Mexico’s Next Big Gold Discovery

by
Matthew D. Gray
Resource Geosciences de Mexico SA de CV
February 2017
The Mexican Roundup, Hermosillo, 2017

La India Mine, Agnico Eagle, Sonora
Sources of Information

All resource estimate and production information is obtained from public domain sources, including:

I. Company press releases and annual reports
II. Public company regulatory filings (SEDAR, EDGAR)
II. Servicio Geologico de Mexico
III. INEGI
IV. USBM
V. USGS
VI. Public domain academic journals

Information is believed to be accurate but has not been independently confirmed by the author!
Conclusions

1. An intrusive related deposit like Peñasquito or Los Guajes is likely to be the next big discovery as measured by contained ounces gold, but ..........
Conclusions

2. Don’t be surprised if a high grade orogenic deposit is the next big discovery, and this deposit type is an attractive exploration target.

Why?
- High grade, long life mine
- Small footprint of UG mine - easier to obtain social license, favors development
- The favored geologic terrain coincides with a relatively favorable logistical/social/political location
Conclusions

3. Where?
Conclusions

3. Where?

In our neighborhood – the Altar trend, Sonora.
Thanks to Chris Osterman for the idea for this talk

(however all ignorance demonstrated herein is exclusively that of M. D. Gray)
Mexico’s potential for orogenic deposits
Geologic characteristics of orogenic deposits

1. Associated with regional scale deformation structures
   - Compressional/transpressional stress

2. All time periods 2.8 Ga (Archean) and later

3. Gold associated with pyrite, pyrrhotite, arsenopyrite, quartz+carbonate veins

4. Deep seated source of hydrothermal fluids
   - Metamorphic dehydration reactions affecting mafic volcanic and/or pyritic carbonaceous sedimentary strata
   - Magmatic for some deposits?
Geologic characteristics of orogenic deposits

5. Relatively low salinity (<10%) CO2 enriched fluids

6. Deposition conditions 1- 3Kbar, 250 – 400° C.

7. 5 – 20km depth of formation

8. Deposited at or above ductile/brittle transition

9. Not lithology dependent, but rheology dependent
   • Adjacent contrasting rheologic characteristics may lead to structural dilation and ore deposition sites
Geologic characteristics of orogenic deposits

10. Both low grade bulk minable zones and as high grade veins
11. Can exhibit vertical continuity of grade over 1km to 3km
12. Native gold, from microscopic to megascopic scale, common
13. Metallurgically “easy” deposits

14. Notable examples:
   o Ashanti, Ghana 67M oz produced
   o Timmins camp, Ontario 60M oz Au produced
   o Kalgoorlie, Australia 52M Oz Au produced
   o Motherlode, California 40M oz Au produced lode
     (60Moz Au produced placer)
Geologic characteristics of orogenic deposits

Age distribution orogenic gold deposits
(from Goldfarb et al. 2010 after Groves 2005)
Geologic characteristics of orogenic deposits

Structural setting

- Second and third order structures off of major regional structures
- The regional structures are critical and necessary, but generally do NOT host the ore deposits
Motherlode, CA, Orogenic Gold Regional Structure
(from Sillitoe, 2008)
Superior Province, Orogenic Gold Regional Structure (from Dube and Gosselin, 2007)
Porcupine Mining District (Timmins) Superior Province
(compiled from Ferguson, 1968; Pyke et al., 1971; Pyke, 1982),
Geologic characteristics of orogenic deposits

Structural setting:

- Transpression
  - strike-slip motion
  - horizontal shortening
  - vertical extension
Dilational environment  
(Sibson, 1986)
Dilational environment
(Drew, 2003)
Vein style dependent on P-T (depth) (from Colvine et al., 1988)
Within a given deposit or district, gold may be present in a variety of structural environments
(Schematic of Rosebel, Suriname Orogenic Gold Deposit, Iamgold from Voicu, 2010)
Vertical extent

Productive vertical extent, epithermal system, 300 to 700m typical

Productive vertical extent, orogenic system, 1000 to 3000m typical
Orogenic gold deposits are an important part of the gold endowment of Mexico.

- 4 of the 15 largest gold mines in Mexico are orogenic deposits

- Orogenic deposit reserves and resources are nearly equal to those of all low sulfidation deposits in Mexico
<table>
<thead>
<tr>
<th>Mine</th>
<th>Company</th>
<th>State</th>
<th>2015 Production, Oz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Peñasquito</td>
<td>Goldcorp</td>
<td>Zac</td>
<td>860,300</td>
</tr>
<tr>
<td>2 <strong>La Herradura</strong></td>
<td><strong>Fresnillo</strong></td>
<td><strong>Son</strong></td>
<td><strong>398,866</strong></td>
</tr>
<tr>
<td><strong>La Herradura</strong></td>
<td><strong>Fresnillo</strong></td>
<td>2016</td>
<td><strong>520,366</strong></td>
</tr>
<tr>
<td>3 El Limon-Guajes</td>
<td>Torex</td>
<td>Gue</td>
<td>279,000*</td>
</tr>
<tr>
<td>4 Los Filos</td>
<td>Goldcorp</td>
<td>Gue</td>
<td>272,900</td>
</tr>
<tr>
<td>5 Pinos Altos</td>
<td>Agnico Eagle</td>
<td>Chi</td>
<td>242,677</td>
</tr>
<tr>
<td>6 <strong>Noche Buena</strong></td>
<td><strong>Fresnillo</strong></td>
<td><strong>Son</strong></td>
<td><strong>158,179</strong></td>
</tr>
<tr>
<td>7 Tayoltita</td>
<td>Primero</td>
<td>Dgo</td>
<td>151,355</td>
</tr>
<tr>
<td>8 Mulatos</td>
<td>Alamos Gold</td>
<td>Son</td>
<td>140,330</td>
</tr>
<tr>
<td>9 Cerro de San Pedro</td>
<td>New Gold</td>
<td>SLP</td>
<td>105,500</td>
</tr>
<tr>
<td>10 La India</td>
<td>Agnico Eagle</td>
<td>Son</td>
<td>104,362</td>
</tr>
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The Mexican Roundup, Hermosillo, 2017
## Top 20 Mexican Gold Producing Mines (less Frisco)

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<tr>
<td><strong>11 San Francisco</strong></td>
<td><strong>Timmins Gold</strong></td>
<td><strong>Son</strong></td>
<td><strong>93,353</strong></td>
</tr>
<tr>
<td>12 Cienega</td>
<td>Fresnillo</td>
<td>Dgo</td>
<td>85,662</td>
</tr>
<tr>
<td>13 Mercedes</td>
<td>Yamana</td>
<td>Son</td>
<td>84,137</td>
</tr>
<tr>
<td>14 El Castillo</td>
<td>Argonaut</td>
<td>Dgo</td>
<td>79,751</td>
</tr>
<tr>
<td><strong>15 Chanate</strong></td>
<td><strong>Alamos Gold</strong></td>
<td><strong>Son</strong></td>
<td><strong>79,312</strong></td>
</tr>
<tr>
<td>16 Dolores</td>
<td>Pan American</td>
<td>Chi</td>
<td>79,100</td>
</tr>
<tr>
<td>17 Palmarejo</td>
<td>Coeur</td>
<td>Chi</td>
<td>70,922</td>
</tr>
<tr>
<td>18 El Gallo</td>
<td>McEwen Mining</td>
<td>Sin</td>
<td>65,967</td>
</tr>
<tr>
<td>19 La Colorada</td>
<td>Argonaut</td>
<td>Son</td>
<td>55,056</td>
</tr>
<tr>
<td>20 Mascota</td>
<td>Agnico Eagle</td>
<td>Chi</td>
<td>45,000</td>
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## Mexico Gold: Production and Inventory by Deposit Type

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<tr>
<td>1 Intrusive Related</td>
<td>1,318,451</td>
<td>34.09</td>
<td>9.97</td>
</tr>
<tr>
<td>2 LSE Epithermal</td>
<td>1,078,145</td>
<td>8.37</td>
<td>4.21</td>
</tr>
<tr>
<td>3 Orogenic</td>
<td>729,710</td>
<td>8.05</td>
<td>2.94</td>
</tr>
<tr>
<td>4 HS Epithermal</td>
<td>244,692</td>
<td>2.41</td>
<td>8.28</td>
</tr>
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</table>
Current Mexico Gold Producers

>150,000 ounces annual gold production
Active gold mines and deposits w/ > 1M Oz.
Mexico’s prospective regions for orogenic deposits

Baja California
• Unfavorable political/social environment

NW Sonora
• Favorable political/social environment
• Altar Trend
Criteria to Assess Prospectivity
Geologic characteristics of orogenic deposits

1. Associated with regional scale deformation structures
2. All time periods 2.8 Ga (Archean) and later
3. Characterized by Au, As, S enrichment
4. Deep seated source of hydrothermal fluids
5. Relatively low salinity (<10%) CO2 enriched fluids
6. Deposition conditions 1-3 Kbar, 250–400° C.
7. 5–20 km depth of formation
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Economic potential of the Altar trend

Altar trend orogenic gold prospectivity checklist

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<td>Deep drilling at La Herradura confirms</td>
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Economic potential of the Altar trend

1. La Herradura deposit is unequivocal proof that Sonora hosts significant orogenic deposits (Quintanar Ruiz, 2008)

2. Other mines and prospects demonstrate regional occurrence of geologically similar deposits
Active gold mines and deposits w/ > 1M Oz.

Altar Trend: >7M oz. gold production since 1997
2016 Au production: ~900,000 oz.

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Economic potential of the Altar trend

1. La Herradura deposit is unequivocal proof that Sonora hosts significant orogenic deposits (Quintanar Ruiz, 2008)

2. Other mines and prospects demonstrate regional occurrence of geologically similar deposits

3. We can disagree about what it is, but the MSM is a regional structure!
   - Boundary between 1.8-1.9 Ga basement of Caborca block and 1.6-1.7 Ga basement of North American block
   - >1000 km of lateral displacement as originally proposed not supported by field evidence
   - Jurassic timing of development not certain
Mojave Sonora Megashear and Gold Deposits

Calvin and Hobbes, by Bill Watterson
Mojave Sonora Megashear and Gold Deposits

Does Megashear have any relationship to gold deposits?
• Yes

Is it a direct genetic relationship?
• Probably not.

Is it relevant?
• It might be.
Superior Province Regional Structures and MSM
(from Dube and Gosselin, 2007, Anderson et al., 2005)
Mojave Sonora Megashear Regional Structure
(from Anderson et al., 2005)
Mojave Sonora Megashear Regional Structure
(from Anderson et al., 2005)
Mojave Sonora Megashear Regional Structure
(from Anderson et al., 2005)
Mojave Sonora Megashear and Gold Deposits
(from MSM map from Anderson et al., 2005)
Mojave Sonora Megashear and Gold Deposits
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Mojave Sonora Megashear and Gold Deposits
(from MSM map from Anderson et al., 2005)

Spatial relationship between gold deposits and MSM
Mojave Sonora Megashear and Gold Deposits

Spatial relationship between gold deposits and MSM is unequivocal, but is it coincidental?

• MSM interpreted to have formed as early as Jurassic

• Altar trend gold deposits much younger
Ages Sonoran Orogenic Gold Deposits

Herradura - 61 Ma vein sericite
- 61 Ma ore related pyrite

Noche Buena - 56 Ma vein sericite

Chanate - 52 Ma vein sericite

San Francisco - 42 Ma vein sericite

Vein sericite dates $^{40}\text{Ar}/^{39}\text{Ar}$ from USGS OFR 2016-1008

Re-Os date from Quintanar, 2008
Mojave Sonora Megashear and Gold Deposits

Age difference between MSM and orogenic gold deposits precludes a direct genetic link, however:

• Altar trend gold deposits coeval with Laramide orogeny (70 to 40Ma)

• Once a structure, always a structure

• Laramide re-activation of MSM?

• MSM was ground prep for Laramide orogenic mineralizing processes?
Future of the Altar trend

- More bulk minable “low grade” deposits will be discovered minable by open pit methods

- Deeper deposits may be exploitable by low cost (relatively) underground bulk mining methods
Future of the Altar trend

Centauro Deep

- Drillhole demonstrated gold mineralization over at least 1500m vertical interval

- ~ 350,000 ounce resource Au at >5 gpt reported by Fresnillo in December 2012

Future of the Altar trend

La Herradura, Noche Buena, El Chanate prove that Altar trend is prospective for bulk minable relatively low grade deposits.

Are there other targets we should be seeking?
Future of the Altar trend

In particular, do high grade orogenic vein deposits occur along the Altar trend?
Future of the Altar trend

In particular, do high grade orogenic vein deposits occur along the Altar trend?

Yes, but they are concealed, and scale and grade is unknown
Future of the Altar trend

Desert prospectors provide conclusive evidence that high grade vein deposits are present.
Orogenic gold deposits, Sonora

Mockingbird Mine, Motherlode region CA
(photo from https://www.collectorsedge.com)

Altar Trend, Sonora
Gold quartz vein float

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Orogenic gold deposits, Sonora

Butte Nugget, Motherlode region, CA
Altar Trend, Sonora

Gold nugget float

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Future of the Altar trend

Exploration drilling has intersected high grade auriferous veins

Fresnillo has drilled some as part of the Centauro Deep program
Future of the Altar trend

Centauro Deep
- Visible gold in drillhole BDS7F
- Intercept of 8.95m @14.3 gpt reported by Fresnillo from drillhole HGT-125

Future of the Altar trend

• Because orogenic gold systems commonly have grade continuity measured over >1km vertical extent, high grade vein systems have significant potential for expansion at depth.

• Mexican mining industry has particular expertise with underground mining of vein deposits.

• When will we see the first head frame along the Altar trend?
Grade/Tonnes Orogenic Gold Deposits
(from Dube and Gosselin, 2007)
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(from Dube and Gosselin, 2007)

The Mexican Roundup, Hermosillo, 2017
Grade/Tonnes Orogenic Gold Deposits (from Dube and Gosselin, 2007)

Timmins, Ontario, 1909
Grade/Tonnes Orogenic Gold Deposits
(from Dube and Gosselin, 2007)
Grade/Tonnes Orogenic Gold Deposits
(from Dube and Gosselin, 2007)

Altar region, Sonora, today
The Altar region, Sonora, in twenty years?

Altar region, Sonora, today

Grade/Tonnes Orogenic Gold Deposits
(from Dube and Gosselin, 2007)
Conclusions
Conclusions

• Headframes coming to the Altar Trend

• Long term growth of orogenic gold production from Altar Trend.
  – new bulk minable and open pit deposits
  – high grade veins, mined by underground methods
Gracias a todos por su atención.
Thank you for your attention.
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