Resource Geosciences Inc. / Resource Geosciences de Mexico SA de CV

Orogenic gold deposits: Mexico's endowment and future developments in the Altar Trend, Sonora

SME - Society for Mining, Metallurgy & Exploration
Arizona Conference 2018 Tucson, Arizona

by
Dr. Matthew D. Gray
Resource Geosciences Inc. / Resource Geosciences de Mexico
3 December 2018

El Chanate Mine, Sonora,
Alamos Gold Inc
(photo credit: from AGI website)

SME Society for Mining, Metallurgy & Exploration
ARIZONA CONFERENCE 2018
DECEMBER 2 – 3 ★ TUCSON, ARIZONA

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. A high grade orogenic deposit might be Mexico's next big discovery
2. 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.

Centauro Pit, La Herradura, Fresnillo PLC

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Thanks to Chris Osterman for the idea for this talk

(however all ignorance demonstrated herein is exclusively that of M. D. Gray)

orogenic deposits – what are they?

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^{o} 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

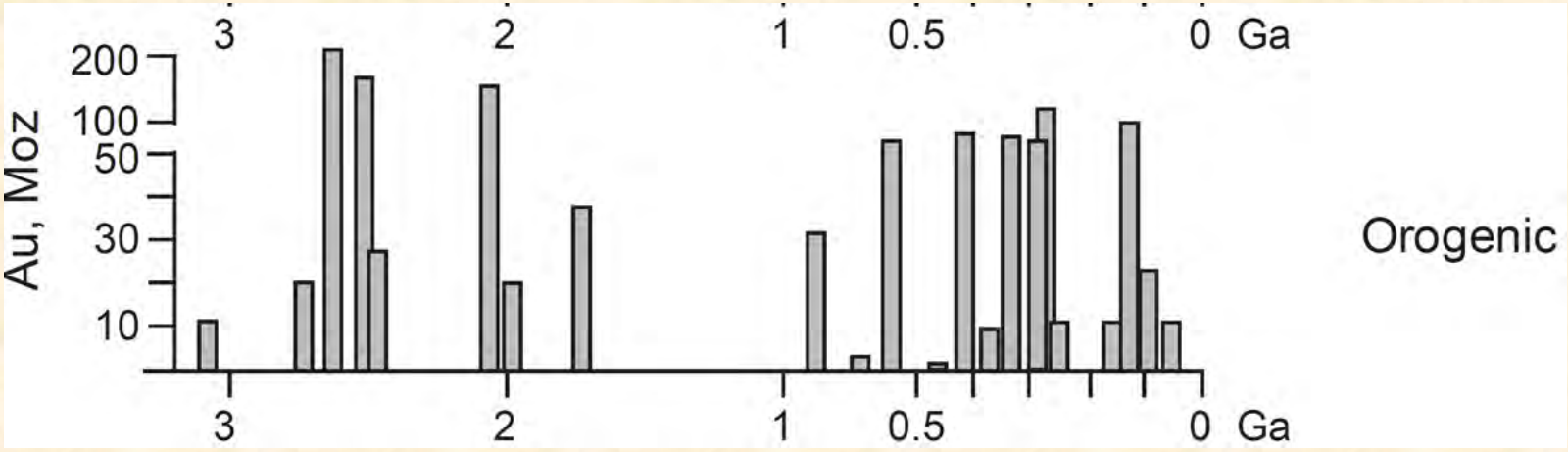
13. Metallurgically “easy” deposits

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

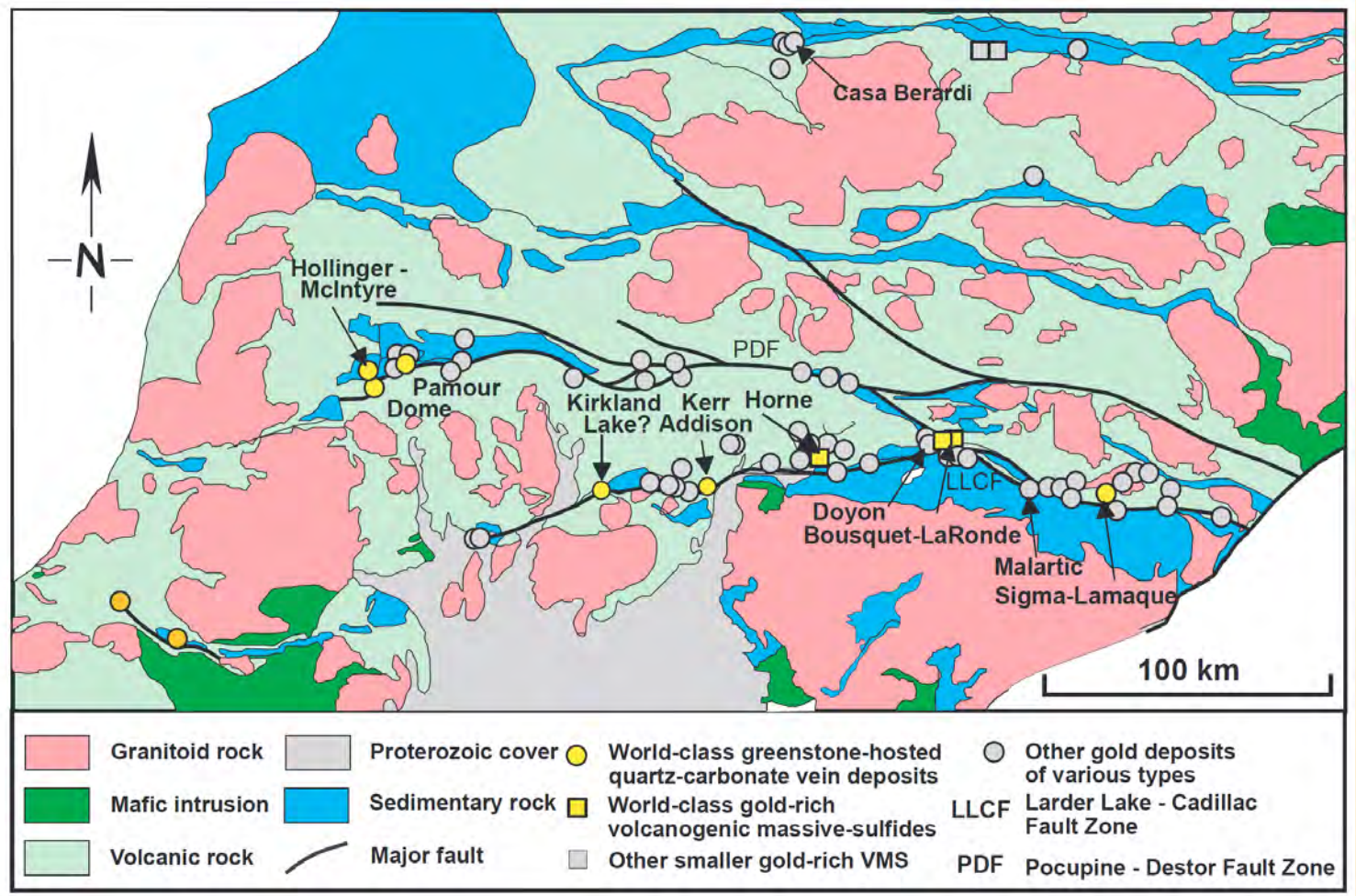
Geologic characteristics of orogenic deposits

Structural setting:

- Transpression

  - strike-slip motion
  - horizontal shortening
  - vertical extension

Superior Province, Orogenic Gold Regional Structure
(from Dube and Gosselin, 2007)



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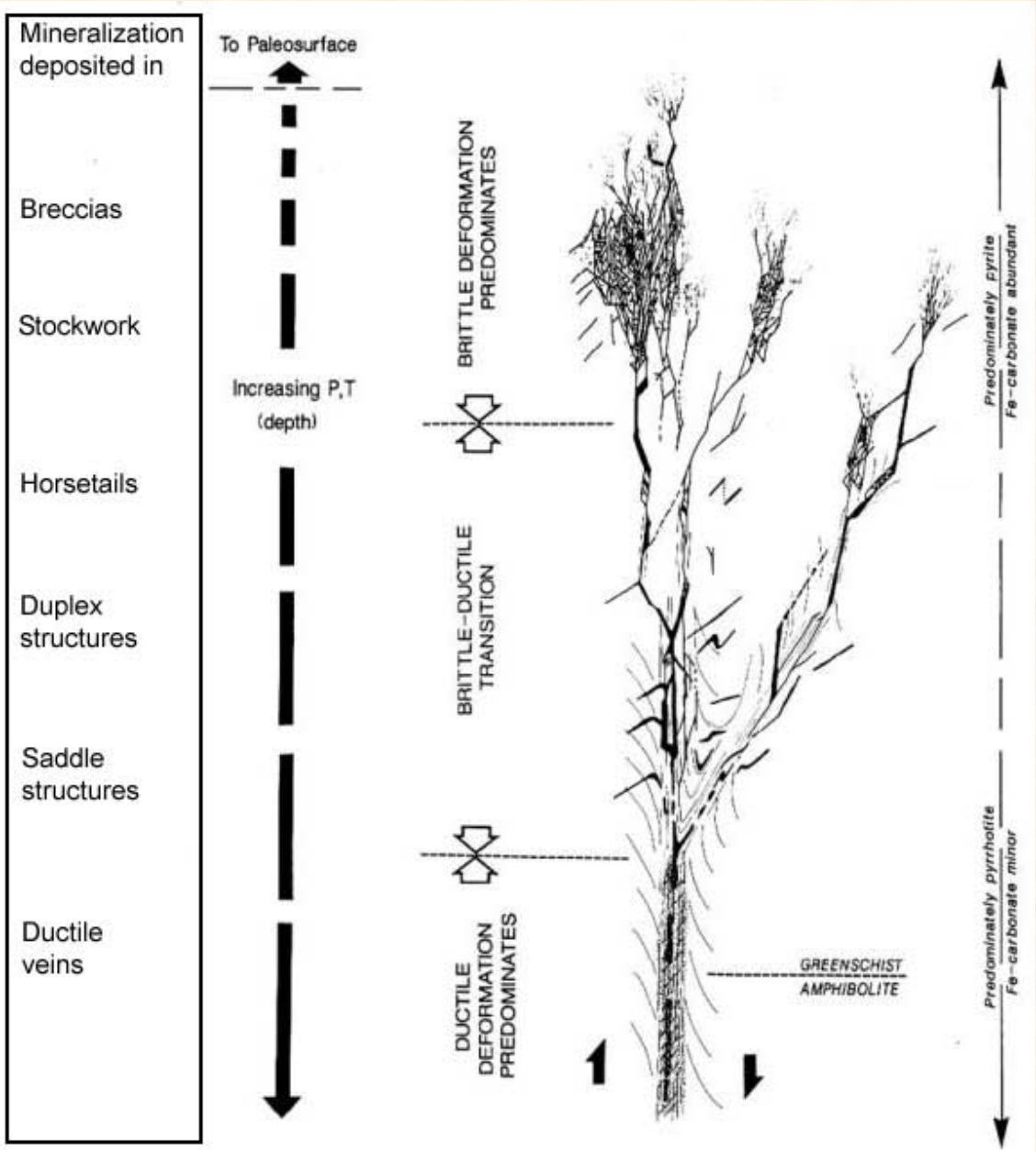

Vein style dependent on P-T (depth) (from Colvine et al., 1988)

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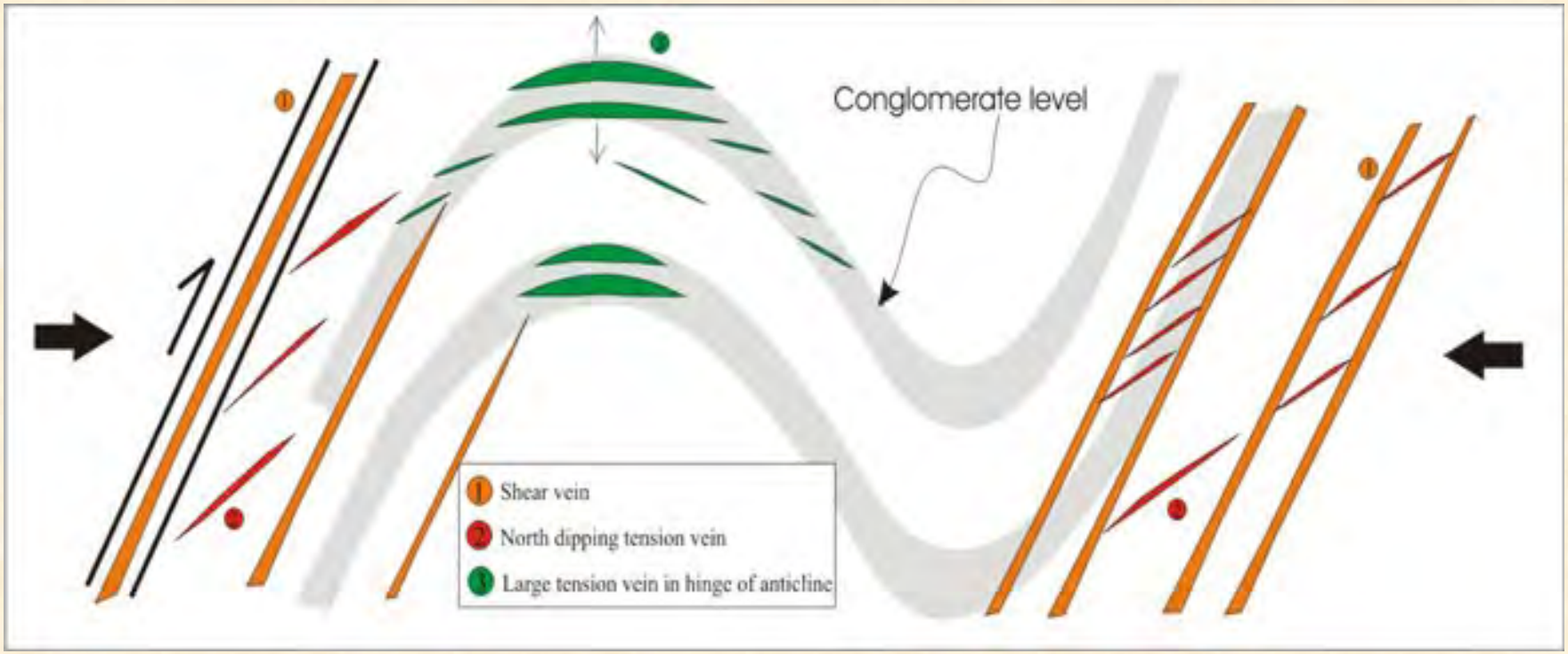
Within a given deposit or district, gold may be present in a variety of structural environments

(Schematic of Rosebel, Suriname Orogenic Gold Deposit, Iamgold from Voicu, 2010)



Vertical extent

500 m

1000 m

1500 m

2000 m

2500 m

3000 m

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

Productive vertical extent, orogenic system, 1000 to 3000m typical

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Orogenic gold deposits are an important part of the gold endowment of Mexico.

- 2 of the 6 largest gold mines in Mexico are orogenic deposits (and are in the Altar Trend)

Top 10 Mexican Gold Producing Mines (less Frisco)

	Mine	Company	State	2017 Production, Oz.
1	Peñasquito	Goldcorp	Zac	476,000
2	***La Herradura***	***Fresnillo***	***Son***	***473,638***
3	El Limon-Guajes	Torex	Gue	240,873
4	Los Filos	Leagold	Gue	191,195
5	Pinos Altos	Agnico Eagle	Chi	180,859
6	***Noche Buena***	***Fresnillo***	***Son***	***172,300***
7	Mulatos	Alamos Gold	Son	160,000
8	Palmarejo	Couer	Chi	121,569
9	Dolores	Pan American Silver	Chi	103,000
10	La India	Agnico Eagle	Son	101,150

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Mexico Gold: Production by Deposit Type

	Deposit Type	2017 Production oz.
1	LSE Epithermal	1,025,689
2	Intrusive Related	980,537
3	Orogenic	789,858
4	HS Epithermal	261,150

- Orogenic deposit reserves and resources are nearly equal to those of all low sulfidation deposits in Mexico

Mexico Gold: Inventory by Deposit Type

	Deposit Type	M oz. Reserves P&P & Resources M&I
1	Intrusive Related	71.65
2	LSE Epithermal	16.87
3	Orogenic	16.37
4	HS Epithermal	13.18

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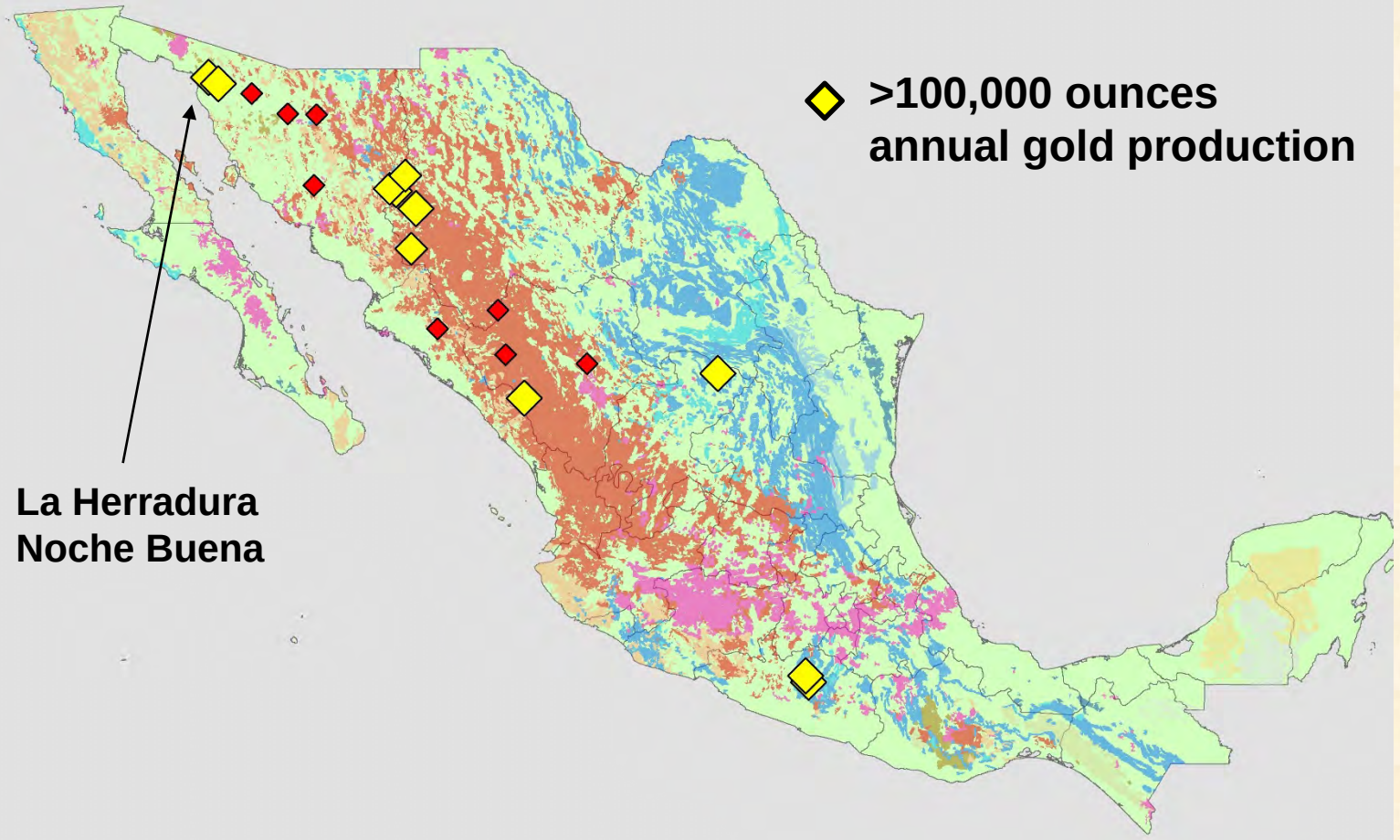
2017: 20 Largest Mexico Gold Producers

(no data available for Frisco mines)



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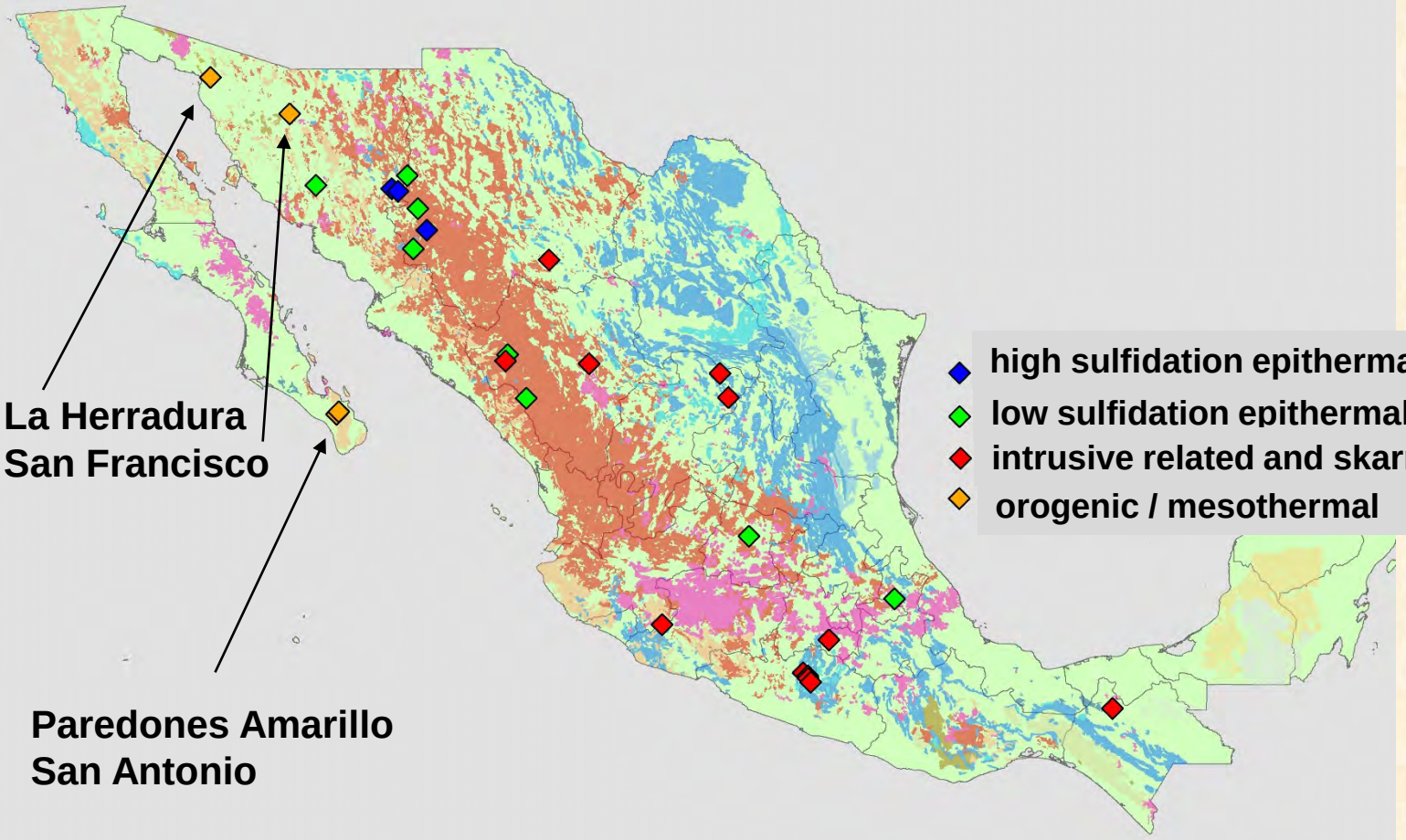
Active gold mines and deposits w/ > 1M Oz.

(no data available for Frisco mines)



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Locations of orogenic deposits in Mexico

Baja California Sur

- Unfavorable political/social environment

NW Sonora

- Favorable political/social environment
- Altar Trend

Altar Trend: Criteria to Assess Prospectivity

Economic potential of the Altar Trend

Altar Trend orogenic gold prospectivity checklist

Needed	Got it?
Economically significant orogenic mineralizing processes affected region?	
Processes operated at regional scale?	
Association with regional feature?	
Systems preserved? Vertical continuity?	

Economic potential of the Altar Trend

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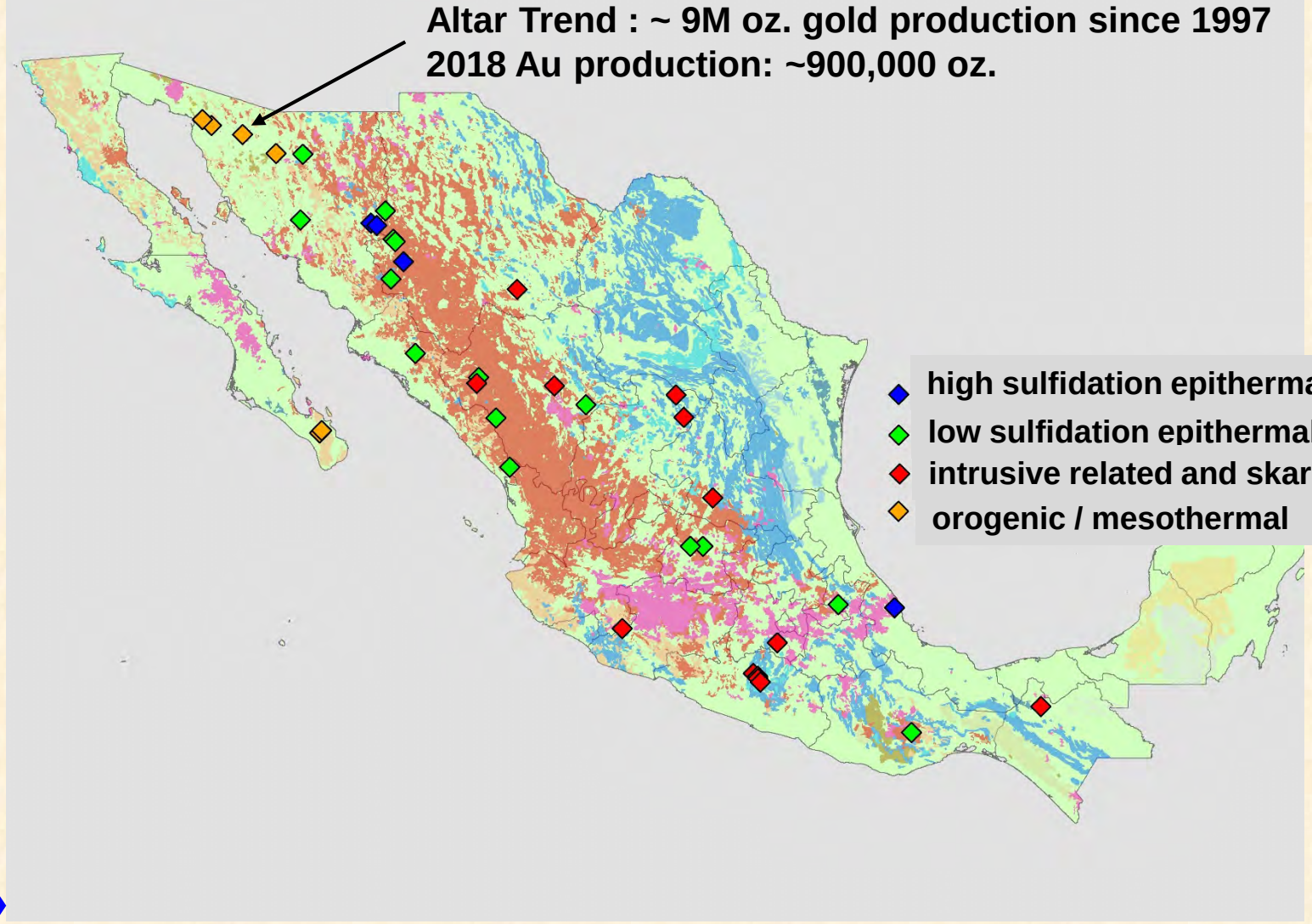
Economic potential of the Altar Trend

Economically significant orogenic mineralizing processes affected region?

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

    - **Metamorphic fluids**
    - **T formation 330^{o} C (pyrite-galena thermometry)**
    - **CO_2 rich fluids**
    - **Trapping pressures 1.6 to 2.7 kbar**
    - **Re-Os date of 61.01 Ma**
    - **Contemporaneous with Laramide orogeny**

All active gold mines and undeveloped deposits w/ > 1M Oz.



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Economic potential of the Altar Trend

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Economically significant orogenic mineralizing processes affected region?	✓ La Herradura (orogenic features documented by Quintanar Ruiz, 2008)
Processes operated at regional scale?	✓ Geologically similar deposits known over 600km trend (Izaguirre et al., 2017)
Association with regional feature?	
Systems preserved? Vertical continuity?	

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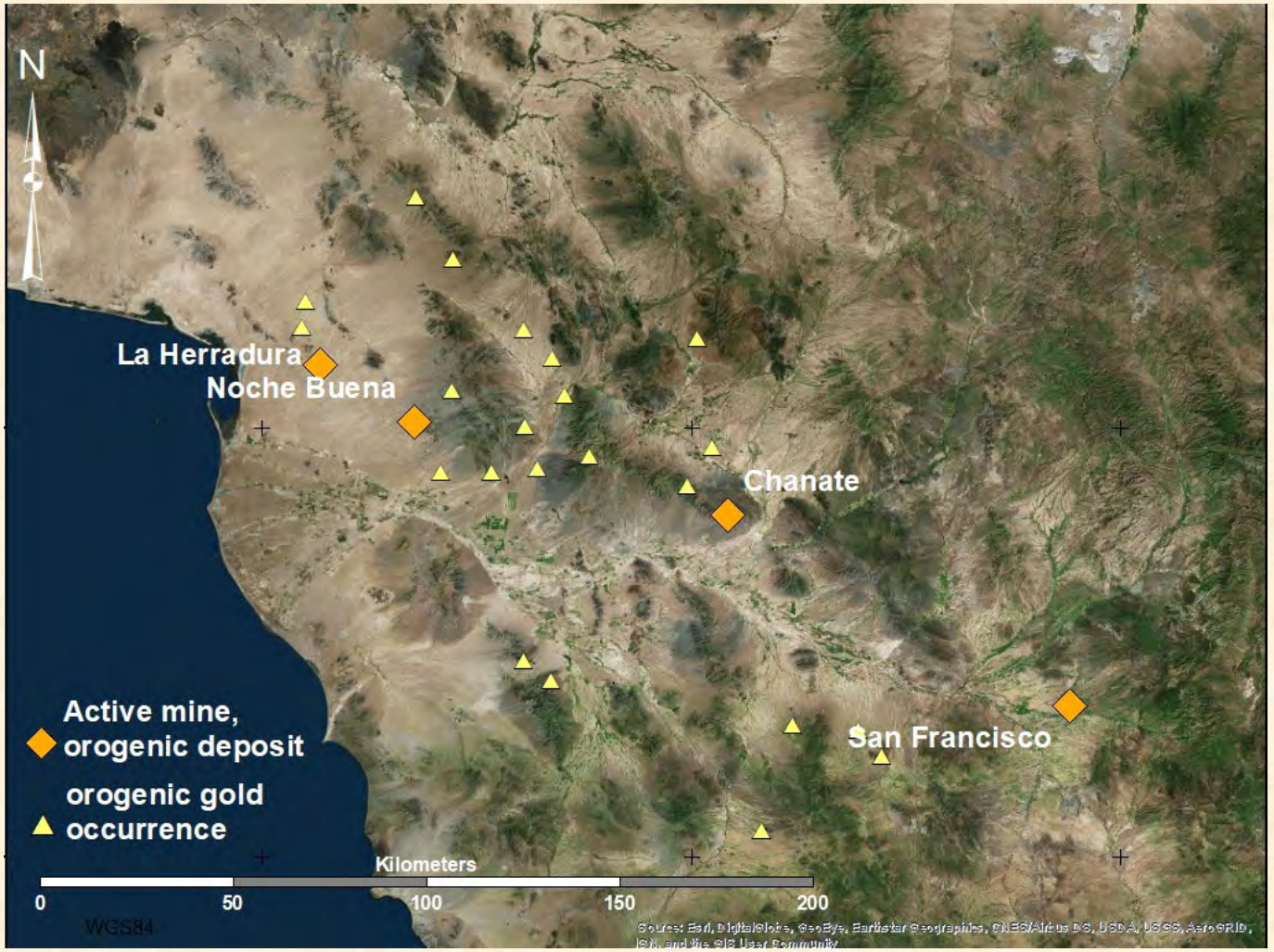
Economic potential of the Altar Trend

Processes operated at regional scale?

1. **Yes. Orogenic deposits occur over minimum 200km long trend demonstrating regional occurrence of geologically similar deposits (Izaguirre et al., 2017)**

    - **600km long trend if southern California and Sierra Madre foothills deposits included**

Regional Distribution Orogenic Deposits



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Economic potential of the Altar Trend

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Association with regional feature?	✓ a) MSM (whatever it is!) b) Boundaries of Paleoproterozoic basement terranes
Systems preserved? Vertical continuity?	

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Economic potential of the Altar Trend

Association with regional feature?

1. **Yes. 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 to SW and 1.6-1.7 Ga basement of North American block to NE
   - >800 km of lateral displacement as originally proposed not well supported by field evidence
   - Jurassic timing of development not certain

Mojave Sonora Megashear and Gold Deposits

Calvin and Hobbes, by Bill Watterson

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Mojave Sonora Megashear and Gold Deposits

Does Megashear have any relationship to gold deposits?

- Yes

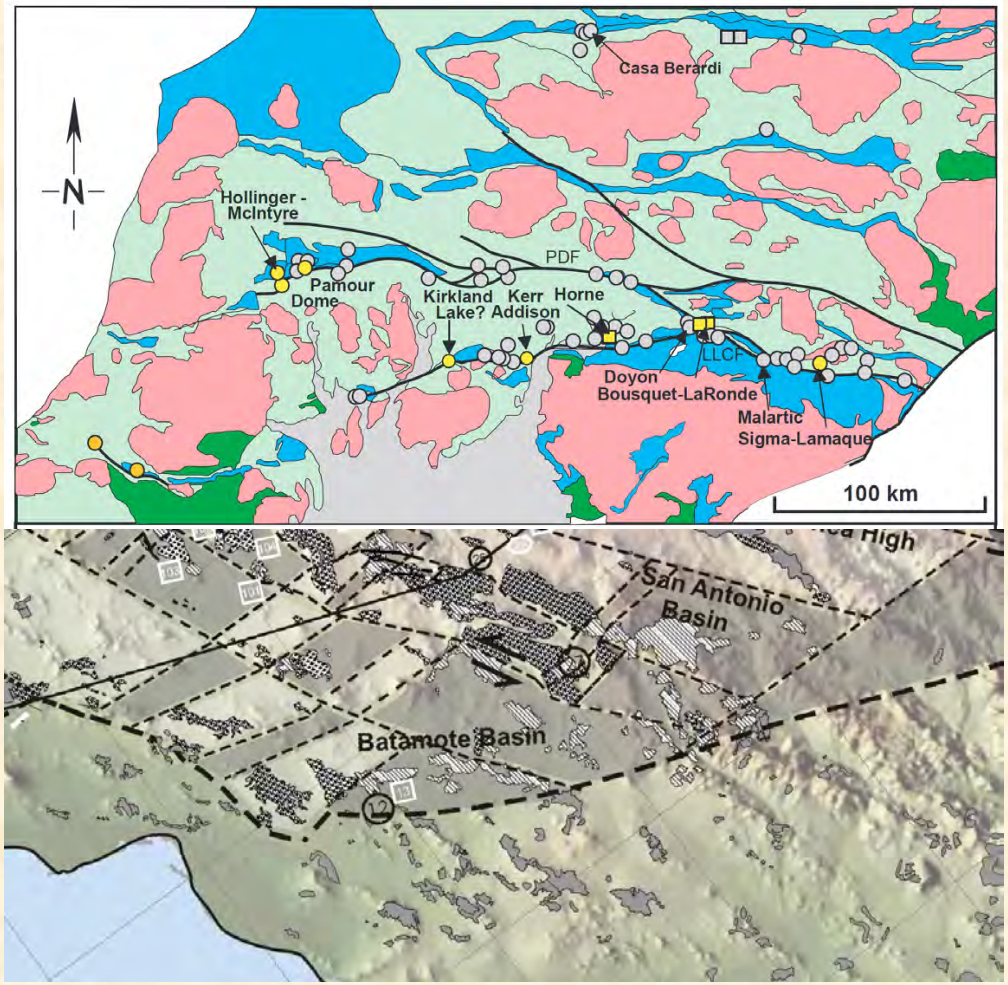
Is it a direct genetic relationship?

- Probably not.

Is it relevant?

- It might be.

Superior Province Regional Structures and MSM
(from Dube and Gosselin, 2007, Anderson et al., 2005)



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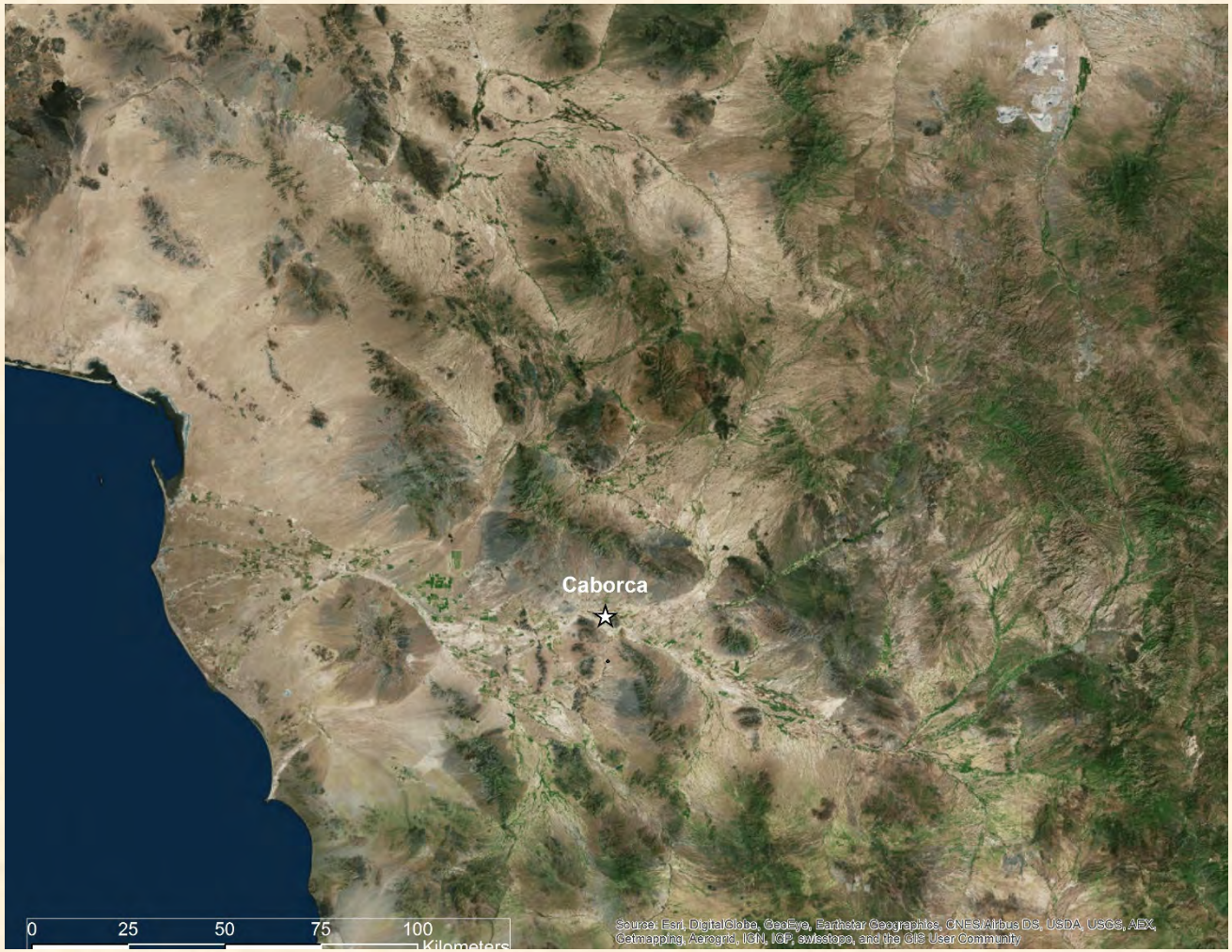
Mojave Sonora Megashear Regional Structure
(from Anderson et al., 2005)



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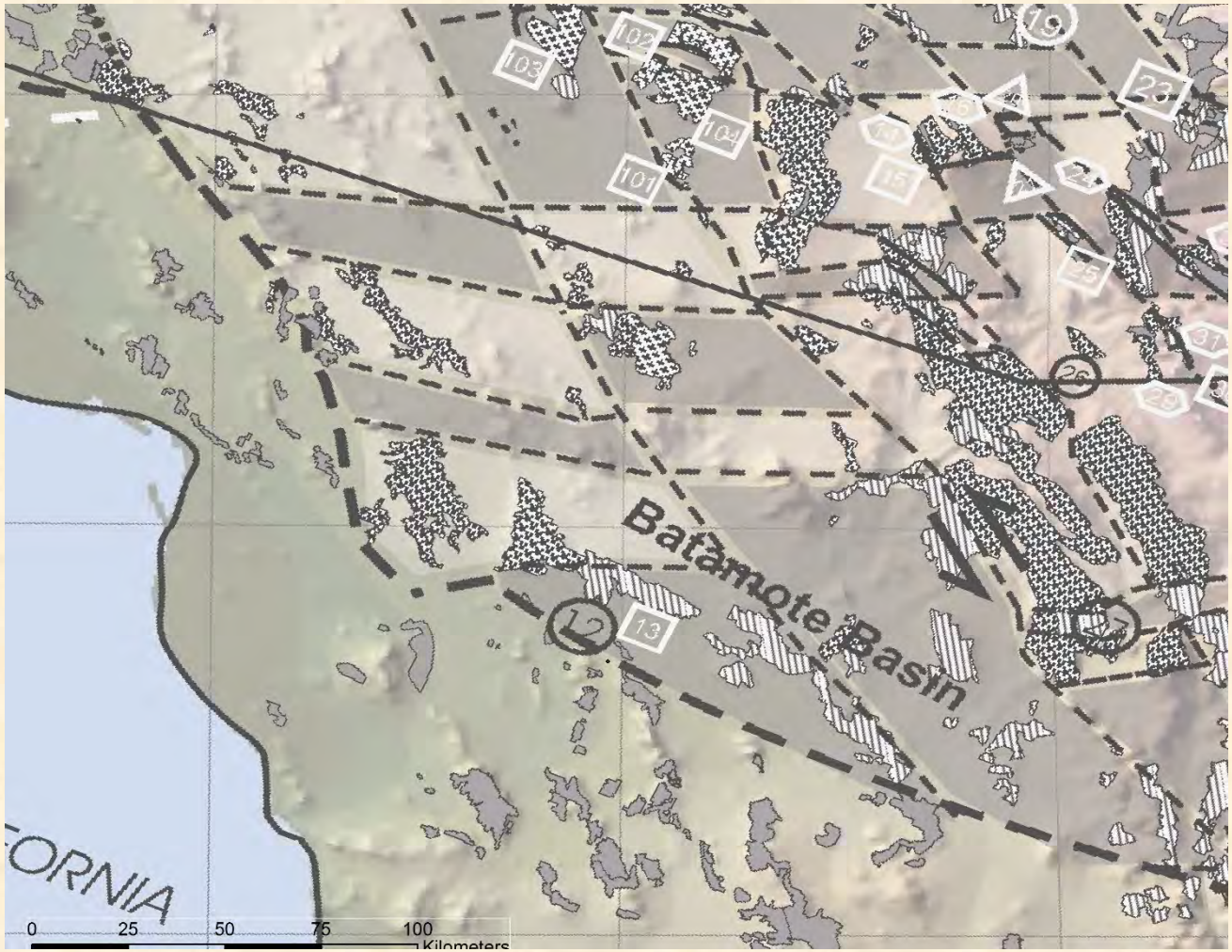

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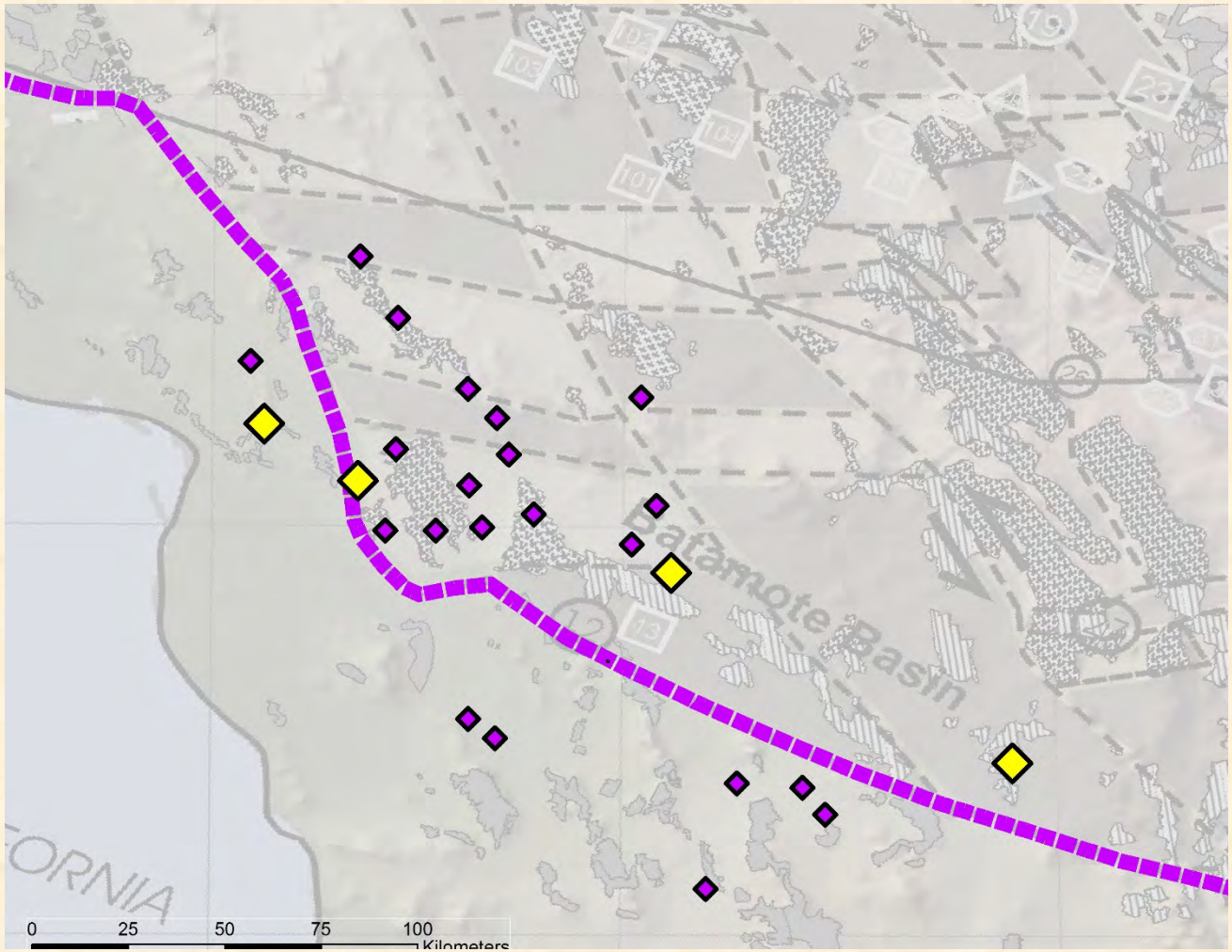
Mojave Sonora Megashear and Gold Deposits
(from MSM map from Anderson et al., 2005)



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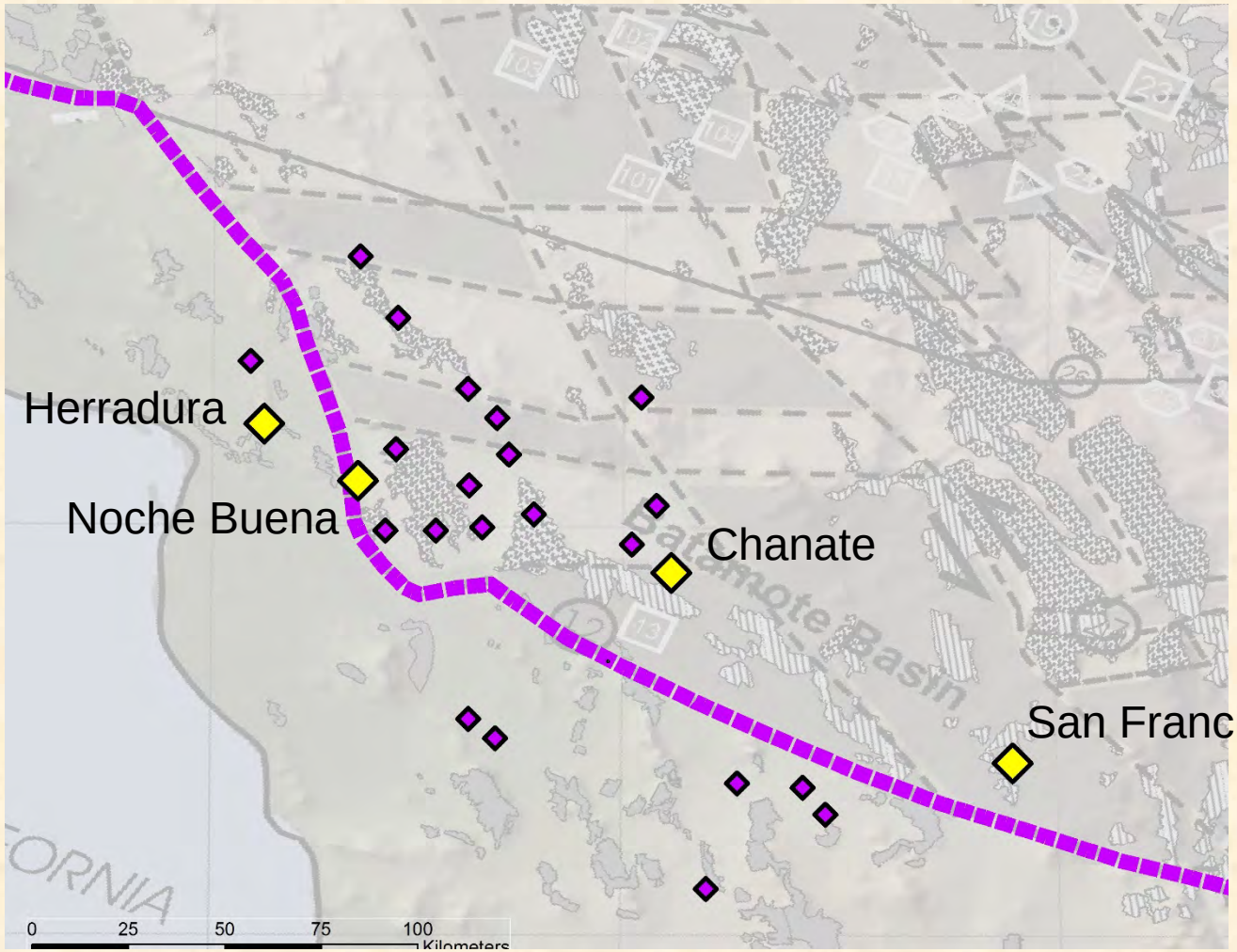

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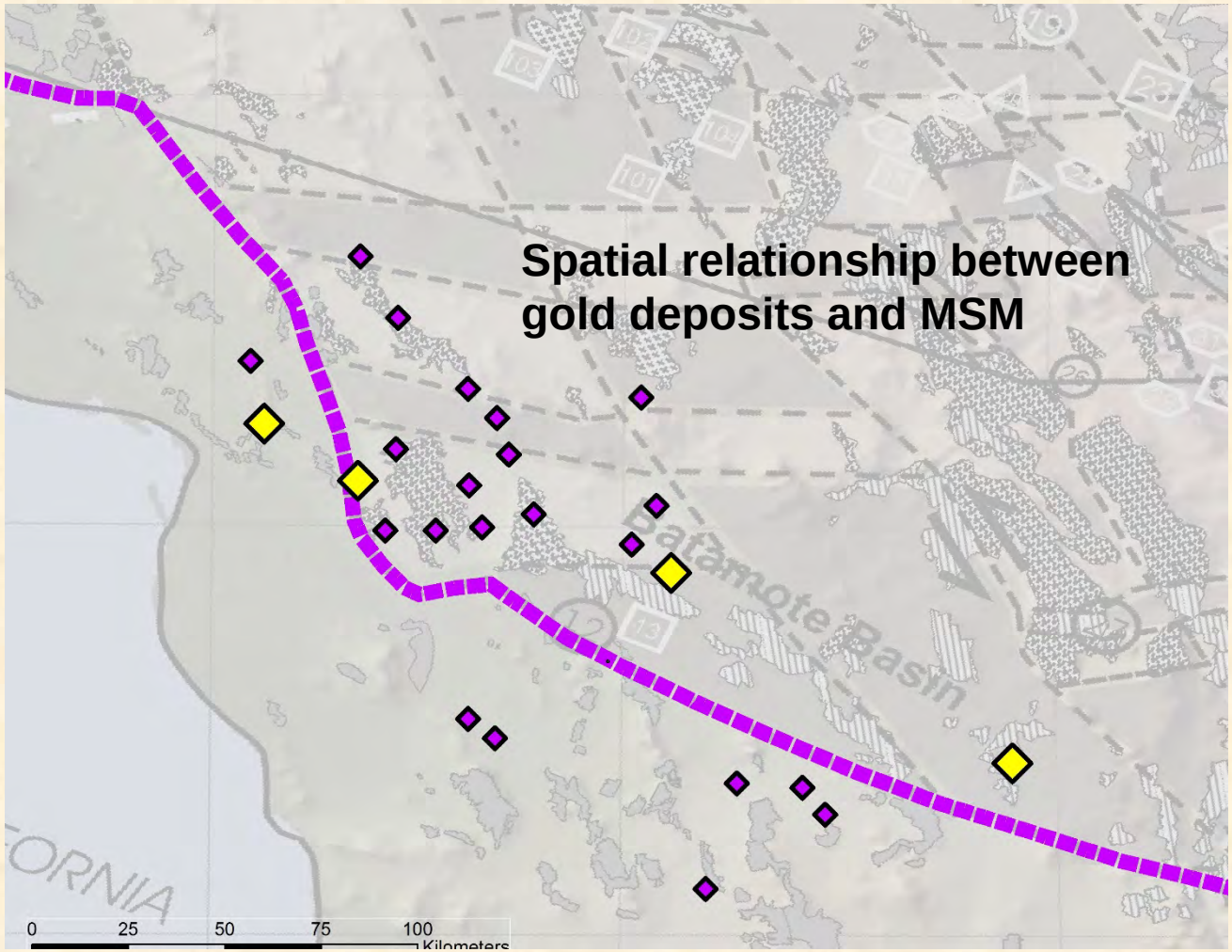

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Mojave Sonora Megashear and Gold Deposits

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

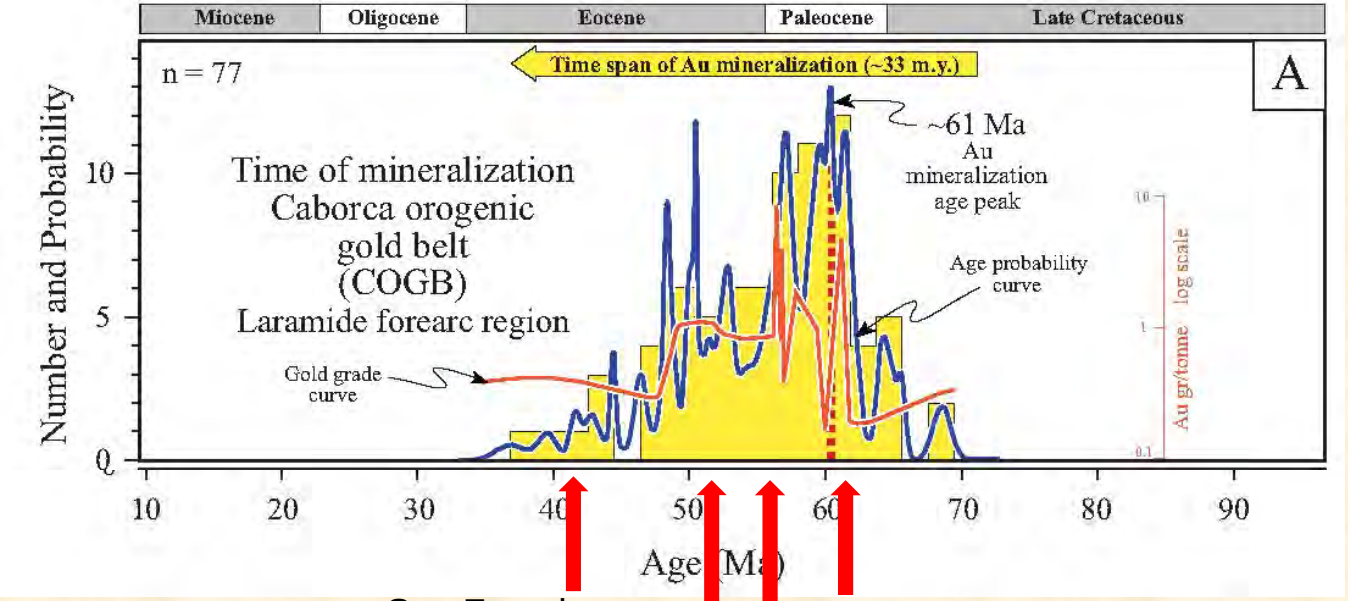
- MSM interpreted to have formed as early as Jurassic
- Altar Trend gold deposits much younger (69 to 36 Ma., Izaguirre et al., 2017)

Geologic characteristics of orogenic deposits

Age distribution Altar Trend orogenic gold deposits

(from Izaguirre et al., 2017)

Vein sericite dates $^{40}Ar/^{39}Ar$ from USGS OFR 2016-1008, Re-Os date from Quintanar, 2008



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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?

Economic potential of the Altar Trend

Altar Trend orogenic gold prospectivity checklist

Needed	Got it?
Economically significant orogenic mineralizing processes affected region?	✓ La Herradura (orogenic features documented by Quintanar Ruiz, 2008)
Processes operated at regional scale?	✓ Geologically similar deposits known over 200km trend
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Systems preserved? Vertical continuity?	

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Association with regional feature?	✓ a) MSM (whatever it is!) b) Boundaries of Paleoproterozoic basement terranes
Systems preserved? Vertical continuity?	✓ Deep drilling at La Herradura confirms

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Economic potential of the Altar Trend

Systems preserved? Vertical continuity?

1. **Yes. Direct drill proof. Fresnillo has drilled deep intercepts indicating vertical continuity and preservation of system.**

   Centauro Deep
   4.7Mt @ 3.9 gpt Au (581,000 ounces)

Future of the Altar Trend

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

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

Future of the Altar Trend

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
(photo from http://www.csmonitor.com)

Altar Trend, Sonora
Gold nugget float

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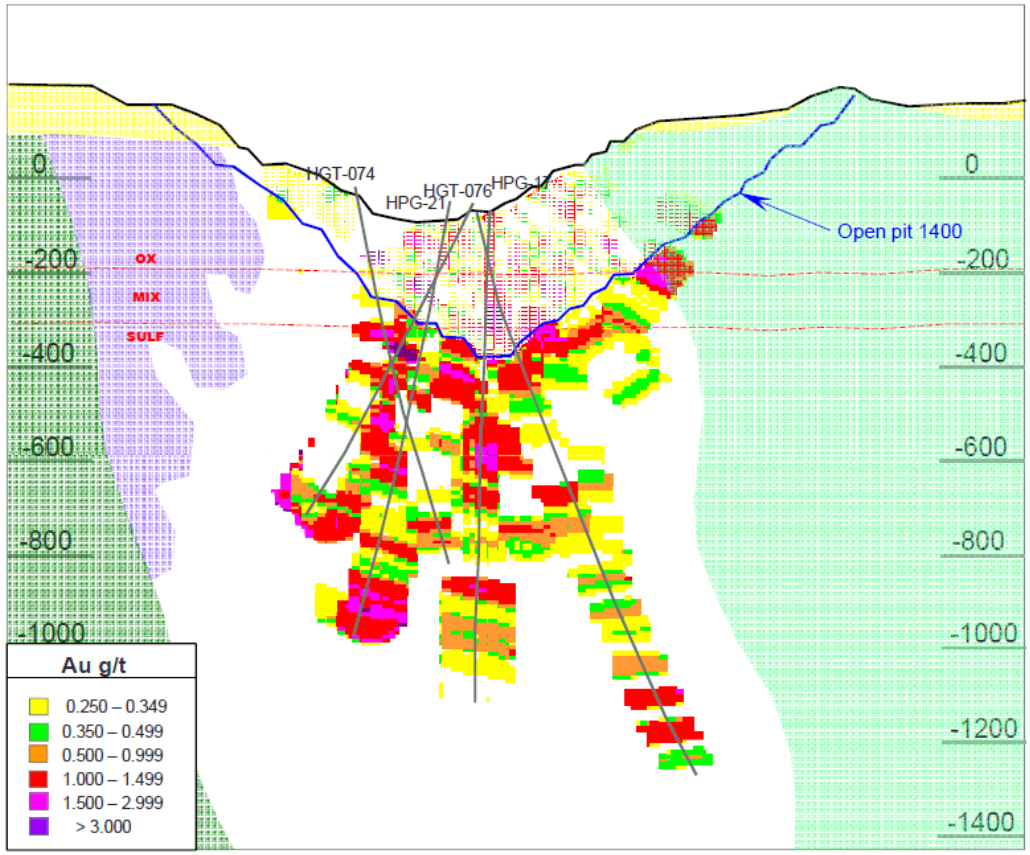
Future of the Altar Trend

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

- Drillhole demonstrated gold mineralization over at least 1500m vertical interval
- ~ 350,000 ounce resource Au at >5 gpt reported by Fresnillo in December 2012

Mineral Resource Dec. 2012 (attributable)			
	Mton	Au gpt	Au (cont)
Indicated	0.83	5.03	130 koz
Inferred	1.05	6.39	220 koz

From October 2013 presentation by Fresnillo, available at http://www.fresnilloplc.com/media/113212/Fresnillo-Exploration-Day-9-Oct-2013.pdf

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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

From October 2013 presentation by Fresnillo, available at http://www.fresnilloplc.com/media/113212/Fresnillo-Exploration-Day-9-Oct-2013.pdf

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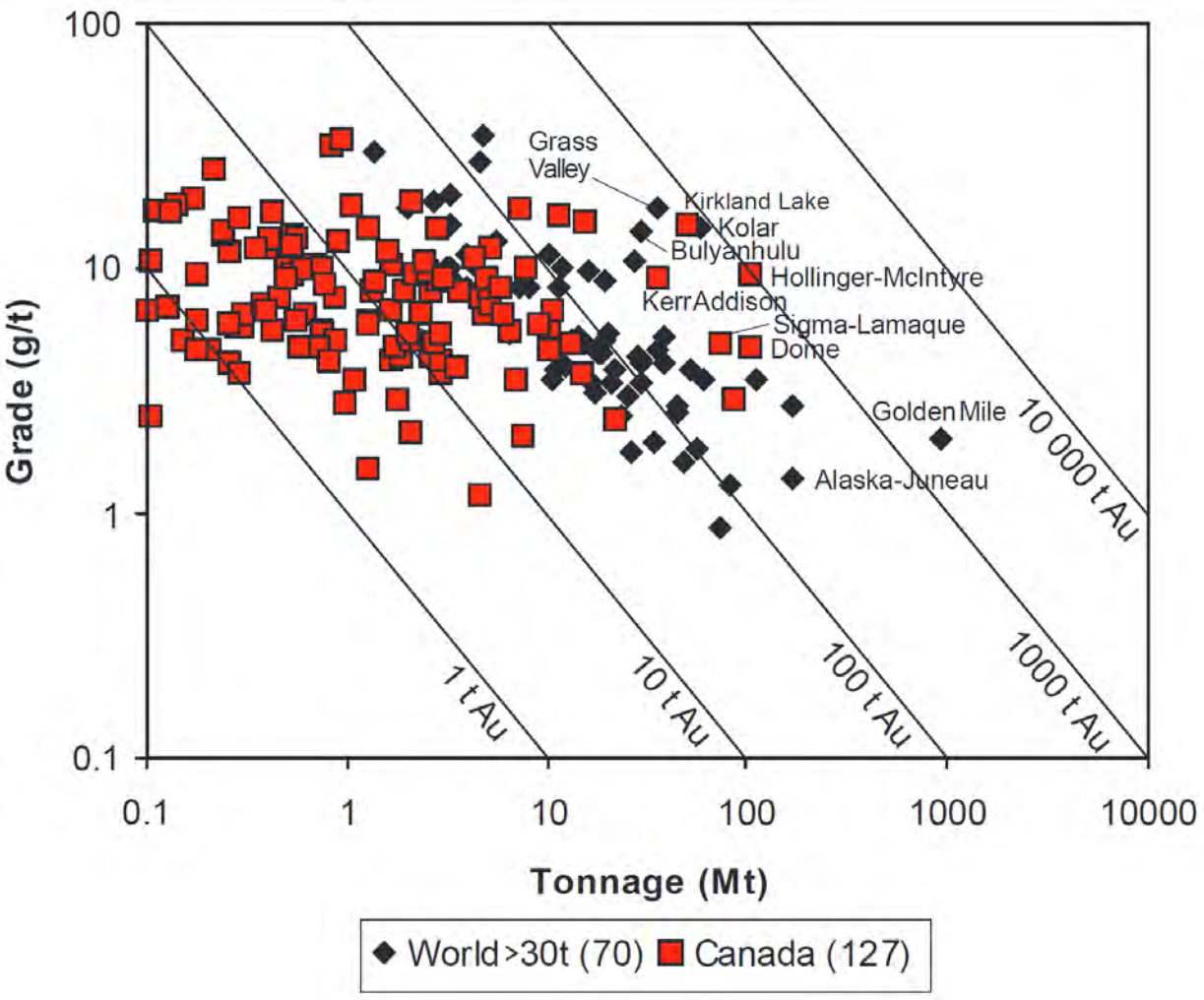
Future of the Altar Trend

- 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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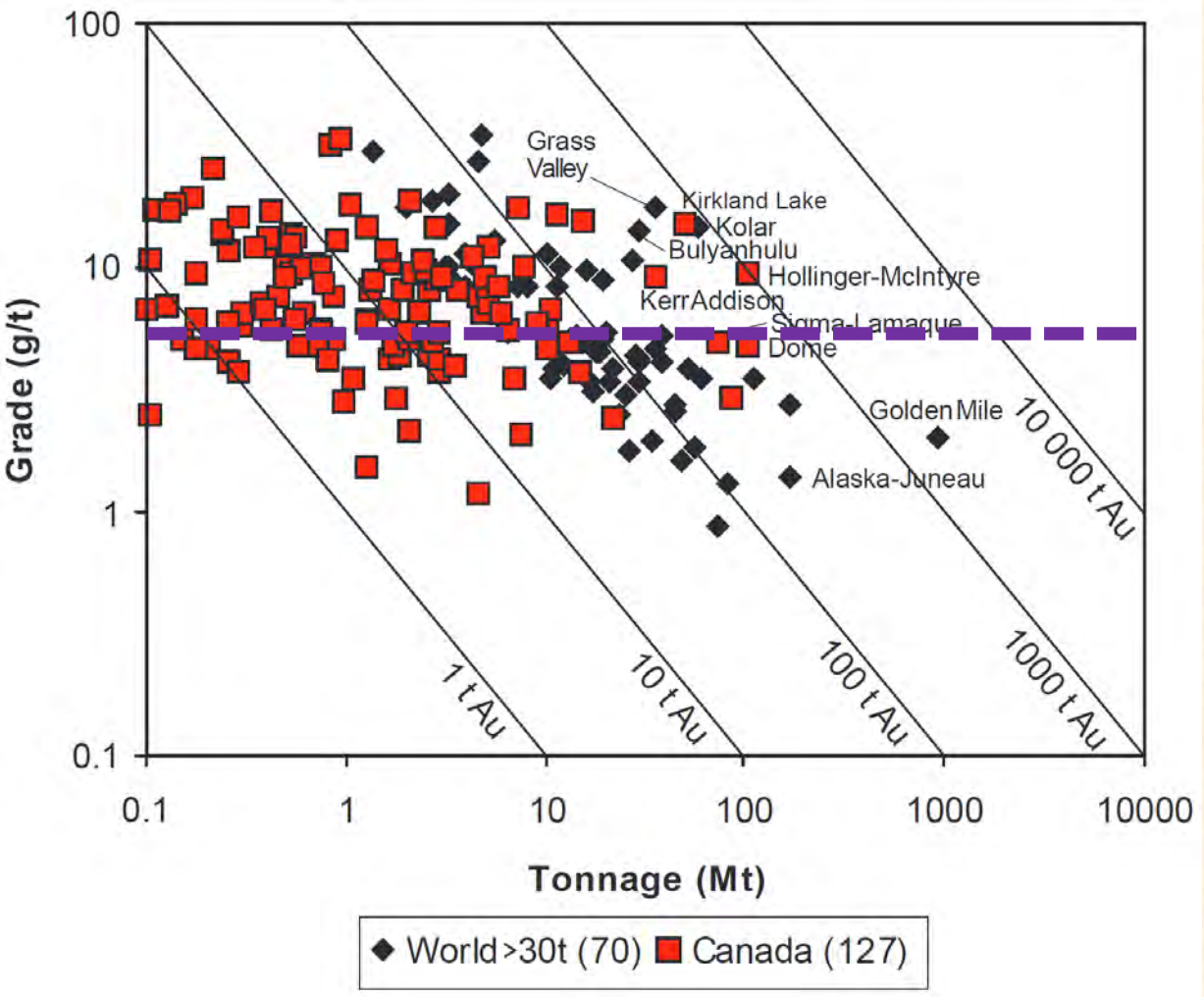

5 gpt

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Grade/Tonnes Orogenic Gold Deposits
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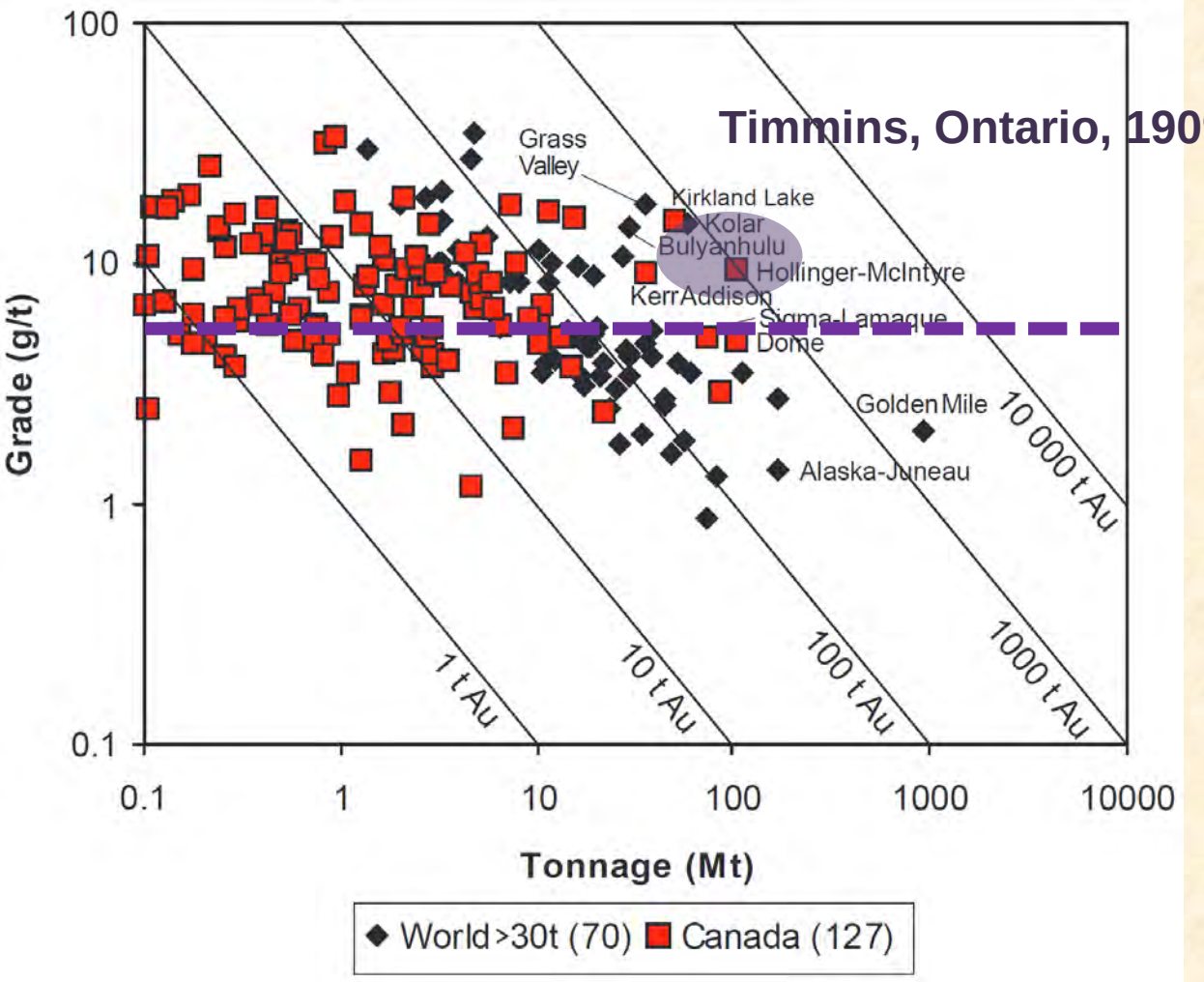

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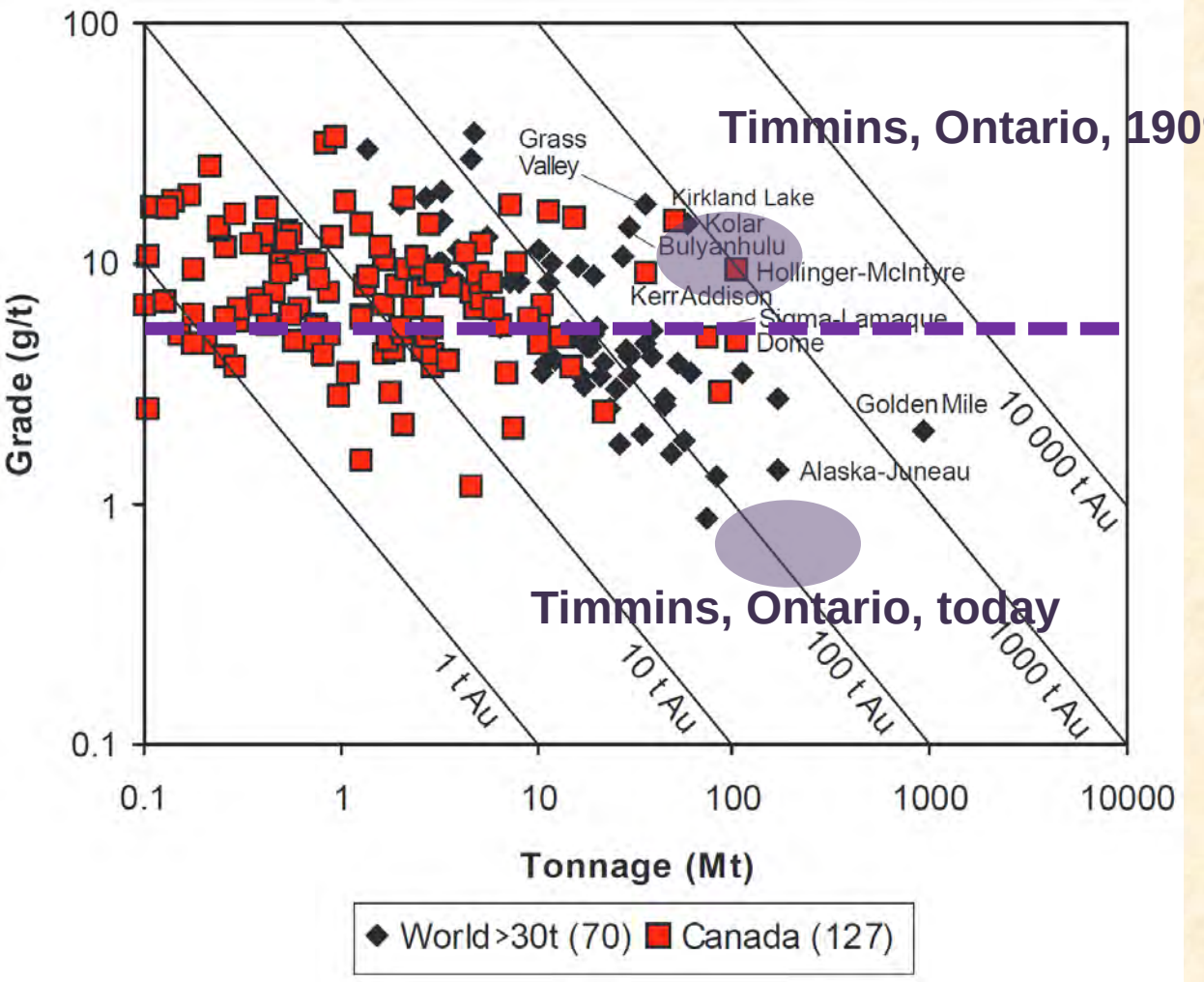

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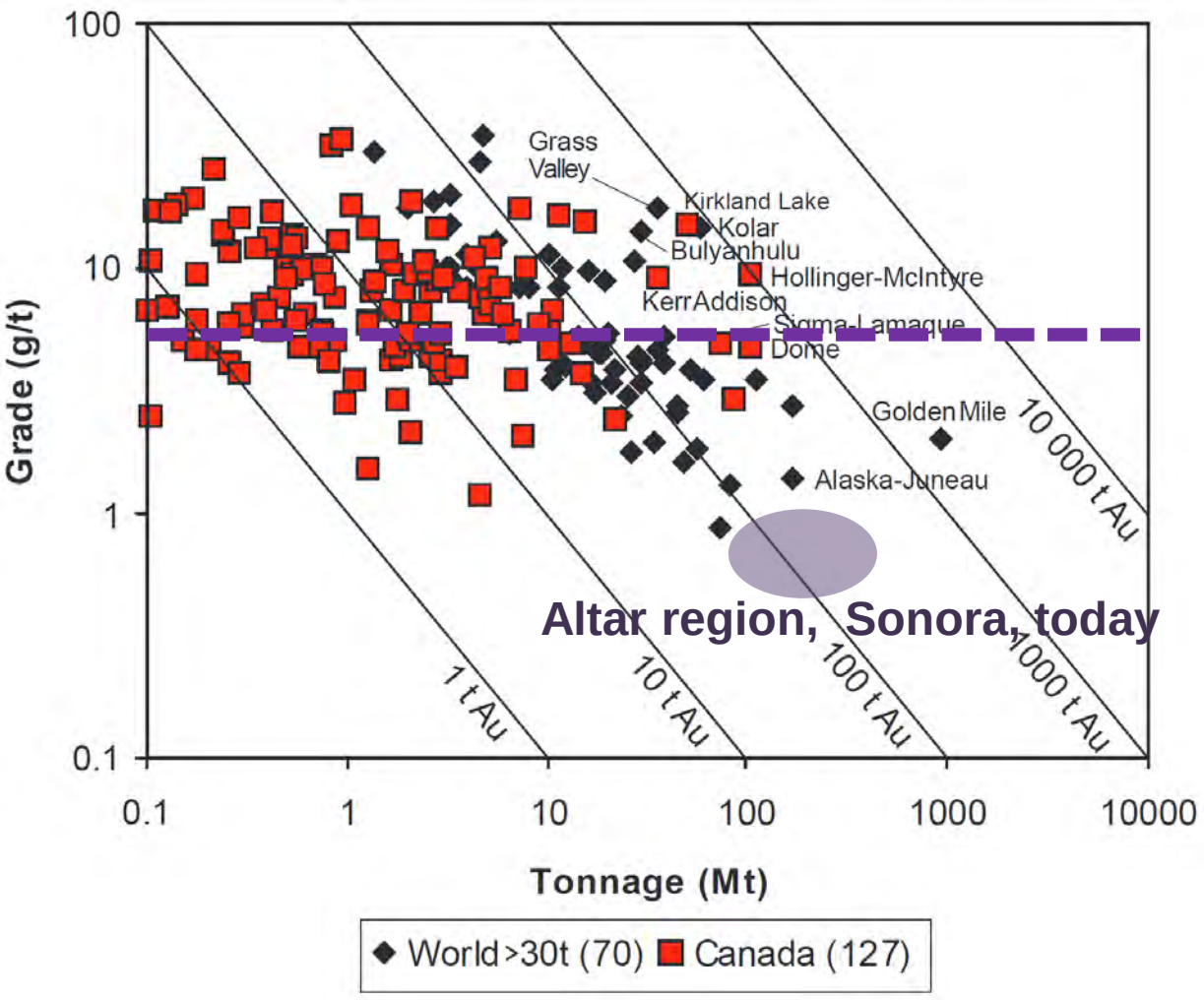

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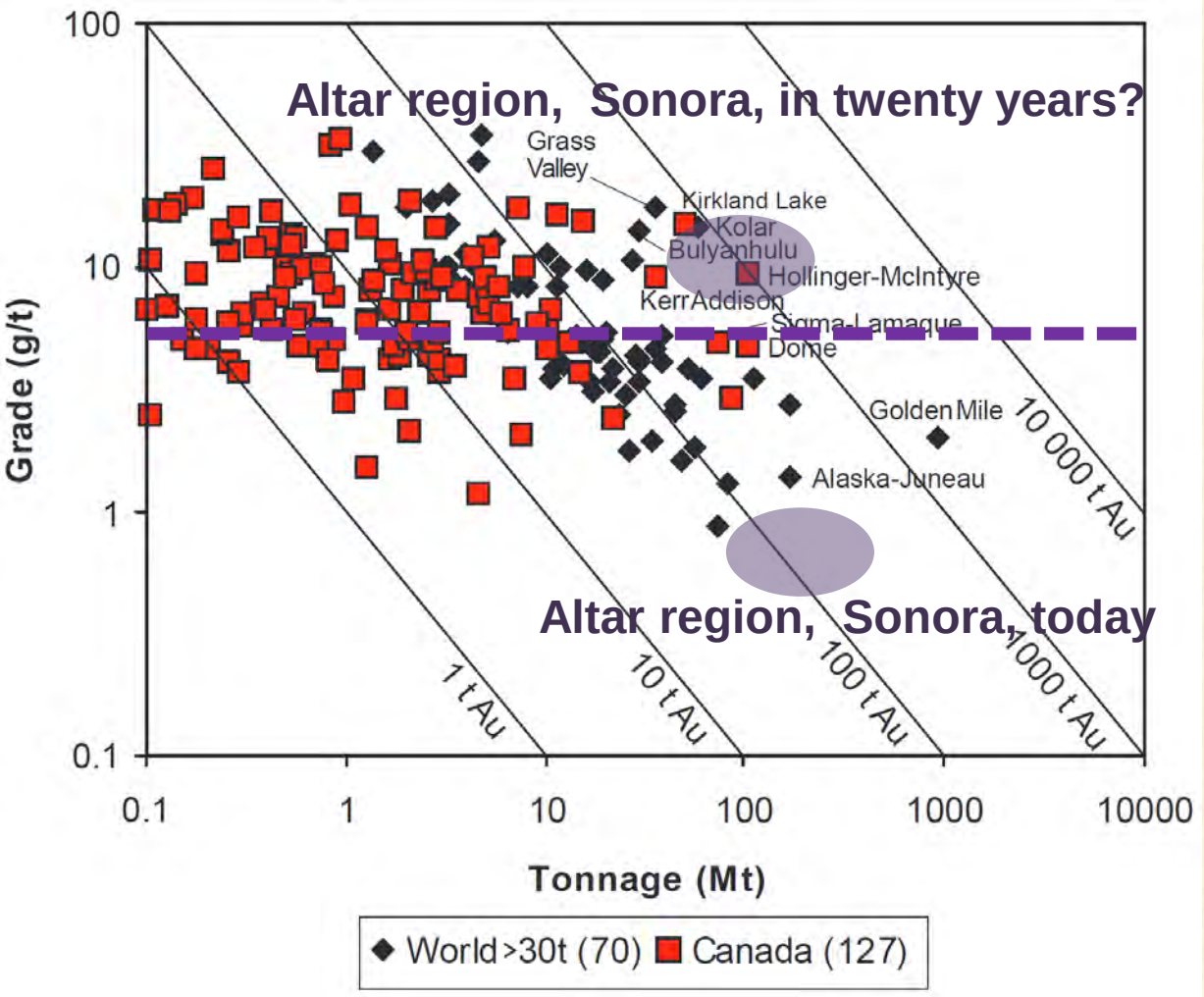

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Conclusions

Conclusions

- Headframes coming to the Altar Trend
- Increasing 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.