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**Rocky Mountain Section**
**68th Annual Meeting**

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


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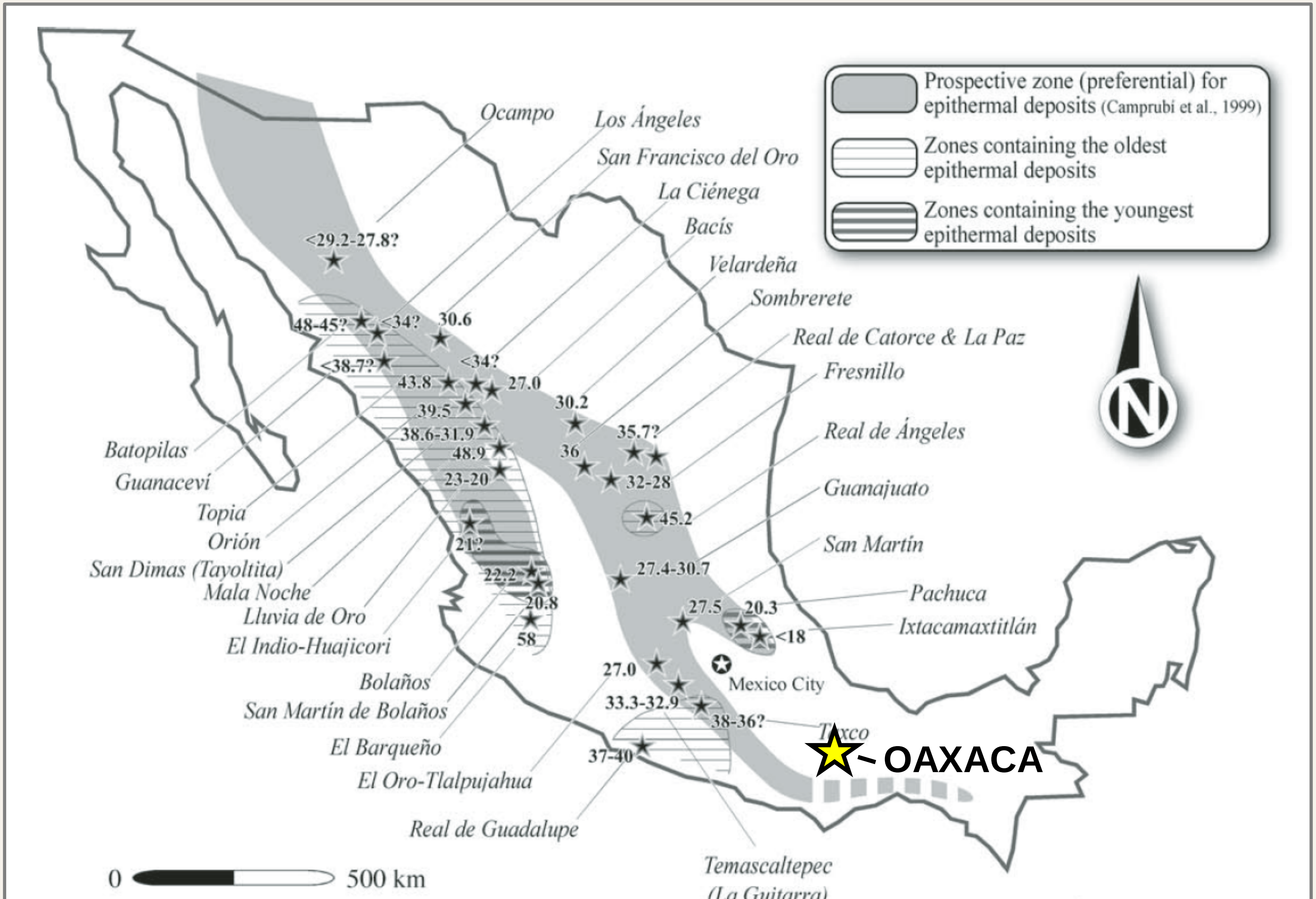
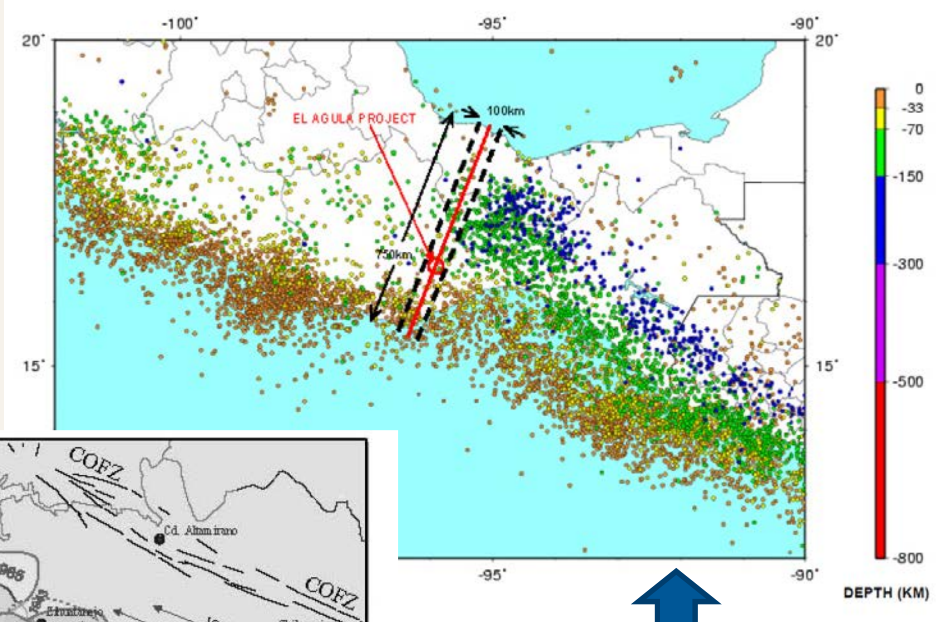
# Mexico Epithermal Deposits
## (Camprubi & Albinson, 2007)



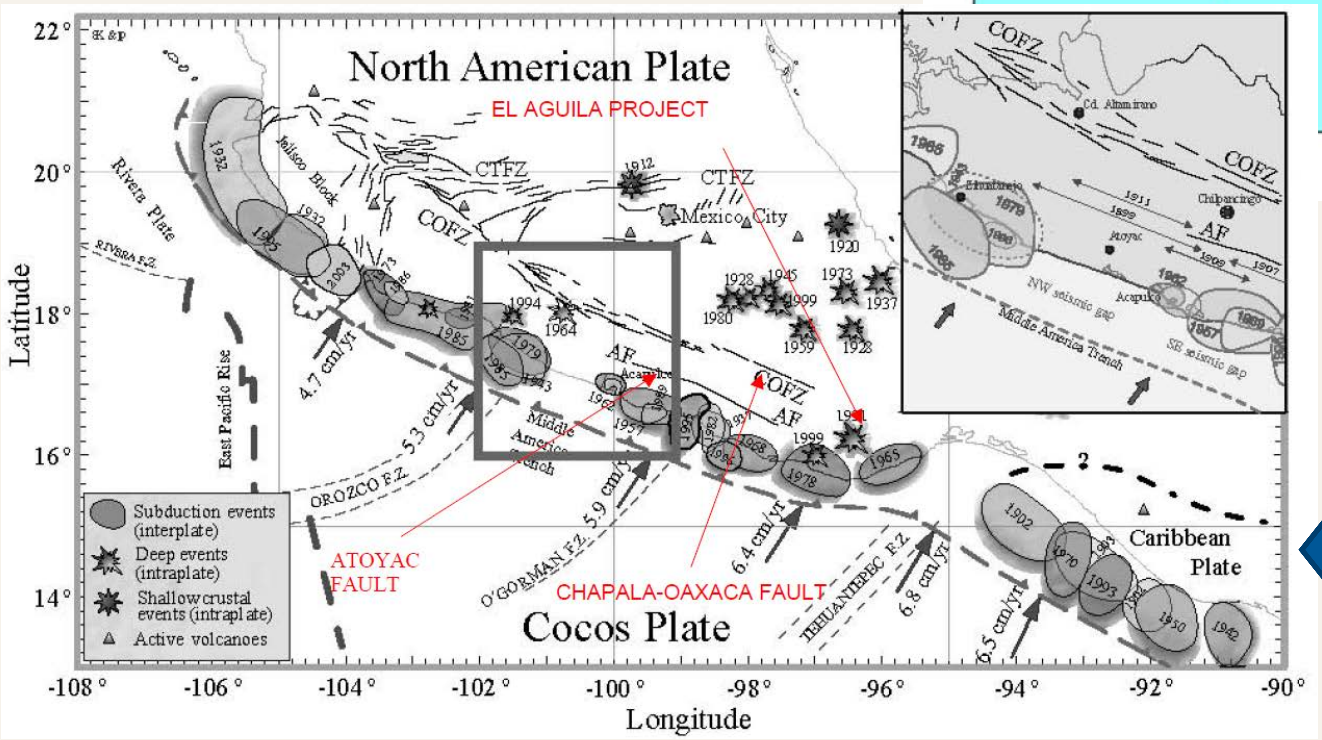
# Mexico Geology
## “Sierra Madre Del Sur”

# 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.**

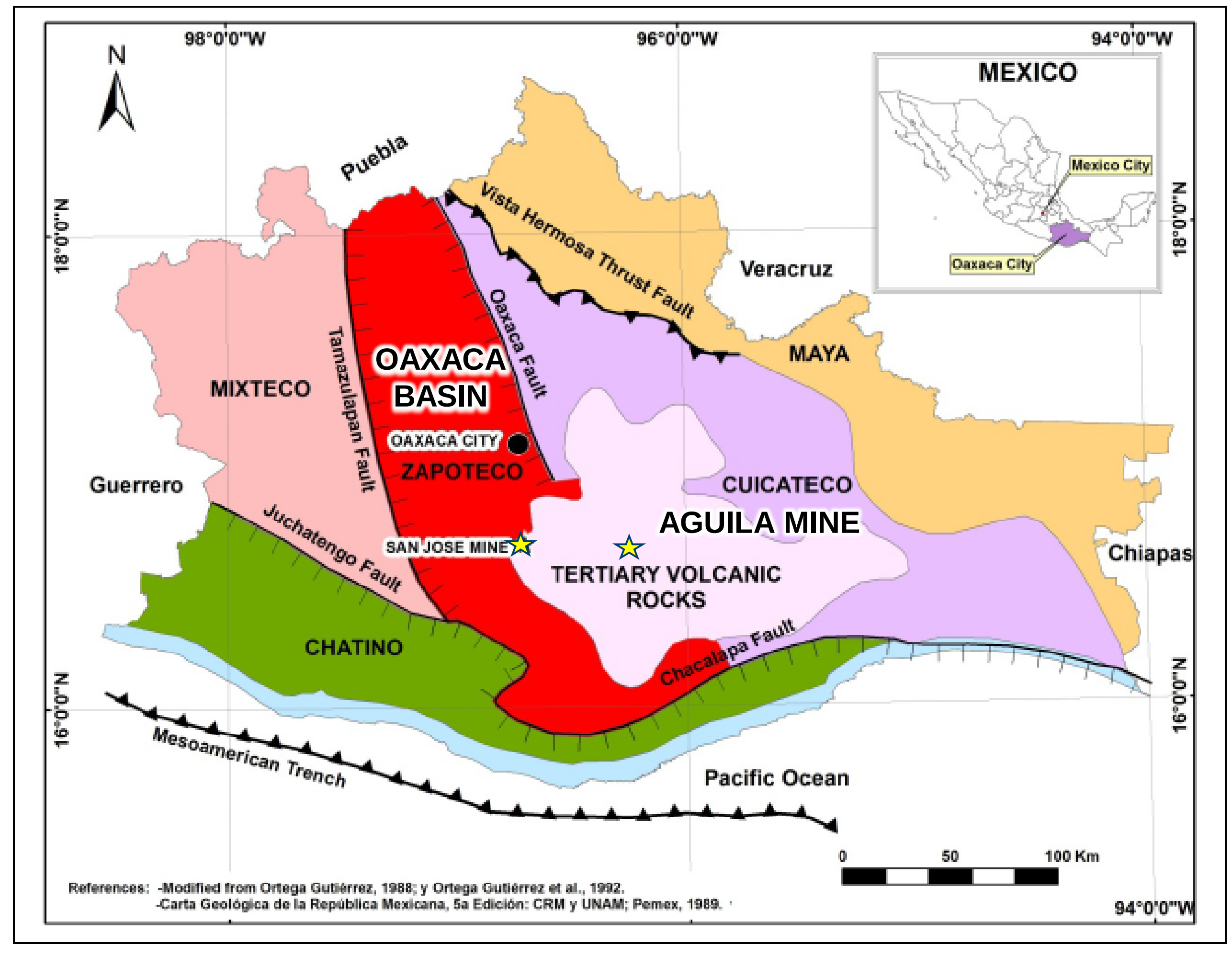



**Seismicity from 1973 to present USGS National Earthquake Information Center (NEIC) database)**



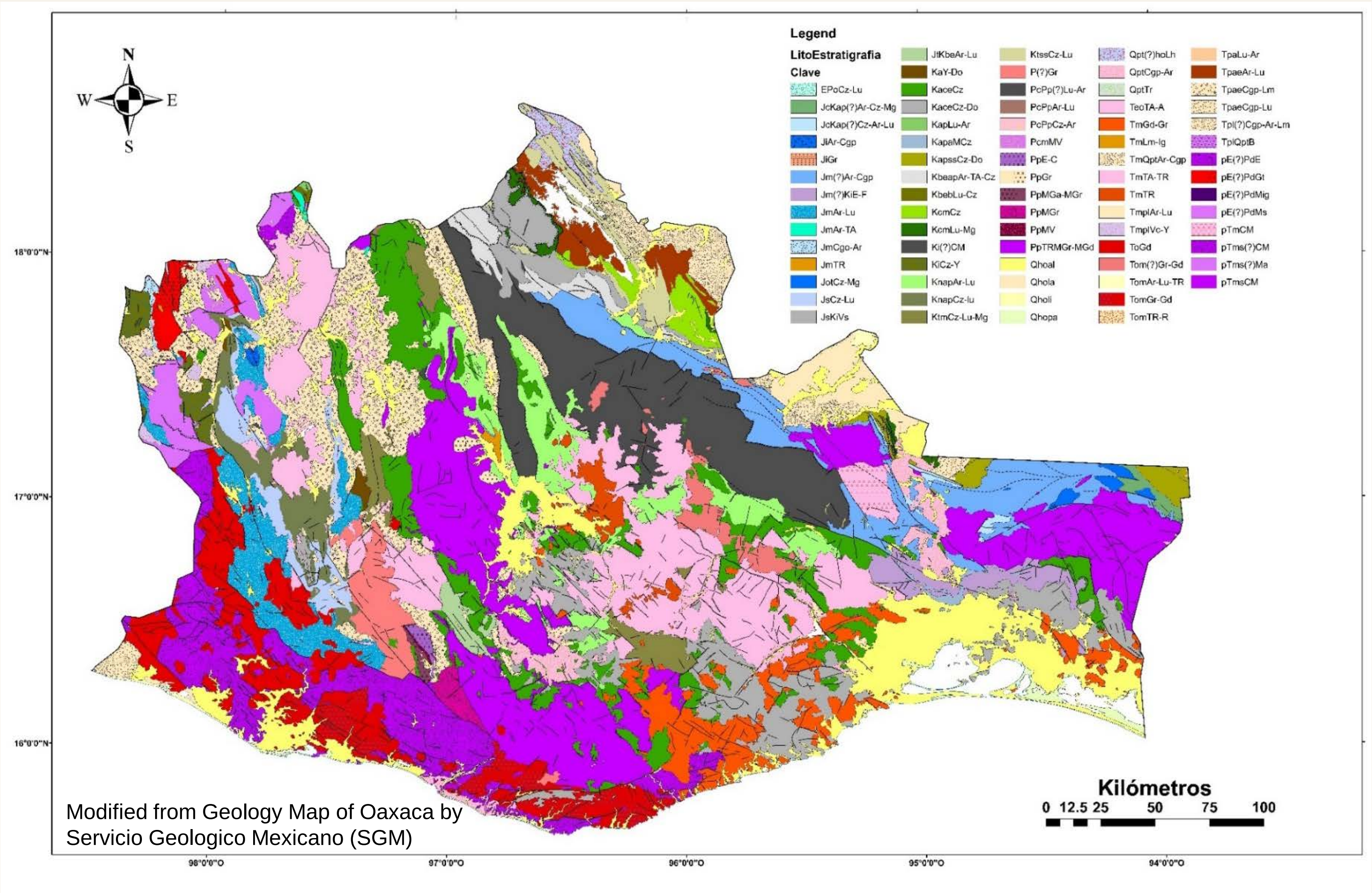

**Seismic Hazard Study – El Aguila Project by Vector Engineering Inc. (after Kostoglodov & Ponce, 1994)**

# 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.**

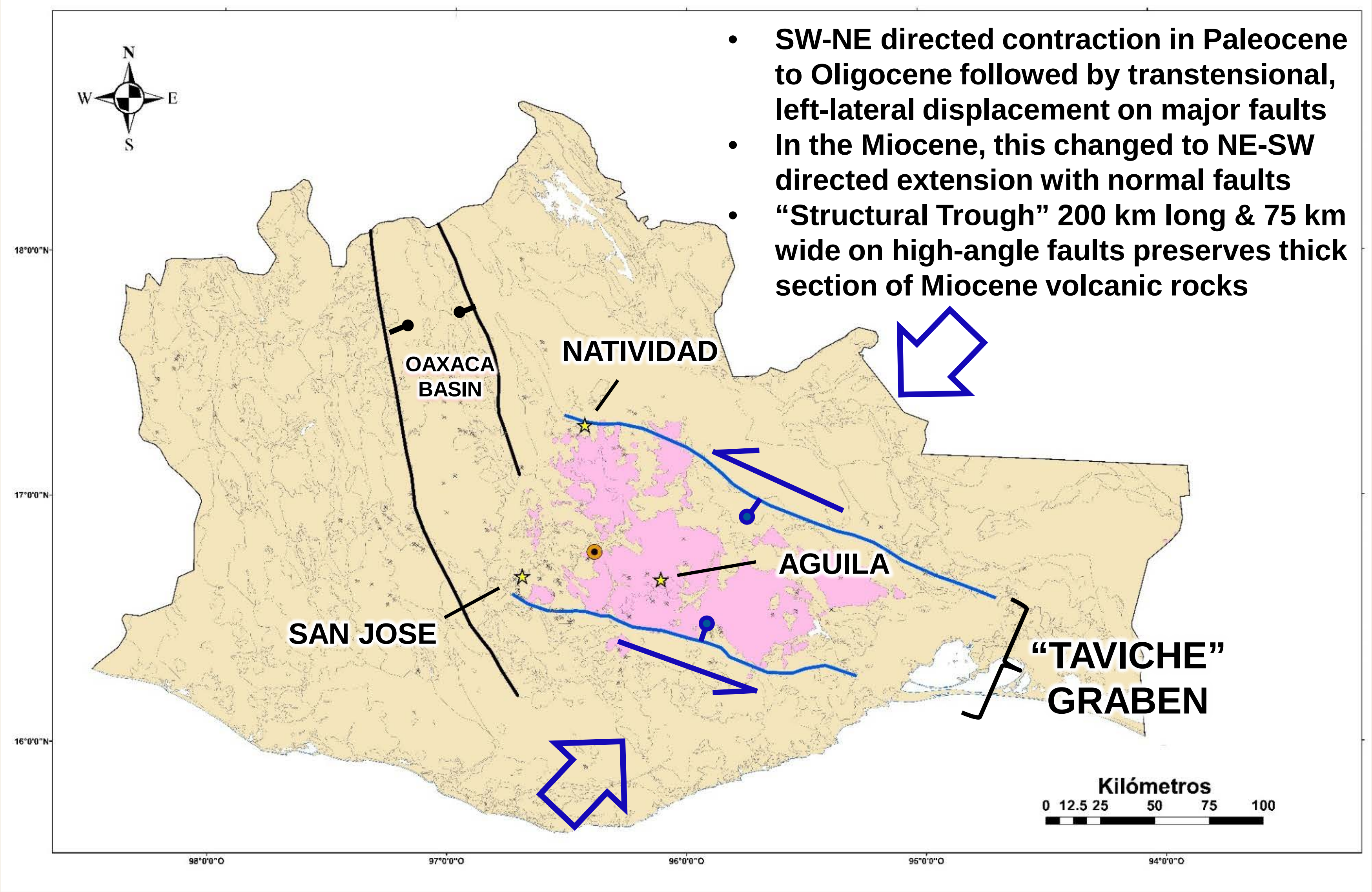
# Oaxaca Geology - Lithostratigraphy




Modified from Geology Map of Oaxaca by
Servicio Geologico Mexicano (SGM)

- **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



# Calderas & Flow Domes (David M. Jones, 2005)

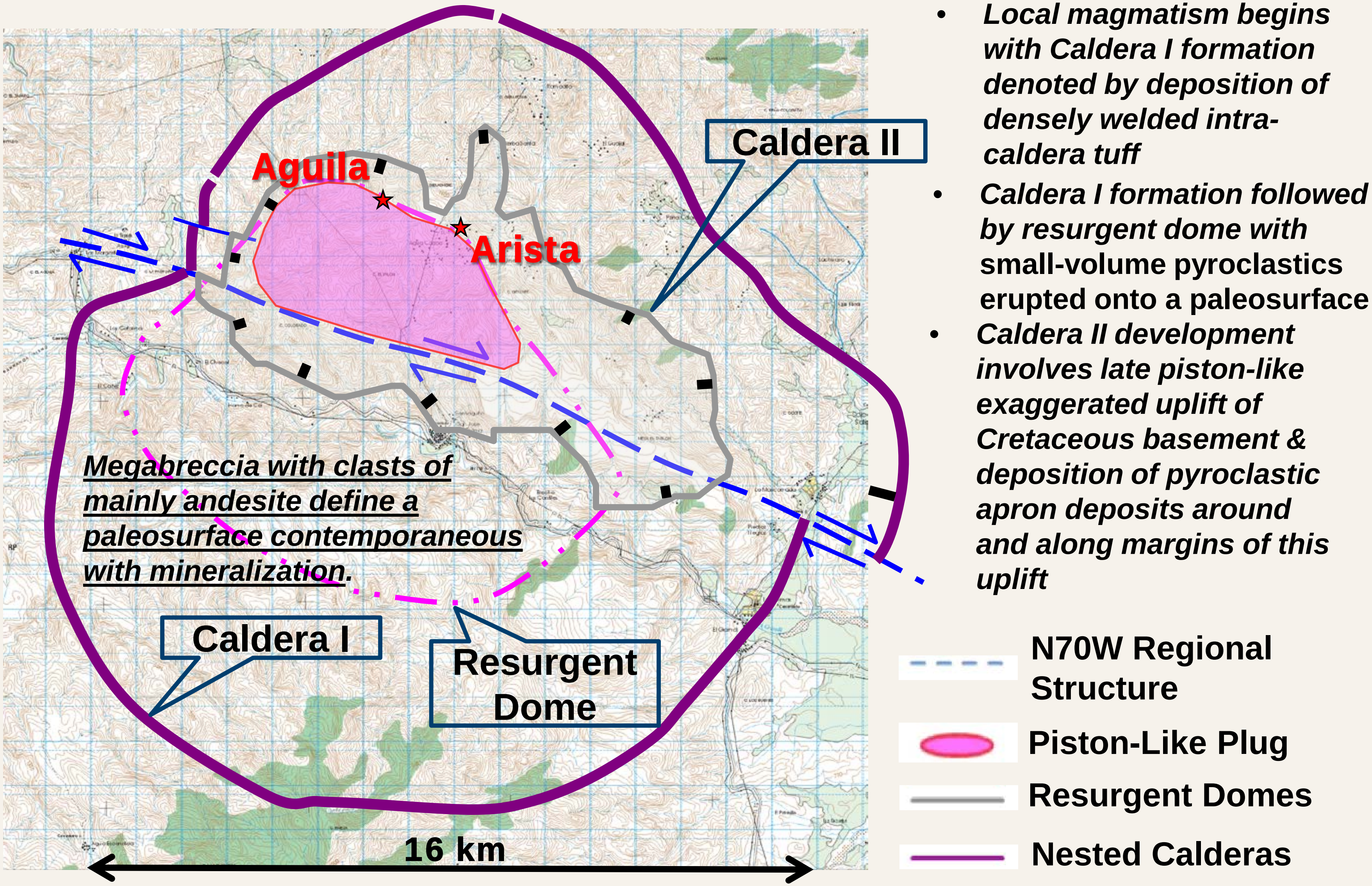
- **Large-scale calderas with medium- to high-level intrusions including andesitic to rhyodacitic flow domes overlain by thick ignimbrite units are associated with epithermal deposits.**
- **Mineralization is intimately related to intra-graben regional strike-slip shearing & caldera magmatism.**
- **There is also a particularly close association between dome margins, dikes, and epithermal vein mineralization.**

**Contorted flow banding & sheeting at margin of rhyodacite dome.**

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

**Sub-horizontal “mushroom- lobe” flow banding in felsite dike.**

# Strike-Slip Shearing & Magmatism



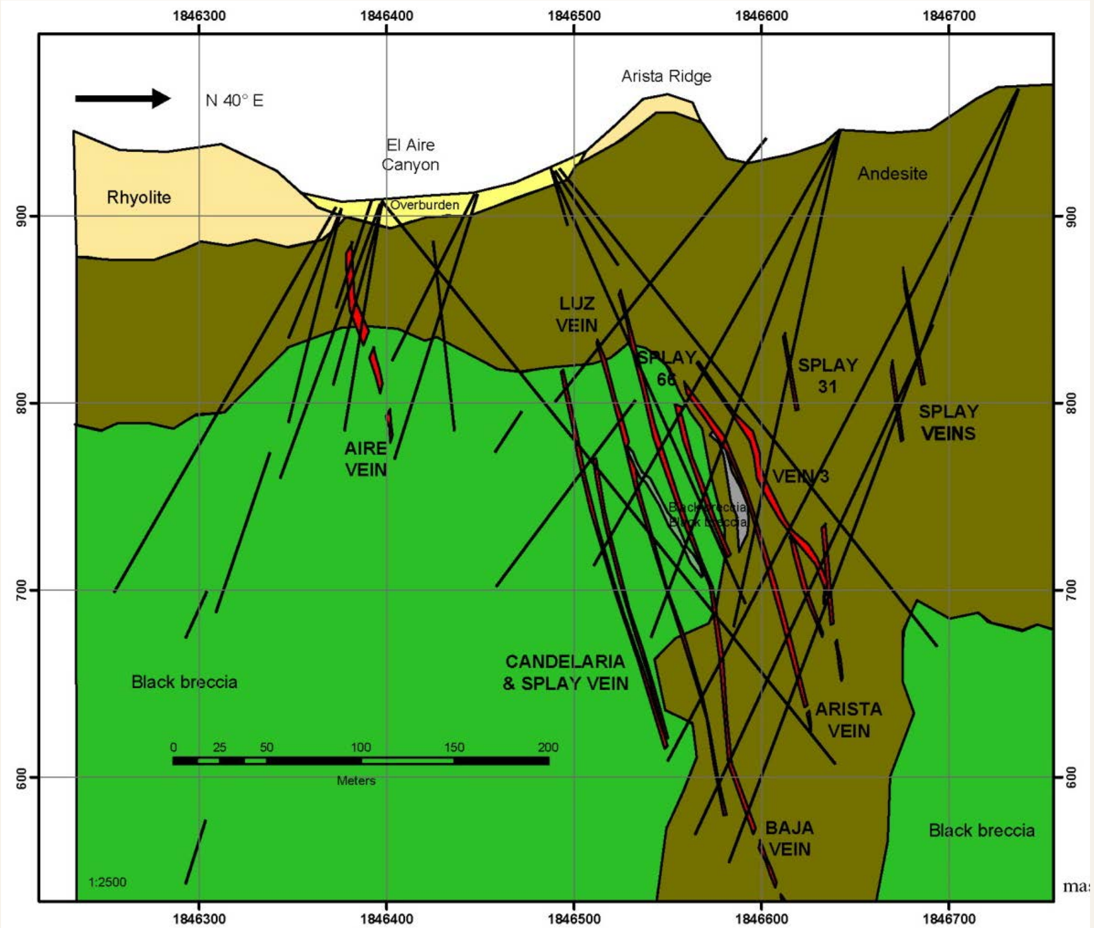

- *Local magmatism begins with Caldera I formation denoted by deposition of densely welded intra-caldera tuff*
- *Caldera I formation followed by resurgent dome with* small-volume pyroclastics erupted onto a paleosurface
- *Caldera II development involves late piston-like exaggerated uplift of Cretaceous basement & deposition of pyroclastic apron deposits around and along margins of this uplift*

# Paleosurface Deposits

**Highest priority exploration targets lie along & below the paleosurface where it intersects annular structures related to resurgence. Important paleosurface indicators:**

- **<u>Travertine</u> deposited from carbonate-bearing water and indicative of a still active hydrothermal system *(Above & upper right*); At Arista, carbonated subsurface water bubbling with $CO_2$ gas and temperatures 42 – 43 degrees centigrade at 400 m depth**
- **<u>Paleosurface fossils</u> 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**

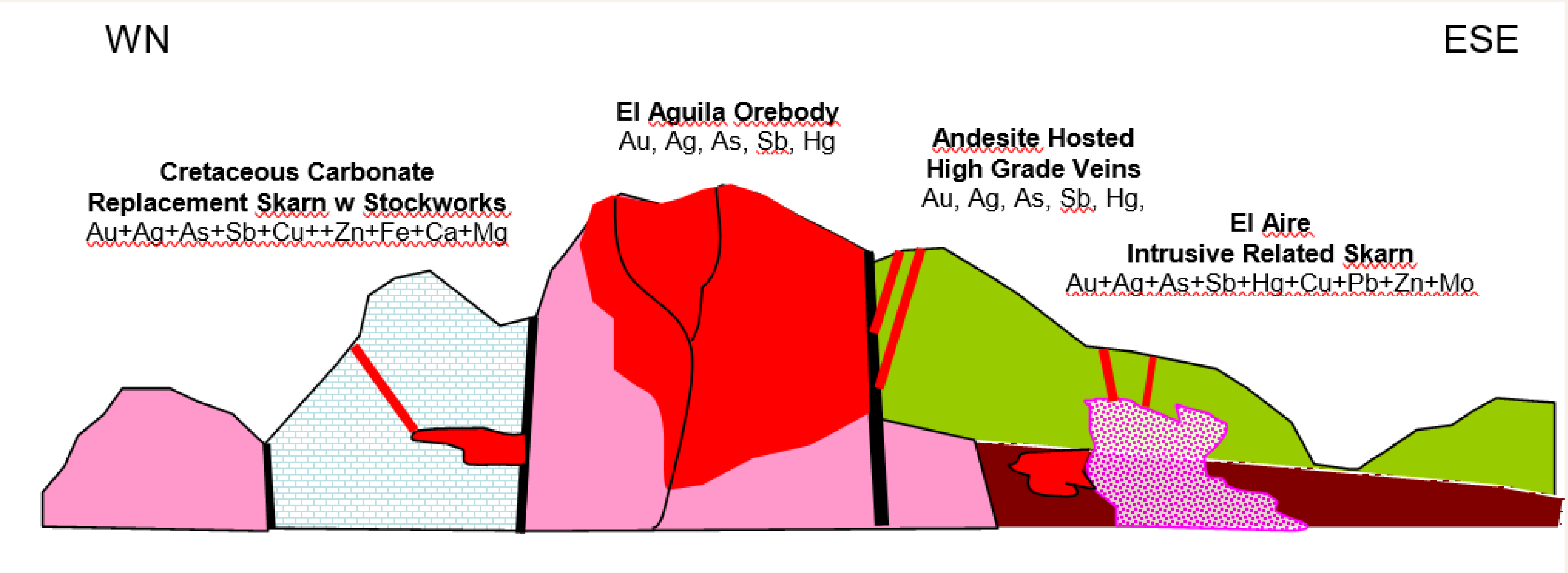
# Arista Vein

**Polymetallic mineralization mainly comprises:**

**pyrite**
**sphalerite**
**galena**
**chalcopyrite**
**argentite/acanthite**
**pyrargyrite**
**tetrahedrite-tennanite**
**arsenopyrite**
**stibnite**

**Fluid Inclusions (quartz):**
**250 - 270° C**
**<2% wt% NaCl**

# Skarn Association
# (Jeffrey A. Jaacks, 2006)




- **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:**
  - **<u>Au+Ag+As+Sb+Hg+Cu+Pb+Zn+Mo(+Bi+W)</u>: representing Au-Ag-Base Metal veins developed in skarn setting peripheral to an intrusive, and**
  - **<u>Au+Ag+As+Sb+Hg</u>: 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 ($CaMn^{2+}Si_2O_6$[1])

- Quartz vein with white fibrous wollastonite

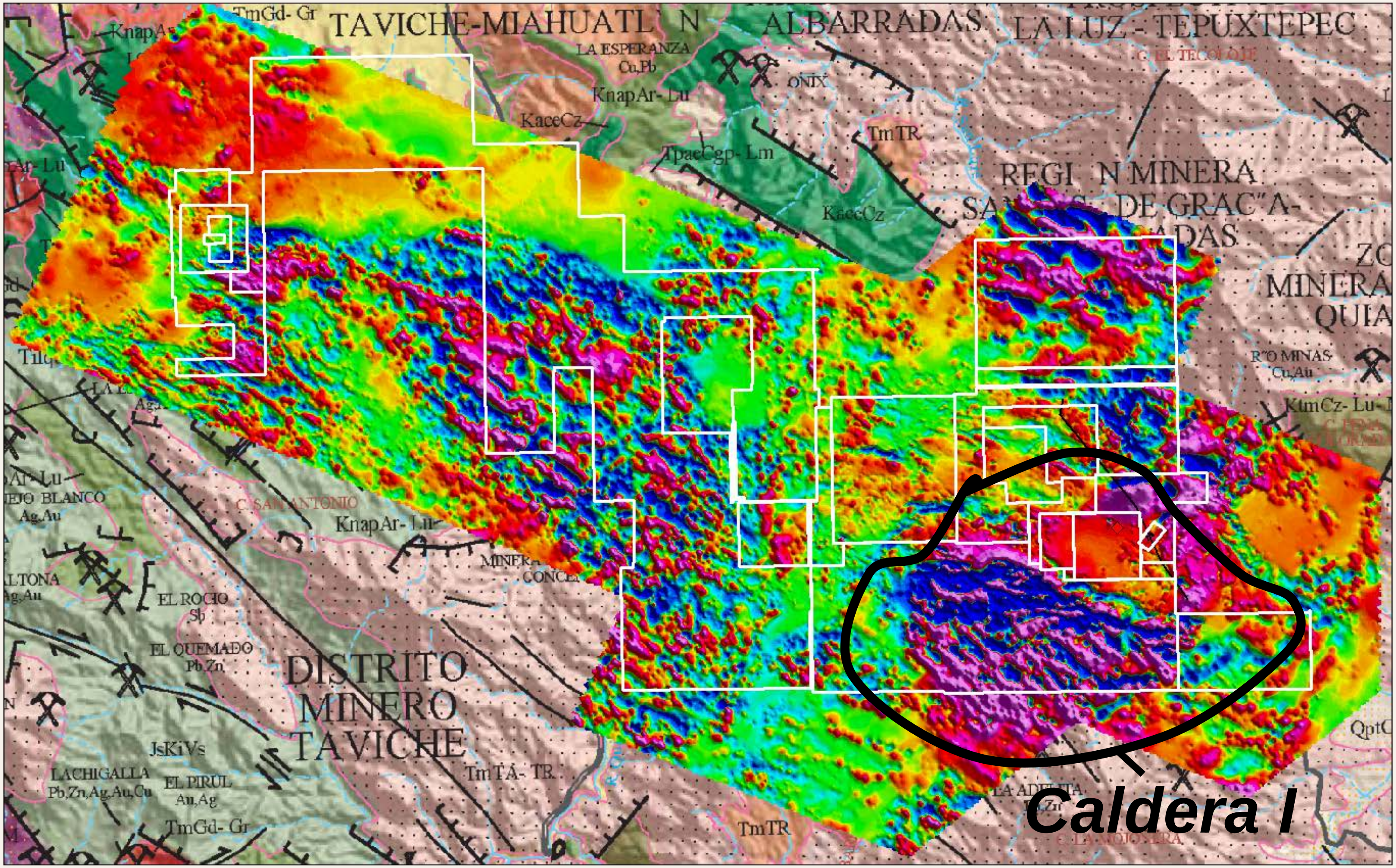
- Banded green pyroxene-sphalerite-galena-chalcopyrite

(Sphalerite Fluid Inclusions: 260 - 300° C; 6 - 16% wt% NaCl)

- Dolomitic limestone cut by calcite-talc-tremolite veins

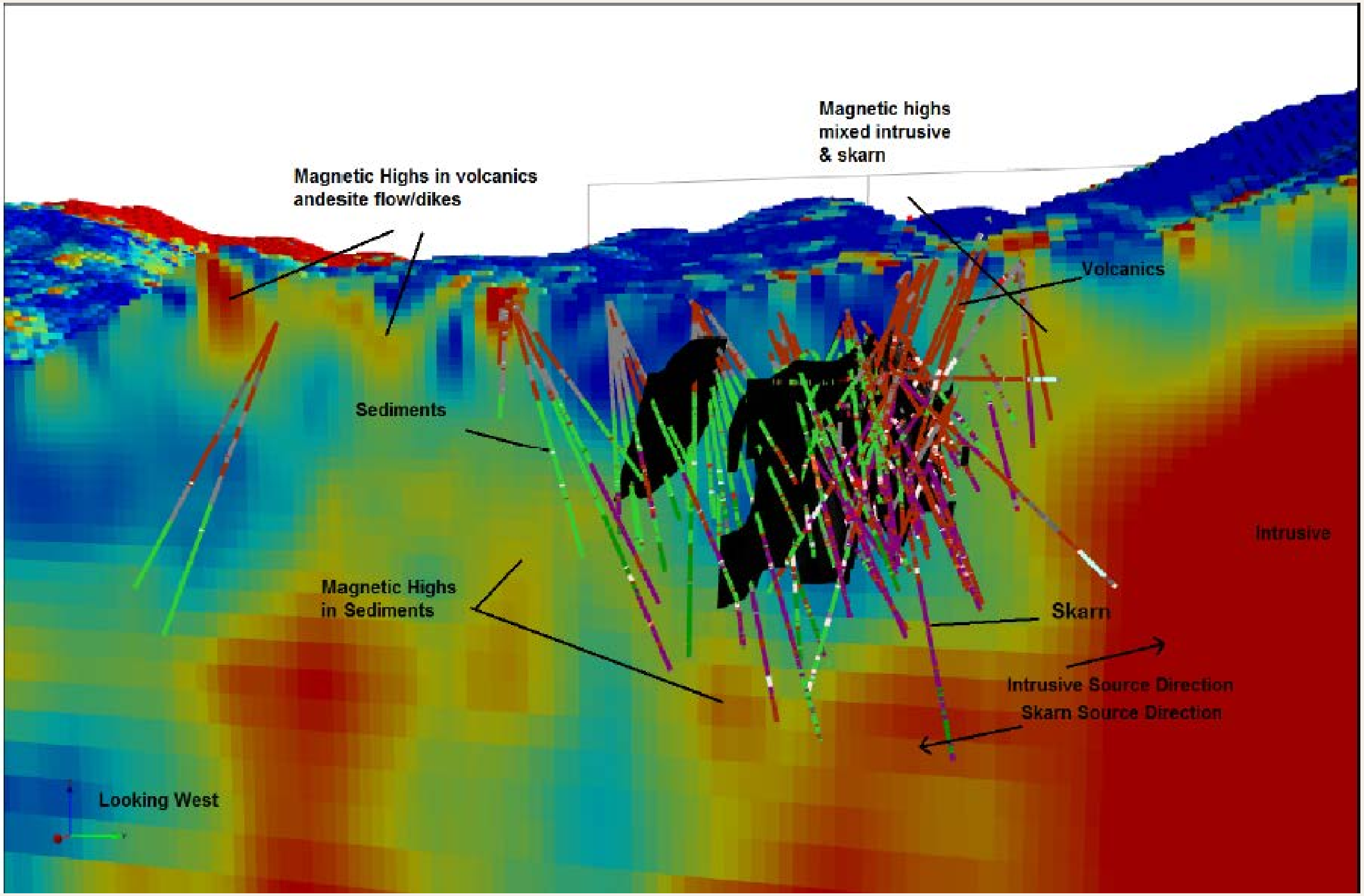
# Magnetics & Intrusives

**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**



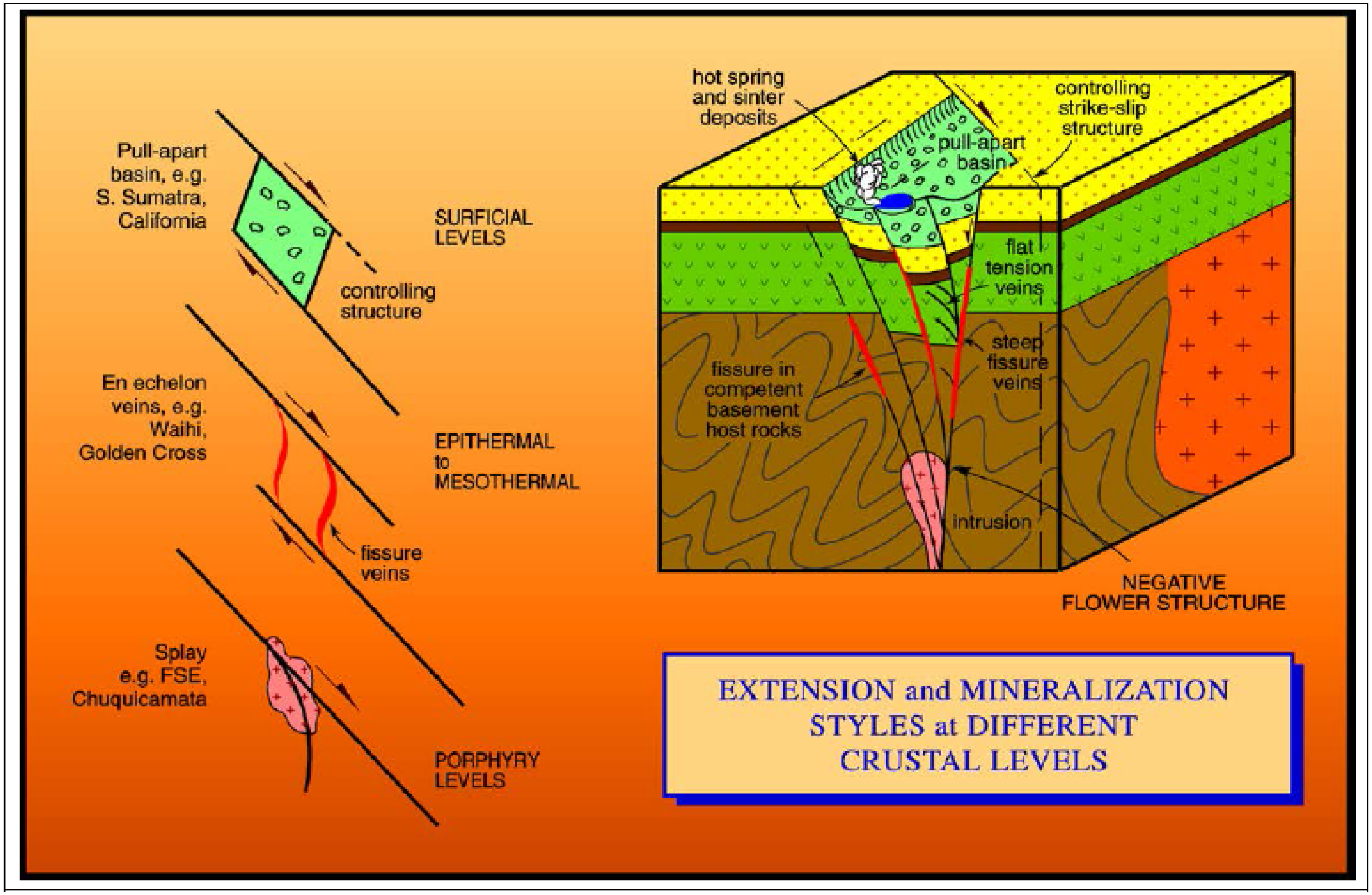
# 3D Magnetics & Geology

- 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)***

| MINE | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | TOTALS |
|---|---|---|---|---|---|---|---|
| **AGUILA (Gold Resource)** | 10,493 | 21,586 | 34,417 | 33,942 | 35,552 | 29,644 | **165,634** |
| **SAN JOSE (Fortuna Silver)** | | 4,524 | 17,918 | 19,031 | 33,496 | 38,526 | **113,495** |
| **TOTALS** | **10,493** | **26,110** | **52,335** | **52,973** | **69,048** | **68,170** | **279,129** |

***SILVER (oz)***

| MINE | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | TOTALS |
|---|---|---|---|---|---|---|---|
| **AGUILA (Gold Resource)** | 111,316 | 2,180,309 | 2,996,743 | 3,032,841 | 3,297,204 | 2,506,000 | **14,124,413** |
| **SAN JOSE (Fortuna Silver)** | | 478,167 | 1,949,178 | 2,527,203 | 4,396,760 | 4,928,893 | **14,280,201** |
| **TOTALS** | **111,316** | **2,658,476** | **4,945,921** | **5,560,044** | **7,693,964** | **7,434,893** | **28,404,614** |

- ***Increasing reserves at both operations indicate more years of production are ahead***