GOLD AND COPPER DISSEMINATION IN THE IGNEOUS-VOLCANIC SALDAÑA FORMATION, NATAGAIMA, TOLIMA, COLOMBIA, AND EXTENSION OF THE MINERAL PROVINCE IN THE ANDEAN CORDILLERA

LOBO-GUERRERO SANZ, A.,

Economic Geology Research Institute, University of the Witwatersrand
Private Bag 3, PO WITS, 2050, Johannesburg, South Africa; ageo@iname.com

KEY-WORDS: Andes, Colombia, copper, disseminated sulfides, gold, hydrothermal alteration, Jurassic, mineral deposits, mineral exploration, Saldaña Formation, South America

The Saldaña Formation is a complex volcano-sedimentary sequence of faulted blocks, composed by tuffs, agglomerates, lava flows, continental-shallow marine rocks, and small andesitic to dacitic porphyritic bodies. Several types of mineralization occur around Saldaña intrusives, including significant Au placers, Au-rich quartz veins, and other deposits exploited since pre-Columbian times. World-class districts such as El Silencio, Angostura and Serranía de San Lucas (Colombia); Nambija (Ecuador); and Cerro Vanguardia (Argentina) occur in Saldaña equivalents.

The Colombian region has significant potential for exploration of mineral deposit types such as: high and low sulfidation epithermal Au and Cu, Au porphyry, Cu porphyry, sediment-hosted Au (so-called “Carlin type”), iron oxide-copper-gold-REE, and exotic Cu accumulations. Few of these mineralizations have been studied in detail, mapped or explored under modern techniques. Old, small-scale miners were only interested in gold deposits that carried over 6gAu/t and placers over 5gAu/m³. No disseminations were sampled before the 1990’s.
EXTENDED ABSTRACT
Jurassic hypabissal and volcanic rocks of the Saldaña Formation, that outcrop west of the Magdalena River in the border of Tolima and Huila departments, constitute one of the best exploration targets for large-tonnage gold and copper disseminations in the Colombian Andes, South America. The Saldaña rocks formed in an aulacogen that extends throughout the Andes from Venezuela into Argentina. Mineralization is known throughout and conforms a continent-wide metallogenic province.
The Natagaima region is located in a small isolated stretch of the Colombian Central Cordillera, between Saldaña and Magdalena rivers, as shown on Fig. 1. The Saldaña Formation is a complex vulcano-sedimentary sequence of faulted blocks, composed by tuffs, agglomerates, lava flows, continental and shallow marine sedimentary rocks and small porphyritic bodies [Lobo-Guerrero U., 1973 and 1975, Caro and Padilla, 1980, Cediel et al, 1980, Guerrero and Tábara, 1982, Mojica and Dorado, 1987, Mojica and Llinás, 1984, Bayona et al, 1994, Clavijo, 1995, Toussaint, 1995, Mojica et al, 1996 and Lobo-Guerrero, 1999]. The size of andesitic to dacitic porphyritic bodies seldom exceeds 4km², as seen on Fig. 2. Most of the outcrops of intrusive rocks are apophysis of larger bodies, too small to map at 1:100,000 scale. A few of the mappable bodies are shown on quadrangles E-7 and E-8 of Fig. 2, as well as on H-3 and H-5. They are composed by well-formed plagioclase phenocrystals up to a few centimeters long that occur in a gray-green aphanitic matrix. Petrographically, their composition varies from tonalite to granodiorite and quartzmonzonite, some grade into diorite and basalt; a few intrusives have been found to be syenitic. Detailed chemical and petrographic studies have not been carried out. Most textures are subvolcanic. Numerous augite phenocrystals and abundant amygdules filled by chalcedony, calcite, chlorite, epidote, zeolites and native copper are evident in the matrix.

Several types of mineralization are known in the region, including world-class gold placers [Wokittel, 1960, Liu et al, 1999, Lobo-Guerrero, 1999, 2002], gold-rich quartz veins, as well as silver, copper, barite, fluorite, antimony, iron and gypsum deposits that have been exploited at small scale since pre-Columbian times [Lleras, 1929, Sucescún, 1950, Wokittel, 1960, Buenaventura, 1976, Buitrago, 1976, Buitrago et al 1974, Forero and Moreno, 1976, Caro and

---

1 172 references were reviewed for the original work of this on-going research project. Most references have been ommitted due to lack of space in this publication, but are available from the author.
TABLE 1
GENERALIZED LITHOLOGIC UNITS OF THE NATAGAIMA AREA
(TOLIMA, CENTRAL CORDILLERA, COLOMBIA)
WITH ENVIRONMENT AND ASSOCIATED MINERAL DEPOSITS

<table>
<thead>
<tr>
<th>UNIT NAME</th>
<th>AGE</th>
<th>LITHOLOGY/ENVIRONMENT</th>
<th>RELATED INTRUSIVES</th>
<th>MINERALIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volcaniclastic deposits</td>
<td>Q</td>
<td>Continental elastic and volcanic deposits</td>
<td>Not exposed</td>
<td>Au placers, exotic Cu</td>
</tr>
<tr>
<td>Honda Formation</td>
<td>T</td>
<td>Continental shales, siltstones, sandstones, mudflows and volcanic ash</td>
<td>T porphyritic stocks</td>
<td>Gypsum veinlets, exotic Cu</td>
</tr>
<tr>
<td>Cretaceous to Tertiary sedimentary sequence</td>
<td>K-T</td>
<td>Marine to continental siliciclastics: conglomerates, sandstones, shales, limestones</td>
<td>None known</td>
<td>Au placers, Paleoplacers (Gualanday Fm.) Exotic Cu</td>
</tr>
<tr>
<td>Saldaña Formation</td>
<td>J</td>
<td>Continental volcanic rocks, sediments, shallow marine deposits, lava flows</td>
<td>J stocks, batholiths, dikes + sills</td>
<td>Low+high sulf. Epithermal Au veins; low sulfidation Au disseminations in stockworks; Au+Cu porphyries, Fe oxide-Cu-Au, Sediment-hosted Au, gypsum veins</td>
</tr>
<tr>
<td>Payandé Formation</td>
<td>J-TR</td>
<td>Limestones, sandstones and shales</td>
<td>None known</td>
<td>Sediment-hosted Au; Cu skarn Au veins + skarn, Replacement deposits</td>
</tr>
<tr>
<td>Luisa Formation</td>
<td>TR</td>
<td>Continental red beds: conglomerates, sandstones and shales, (evaporites)</td>
<td>Mafic small bodies</td>
<td>Sediment hosted Au, Manto type Pb-Zn, evaporites, Sediment-hosted Cu, Sabkhas</td>
</tr>
<tr>
<td>Tierradentro Gneiss &amp; Granulites</td>
<td>PE</td>
<td>High grade metamorphic rocks (granulites and gneisses)</td>
<td>Pz stocks</td>
<td>Shear zones with Au, Mesothermal Au</td>
</tr>
</tbody>
</table>

NOTE: Main terms are underlined


The Saldaña Formation was deposited in an aborted rift basin overlying Triassic continental red beds and a carbonate platform. Jurassic subduction produced magmatism and vulcanism. Cretaceous and Tertiary sediments were deposited on top. Mineral deposits are the result of Jurassic, porphyritic forced intrusions that were emplaced along weak zones of the tuffs and other units of the Saldaña Formation. Table 1 presents main rock units of the greater Tolima province along with known and potential gold-copper mineralization. General geometry of the Colombian Permian to Jurassic intra-continental rift is shown on Fig. 3. Known Triassic to Jurassic age mineral districts are shown by pentagons. Note the large alluvial fans that conform the Triassic red beds.

In the region covered by this study, the Saldaña Formation extends for 1200 km$^2$; evidence of fertile intrusive rocks, hydrothermal alteration and mineralization occur throughout [Lobo-Guerrero, 2002]. Fig. 2 is a simplified geological map of the Natagaima area. Stars show prospects and mineralized occurrences evaluated by the author. 15,400 hectares within that region have high potential to host disseminated gold associated with the upper portion of copper-gold porphyry systems. The study area amounts to about one third of the total known outcrops of the Saldaña Formation in the Colombian Andes [Mojica and Kammer, 1995b and Lobo-Guerrero, 1999].

Jurassic regional tectonics is not well documented, but seems to have been governed by the extensional rifting events that occur throughout the western margin of South America [Barrero et al, 1969, Lobo-Guerrero U., 1975, Candanedo et al, 1978, Mojica and Dorado, 1987, Butler and Schamel, 1988, Mojica and Franco, 1992, Lobo-Guerrero U. and Flóres, 1994, Cortés and Bayona, 1995, Kammer, 1995, Lobo-Guerrero, 1995]. As seen on Fig 3, extensional faults that run parallel to the main branches of the aulacogen offered sites for fluid migration and mineral deposition. Many NNE-SSW trending faults in Fig. 2 seem to have been normal syn-rift faults; they later rotated clockwise. Initially most of the NNW-SSE trending faults had normal displacement, but currently show strike slip movement to accommodate for sinistral shearing. Circular structures are not uncommon. Current structural regimes in the area are compressive; thrusting has overprinted earlier tectonics.

Abundant sub-vertical high and low sulfidation veins are mineralized with various sulfides, and copper, silver and gold minerals [Lleras, 1929, Reymond, 1944, Wokittel, 1960, Forero and Moreno, 1976, and Lobo-Guerrero, 1999]. Gold and copper disseminated mineralization has also been detected in stockworks, brecciod quartz veins, individual porphyritic bodies and well-packed breccias found along the contact between intrusive and volcanic rocks. Fig. 4 shows typical field settings, where mineralized veins, stockworks and hydrothermal breccias mingle with small porphyritic bodies. Occasional diatremes occur throughout.

A large portion of the Saldaña Formation is covered by secondary copper minerals and epidote. Primary copper mineralization is generally associated with local intense sericitization and silicification (The highest hill on Fig. 4 is strongly silicified). Repetitive intrusions have produced overprinting of hydrothermal alteration and mineralization. Numerous gossans with
high contents of free gold have been mapped. At least 22 zones of interest with potential large-tonnage gold and copper mineralization have been identified to date. Some of them are indicated on Fig. 2. As partially shown on that map, most occurrences are strongly linked to fracture zones.

Few of the abovementioned mineralizations have been studied in detail, mapped or explored under modern techniques. Old, small-scale miners were only interested in gold deposits that carried more than 6gAu/t and placers over 5gAu/m$^3$. No disseminated deposits were even sampled before the 1990’s. In the author’s experience, this part of Colombia has an excellent potential for the exploration of large-tonnage gold and copper disseminations that could be operated economically [Liu et al, 1999, Lobo-Guerrero and Palacio, 2002, Lobo-Guerrero, 2002].

The geological environment that generated the Saldaña Formation and its associated gold and copper mineralization extends throughout the Colombian Andes from Guajira to Putumayo [Clavijo, 1995, Gendall et al, 2000, Lobo-Guerrero, 1995, 1997, Mojica et al, 1996, Pagnacco, 1962, Pulido et al, 1986, Radelli, 1960, 1962b, 1962c, Sillitoe et al, 1984, Toussaint, 1995, Trumpy, 1943, Wokittel, 1957a, 1957b, Barrero et al, 1972] (See Fig. 3), and furthermore along the Andean Cordillera, from Venezuela to Argentina [Jaillard et al, 1990, Megard, 1987 and various articles in Cordani et al, 2000]. Examples of geological units that correlate with the Saldaña Formation have been described by many authors through all the Andean Cordillera; Table 2 lists some relevant articles.

(in Colombia, see Fig. 3) [Liu et al, 1999], Nambija [Hammarstrom, 1992] and San Carlos [Litherland et al, 1992, Gendall et al, 2000], Serranía del Cóndor (in Ecuador), and (in Peru) [Quispesivana and Zárate, 2000], Cerro Vanguardia, Patagonia (in Argentina) [Riveros, 2002, Schalamuk et al, 1997, Zappettinni, 1999] all occur in correlatives of the Saldaña Formation and fall within a similar age span in the continent-wide metallogenic province. Table 3 shows a summation of known production plus reserves and resources from some of these districts. The Serranía de Perijá (that spans between Colombia and Venezuela) contains numerous, under-explored gold and copper deposits associated to Jurassic events [Bueno, 1995, Chigne et al, 1995, Kondakov and Kouzmenko, 1995, Pagnacco, 1962a, Radelli, 1960, 1962a, 1962c, Rodríguez, 1986, Ujueta and Llinás, 1990, Wokittel, 1957a, 1957b]. As indicated on Fig. 3, part of this province extends into the Mexican terranes of Guerrero and Oaxaca.

**TABLE 2**

**SOME REFERENCES ON ANDEAN CORRELATIVES OF THE SALDAÑA FORMATION**

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>REFERENCES</th>
</tr>
</thead>
</table>

**TABLE 3**

**WORLD-CLASS GOLD DEPOSITS IN EQUIVALENTS OF SALDAÑA FORMATION**

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>DISTRICT/DEPOSIT</th>
<th>TOTAL PRODUCTION + ALL RESERVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLOMBIA</td>
<td>Segovia/Zaragoza, Antioquia</td>
<td>~1500 ton Au</td>
</tr>
<tr>
<td></td>
<td>Angostura, Santander</td>
<td>&gt;700 ton Au</td>
</tr>
<tr>
<td></td>
<td>Serranía de San Lucas, Bolívar</td>
<td>&gt;&gt;500 tonAu</td>
</tr>
<tr>
<td>ECUADOR</td>
<td>Nambija, Serranía del Cóndor</td>
<td>&gt;300 ton Au</td>
</tr>
<tr>
<td></td>
<td>San Carlos, Serranía del Cóndor</td>
<td>&gt;~5x10^6 ton Cu</td>
</tr>
<tr>
<td>ARGENTINA</td>
<td>Cerro Vanguardia, Patagonia</td>
<td>~500 ton Au</td>
</tr>
</tbody>
</table>

**REFERENCES**


