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Present copper-rich “gel” formation in the giant porphyry copper deposit of Chuquicamata (northern Chile)

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In the frame of a project focused on supergene processes in the Chuquicamata deposit (Pinget et al., 2011 and 2012), copper-rich “gel” crusts that are presently precipitated in the exotic deposit of Mina Sur, south of the Chuquicamata porphyry deposit (Fig. 1A, 1B), are studied.

The “gels” are precipitated from moderately saline waters containing up to several 100 mg Cu/l. Three groups of copper-rich “gels” (up to 61% Cu in weight, Table 1) have been distinguished according to the pH of the waters from which they precipitate. In “gels” formed from waters with pH between 5.8 and 6.0, posnjakite (Cu₄(SO₄)(OH)₆), brochantite (Cu₄(SO₄)(OH)₆), malachite (Cu₂(CO₃)(OH)₂) and possibly dioptase CuSiO₂(OH)₂ were identified using XRF, XRD, SEM and ESEM analyses. In “gels” precipitating from waters with pH between 7.2 and 7.7, devilline (CaCu₄(SO₄)₂(OH)₆·3(H₂O) is mainly present. A third group of “gels” consists mainly of atacamite (Cu₂Cl(OH)₃) and were precipitated of water with a pH of 5.7. In addition to the above copper minerals, the “gels” contain also gypsum, a not yet identified sodium sulphate, and halite (Fig. 2A). The sodium sulphate occurs as lenticular crystals (Fig. 2A) and as efflorescent aggregates (Fig. 2B).

The possibility of using the precipitation mechanisms of the present copper gels as analogue for the formation of copper minerals in the exotic Mina Sur is examined.

Table 1: Semi quantitative analyses of “gel” sampled at Mina Sur (XRF, using UniQuant,in wt-%). Part of the aluminium content may be due to clay particles transported in suspension and incorporated in the gel crusts.

<table>
<thead>
<tr>
<th>Gels sample</th>
<th>pH</th>
<th>Na₂O</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>MnO</th>
<th>Fe₂O₃</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>CaO</th>
<th>SO₃</th>
<th>Cl</th>
<th>Cu</th>
<th>Zn</th>
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</thead>
<tbody>
<tr>
<td>2 Nord</td>
<td>7.2–7.7</td>
<td>b.d.</td>
<td>0.3</td>
<td>5.3</td>
<td>1.7</td>
<td>0.1</td>
<td>0.5</td>
<td>b.d.</td>
<td>0.3</td>
<td>2.4</td>
<td>15.7</td>
<td>1.3</td>
<td>57.5</td>
<td>0.1</td>
</tr>
<tr>
<td>2 Sud</td>
<td>7.2–7.7</td>
<td>b.d.</td>
<td>0.8</td>
<td>1.4</td>
<td>6.2</td>
<td>0.1</td>
<td>1.1</td>
<td>b.d.</td>
<td>0.8</td>
<td>5.4</td>
<td>19.8</td>
<td>1.6</td>
<td>49.4</td>
<td>0.5</td>
</tr>
<tr>
<td>7C</td>
<td>5.8–6.0</td>
<td>5.2</td>
<td>2.3</td>
<td>3.1</td>
<td>3.5</td>
<td>0.1</td>
<td>0.8</td>
<td>b.d.</td>
<td>0.9</td>
<td>7.4</td>
<td>23.4</td>
<td>3.3</td>
<td>39.1</td>
<td>0.4</td>
</tr>
<tr>
<td>7C</td>
<td>5.8–6.0</td>
<td>b.d.</td>
<td>1.0</td>
<td>3.0</td>
<td>2.3</td>
<td>0.1</td>
<td>0.7</td>
<td>b.d.</td>
<td>0.8</td>
<td>6.9</td>
<td>21.7</td>
<td>3.4</td>
<td>47.1</td>
<td>0.4</td>
</tr>
<tr>
<td>EX 2</td>
<td>5.7</td>
<td>b.d.</td>
<td>b.d.</td>
<td>2.7</td>
<td>2.8</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
<td>0.1</td>
<td>0.5</td>
<td>2.5</td>
<td>13.4</td>
<td>81.6</td>
<td>0.1</td>
</tr>
</tbody>
</table>

(b.d. = below detection limit)
Figure 1: A) Outcrop of copper rich "gel" being precipitated from water with pH between 7.2 and 7.7 (Mina Sur). B) Malachite overgrown by copper "gel" precipitated from water with pH between 5.8 and 6.0. C) SEM photograph of atacamite precipitated from a water with pH of 5.7. D) ESEM photograph of "gel" with a probable devilline aggregate.

Figure 2: Phases formed by drying gels formed from water with pH between 7.2 and 7.7. Microscope observation shows that the phases precipitate in the following order: gypsum, sodium sulphate and halite.

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