PART III: CONCLUSION AND RECOMMENDATION

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Chapter 1 Conclusion

In this fiscal year, the first year of the two-year survey, 40 points consisting of mineral showings and alteration zones were selected and the ground truth was carried out for those points, based on analysis of the existing data, analysis of airborne magnetics and radiometric data, analysis of satellite images, and analysis and interpretation of geochemical data of stream sediments. In the stage of analysis of the existing data, the target was concentrated to SEDEX type lead/zinc deposits, porphyry type copper and copper/gold deposits, and epithermal gold deposits as deposit types with high economic values. Comprehensive examination was made with the above mentioned four analyses together with results of ground truth and laboratory tests. As a result, the following conclusions were reached.

1) SEDEX type lead/zinc deposits and volcanogenic massive sulfide deposits

For exploration of SEDEX type lead/zinc deposits, there are only a few clues because deposits of this type generally have a weak alteration halo differently from other hydrothermal deposits. With drilling cores which intersected El Aguilar deposits provided by Compania Minera Aguilar S.A. for this survey, it was attempted to delineate ore horizons, hanging wall and footwall by the statistical analysis of the geochemical data. As a result, it was found that there was a difference in chemical composition between them, and methodology such as lithogeochemical exploration would be an effective method.

According to the interpretation of sedimentary basins by Sureda (1999), it is inferred that a zone with a possibility of hydrothermal activities is a zone from El Aguilar to Pumahuasi, which corresponds to the central part of a sedimentary basin of the secondary to tertiary order (the area with distribution of Lower Ordovician Santa Victoria Group). In the vicinity of El Aguilar deposits (Zone 15), including Rio Grande located in this zone, an ore horizon inferred from lithogeochemistry extends north and south direction. Therefore, this area is considered to be a zone with the highest possibility of the existence of deposits. In the Ordovician system on the east side, the upper part of the Santa Victoria Group are distributed and SEDEX type lead/zinc deposits are expected in the deeper level.

The sulfur isotopic ratio of lead in vein-type lead, zinc and barite deposits in the area with distribution of the Ordovician system represent -3 to 4‰, while that of lead in El Aguilar deposits is as heavy as 15 to 25‰. Therefore, the origin of sulfur of these deposits is considered to be different.

La Colorada deposits distributed on the west side of the area in the Ordovician system were regarded as volcanogenic massive sulfide deposits because the deposits were accompanied by volcanic rocks in the vicinity, because filling texture with sulfide minerals in the space of brecciated

volcanic rock is observed and because the content of copper is higher than those of lead and zinc compared with typical SEDEX deposits. Although the control factor of this deposit are not clear, if it was formed accompanying volcanic activity, it is expected that similar deposits exist in the whole magmatic arc of the Ordovician on the west side in the north part of the survey area.

2) Porphyry type copper and copper/gold deposits

Miocene to Pliocene magmatic arcs developed near the border between Chile and Argentina. In this area, four volcanic rocks extend like an arm in the SE direction from these north south trending main magmatic arc. We tentatively called them No.1 to No.4 arms for convenience. Distribution of porphyry type copper and copper/gold deposits and epithermal gold deposits are restricted in these four arms. Therefore, these four zones can be fundamentally mentioned as highly potential zones. Particularly, Arm No. 4 has some porphyry type deposits and alteration zones such as Bajo de la Alumbrera, Bajo de la Agua Tapada, and Filo Colorado. Although distribution of volcanic rocks is very small near Inca Viejo halfway between Arms **No. 2 and No. 3**, it is assumed from the results of airborne magnetics that the potentiality of intrusive rocks exists in the shallow part of the vicinity. In addition, mineralized zones including Inca Viejo, Diablillos, Condor Yacu and Centenario are known. Therefore, even though the distribution of volcanic rocks is very small, these zones can be regarded as those with high potential for the presence of porphyry type copper and copper/gold deposits and epithermal gold deposits.

In the SE tending extension of each arm, small-scale intrusive rocks are scattered, which are not expressed on a small scale geological map. Porphyry type copper and copper/gold mineralizations are observed inside and outside those rocks. This mineralization corresponds to Agua Rica deposits of Arm No. 4, El Alisal and El Pago of Arm No.3 and Panco Arias alteration zone of Arm No. 2. These have been also extracted as alteration zones in the analysis of the satellite image.

Regarding porphyry type copper and copper/gold deposits, the potential for the existence of deposits is thought to be high, as mentioned above. Substantially minute investigations have been already carried out, and room for exploration is considered to exist in the SE tending extension of each arm.

In three north arms of the four, there are resurgent calderas accompanied by ignimbrite, and erosion of volcanic body has not advanced so much yet. Therefore, if porphyry type copper and copper/gold deposits are formed in these volcanic arms, those deposits exist in the deeper level and cannot be the object of exploration.

It is considered that epithermal gold deposits are at the favorable level of erosion. In particular, Rachaite and Incachule alteration zones are obviously inside the caldera wall and can be

regarded as products of the volcano-hydrothermal system. A similar presumption can be applied to alteration zone on the east side of Galan caldera extracted from the analysis of the satellite image.

3) Analysis of the ASTER image

The following method was employed this time for the first time: First, the false image, the color-ratio composite and the semi-grain model image were prepared from the ASTER image. Alterations were then extracted and checked with the known deposits and alteration zones. Alterations could be extracted with almost no omission, and the effectiveness of this analysis was verified.

Chapter 2 Recommendation for Phase-2 survey

This year, the potential of the whole survey area was assessed by the analyses of the existing data, satellite images, data of airborne geophysics and radiometric exploration, and data of geochemistry of stream sediments and by the ground truth. For the second year survey, we would like to recommend regarding zones that are thought to have high potential for the existence of deposits but have been surveyed insufficiently, and future surveys of which are expected to lead to the discovery of deposits, among potential zones extracted in the evaluation of the whole survey area.

1) SEDEX type lead/zinc deposits and volcanogenic massive sulfide deposits

In the survey area, El Aguilar Mine is only the operating mine as SEDEX type lead/zinc deposits. For the exploration of deposits of this type, clues for exploration of which are a few, what is desired is a methodology that enables:

a) First of all, grasping precisely the characteristics of El Aguilar deposits (including Esperanza deposits) and factor which control the mineralization, and

b) Deductively applying exploration elements lead by the above-mentioned grasping and general exploration elements of the main SEDEX type lead/zinc deposits in the world to surrounding similar geological environment. There is a similarity that the representative SEDEX type lead/zinc deposits in the world are formed in small-scale sedimentary basins with anoxic environments in large-scale sedimentary basins such as passive margin (for example, Sangster and Macintyre, 1983; Lydon, 1995). Sureda (1999) inferred that El Aguilar deposits were formed in Padrioc Basin of the third order spreading north and south from El Aguilar to Pumahuasi. From the viewpoint of the regional area, it is desirable to re-analyze (re-examine) sedimentary basins in terms of positioning of El Aguilar deposits in the Ordovician system, based on the existing sedimentological data.

The ore horizon of the El Aguilar deposits is generally considered, from mega-fossils, as Acoite formation of the Lower Ordovician. Tracing of horizons hosting deposits is important as well as the above-mentioned analysis of sedimentary basins. It is desired to clarify the stratigraphy by using Lower Paleozoic microfossils with high resolution (conodont and radiolaria).

The lithogeochemical exploration method with argillaceous rocks used is an effective methodology for SEDEX type lead/zinc deposits with a few clues for exploration. It is desirable that this method should be employed in surveys of surrounding places, and, at the same time, additional tests should be made around the said deposits so as to heighten the accuracy of this method.

Concretely, in addition to stratigraphical division with microfossils, it is necessary to clarify horizons hosting deposits by using lithogeochemistry in **Zone 15 (El Aguilar area)** including Rio Grande It is also necessary to extract, by the similar method, horizons hosting deposits in the east-

to-west route (**Zones 2, 3 and 5**) (**Pumahuasi and Santa Victoria area**) connecting Pumahuasi, Santa Rosa and La Cienaga mineral showings.

In La Colorada deposits, massive sulfide deposits were identified by drilling of Pacific Rim Co., Ltd. It is indispensable to grasp the characteristics of this deposit by using drill core. Similarly to El Aguilar, lithogeochemical exploration is required for extraction of horizons hosting deposits. In the case of volcanogenic massive sulfide deposits, it is expected that a hydrothermal alteration zone exists in the hanging wall and footwall, and confirmation of its existence is necessary. Because development of calc-alkali volcanic rocks is observed, the said deposits are different in tectonic setting from El Aguilar deposits, but the environment of the generation is almost unknown. Therefore, it is desired to make examinations with the existing data from the viewpoint of volcanic activity and generation of massive sulfide deposits, based on an understanding of the characteristics of La Colorada Deposits.

Concretely, it is desirable to carry out investigation in **Zone-18 (La Colorada area)** including La Colorada deposit and Limeca mineral showing where similar type of mineralization to those of La Colorada have been discovered.

As for porphyry type copper and copper/gold deposits and epithermal gold deposits, known places of mineral showings and alteration zones in and around the survey area were surveyed in detail by foreign exploration companies in the latter half of 1990s, as shown in Table I-3-2-4-1.

It is hard to say that porphyry type copper and copper/gold deposits have been fully investigated in small-scale stock of the Neogene in the basement rocks located in the extension of volcanic rock arms away from the main body of volcanic rock. Concretely, areas to be investigated are **Zone-28 (Pancho Arias area), Zone-46 (El Alisar-El Pago area)**. El Pago was not extracted as a potential zone in the analysis of the existing data carried out this time. Latter have been extracted by analysis of the satellite images as alteration zones. It is desirable to grasp the characteristics and the extension of alteration halo.

Regarding epithermal gold deposits, many mineral showings are found in the arms of volcanic rocks. It has been clarified from the analysis of satellite images and the ground truth carried out this time that there is development of argillized alteration zones accompanied by base metal on the wall of annular structure or resurgent calderas such as Rachaite, Incachule and Pan de Azucar. These zones show the shallow part of the hydrothermal system, and it is expected that epithermal gold deposits exist in the deeper level.

Concretely speaking, the target is the zone around Pozuelos depression starting from Cornazuli caldera where Rachaite alteration zone is located in the north part of the survey area to the vicinity of Pozuelos depression (**Pan de Azucar-Rachaite area**) where Pan de Azucar deposits exist, and the zone surrounding Galan caldera (**Galan area**) in the south part of the survey area. For the whole area of the former, including Zones-7 and-9, it is desirable to investigate both the existing

alteration zones and alteration zones extracted from satellite images, regarding characteristics of alteration, distribution and the presence or absence of mineralization. Particularly, as this area is located at the south end of the Bolivian tin belt, and mineralization of tin in Pan de Azucar deposit is known, the potential for vein type polymetallic deposits is considered high. On the other hand, from the analysis of satellite images, alterations were extracted in the caldela wall and on its southeast side around Zone-39 and Galan caldela in the latter zone. However, this zone has not been sufficiently surveyed yet. It is desirable to investigate the characteristics and the distribution of alteration, and the presence or absence of mineralization.