is 16.5Ma.

(b) Dacite (quartz diorite) bodies have intruded in the Seweden District and their vicinity is widely altered.

(c) Andesite (quartz diorite: 21Ma) bodies have intruded into andesitic clastic rocks (Mandalika Formation) of similar age.

(5) Development of geologic structure and mineralization

Tertiary System consisting mainly of the Mandalika Formation occurs in the three districts of Tempursari, Seweden, and Prambon where mineralization has been detected. The area of Tertiary System distribution is, as mentioned earlier, located in the Southern volcanic zone of the southernmost part of Java, and it is believed that similar tectonic environment prevailed after the Tertiary Period.

Of the three districts, the Tempursari consists of rugged topography and in the northern part Quaternary volcanoes are in direct contact with the Tertiary System, and further north volcaniclastic Wuni Formation and limestone Wonosari Formation could have deposited but they would have been almost totally eroded out. Also the elevation exceeds 1,000m in the north and units underlying the Mandalika Formation could be exposed. But the exposed area of intrusive bodies such as diorite is small, and possibility of granites bodies occurring in the subsurface zones is high. Thus the central parts of mineralization associated with these intrusive activities possibly occur in subsurface zones.

As mentioned earlier, the geology of the Tempursari District consists almost solely of the Mandalika Formation and the structure is not clear. But it is inferred that the general trend is E-W strike with southern dip. The prevailing strike of the faults of this district is NE-SW and thus the structure of the area was formed under N-S compressional stress field. Although data are lacking regarding the age of mineralization in this district, since mineralization is not found in the Wuni Formation to the west of the district, the possibility of pre-Middle Miocene mineralization is high.

Seweden District has the lowest elevation among the three districts and the limestone of the Wonosari Formation is thick in the southern part. Thus the subsequent uplift is considered to be smaller than that of the Tempursari District. However in the northern part of this district, intrusive rocks with several-hundred-meter diameter are exposed and the limestone in the vicinity was not affected by contact metamorphism (there are rare occurrences of recrystallized floats in the area). Therefore in this district, it is inferred that uplifting movement was most active associated with

strong erosion before the deposition of Wonosari Formation, followed by change of environment favorable to the deposition of limestone. Mineralization most probably occurred before the deposition of Wonosari Formation. Thus it is possible that the parts of units affected by mineralization was exposed before the Wonosari deposition and is presently again eroded in this district.

There is a clear N-S to NNE-SSW fault system in the western part of this district and the silicified rocks occur along the NNE-SSW system and these faults appear to control the mineralization. Also these faults cut through the Wonosari limestone. Therefore it is possible that mineralization occurred after the Wonosari deposition and that faults existed before the mineralization.

Within the three districts, post-Mandalika Formation geologic units are the thickest in the Prambon District. The uplift after Wonosari deposition is considered to have been strong in this district together with the Tempursari District. The predominant direction of the quartz veins is N-S to NNW-SSE. The strike of the faults is dominantly NE-SW and they cut through the Wonosari limestone. As mineralization do not occur in the faults cutting through Wonosari Formation, and they are believed to have formed in the period before Late Miocene to Pliocene. However, the hypothesis that, the auriferous quartz veins and faults were formed in the same stress field and that the area was under N-S to NNW-SSE trending compressional stress at the time of fracture formation, cannot be denied.

Eastern Java where the present survey area is located is an accretionary zone formed by the subduction of the India Ocean Australian Plate and is believed to have been in a regional N-S trending compressional field. From the above it can be assumed that the NNE-SSW~NE-SW faults are shear faults, and the gold-silver-copper-lead-zinc-bearing quartz veins were formed in the N-S~NNE-SSW tensional fractures. The age of this mineralization can only be determined to be during Middle Miocene to Pliocene.

(6) Alteration zones

In the Tempursari, Seweden, and Prambon Districts, sericitization and argillization characterized by kaolin minerals and smectite are developed. Parts of the kaolin minerals could have been formed by weathering, but many of them are believed to be the product of hydrothermal activity from the pyrite dissemination and mode of quartz vein occurrences. Also propylitization characterized by chlorite are developed in the vicinity of argillization in these three districts. Hydrothermal activity is not developed in the Purwoharjo District.

(a) Tempursari district: Sericite and mixed-layer clay minerals often accompanied by smectite are developed from the upper reaches of the Ngrawan River to the middle reaches of the Gede River. These are believed to have developed in a sheath-like manner enveloping faults, and propylitized zones are developed surrounding them. The extent of acidic alteration in the Tempursari District is believed to be limited. Kaolin and alunite are observed in some parts, and these are considered to have formed by interaction with rainwater in secondary supergene process near the surface. Epidote and paragonite are also detected.

(b) Seweden District: Dickite was found to occur widely in the vicinity of Putih River Basin by spectrometer PIMA during the second year survey and subsequently identified as kaolin minerals by X-ray diffraction. The mode of occurrence of these minerals, however, indicates that kaolinite was formed by weathering of sericite, quartz, and pyrite mixture. Therefore, the alteration minerals of this district are not necessarily of hydrothermal origin. Pyrophyllite is also detected and kaolinite formed by hydrothermal alteration probably also exists. All in all, the white clay alteration zone near the Putih River in this district is a product of overlapping hydrothermal alteration and weathering, and the possibility of alteration zone in the upper part of porphyry copper deposits or hydrothermal mineral deposits cannot be denied.

(c) Prambon district: Wide area of this district is propylitized to green color, and alteration zone consisting of mainly sericite, quartz, pyrite are developed in the mineralized zones. Smectite and halloysite are often associated with these zones and many of them are thought to have been formed by weathering. Namely, these were probably originally hydrothermal sericitization products which were formed by secondary reaction with rainwater.

(7) Environment of mineralization

(a) Tempursari: Although the homogenization temperature of the samples is uneven, the mean value is high at 231－293° C and it is harmonious with the mode of occurrence of the alteration zone in the vicinity. The alteration zone in the Ngrawan Basin is generally quartz, sericite, chlorite, carbonate minerals, and smectite.

(b) Seweden : Although some samples have high homogenization temperature such as 236° C, 277° C., and 375° C., others are low and it is believed that they were formed under epithermal environment. The quartz veins in the western part contain inclusions with two differing temperatures and salinities.

(c) Prambon: The homogenization temperature and salinity of the quartz veins are lower than the other two districts at about 200° C, and about 1%. This may indicate the possibility of the mineralization extending downward.

It is seen from the above that, although the number of samples is small, the homogenization temperature of the quartz veins in the three districts is high, but the salinity does not vary very much and the average is low at less than 2.0%. Thus it is considered that the mineral potential for epithermal gold-silver deposits is high in the Prambon District, while potential for high temperature polymetallic deposits, skarn and porphyry copper deposits is higher in the Tempursari and Seweden Districts. Also the existence of irregular goethite veins in the vicinity of diorite intrusive bodies and small exposures containing epidote indicating skarn-type mineralization is suggested in the northern part of the Seweden District.

(8) Similarities of geologic environment in neighboring deposits

Although further east of the present survey area, Batu Hijau mine is operating in the Sumbawa Island which is considered to have similar geologic environment. On the other hand to the west, Pongkor gold mine is working in western Java. Tertiary volcanic rocks also extend to the vicinity of the latter mine and these rocks host the quartz veins. The difference, however, is that mineralization also occurs in the Pliocene volcanic rocks in Pongkor.

The inferred regional tectonics is as follows. The strike of the Cretaceous and Tertiary accretionary zones, NNW-SSE, is slightly diagonal to the direction of the present trench. Therefore, Cretaceous accretionary zone is exposed in western Java while Tertiary accretionary zone is observed in the eastern part. The boundary of these two accretionary zones crosses the geochemical survey (reconnaissance) area. Thus it is believed that the western part is affected by the older NNW-SSE compressional stress while the eastern part is affected by younger N-S compressional field.

(9) Epithermal deposits and porphyry copper deposits

(a) Alteration zones

Alteration consisting of sericite + quartz + pyrite ± smectite ± gypsum, and alunite may not necessarily be a direct indication of porphyry copper-type mineralization. But this is a very common mineral combination in altered zones associated with porphyry copper deposits. Ulrich and Heinrich (2001) says that alteration zones consisting of sericite+pyrite+clay minerals+ gypsum occur with porphyry copper deposits and that these are overprinted on potash alteration and

propylitic alteration (Bajo de la Alumbrera porphyry Cu-Au deposit). Also in Bajo de la Alumbrera deposit, alteration consisting of magnetite+quartz occurred before the main potash alteration associated with mineralization. Such mineral combination is recognized in Tempursari District at a tributary of the Ngrawan River where copper mineralization is confirmed. On the other hand, silicification is known but magnetite is not found in Seweden.

Thus although the sericite+pyrite alteration in Tempursari and Seweden cannot be construed as an evidence of porphyry copper-type mineralization, it indicates a high possibility of the existence of such mineralized zones.

(b) Epithermal deposits and porphyry copper deposits

Porphyry copper type mineralization and high-sulfidation-type epithermal mineralization are thought to occur in similar geologic environment (Hedenquist et al., 1998 etc.). Hedenquist and Arribas (1998) studied the genetic relation of Far Southeast porphyry copper deposit and the Lepanto epithermal deposit. Guilbert (2001) examined the classification of hydrothermal deposits and their mutual relations. In it he introduced a new classification of "mineral deposits associated with intrusive bodies" with regard to "porphyry environment" and asserted that with Au-Bi-W-As-Te-Sb concentration the alteration is of limited scale compared with that of porphyry deposits and explained their characteristics. Hedenquist (2003) reviewed the past studies of high sulfidation type mineralization and summarized their characteristics. From these works, it is considered that the existence of high sulfidation type gold deposits would be a strong lead for porphyry copper exploration. However, from various reasons such as the level of erosion, there are many cases where hydrothermal high sulfidation gold deposits do not exists in the vicinity.

On the other hand, the direct relation between porphyry deposits and low sulfidation type gold deposits is not clear. In some cases the low sulfidation gold deposits are described to occur far from the porphyry deposits. But the characteristics of the porphyry copper deposits in the Southwest Pacific are; high gold grade, many are associated with dioritic igneous rocks, scale of the deposits are relatively small and in some cases the argillic or the phyllic zones of the Lowell-Guilbert model are not developed in the associated alteration zone. Also care is needed regarding the advanced argillic zones because both hypogene and supergene origin can be considered.

Regarding the mineralization in the Tempursari and Seweden Districts, such epithermal characteristics are manifested by, *inter alia*, although in small amount, pyrophyllite is identified together with kaolin minerals and alunite, relatively large amount of pyrite occurs in argillized zone,

As content is high in some samples, covelline is detected in Seweden. However, the widespread alteration mineral is sericite and vuggy quartz hardly occur, and it is difficult to clearly define whether the gold is of low or high sulfidation type and to use it as a lead to blind porphyry deposits. Thus it cannot be said with certainty that probability of ore occurrence is high immediately below the copper-gold alteration zone confirmed in the survey area. But faults are expected to occur in this area and silicified zones occur along these faults and it is a reasonable assumption to anticipate porphyry copper deposit below the strongest surface alteration zone.

4 - 2 Mineral potential

(1) Tempursari District

There is no clear indicator of porphyry copper deposits in this district, but in the Ngrawan River Basin in the northeastern part, argillization is widespread with gold and silver mineralization near diorite intrusive bodies, which suggests the upper zone of ore deposits. Thus this area is concluded to have the highest potential in this district.

(2) Purwoharjo District

Geochemical anomalies in this district are very possibly not manifestations of mineralization, and data indicating existence of mineral potential are nil.

(3) Seweden District

Gold and copper mineralization is observed in the alteration zone to the south of Blitar in the central eastern part of the district.

(4) Prambon district

Mineralization is found widely and particularly promising zone was discovered by the second-year and present geological survey in the Suren River Basin in the northern part of the area, where many epithermal gold-bearing quartz veins were found and some have high gold grade. This quartz vein zone is considered to have the highest gold-silver potential in this district. Also lead-zinc bearing quartz veins to the south in the basins of Sumurup and Beloran Rivers are considered to have high mineral potential, but these areas were not surveyed this year.

Table 1-6 Summary of Geological Survey

District	Mineralization	Geochemical anomaly	Expected type of ore deposits
1. Tempursari	-Wide alteration, quartz veinlets Alteration mineral: Sericite -Rock:0.16g/tAu(max) 0.11%Cu(max)	Soils: Au, Ag, Cu	? (porphyry copper type?)
2. Purwoharjo	-No mineralization on surface	Stream sediments: Cu (Phase 2) (high Cu in Wuni Formation)	-
3. Seweden	-Wide alteration zone, quartz veinlets -Sericite alteration Kaolin alteration -Rock:0.2 g/t Au(max) 0.81% Cu (max)	Soil: Au, Zn, As, Sb, Mo	Au-Ag-quartz vein (possible porphyry copper at depth?)
4. Prambon	-quartz vein, pyrite dissemination -sericite alteration	Stream sediments: Au, Ag, As, Sb, Mo Panning: Au Rock:0.8 g/t Au	Au-Ag-quartz vein (possible porphyry copper at depth?)