Epithermal Deposits Related to Caldera Development in Newly-Identified Graben, Oaxaca, Mexico

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Mexico Epithermal Deposits (Camprubi & Albinson, 2007)
Mexico Geology
“Sierra Madre Del Sur”
Seismotectonics of Southern Mexico

- Tertiary volcanism & ore deposits are superimposed on composite thrust-bound basement terranes associated with evolution of NW-trending oblique right-lateral convergent Cocos-North American plate margin.
- More than 8,000 earthquakes with magnitude greater than 4.0 in 40 years.

Seismic Hazard Study – El Aguila Project by Vector Engineering Inc. (after Kostoglodov & Ponce, 1994)

Seismicity from 1973 to present USGS National Earthquake Information Center (NEIC) database
Tectonostratigraphic Terranes of Oaxaca

- Cuicateco Terrane consisting of Mesozoic volcanosedimentary sequence formed in a submarine volcanic arc with a complex metamorphic basement, and
- Zapoteco terrane consisting of Proterozoic continental crust of mainly crystalline basement rocks overlain nonconformably by rare Paleozoic strata.
- Tertiary volcanics dominated by rhyolitic to andesitic tuffs, minor flows, agglomerates & ignimbrites
- Generally accepted potassium-argon dates are Miocene
- Primarily underlain by Cretaceous limestones, sandstones and siltstones
Miocene “Taviche” Graben

- SW-NE directed contraction in Paleocene to Oligocene followed by transtensional, left-lateral displacement on major faults.
- In the Miocene, this changed to NE-SW directed extension with normal faults.
- “Structural Trough” 200 km long & 75 km wide on high-angle faults preserves thick section of Miocene volcanic rocks.
Large-scale calderas with medium- to high-level intrusions including andesitic to rhyodacitic flow domes overlain by thick ignimbrite units are associated with epithermal deposits.

Mineralization is intimately related to intra-graben regional strike-slip shearing & caldera magmatism.

There is also a particularly close association between dome margins, dikes, and epithermal vein mineralization.

David Jones explaining caldera-setting with dome feature in background.

Contorted flow banding & sheeting at margin of rhyodacite dome.

Sub-horizontal “mushroom- lobe” flow banding in felsite dike.
Local magmatism begins with Caldera I formation denoted by deposition of densely welded intra-caldera tuff.

Caldera I formation followed by resurgent dome with small-volume pyroclastics erupted onto a paleosurface.

Caldera II development involves late piston-like exaggerated uplift of Cretaceous basement & deposition of pyroclastic apron deposits around and along margins of this uplift.

Megabreccia with clasts of mainly andesite define a paleosurface contemporaneous with mineralization.

Strike-Slip Shearing & Magmatism
Highest priority exploration targets lie along & below the paleosurface where it intersects annular structures related to resurgence. Important paleosurface indicators:

- **Travertine** deposited from carbonate-bearing water and indicative of a still active hydrothermal system (*Above & upper right*); At Arista, carbonated subsurface water bubbling with CO₂ gas and temperatures 42 – 43 degrees centigrade at 400 m depth
- **Paleosurface fossils** like this bark and twig impression (*Lower right*)
Arista Deposit

- Arista deposit is main epithermal vein system at Aguila mine
- Drilling has defined vein system to a depth of more than 600 meters
- Low & Intermediate sulfidation systems 400 to 1,000 m below paleosurfaces
- Arista deposit is a intermediate sulfidation epithermal vein system
Arista Vein

Polymetallic mineralization mainly comprises:
- pyrite
- sphalerite
- galena
- chalcopyrite
- argentite/acanthite
- pyrargyrite
- pyrargyrite
- tetrahedrite-tennanite
- arsenopyrite
- stibnite

Fluid Inclusions (quartz):
- 250 - 270° C
- <2% wt% NaCl
• Before discovery of Arista, studies already showed that precious & base metals introduced in 2 separate events: early skarn followed by epithermal.

• Geochemical sampling studies indicated 2 different metal associations:
  
  • Au+Ag+As+Sb+Hg+Cu+Pb+Zn+Mo(+Bi+W): representing Au-Ag-Base Metal veins developed in skarn setting peripheral to an intrusive, and
  
  • Au+Ag+As+Sb+Hg: a more limited element suite, more typical of a volcanic hosted epithermal Au-Ag vein system
Skarn Alteration
(Lawrence D. Meinert, 2010)

- Multiple generations of quartz-galena and tan bustamite ($\text{CaMn}^{2+}\text{Si}_2\text{O}_6$\[^1\])
- Quartz vein with white fibrous wollastonite
- Banded green pyroxene-sphalerite-galena-chalcopyrite
  (Sphalerite Fluid Inclusions: 260 - 300° C; 6 - 16% wt% NaCl)
- Dolomitic limestone cut by calcite-talc-tremolite veins
Magnetics & Intrusives

Interpretation of magnetic data by geophysicist, Bob Ellis, using standard digital image processing techniques & inversion modeling, helped extend known mineralized structures & identify areas of potential magnetite destructive alteration & skarn mineralization.
3D Magnetics & Geology

- Integrating 3D modeling with geology has been helpful in targeting at the mine scale & provides better understanding of the regional geology
- Mag low associated with Arista deposit & mag highs mixed intrusives & skarn
Exploration Model
(Corbett, 2006)

- Extension-related pull-apart basin model for proposed “Taviche Graben” and related veins/skarn
- Controlling strike-slip structure creates pull-apart basin into which were deposited Miocene volcanics with hot spring & sinter deposits & steep, en echelon fissure veins & intrusions/skarn
### OAXACA 2010 – 2015
### Gold & Silver Production

#### GOLD (oz)

<table>
<thead>
<tr>
<th>MINE</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>TOTALS</th>
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<tbody>
<tr>
<td>AGUILA (Gold Resource)</td>
<td>10,493</td>
<td>21,586</td>
<td>34,417</td>
<td>33,942</td>
<td>35,552</td>
<td>29,644</td>
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<td>17,918</td>
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<td>38,526</td>
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<td>69,048</td>
<td>68,170</td>
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#### SILVER (oz)

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<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>TOTALS</th>
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</thead>
<tbody>
<tr>
<td>AGUILA (Gold Resource)</td>
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<td>4,928,893</td>
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<tr>
<td><strong>TOTALS</strong></td>
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<td>4,945,921</td>
<td>5,560,044</td>
<td>7,693,964</td>
<td>7,434,893</td>
<td>28,404,614</td>
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- Increasing reserves at both operations indicate more years of production are ahead