LARGE SCALE CENOZOIC EXTENSION IN SW NEW MEXICO AND THE TECTONIC SETTING OF A LARAMIDE PORPHYRY CU-AU SYSTEM IN THE MALONE AND TYRONE MINING DISTRICTS: A REGIONAL EXPLORATION SYNTHESIS

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Regions of extreme Cenozoic extension in the Cordillera of western North America are associated with multigenerational normal faults. These faults have significantly tilted and dismembered many Laramide and older porphyry Cu deposits, particularly in the Basin and Range of Nevada and Arizona.

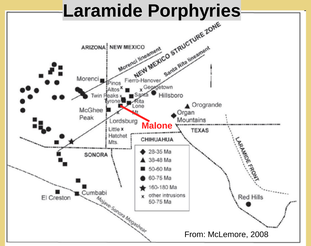
Southwest New Mexico from the San Vicente valley to the Arizona border is part of an unrecognized region of extreme extension superimposed upon broad Laramide uplift. Oligocene and older rocks are tilted generally NE at up to 75°; and Laramide porphyry deposits are tilted 20° to 35° NE in the Lordsburg district, up to 45° at Tyrone, and 50° to 75° in the Malone district

Porphyry-skarn systems NE of the San Vicente graben; including Chino, Pinos Altos, and the Hanover-Fierro district, are all relatively upright and undisturbed by extension. Pinos Altos rocks at the Lone Mountain deposit, just NE of the graben, are tilted NE - reflecting Laramide uplift - but Oligocene volcanic rocks are flat. At Malone, a basal Cenozoic conglomerate with veined and altered clasts dips up to 65° NE, and overlying volcanic and sedimentary rocks are unaltered. Below the unconformity, several km2 of Precambrian crystalline rocks have vein controlled quartz-sericite-pyrite cutting propylitic alteration. Sizable local zones have sheeted and stockwork quartz-pyrite veins with Au-Pb-Zn-Cu mineralization and pervasive, weak to moderate qtz-ser-py alteration. This is characteristic of the lateral margin of a porphyry Cu system, and is roughly similar to what is found within 0.5 km of open pits at nearby Tyrone. Malone outcrops may be the margin of a NE tilted, faulted porphyry system concealed at depth.

Multiple generations of SW down normal faults separate Malone from Tyrone, and include at least one major low angle fault. Cross-section reconstruction from Lordsburg NE through Malone, Tyrone, Lone Mountain, and Chino indicates that the Malone and Tyrone mineralization were once contiguous, and both appear related to the Tyrone stock, which is now tilted significantly to the NE.

The Malone-Tyrone system was enormous, comparable in size to Morenci or even Chuquicamata. Recognizing Cenozoic extension and understanding the effects on this system in SW New Mexico is critical for future exploration. This principle holds true throughout the Cordillera.

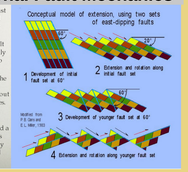
Southwest US Laramide Porphyries



From: McLemore, 2008

Southwest US Extensional Fault Mechanics

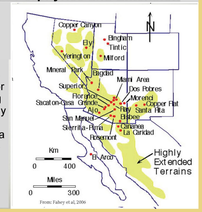
- Extension in the upper crust is accomodated by normal faults with 60 to 70 degree initial dips. (1)
- As the faults move, they till to shallower angles. Initially flat lying volcanics are also tilted. (2)
- The angle of the faults to the layered rocks remains roughly the same throughout extension – 60 to 70 degrees.
- At shallower angles, fault movement becomes more difficult due to friction, and a second generation of faults may begin. Again, typically with 60 to 70 degree initial dips. (3 and 4)



Southwest US - Porphyries and Extension

Mesozoic porphyry deposits and zones of post-mineral faulting (Oligocene-Micoene)

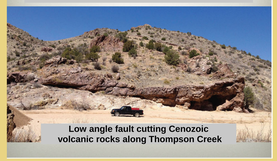
Deposits or districts known to have major post mineral faulting and tilting include Ely and Yerington in Nevada; Milford area in Utah; Ajo, Globe-Miami district, Ray, San Manuel and Sierrita-Pima in Arizona



Malone District - Structural Geology

Low angle fault cutting granite gneiss south of district

Malone District - Structural Geology



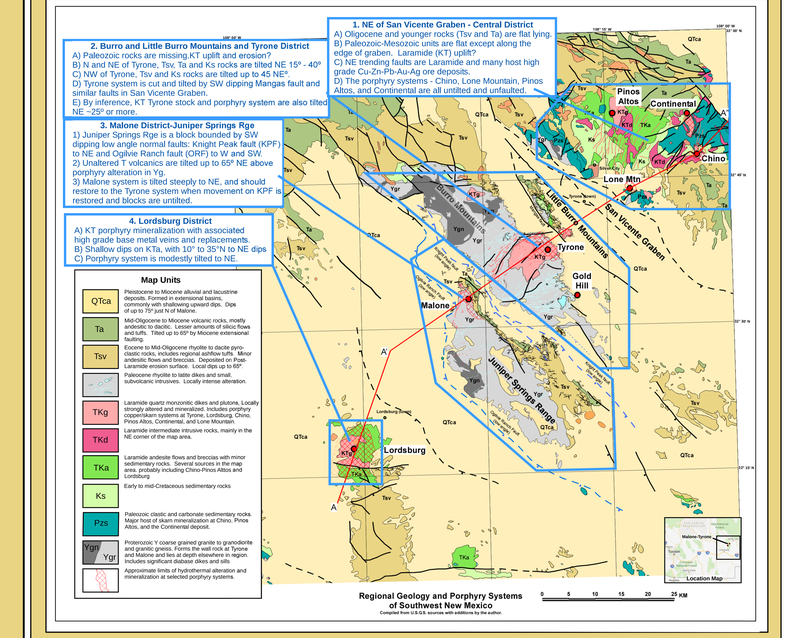
Low angle fault cutting Cenozoic volcanic rocks along Thompson Creek

1. NE of San Vicente Graben - Central District
A) Oligocene and younger rocks (Tsv and Ta) are flat lying
B) Paleozoic-Mesozoic units are flat except along the edge of graben. Laramide (KT) uplift?
C) NE trending faults are Laramide and many host high grade Cu-Zn-Pb-Au-Ag ore deposits.
D) The porphyry systems - Chino, Lone Mountain, Pinos Altos, and Continental are all untilted and unfaulted.

2. Burro and Little Burro Mountains and Tyrone District
A) Paleozoic rocks are missing,KT uplift and erosion?
B) N and NE of Tyrone, Tsv, Ta and Ks rocks are tilted NE 15° - 40°
C) NW of Tyrone, Tsv and Ks rocks are tilted up to 45 NE°.
D) Tyrone system is cut and tilted by SW dipping Mangas fault and similar faults in San Vicente Graben.
E) By inference, KT Tyrone stock and porphyry system are also tilted NE ~25° or more.

3. Malone District-Juniper Springs Rge
1) Juniper Springs Rge is a block bounded by SW dipping low angle normal faults: Knight Peak fault (KPF) to NE and Ogilvie Ranch fault (ORF) to W and SW.
2) Unaltered T volcanics are tilted up to 65º NE above porphyry alteration in Yg.
3) Malone system is tilted steeply to NE, and should restore to the Tyrone system when movement on KPF is restored and blocks are untilted.

4. Lordsburg District
A) KT porphyry mineralization with associated high grade base metal veins and replacements.
B) Shallow dips on KTa, with 10° to 35°N to NE dips
C) Porphyry system is modestly tilted to NE.



Map Units

- QTca — Pleistocene to Miocene alluvial and lacustrine deposits. Formed in extensional basins, commonly with shallowing upward dips. Dips of up to 75º just N of Malone.
- Ta — Mid-Oligocene to Miocene volcanic rocks, mostly andesitic to dacitic. Lesser amounts of silicic flows and tuffs. Tilted up to 65º by Miocene extensional faulting.
- Tsv — Eocene to Mid-Oligocene rhyolite to dacite pyroclastic rocks, includes regional ash/flow tuffs. Minor andesitic flows and breccias. Deposited on Post-Laramide erosion surface. Local dips up to 65º
- Paleocene rhyolite to latite dikes and small, subvolcanic intrusives. Locally intense alteration.
- TKg — Laramide quartz monzonitic dikes and plutons. Locally strongly altered and mineralized. Includes porphyry copper/skarn systems at Tyrone, Lordsburg, Chino, Pinos Altos, Continental, and Lone Mountain.
- TKd — Laramide intermediate intrusive rocks, mainly in the NE corner of the map area.
- TKa — Laramide andesite flows and breccias with minor sedimentary rocks. Several sources in the map area, probably including Chino-Pinos Altos and Lordsburg
- Ks — Early to mid-Cretaceous sedimentary rocks
- Pzs — Paleozoic clastic and carbonate sedimentary rocks. Major host of skarn mineralization at Chino, Pinos Altos, and the Continental deposit.
- Ygn / Ygr — Proterozoic Y coarse grained granite to granodiorite and granitic gneiss. Forms the wall rock at Tyrone and Malone and lies at depth elsewhere in region. Includes significant diabase dikes and sills.
- Approximate limits of hydrothermal alteration and mineralization at selected porphyry systems.

Regional Geology and Porphyry Systems of Southwest New Mexico
Compiled from U.S.G.S. sources with additions by the author.

0 5 10 15 20 25 KM

FAULTED PORPHYRY SYSTEMS

Recognition of the effects of major faulting in North American porphyry deposits goes back at least as far as the 1950's, and exploration successes have shown the value of paying close attention to regional Cenozoic structures superimposed on Laramide and older systems. David Lowell's spectacular discovery of the Kalamazoo deposit - a fault block offset from the tilted San Manuel system- was the first important fruit of these structural ideas. Work at the Yerington and Robinson districts in Nevada and Mission-Pima and Globe-Miami districts in Arizona has widened the scope of exploration areas affected by extreme extension, and has improved our understanding of the mechanics of normal faulting over the years.

However, there are still significant tracts of the Cordillera where exploration geologists have not recognized the effects of Cenozoic extension and the complications of multigenerational normal faults. The exploration implications of this are huge.

Southwest New Mexico has a major endowment of porphyry copper mineralization and a long mining history. However the existence of large areas with extreme Tertiary extension and multigenerational normal faults has not been well understood. The region from Lordsburg to Silver City has several well known porphyry systems, and the potential for fault offset mineralization is potentially very lucrative.