SILVER-BEARING SULFOSALTS
FROM THE METAMORPHOSED RAMPURA AGUCHA
Zn–Pb–(Ag) DEPOSIT, RAJASTHAN, INDIA

WOLFRAM HÖLLER
Institut für Geowissenschaften, Montanuniversität Leoben, Peter-Tunner-Straße 5, 8700 Leoben, Austria

SUBBARAJU MOHANDAS GANDHI
Hindustan Zinc Limited, Yashad Bhavan, 313001 Udaipur, India

INTRODUCTION

Rampura Agucha is a stratiform, sediment-hosted Zn–Pb–(Ag) deposit located some 220 km southwest of Jaipur in Rajasthan State, India (Fig. 1). Since its discovery in 1977, Rampura Agucha has become one of the most significant base-metal deposits in India, producing 900,000 t/a of ore. The proven reserves are 39.2 Mt, probable reserves 13.8 Mt, and possible reserves 10.7 Mt (total 63.7 Mt), grading 13.6% Zn, 1.9% Pb, 9.58% Fe and 45 ppm Ag (HZL Staff 1992).

The deposit occurs in the oldest part of the Bhilwara Supergroup, at the contact with the Archean basement ("Banded Gneissic Complex", BGC). The Bhilwara Supergroup, consisting of a pile of metasedimentary rocks intruded by igneous rocks, developed as a result of intracratonic rifting of the Archean basement about 2.0 Ga ago. The deposit was formed by convective circulation of seawater in zones of crustal extension during incipient rifting (Deb 1992). The metals, derived from the hydrothermal system, were accumulated in a trough with biological activity, as indicated
by high contents of graphite and light $\delta^{13}C$ values (Deb 1992, Deb & Sarkar 1990). This suggests a relatively deep-water, reducing environment during sedimentation, in which bacterial reduction of sulfates to sulfides would have been crucial for mineralization. Pb isotope studies suggest a model age of $1.8 \pm 0.04$ Ga for the Rampura Agucha deposit (Deb et al. 1989). At 1.5 Ga, the lower crustal rocks of the BGC were thrust over the western margin of the Bhilwara Supergroup, resulting in upper amphibolite facies metamorphism (Deb et al. 1989, Deb & Sarkar 1990, Sugden et al. 1990) in the Rampura Agucha area.

The results reported herein form part of an ongoing geoscientific investigation directed toward a characterization of mineralogy, geochemistry and genesis of the Rampura Agucha deposit. This work is being carried...
out by staff of the Institute of Geological Sciences, Mining University, Leoben, Austria, in collaboration with Hindustan Zinc Ltd. The aim of this paper is to report the results of a detailed study of the ore minerals, their distribution and chemistry within the Rampura Agucha deposit, in order to enhance recovery of these metals during ore extraction and concentration. A study of the textures and the relation of the ore minerals to metamorphism is another important part of this paper.

**Geological Setting and Orebody**

The deposit occurs in a doubly plunging synformal structure of elliptical shape, comprising sillimanite- and graphite-bearing mica schist enclosed in garnet - biotite - sillimanite gneiss, with minor bands of amphibolite and calc-silicate rocks, as well as aplite, granitic pegmatite and mylonite. The orebody, hosted by a graphite - mica - sillimanite schist, is lens-shaped, with a northeast–southwest strike length of 1600 m and a width varying from a few meters in the northeast to as much as 100 m in the central and southwest section (Fig. 2). The orebody dips between 50 and 80° (average dip of approximately 60°) southeast and has been proved by drilling to a depth of 370 m from the surface (Gandhi et al. 1984). The semimassive orebody exhibits sharp contacts with the footwall and the hanging-wall rocks. No major faults have been detected in the orebody, although minor faults have been traced in some segments of the ore zone (Gandhi et al. 1984). The deposit has an oxidized gossan and a small zone of partially oxidized material between gossan and protore. Since the greater part of the area is capped with soil cover, and fresh outcrops are scarce, much of the detailed geological information was obtained from drill cores.

The mineralization occurs predominantly as disseminations in a schist, consisting of quartz, feldspar (alkali feldspar and plagioclase), sillimanite, graphite and various micaceous minerals (muscovite, biotite and chlorite). Sphalerite, by far the most widespread sulfide mineral, occurs with galena, pyrite and pyrrhotite in varying proportions, with numerous inclusions of rounded to subrounded grains of feldspar and quartz. Graphite, a common gangue mineral, represents 6 to 10 vol.% of the bulk of average ore. A large variety of minor sulfide phases occurs within the ore, the most important being pyrargyrite, freibergite and Ag-(Pb)-Sb sulfosalts. Ore microscopy of samples from 20 drill-core intersections did not reveal any zonation of those metals within the orebody, although the Zn:Pb:Fe proportions vary within meters. Although sphalerite is the most important base-metal sulfide at Rampura Agucha, small sections of the orebody can be dominated by either galena or pyrrhotite. Peak metamorphic conditions of upper amphibolite to granulite facies were estimated by garnet–hornblende and garnet–biotite thermometry (650–700°C), sphalerite barometry and fluid-inclusion studies (~6 kbar) (Ranawat et al. 1988, Deb 1992). The metamorphism

![Fig. 2. Simplified geological map of Rampura Agucha orebody and surrounding rocks.](image-url)
was isochemical, but led to a redistribution of the sulfide minerals within the orebody. High-grade peak metamorphism was followed by a clockwise retrograde P-T cooling path. The deposit also underwent polyphase deformation (Ray 1980). The high-grade metamorphic event resulted in a high degree of recrystallization (aggregates of sulfides with grain sizes exceeding 3 mm) and an obliteration of most of the primary sedimentary textures. Primary mineral banding is very rare, but can be observed in a few polished sections, indicating a synsedimentary origin. Remobilization of galena and sphalerite and, to a lesser degree, of pyrrhotite is common; quartz and feldspar, which are highly deformed, exhibit numerous cracks, filled with sulfides and sulfosalts. Sandwich-like intergrowths of sulfides with graphite and phyllosilicates are very common. The characteristic ball texture described by Ranawat et al. (1988), consisting of rolled porphyroclasts of silicates and sulfides, has been observed in several samples. Oxide minerals (rare Cr-V oxides, gahnite and pyrophanite) were formed by interaction of silicate and sulfide minerals as a consequence of high-grade metamorphism (Höller & Stumpfl 1995).

**METHODS OF INVESTIGATION**

Detailed ore petrography of 97 drill-core chip samples from across the strike length and depth of the orebody has been documented to investigate metal zoning in the orebody and Ag-zoning in tetrahedrite-tennantite-group minerals, and simply to establish the identity of the Ag minerals. The sulfides were analyzed with an ARL-SEMQ electron microprobe (wavelength-dispersion spectrometry) at the Institute of Geological Sciences, Leoben, using matrix corrections according to the procedures of Bence & Albee (1968). Acceleration voltage used for sulfide analysis was generally 15 kV, and for Pb-bearing phases, 25 kV, with a beam current of 20 nA. Pure metals (Ag, Cd, Co), alloys (SeCu) and natural chalcopyrite (Fe, Cu, S), sphalerite (Zn), galena (Pb), bismuthinite (Bi), and breithauptite (Ni) were used as standards for the analysis of sulfides and sulfosalts.

**SULFIDES, GRAPHITE AND SULFOSALTS**

*Sphalerite*, which is the predominant sulfide mineral, occurs as coarse- to fine-grained aggregates in
close association with galena, pyrrhotite and pyrite. The coarse-grained variety locally retains evidence of metamorphic recrystallization: characteristic 120° triple-point grain junctions and homogeneous Fe contents (up to 11.5% Fe, 0.5% Mn, 0.3% Cd). A small grain of sphalerite (15 μm across) with inclusions of chalcopyrite contains considerable amounts of Cd (up to 9 %) and Mn (up to 10%). Aggregates of sphalerite commonly contain inclusions of galena and graphite, as well as exsolved blebs of pyrrhotite.

Galena occurs as coarse-grained aggregates in close association with sphalerite and pyrrhotite, or encloses subrounded gangue minerals and other sulfides. Remobilization of galena along fissures and cleavages of gangue minerals is widespread. The concentration of minor constituents, such as Bi, Sb, Ag and Se, is below the detection limit of the electron microprobe.

Pyrite forms granular aggregates of polygonal crystals (up to 5 mm across), but may be intergrown with pyrrhotite and marcasite. Large porphyroblasts of pyrite show brittle fractures filled with other sulfide minerals. Porphyroblasts of pyrite within cataclastic sphalerite indicate the formation of at least some of the pyrite after cataclasis.

Pyrrhotite generally forms coarse aggregates of polygonal grains, displaying metamorphic crystallization. It occurs as fine-grained aggregates intergrown with other sulfides or as exsolved inclusions in sphalerite. Pyrrhotite grains are often incipiently (or completely) decomposed to a granular product.

Fig. 3. Modes of occurrence of Ag-rich minerals under reflected light in oil immersion. (a) Anhedral freibergite (Frei) in remobilized galena (Gn). (b) Subhedral grain of freibergite in galena at the grain contact with quartz (Qtz). Adjacent grain is pyrrhotite (Po). (c) Flakes of boulangerite (Boul) in galena. (d) Subhedral to euhedral exsolution-induced bodies of dyscrasite (Dys) in galena. (e) Pyrargyrite (Pya) intergrown with chalcopyrite (Ccp) and remnants of pyrite (Py), probably occurring as a pseudomorph after freibergite and pyrite and rimmed by galena (Gn) and biotite (Bt). (f) Complex intergrowth of Pb-Ag-Sb sulfosalt (light grey, arrows) with surrounding pyrargyrite and boulangerite in galena. (g) Complex intergrowth of argentite (Arg) and pyrargyrite (Pya) relics in stephanite (Stp) adjacent to pyrite (Py, poorly polished). Sulfosalt to the right is pure stephanite, rimmed by galena and quartz (Qtz). (h) Intergrowth of gudmundite (Gud), chalcopyrite (Ccp) and sphalerite (Sp), rimmed by galena and plagioclase (Pl).
Grains of freibergite are chemically homogeneous, freibergite from ten samples. In this deposig single detected across individual grains, although different and no marked compositional changes were analyses were carried out on forty-six grains of extent of Ag-for-Cu substitution. Electron-microprobe analyses were carried out on forty-six grains of freibergite from ten samples. In this deposit, single grains of freibergite are chemically homogeneous, and no marked compositional changes were detected across individual grains, although different grains of the same sample may vary. The Ag-content of most grains ranges from 28 to 36%, with a maximum around 31%; the Cu-content ranges from 10 to 18%, with a maximum around 15% (Table 1). The lowest Cu-contents correspond to the highest Ag-contents, suggesting a Ag-for-Cu substitution (Fig. 4). Three grains of freibergite show lower Ag-contents (17-20%), and two grains show higher Ag-contents (38 and 41%). Despite these differences in Ag-content, these grains show the same textural criteria and color as grains with common Ag and Cu contents (around 31% Ag) in the same sample. There is no correlation between the contents of Fe (4.1–8.3%), Zn (0–2.1%), As (0–1.6%), and Ag or Cu. At Agucha, the freibergite is similar in composition to freibergite from Mount Isa (Riley 1974). A study of freibergite from several profiles through the entire orebody, from footwall to hanging wall, did not reveal any Cu-for-Ag zoning.

**Table 1. Chemical Composition of Silver-Bearing Minerals from the Rampura Agucha Deposit and of Freibergite from Mt. Isa.**

<table>
<thead>
<tr>
<th></th>
<th>Arg</th>
<th>Stp 1</th>
<th>Stp 2</th>
<th>Pya 1</th>
<th>Pya 2</th>
<th>Frel 1</th>
<th>Frel 2</th>
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<td>As</td>
<td>2.57</td>
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<td>15.08</td>
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<td>22.33</td>
<td>25.19</td>
<td>25.85</td>
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<td>Pb</td>
<td>0.05</td>
<td>0.36</td>
<td>1.01</td>
<td>0.70</td>
<td>0.65</td>
<td>1.39</td>
<td>0.82</td>
<td>0.70</td>
</tr>
<tr>
<td>Cu</td>
<td>0.50</td>
<td>0.51</td>
<td>0.25</td>
<td>14.95</td>
<td>13.28</td>
<td>10.86</td>
<td>13.30</td>
<td></td>
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<tr>
<td>Zn</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.12</td>
<td>0.61</td>
<td>0.23</td>
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</tr>
<tr>
<td>Pb</td>
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<td>0.20</td>
<td>0.22</td>
<td>-</td>
<td>-</td>
<td>0.34</td>
<td>-</td>
<td>-</td>
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**Σ** 100.82 | 100.21 | 100.64 | 99.79 | 100.75 | 99.83 | 100.20 | 99.84 | 99.10

<table>
<thead>
<tr>
<th>Dys 1</th>
<th>Dys 2</th>
<th>Sulf 1</th>
<th>Sulf 2</th>
<th>Sulf 3</th>
<th>Sulf 4</th>
<th>Rou 1</th>
<th>Rou 2</th>
<th>My</th>
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<tr>
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<td>16.32</td>
<td>18.14</td>
<td>16.70</td>
<td>17.46</td>
<td>18.62</td>
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<td>21.55</td>
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<tr>
<td>Ag</td>
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<td>0.09</td>
<td>0.13</td>
<td>0.44</td>
<td>1.76</td>
<td>1.86</td>
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<td>4.87</td>
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<td>3.04</td>
<td>5.40</td>
<td>6.30</td>
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<tr>
<td>Pb</td>
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<td>0.97</td>
<td>0.96</td>
<td>1.01</td>
<td>3.95</td>
<td>4.18</td>
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<tr>
<td>Cu</td>
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<td>0.04</td>
<td>0.10</td>
<td>0.10</td>
<td>0.06</td>
<td>0.20</td>
<td>0.18</td>
<td>0.16</td>
</tr>
<tr>
<td>Zn</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.33</td>
<td>0.20</td>
<td>0.08</td>
<td>0.29</td>
</tr>
<tr>
<td>Pb</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Σ</td>
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<td>10.00</td>
<td>7.00</td>
<td>7.00</td>
<td>29.00</td>
<td>29.00</td>
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</tr>
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</table>

**Σ** | | | | | | | | |

Pyrargyrite ($\text{Ag}_3\text{SbS}_3$) is the predominant Ag-bearing phase of the Agucha orebody. It commonly occurs as anhedral, disseminated grains (5–35 μm across) in veinlets together with remobilized galena, chalcopyrite and Sb-minerals. It also forms complex intergrowths with (or a narrow rim around) Ag–Pb–Sb sulfosalts (Fig. 3f). Pyrargyrite also occurs in close association with pyrite and pyrrhotite, where it forms larger subhedral to euhedral grains (up to 100 μm across), and it tends to be associated with chalcopyrite (Fig. 3e). Individual grains are chemically homogeneous; although arsenopyrite is present in the same ore zones, As-contents do not exceed 1% (Table 1).

Ag–Pb–Sb sulfosalts are common but not as widespread as pyrargyrite and freibergite. They are located invariably in the interior of large aggregates of galena, where they typically occur as anhedral inclusions.

**Fig. 4.** Variation of Ag and Cu in freibergite from Rampura Agucha, calculated on the basis of 29 atoms.
(10–25 μm across). Occasionally complex intergrowths with pyrargyrite (Fig. 3f) occur within large aggregates of galena. Their color in reflected light resembles that of galena, but the reflectivity is slightly lower. The Ag–Pb–Sb sulfosalts are strongly anisotropic and lack internal reflections. Microprobe analyses reveal considerable compositional variations (Fig. 5, Table 1). A few grains are significantly zoned (Fig. 6). Seven data points encountered (Fig. 5) plot near the idealized composition of freieslebenite (AgPbSbS₃).

**Boulangerite** (Pb₅Sb₄S₁₁) forms flakes (10–50 μm across) in galena (Fig. 3c) and is commonly encountered in complex intergrowths with Ag–Pb–Sb sulfosalts and pyrargyrite (Fig. 3f). Although most aggregates are devoid of Ag, some grains contain up to 2% Ag (Fig. 5, Table 1). Dyscrasite (Ag₅Sb₆) forms tiny, single-phase subhedral to euhedral grains (<10 μm across) that are characteristically disseminated in the interior of large aggregates of galena (Fig. 3d). It is not found in contact with other Ag minerals. Low contents of Pb, Sb and S have been determined (Table 1). Stephanite (Ag₅SbS₆) (5–50 μm across) is found in a few Ag-rich samples and occurs in close association with galena, pyrargyrite and pyrite (Fig. 3g). Minor contents of As and Cu have been detected (Table 1). Argentite (Ag₂S) is rare and forms tiny anhedral grains (<5 μm) in close association with pyrargyrite and stephanite (Fig. 3g). Polybasite (Ag, Cu)₆Sb₂S₁₁ (Mukherjee et al. 1991) and miargyrite (AgSbS₂) also are rare but occur as vein minerals in sphalerite. Miargyrite contains up to 0.4% As, and all other trace elements are below the detection limit.

**DISCUSSION**

The regional metamorphic history (Ranawat & Sharma 1990, Deb et al. 1989) includes a high-grade event with peak conditions of 650–700°C and ~6 kbar in the Rampura Agucha area, and it affected the stratiform orebody. The high-grade metamorphism was almost isochemical on a large scale, although a number of components have been redistributed locally during metamorphism and retrogression. It is difficult to determine which features in the ore relate to the prograde event and which reflect retrograde equilibration. The high-grade metamorphic event resulted in thorough recrystallization of most sulfides, development of triple-point junctions, ductile deformation of pyrite and arsenopyrite, the development of porphyroblasts and the formation of characteristic metamorphic minerals such as sillimanite and garnet.

Primary sulfide minerals were homogenized, so that original compositional zoning, if ever present, is no longer observable. Only Ag–Pb–Sb sulfosalts, which seem to have formed during the waning stage of the metamorphic event, may be zoned (Fig. 6). The ore minerals seem to have behaved differentially during metamorphism. Pyrite, pyrrhotite and sphalerite tend to maintain a constant shape, whereas galena, which was by far the most mobile sulfide, almost everywhere exhibits evidence of plastic deformation and remobilization. To a lesser extent, sphalerite and pyrrhotite were remobilized into the silicate minerals during and after high-grade metamorphism. All sulfide minerals except pyrite commonly fill fractures in quartz, feldspar, and mica; there, stephanite, freibergite and
pyrargyrite may be minor constituents.

Galena-rich samples from the Rampura Agucha orebody contain eight defined Ag-bearing ore minerals and a number of intermediate compositions in the ternary system PbS–Ag2S–Sb2S3. Sphalerite-dominated samples tend to be devoid of any Ag-bearing minerals. Pyrargyrite, freibergite and Ag–Pb–Sb sulfosalts represent the most widespread Ag-minerals. Stephanite, argentite, miargyrite, dyscrasite and polybasite are less common. Sulfosalts are highly susceptible to retrogression and generally undergo continual re-equilibration to lower temperatures (Vaughan & Craig 1978). Freibergite, boulangerite and argentite are most probably prograde sulfosalts at Rampura Agucha, present at the peak of metamorphism. The upper limits of stability for iron-rich tetrahedrite (6.9 at.% Fe) and S-rich argentite are 661°C in the system Cu–Fe–Sb–S (Tatsuka & Morimoto 1977) and 622°C in the system Ag–Sb–S (Keighin & Honea 1969), respectively. At higher temperatures, these minerals melt. Boulangerite has an upper stability limit of 637°C in the system Pb–Sb–S (Salanci 1979). The limited solubility of Sb2S3 in galena (3 mol% at 640°C; Salanci 1979) would also suggest the appearance of a separate Sb2S3-bearing phase at this stage. However, interpretation of these stability limits could be ambiguous. The stability curves are pressure-dependent, in the order of 6–10°C per kbar or less in the system Pb–Sb–S (Garvin 1973), and additional elements such as Zn or As also may result in a shift of the stability curves (Craig & Kullerud 1968, Tatsuka & Morimoto 1973, 1977). Pyrargyrite, the most common Ag-mineral, has an upper stability limit of 637°C in the system Pb–Sb–S (Salanci 1979). It has been demonstrated at several metamorphosed deposits that freibergite, tennantite and tetrahedrite break down during cooling. At Broken Hill, New South Wales (Plimer 1980, Both & Stumpfl 1987), tetrahedrite reacts to chalcopyrite and gudmundite. At Rajpura Dariba, Rajasthan (Kanika Basu et al. 1984) and Cofer, Virginia (Müller & Craig 1983), the tetrahedrite–tennantite-group mineral decomposes to arsenopyrite, chalcopyrite, gudmundite and sphalerite. At Långdalen, Sweden (Karup-Møller et al. 1989), freibergite has reacted to pyrargyrite and chalcopyrite. An upper stability limit of gudmundite of 280 ± 10°C in the system Fe–Sb–S (Clark 1966) indicates that reaction (1) took place at the end of the retrograde stage of the metamorphic evolution. Pyrargyrite and stephanite may also have formed by a breakdown of Ag–Pb–Sb sulfosalts. Replacement of Ag–Pb–Sb sulfosalts (presumably freieslebenite; Fig. 3f) by pyrargyrite and boulangerite in galena suggests the following retrograde reaction:

\[
\text{Ag}_3\text{Pb}_{12}\text{Sb}_{3}\text{S}_{8.6} \rightarrow \text{Ag–Pb–Sb sulfosalt}
\]

(3)

p+yargyrite galena boulangerite

A similar reaction is reported from other localities: for example, at Tetyukhe, Russia, andorite is replaced by pyrargyrite, owyheeite and stephanite (Natarov et al. 1972); at Rivertree, New South Wales, owyheeite is replaced by pyrargyrite and galena (Lawrence 1962); at the Meerschaum mine, Mt. Wills, Victoria, andorite is replaced by miargyrite and owyheeite (Birch 1981), and at Morea, Nevada, andorite is replaced by diaphorite, diaphorite by owyheeite, and owyheeite by galena and pyrargyrite (Williams 1968). Although some compositions of Ag–Pb–Sb sulfosalts from Agucha plot close to the idealized composition of freieslebenite (AgPbSbS4), most display intermediate compositions between the end-member minerals. A few grains are zoned, and no obvious trend in zoning patterns was observed, although an influence of retrograde metamorphism on the zonation of Ag–Pb–Sb sulfosalts cannot be ruled out. Hoffman & Trdlicka (1978) compared compositions of owyheeite (Ag3Pb2Sb2S13) from seven deposits, and showed that the chemical compositions are highly variable (40.77–46.45 wt.% Pb). Möölo et al. (1984) showed that substitution of the major cations (mainly 2Pb2+ ↔ Ag+ + Sb3+) is responsible for the significant variation in the composition of owyheeite from thirteen ore deposits. The lowest Ag-contents of some zoned Ag–Pb–Sb sulfosalts from the Agucha deposit correspond to the highest Pb- and Sb-contents, suggesting mainly an Ag-for-(Pb+Sb) substitution (Fig. 6).

Stephanite, a relatively common retrograde mineral, is found in small amounts in many Ag-deposits. It is a typical secondary mineral phase that formed from other Ag-sulfosalts. Stephanite has an upper stability limit of 197 ± 5°C in the system Ag–Sb–S (Keighin & Honea 1969), indicating formation at the end of the retrograde metamorphic path. Relics of argentite and pyrargyrite in stephanite grains (Fig. 3g) indicate the following

\[
\begin{align*}
\text{CuFeZnSb}_2\text{S}_3 + \text{FeS}_2 & \rightarrow \\
\text{tetrahedrite pyrite} & \\
\text{CuFeS}_2 + \text{FeSbS} + \text{ZnS} & \rightarrow \\
\text{chalcopyrite gudmundite sphalerite} & \\
\text{AgCuFeZnSb}_2\text{S}_3 + \text{FeS}_2 & \rightarrow \\
\text{freibergite pyrite} & \\
\text{CuFeS}_2 + \text{AgSbS}_3 & \pm \text{ZnS} & \rightarrow \\
\text{chalcopyrite pyrargyrite sphalerite} & \\
\end{align*}
\]
The formation of stephanite at the expense of pyrargyrite and argentite is also reported from Garpenberg Norra, central Sweden (Sandecki 1983).

Dyscrasite, a common Ag-bearing inclusion in galena (Sharp & Buseck 1993) forms tiny inclusions (<20 μm, Fig. 3d) uniformly distributed in the interior of large aggregates of galena (>3 mm). These types of inclusions have been interpreted as due to exsolution of an Ag–Sb rich phase from galena, attributed to a decreasing solubility of these elements in galena at lower temperatures. On the basis of their experimental work, Hall & Czamanske (1972) and Sandecki & Amcoff (1981) suggested the formation of Ag–Sb phases by exsolution from galena between 350 and 400°C.

CONCLUSIONS

This study of Ag-bearing sulfosalts has established the mineral composition and paragenesis of freibergite, pyrargyrite, stephanite, dyscrasite, various Ag–(Pb)–Sb sulfosalts and several minor important Ag minerals from the Agucha deposit. The present Ag-mineralogy reflects the metamorphic evolution of this stratiform deposit. The premetamorphic Ag-minerals, present at the time of formation of the deposit, remain unknown owing to the event of high-grade metamorphism that transformed both the silicate and sulfide assemblages. Freibergite, as well as argentite, which were apparently present at the peak of metamorphism, were partially consumed during retrogression. As a result, a low-temperature assemblage comprising pyrargyrite, stephanite, gudmundite and chalcopyrite formed in close association with galena. Pyrargyrite also formed by decomposition of Ag–Pb–Sb sulfosalts. Dyscrasite exsolved from galena owing to retrograde cooling and decompression.

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