Chapter 4 Integrated Discussion of Survey Result

4-1 Characteristics of the mineralization of Teloloapan Subterrane

It is known that marine volcanic sedimentary rocks of the late Jurassic Period to the Cretaceous Period are widely distributed and there are many volcanic massive sulfide deposits in the Teloloapan subterrane distributed north to south at the east end of Guerrero Terrane, which is the largest geological structure zone in Mexico. The main deposits are the Tizapa, Santa Rosa, Aurora, Rey de Plata, and Campo Morado deposits in this order from north. The Tizapa deposit is now under operation.

The ores found in these deposits are all complex ores mainly composed of Zn and containing Pb, Cu, and Ag, but there are differences; the ores in the Tizapa and Campo Morado deposits are rich in pyrite and those in the Rey de Plata deposit contain barite.

For the ore horizon, the Tizapa deposit has almost one ore body interleaved between thick pelitic schist and calcareous slate and the ore body appears at the top of green schist. Acidic volcanic rocks are distributed slightly away from the ore bodies. In the Rey de Plata deposit, an ore body accompanies sedimentary rock in acidic – intermediate pyroclastic rocks on top of andesitic volcanic rocks and is divided into several smaller ones. The upper part of these volcanic rocks is covered with calcareous sediments, but nothing known about the lower part. In the Campo Morado deposit, several ore bodies have been formed at the boundary between acidic pyroclastic rocks and sedimentary rocks.

4-2 Characteristics of Mineralization and Geological Structure in Survey Area

1) Igneous Activity and Sedimentary Environment

The survey area is characterized by the existence of submarine volcanic rocks of the Villa Ayala Formation and sedimentary rocks formed in the hiatuses of these volcanic rocks.

The submarine volcanic rocks of the Villa Ayala Formation are mainly composed of andesitic underwater hydroclastic rocks and are accompanied by dacitic volcanic rock. They are divided into the lower and upper layers with the sedimentary

rocks being the boundary between them.

The lithofacies of the lower layer changes toward the upper part from pyroxene andesitic lava (massive, autobrecciated) to hyaloclastite (alternation of layers of sandy or tuffaceous slate) of fine grain in the eastern part of the La Campana district to the Santiago Salinas district. This volcanism ended with dacite containing a lot of plagioclase phenocryst. Judging from the lithofacies of lava and coarse rocks, the development of the schistose structure by cleavage is apparently weak, but the schistose structure is clear from the lithofacies of fine grains and dacite.

The lithofacies changes from andesite with a well-developed schistose structure and dacitic tuff to sedimentary rocks in the southwestern part to the northwestern part of the La Campana district, and crystalline dacite is missing.

The sedimentary rocks are composed of black slate with a well-developed cleavage, calcareous slate, sandy limestone, and tuff, and pass through the northern part of the La Campana district to the Capire district north and south and continue to the western part of the Santiago Salinas district. The layer is thickest (200 m or more) in the northern part of the Capire deposit where black slate and calcareous slate are predominant. The layer is several tens of meters in the southern part of the Santiago Salinas district and disappears in the western part. In the La Campana district, sandy tuff is predominant toward the northwest and the layer is 50-meter thick, which is cut off by a fault and disappears in the north.

The upper layer begins with dacitic tuff. It is mainly composed of andesitic tuff and lava and accompanied by dacitic vitric tuff. In the La Campana district, it is often accompanied by thin layers of slate, which suggests that this district was in an environment where sedimentary rocks were formed in small hiatuses of volcanic activities. Tuff and sedimentary rock has a well-developed schistose structure by cleavage.

2) Mineralization and Alteration Types and Periods

There were signs of mining in the Manto Rico deposit in the La Campana district, the Capire deposit of the Capire district, and the Aurora 1 deposit. All of these

deposits produce black ores mainly containing Pb and Zn in the sedimentary rocks and are accompanied by barite and gypsum. Tuff containing mad balls is distributed near the deposits. The previous drilling survey revealed a mineralization zone of low grade (73 g/t of Ag, 1.13% of Zn, 1.2 mt) in the sedimentary rock in an underground shallow place between the Capire deposit and the Aurora 1 deposit. These deposits are partially accompanied by sericitization and pyritic network veins, but no remarkable wide-ranging alteration zones have been recognized nearby. Band-like mineralization containing Pb, Zn, and Cu at MJZC-8 is the same type as these. Judging from the occurrence, this mineralization was formed almost at the same time as the sedimentary rocks and the ore bodies underwent regional metamorphism later.

Other mineralization and alteration is found near Tlanilpa, in the northern part of Aurora 1 deposit, near the northern part of La Campana, and in the Santiago Salinas district.

The same type of deposit occurs near the Tlanilpa and in the Santiago Salinas district. The deposits are controlled by the horizon at the boundary between dacitic tuff at the uppermost of the lower volcanic rocks and sedimentary rocks. Fine-grained pyritic dissemination and network veins occur in dacite on the outcrop and fine pyrite is accumulated in layers in sedimentary rocks. Massive – disseminated, bedded pyritic layers were recognized in the same horizon from the boreholes of MJZC-4 to MJZC-7. The analysis revealed that Ba indicated 1,000 – 2,000 ppm, but the grade is low on the whole. The examination under a microscope revealed a very small amount of sphalerite and chalcopyrite, except pyrite.

Remarkable fine-grained pyritic dissemination zones and sericitized mineralization and alteration zones in foliated tuff are distributed over a wide area around the northern part of the La Campana. They were recognized at the boreholes of MJZC-8 and MJZC- 9. In addition to pyrite, a trace of chalcopyrite and sphalerite were recognized under a microscope. The disseminations develop in parallel with cleavage and some bedded disseminations are found, which may have been formed by hydrothermal activities before regional metamorphism. Since alteration partially occurred in the lower part of the upper sedimentary rocks, there is a strong possibility

that the hydrothermal activities continued after the formation of the foliated tuff.

As the mineralization and alteration in the northern part of the Aurora 1 deposit, fine- or medium-size-grained pyritic dissemination is found in upper volcanic rocks and the dissemination tends to develop in parallel with the cleavage plane in the form of a lens or network. The hydrothermal activities may have occurred before the regional metamorphism activities because alteration is composed of sericitization and chloritization and no structure that cuts off cleavage has been recognized.

In addition, a small amount of pyrite and calcite and some quartz veins that cut off the schistose structure exists, which suggests the occurrence of hydrothermal activities after the metamorphic activities.

3) Geochemical Characteristics

The mineralization in sedimentary rock is accompanied by a portion rich in Pb and Zn. Ores captured in the Capire and Aurora deposits or at MJZC-8 contain several percent of Zn and Pb, but contain less than 1% of Cu. Like the ores of the Rey de Plata deposit, these ores contain less than 10% of Fe. The ores present a stark contrast to the main ores of the Tizapa deposit, which exceed 30% (Watanabe: 2003). This contrast shows that there is a distinct difference in the amount of pyrite contained in the ores of these deposits.

Ores of the Capire and Aurora deposits often contain several percent of Ba. The pyritic layer present at the boundary between the lower volcanic rocks and sedimentary rocks is poor in Cu, Pb, and Zn but relatively rich in Ba. It often contains 1,000 ppm or more.

The alteration zone that develops in the foliated tuff in La Campana was recognized even from the boreholes. The alteration zone at MJZC-8 indicated Ba (about 0.2 – 0.4%), Zn (445 ppm), and Ag (about 9 ppm), which suggests the possibility of ore showing nearby.

For the geochemical behavior of the rocks, the chemical analysis of cores revealed that the variation of Cu+Pb+Zn is almost linked together with a change in As. Elements such as As, Ba, Cd, Mo, Pb, and Sb in sedimentary rock indicate high values

in the plane. The analysis of trace elements showed that some anomaly areas are scattered in existing mineral showings and sedimentary rock distribution areas, which suggests that the same mineralization as that of the Aurora and Capire deposits occurred in various places on a small scale or blooms are present.

The alteration index calculated from the main elements is generally low and anomaly spots are scattered, which shows that the alteration condition of the district is not so remarkable.

Consequently, although small-scale mineralization is recognized over a wide range in this district, there is a possibility that intense mineralization which had formed large-scale deposits was not present.

4-3 Mineralization Model

Hydrothermal activity related to volcanic massive sulfide mineralization in the Aurora area followed last-stage activity of dacitic tuff in the lower volcanic rocks of the Villa Ayala Formation and continued intermittently into activity of upper volcanic rocks. The major hydrothermal activity can be divided into three periods (Fig 1-4-1).

The first period is mostly the mineralization and alteration of pyrite that occurred at the end of activity of dacitic tuff in the lower volcanic rocks of the Villa Ayala Formation. The centers of the hydrothermal activity are provably in the southeastern part of the Santiago Salinas, near the Tlanilpa showing, and in the northwestern part of the La Campana. Although the hydrothermal activity shows a tendency of a slightly high content of Ba, it is not accompanied by the mineralization of Pb or Zn.

The second period is the mineralization that mainly consists of Zn formed in interbedded sedimentary rocks and is accompanied by Pb, Cu, Ag, and Ba.Old mines such as Aurora, Capire, Manto Rico, and ore showing at MJZC-8 may have been formed in this period. Relatively small-scale hydrothermal activity might have occurred over a wide area in a scattered manner because small ore bodies are widely distributed and there is no strong alteration zone over a wide area. Previous

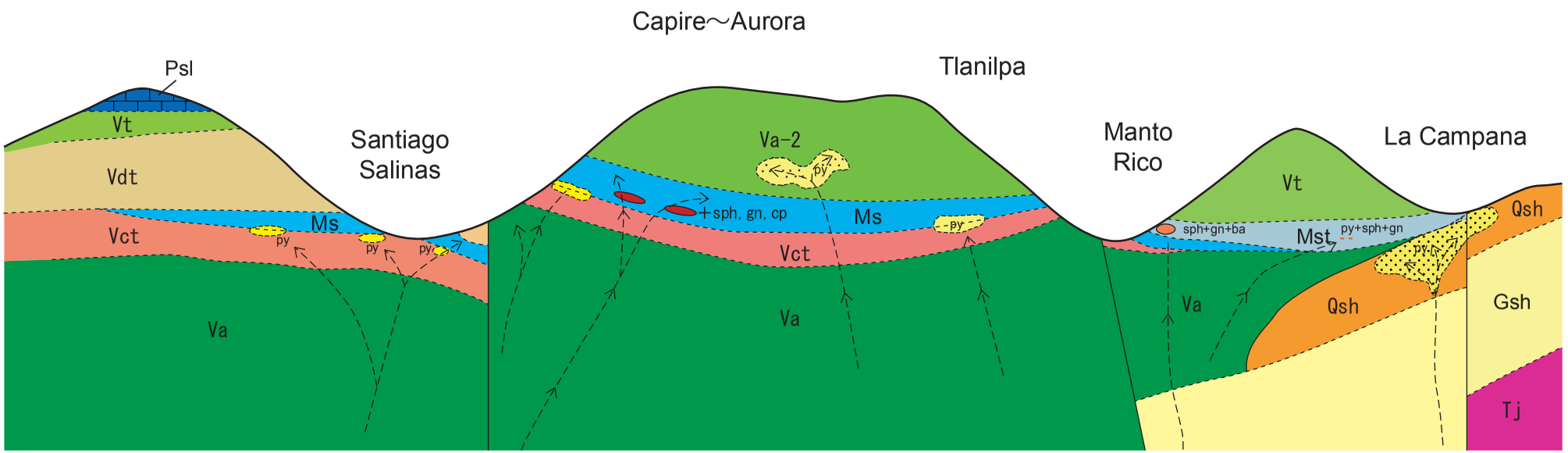
surveys revealed that the most concentrate of ore body was recognized at an underground shallow depth between the Capire deposit and the Aurora 1 deposit, where an ore body was 1.2-mt with an average grade of Zn of 1.13% and Ag of 73 g/t.

The third period is a pyritic dissemination zone developing in parallel to a schistose structure that occurred in the upper volcanic rocks north of the Aurora 1 deposit. Petrograhic and geochemical exploration showed that this dissemination zone is unproductive, although it shows a high alteration index.

As described above, generally speaking, the mineralization in this area occurred at the last stage of the submarine volcanic activity of the Villa Ayala Formation placed between the Tejupilco schist and the sedimentary rocks of the Pachivia Formation. This agrees with the general characteristics of massive sulfide deposits frequently seen on the Teloloapan Subterrane situated on the eastern tip of the Guerrero Terrane. Small mineralization zones, however, are scattered throughout this area. In contrast to this characteristic, the Tizapa deposit consists of a single large ore body (>10 mt) and the Rey de Plata deposit consists of several medium-size ore bodies. The development of the hydrothermal systems may have been more sporadic in this area than in the Tizapa and Rey de Plata deposits. Consequently, it can be concluded that there is a strong possibility that no single large ore body may have been formed in this area.

4-4 Potential for Ore Deposits

A geological detailed survey and a drilling survey of the Capire, La Campana, and Santiago Salinas districts determined ore showing in sedimentary rock and between lower volcanic rocks and sedimentary rocks. Mineralization may have occurred in a distributed way because remarkable alteration cannot be seen in the vicinity of a mineral showing and mineralization of Pb and Zn in sedimentary rock is scattered over a wide range. Although some places such as the southern part of La Campana and the eastern part outside the Capire district have not yet been explored, it is difficult to expect the presence of large-scale deposits.



Pachivia Formation
Psl Calcareous slate

Villa Ayala Formation
Upper Volcanic Unit
Vt Glassy tuff, andesitic tuff
Vdt Dacitic tuff
Sedimentary Rocks
Ms Calcareous slate, limestone
Mst Sandy tuff and slate

Lower Volcanic Unit
Vct Dcaitic tuff
Va Andesitic lava, tuff
Qsh Foliated tuff
Gsh Foliated andesite, tuff

Tejupilco Schist
Tj Pssamitic and pelitic phyllite

Hydrothermal system

py pyrite
sph spharelite
gn galena
cp chalcopyrite
ba baraite

Fig.1－4－1 Integrated Interpretation Map