The carbonate-hosted Zn-Pb San Gregorio deposit (Colquijirca District, Central Peru) as part of a high sulfidation epithermal system

FONTBOTÉ, Lluis, BENDEZÚ, Ronner

Abstract

The recently discovered world class San Gregorio Zn-Pb deposit in Central Peru, has formed by high level carbonate replacement through very acid fluids coming from a high sulfidation system related to a Tertiary volcanic neck, which produces also Au-Ag, Cu-Au and Zn-Pb-Ag ores in other parts of the same district. To our knowledge San Gregorio is the first "carbonate-hosted epithermal Zn-Pb high sulfidation deposit" recognized as such.

Reference

**ABSTRACT.** The recently discovered world class San Gregorio Zn-Pb deposit in Central Peru, has formed by high level carbonate replacement through very acid fluids coming from a high sulfidation system related to a Tertiary volcanic neck, which produces also Au-Ag, Cu-Au and Zn-Pb-Ag ores in other parts of the same district. To our knowledge San Gregorio is the first "carbonate-hosted epithermal Zn-Pb high sulfidation deposit" recognized as such.

1 INTRODUCTION
The genesis of epithermal high sulfidation systems is relatively well constrained. However, little attention has been paid to their interaction with carbonate rocks. This contribution makes the case that epithermal high sulfidation systems affecting carbonate rocks may produce economic Zn-Pb ores displaying an advanced argillic mineral association which includes up to 5-10% of hypogene alunite. We give evidences that the recently discovered world class San Gregorio Zn-Pb deposit in Central Peru, has formed by high level carbonate replacement through very acid fluids coming from a high sulfidation system related to a Tertiary volcanic neck, which produces also Au-Ag, Cu-Au-Ag and Zn-Pb-Ag ores in other parts of the same district.

2 ORE DEPOSITS IN THE COLQUIJIRCA DISTRICT
The San Gregorio deposit (Fig. 1), discovered during 1994-1995 (70 Mt @ 7.3 % Zn, 2.18 % Pb and 0.57 oz/t Ag, Yaringaño et al., 1997), constitutes one of the two largest base metal discoveries of the last 20 years in Peru. It occurs 5 km south of the Zn-Pb-Ag Colquijirca deposit (Fig 1, Lindgren, 1935, McKinstry, 1936, Lehne, 1990), a main silver producer in Peru. Between San Gregorio and Colquijirca, the Marcapunta volcanic complex (11.5±0.4 Ma, Vidal et al., 1984) hosts disseminated Au-Ag (central part of Marcapunta) and massive Cu-As-Au-Ag high sulfidation epithermal deposits, (Marcapunta Norte and Sur and Smelter, Fig. 1, Vidal et al., 1984, Vidal et al., 1997).
Fig. 2 NS cross section of the Colquiri District with distribution of key alteration minerals.
Table 1 Main mineralogical and elemental components of typical ore and host rock samples at San Gregorio (DDH 22G-95) showing an ideal replacing path from relictic dolostone to "sulfide rock" or "high-silica sulfide rock" with intermediate formation of massive Fe-Zn rhodochrosite. The lost of ignition (LOI) is an indirect indicator of sulfide (PBR-12, 15, 25 and 27) and carbonate (PBR-17 to 22) content.

<table>
<thead>
<tr>
<th>Sample/depth (m)</th>
<th>Zn (XRF%)</th>
<th>Pb (XRF%)</th>
<th>Ag (ppm ICP)</th>
<th>Cu (ppm ICP)</th>
<th>As (ppm ICP)</th>
<th>SiO2 (XRF%)</th>
<th>Al2O3 (XRF%)</th>
<th>Fe2O3 (XRF%)</th>
<th>MnO (XRF%)</th>
<th>MgO (XRF%)</th>
<th>CaO (XRF%)</th>
<th>LOI (%)</th>
<th>Mineral Association (XRD)</th>
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<tbody>
<tr>
<td>PBR-15</td>
<td>35*</td>
<td>3.57</td>
<td>&gt; 100</td>
<td>14.9</td>
<td>274</td>
<td>20.61</td>
<td>7.98</td>
<td>11.20</td>
<td>0.01</td>
<td>0.01</td>
<td>0.07</td>
<td>19.9</td>
<td>qz, kaol, alunite</td>
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<td>PBR-27</td>
<td>25*</td>
<td>2.82</td>
<td>&lt;0.2</td>
<td>13.8</td>
<td>247</td>
<td>38.23</td>
<td>14.49</td>
<td>2.47</td>
<td>0.03</td>
<td>0.08</td>
<td>0.32</td>
<td>15.1</td>
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</tr>
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<td>PBR-26</td>
<td>33*</td>
<td>4.99</td>
<td>&lt;0.2</td>
<td>3.1</td>
<td>111</td>
<td>49.29</td>
<td>7.70</td>
<td>2.98</td>
<td>0.04</td>
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<td>0.15</td>
<td>9.43</td>
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<td>PBR-25</td>
<td>6.28</td>
<td>0.70</td>
<td>&lt;0.2</td>
<td>8.4</td>
<td>82</td>
<td>67.67</td>
<td>8.87</td>
<td>2.14</td>
<td>0.06</td>
<td>0.10</td>
<td>0.47</td>
<td>8.54</td>
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<td>Massive Fe-Zn</td>
<td>6.84</td>
<td>0.49</td>
<td>&lt;0.2</td>
<td>1</td>
<td>19</td>
<td>2.76</td>
<td>0.57</td>
<td>15.28</td>
<td>33.94</td>
<td>2.82</td>
<td>0.96</td>
<td>31.7</td>
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<td>rhodochrosite</td>
<td>7.89</td>
<td>0.54</td>
<td>&lt;0.2</td>
<td>1.2</td>
<td>85</td>
<td>0.81</td>
<td>0.52</td>
<td>16.23</td>
<td>32.97</td>
<td>2.65</td>
<td>1.53</td>
<td>31.0</td>
<td>Fe-Zn rhodochrosite</td>
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<td>Relictic dolostone</td>
<td>0.03</td>
<td>0.07</td>
<td>n.a</td>
<td>n.a</td>
<td>n.a</td>
<td>11.53</td>
<td>2.77</td>
<td>1.78</td>
<td>0.20</td>
<td>11.4</td>
<td>0</td>
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<td>PBR-18</td>
<td>290.45</td>
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<td></td>
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<td>PBR-22</td>
<td>0.30</td>
<td>0.03</td>
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<td>n.a</td>
<td>n.a</td>
<td>1.14</td>
<td>0.54</td>
<td>1.16</td>
<td>0.86</td>
<td>16.2</td>
<td>0</td>
<td>23.6</td>
<td>dolomite, (qz)</td>
</tr>
</tbody>
</table>

* Out of range.

3 SAN GREGORIO

Fig. 2 shows a schematic cross section of the Colquiurca District in which the San Gregorio deposit occurs at its southern part. The San Gregorio deposit is made up by stacked several tens of meters thick orebodies (up to 15% Zn and 5% Pb) replacing a 300 m thick carbonate sequence and with at least up to 1000 m (NS) and 600 m (EW) lateral extension. Lithostratigraphic correlations based on drill cores and supported by paleontological determinations (A. Pardo in Bendezú, 1997) and trace element analyses indicate that the host carbonate rocks belong entirely to the Upper Triassic-Lower Jurassic Pucará Group (and not in part to the Lower Tertiary Pocobamba Formation as proposed by Vidal et al. (1997).

The carbonate rocks are extensively altered. The richest ores are contained in what locally is called "sulfide rock" which is the result of complete decarbonatization of Pucará dolostones and limestones and development of an advanced argillic assemblage, basically quartz, alunite, and kaolinite, with more than 30% of total sulfides (Table 1). The ore mineralogy is simple and extremely fine-grained, generally limited to sphalerite, galena, and very minor marcasite commonly less than 40 µm, giving the macroscopic appearance of an unconsolidated detrital rock. In places, the quartz together with, less abundant, alunite and kaolinite amount above 75% by weight of the rock ("high silica sulfide rock," Table 1). A few intercalations of relictic original host rock have been preserved within the main mineralized area and display dolomitic composition (relictic dolostone in Table 1). Minor bodies of massive Fe-Zn rhodochrosite occur at the transition between relictic dolostone and sulfide rocks (Table 1). The zonal "sulfide rock" - >massive Fe-Zn rhodochrosite - >relictic dolostones is controlled by rapid pH increase as very acid fluids are neutralized by carbonate rocks. That the fluid responsible for the formation of the advanced argillic alteration of the "sulfide rock" was able to transport and precipitate up to 15% Al2O3 in originally carbonate rocks poor in aluminium.

In the upper part of San Gregorio occurs a cap consisting of a silicified cover up to several tens of meters thick and a tabular body consisting of massive alunite, kaolinite and quartz with thickness of up to 50 m. Its morphology and the presence of relictic "sulfide rock" cut by alunite-kaolinite veins suggest that it has been formed by steam-heated acid waters and that is superimposed on the main mineralization phase. This cap displays high Ag and, in places, Bi values.

4 ZONING AT THE DISTRICT SCALE

The cross section of Fig. 2 and Table 2 show that at district scale, north and south of the epithermal high sulfidation Au-Ag deposit of Marcapunta, a similar zoning in terms of alteration and mineralization exists. Massive enargite-pyrite
bodies (Smelter) characterized by strong alunitization and silicification replace Miocene volcanic and Eocene carbonate rocks directly north of the volcanic vent. Typical copper grades range from 1 to 4 %, and Au contents may be as high as 2 ppm for tens of meters of thickness. Zn and Pb are typically low but in small areas can amount up to 6% and 0.5%, respectively, with increasing Zn-Pb grades with greater distance from the Marcapunta center. These ores show a complete transition to the north into the Colquijirca Zn-Pb-Ag mantos, hosted by Eocene Calera limestones. At Colquijirca the alteration is not as strong as in San Gregorio but our survey reveals the ubiquitous presence of argillic assemblages in the mantos with kaolinitic and dickite, and in places also alunite. Ongoing drilling shows that between Marcapunta and San Gregorio massive enargite-pyrite bodies occur in the Eocene Shuco Conglomerate. Preliminary sulfur and lead isotope determinations suggest a common metal source for the whole district and a sulfidation system, where the disseminated Au-Ag mineralization of Marcapunta and the massive-enargite bodies of Smelter occur.

San Gregorio is to our knowledge the first "carbonate-hosted epithermal Zn-Pb high sulfidation deposit" recognized as such. It can be suggested that a complete transition between Zn-Pb ores formed by high temperature carbonate replacement (e.g. Cerro de Pasco) and at epithermal conditions (e.g. San Gregorio) exists. In Peru, other examples of Zn-Pb deposits and districts which possibly are parts of carbonate-hosted epithermal high sulfidation systems are Matagente, Azulcocha, Cercaquio, and Hualgayoc. The exploration potential of the model presented in this work should be emphasized, as possibly other "San Gregorios" occurring near to high sulfidation systems may have been overlooked. This is in part because the Zn-Pb minerals may be almost not recognizable with the naked eye or even with a hand lens as it is the case in San Gregorio.

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REFERENCES


