# Wulfenite in Arizona

## Arizona Mining & Mineral Museum

Arizona Mining and Mineral Museum
Dr. Jan C. Rasmussen, Curator Sept. 8, 2008

# Museum Mission

- To educate the people of Arizona about the aesthetic & practical value of minerals and mining in our daily lives,
- To maintain and develop an outstanding museum.


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# Wulfenite in Arizona

Mineralogy:

- Chemical & Physical Characteristics
- Mineralogical Associations

Geologic Setting:

- Alkali-calcic – lead-zinc-silver districts – best specimens
  - Laramide – 80 - 65 Ma - 15%
  - mid-Tertiary – 25-15 Ma – 30%
- Calc-alkalic – in outer Pb-Zn-Ag zones of Laramide porphyry copper deposits - 25%
- Quartz alkalic – in Pb-Zn-Ag zones
- Peraluminous


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# Wulfenite in Arizona

Glove mine, Santa Cruz Co.

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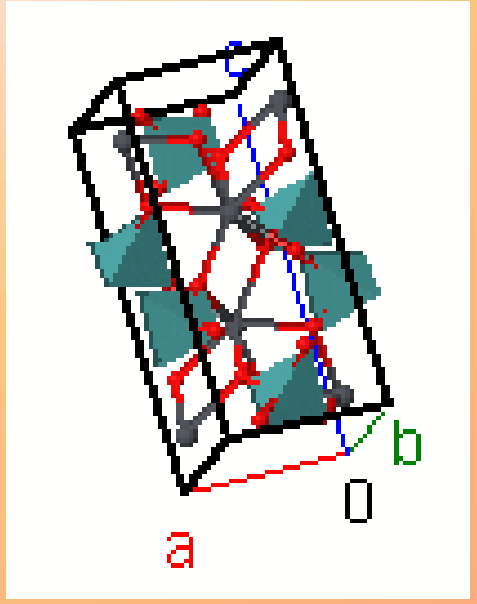
# Wulfenite Mineralogy

- Chemical Characteristics
  - $PbMoO_4$




Los Lamentos, Mexico
Donor: Verna Lichleitern

Common impurities:
W, Ca,V, As, Cr, W, Ti





# Wulfenite Mineralogy

- Physical Characteristics
  - tetragonal – tabular (flat square) crystals
  - H=2. 5-3
  - yellow, orange

Oujda, Toussit, Morocco
Donor: James Brown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# Mineralogical Associations

- cerussite $PbCO_3$
  - oxidation of galena
  - orthorhombic
  - H = 3-3.5
  - heavy, SG = 6.5
  - 60 degree twins
  - reticulated network
- mimetite, vanadinite, smithsonite, pyromorphite, limonite, anglesite, hemimorphite, fluorite
- not molybdenite

Cerussite, Tiger (Mammoth-St. Anthony mine)
On loan from AMMMF



# Mineralogical Associations

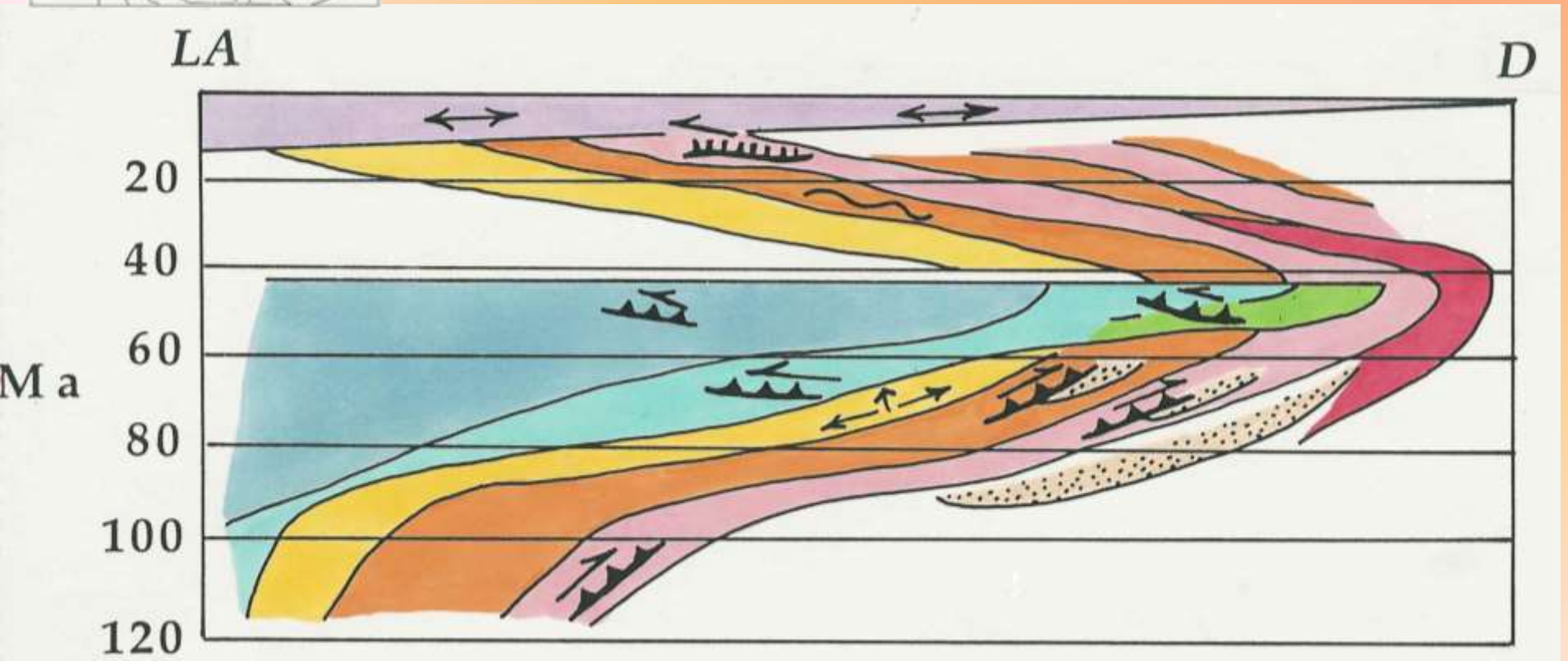
- vanadinite $Pb_5(VO_4)_3Cl$
  - hexagonal prisms
  - barrel shaped
  - Soft, H=2.75-3
  - Heavy, SG=6.8-7.1
  - No cleavage

Old Yuma mine, northern Tucson Mts., Pima County



# Time-Distance Diagram

Orange = alkali-calcic = Pb-Zn-Ag
Pink = quartz alkalic = Au, Cu, Pb-Zn
Yellow = calc-alkalic = Cu, Mo, Zn
Blue = peraluminous = Au, W





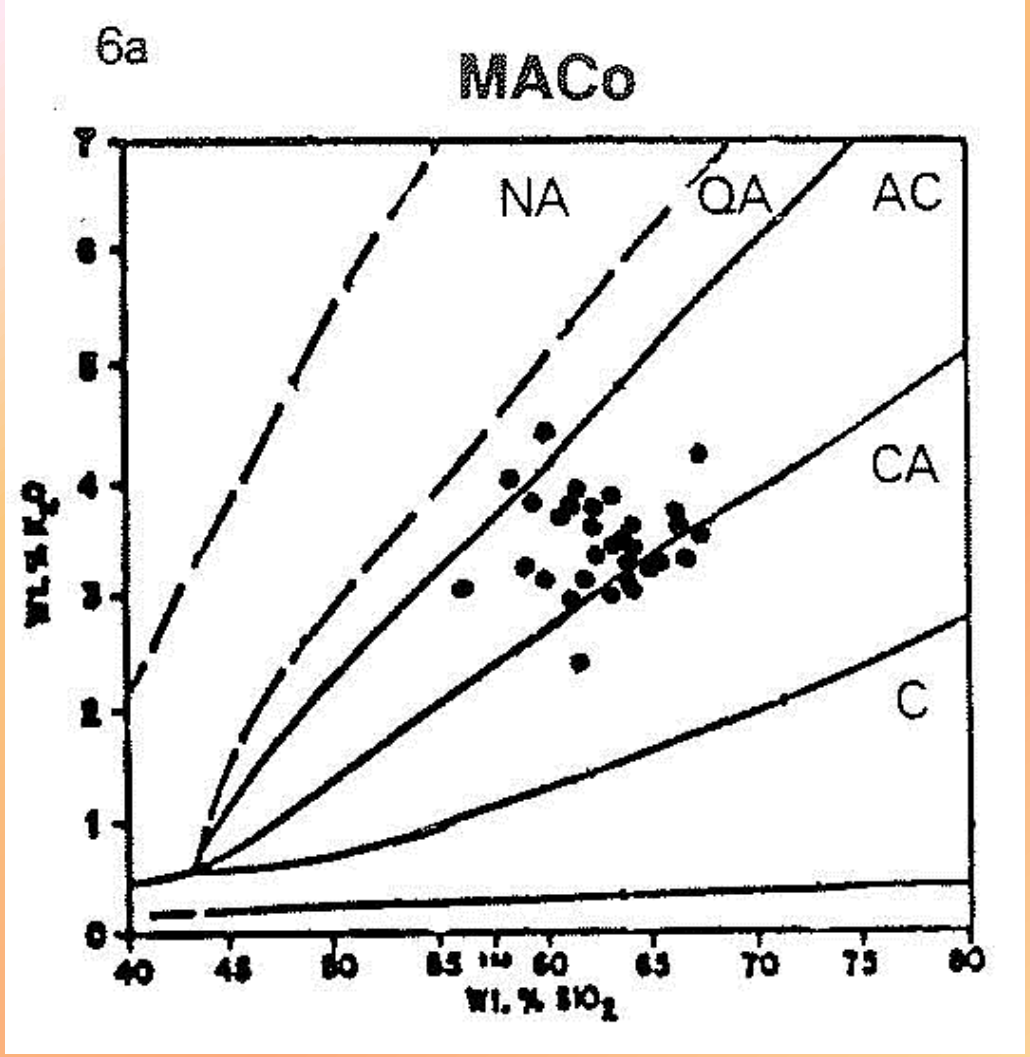

# Wulfenite Geologic Settings

- Alkali-calcic – lead-zinc-silver districts – best specimens
  - Laramide – 80 - 65 Ma - 15%
  - mid-Tertiary – 25-15 Ma – 30%
- Quartz alkalic – in Pb-Zn-Ag zones
  - Jurassic –
  - Laramide -
  - mid-Tertiary –
- Calc-alkalic – outer Pb-Zn-Ag zones of Laramide porphyry copper deposits - 25%
- Peraluminous
  - Precambrian
  - Jurassic





# Alkali-calcic Lead-Zinc-Silver




$\%K_2O$

Whole rock geochemistry of associated plutonic rock (granite or quartz monzonite)

$\%SiO_2$

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# Alkali-calcic Lead-Zinc-Silver

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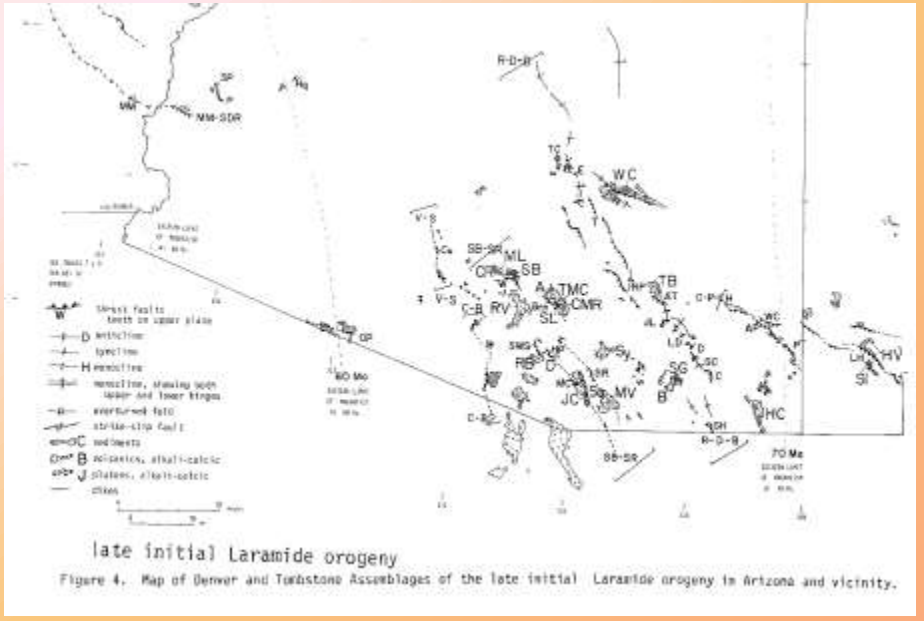
mid-Tertiary – 25-15 Ma – 30%





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# Alkali-calcic Lead-Zinc-Silver

- Laramide – 80 - 65 Ma - 15%
  - Glove mine – Santa Rita Mountains
  - Emerald-Silver Plume, Toughnut mines - Tombstone area
  - Silver Bill, Defiance, Mystery, Tom Scott mines – Turquoise district (Courtland-Gleeson area)
  - Total Wreck mine (Empire Mts.)





# Laramide Lead-Zinc-Silver - 15%

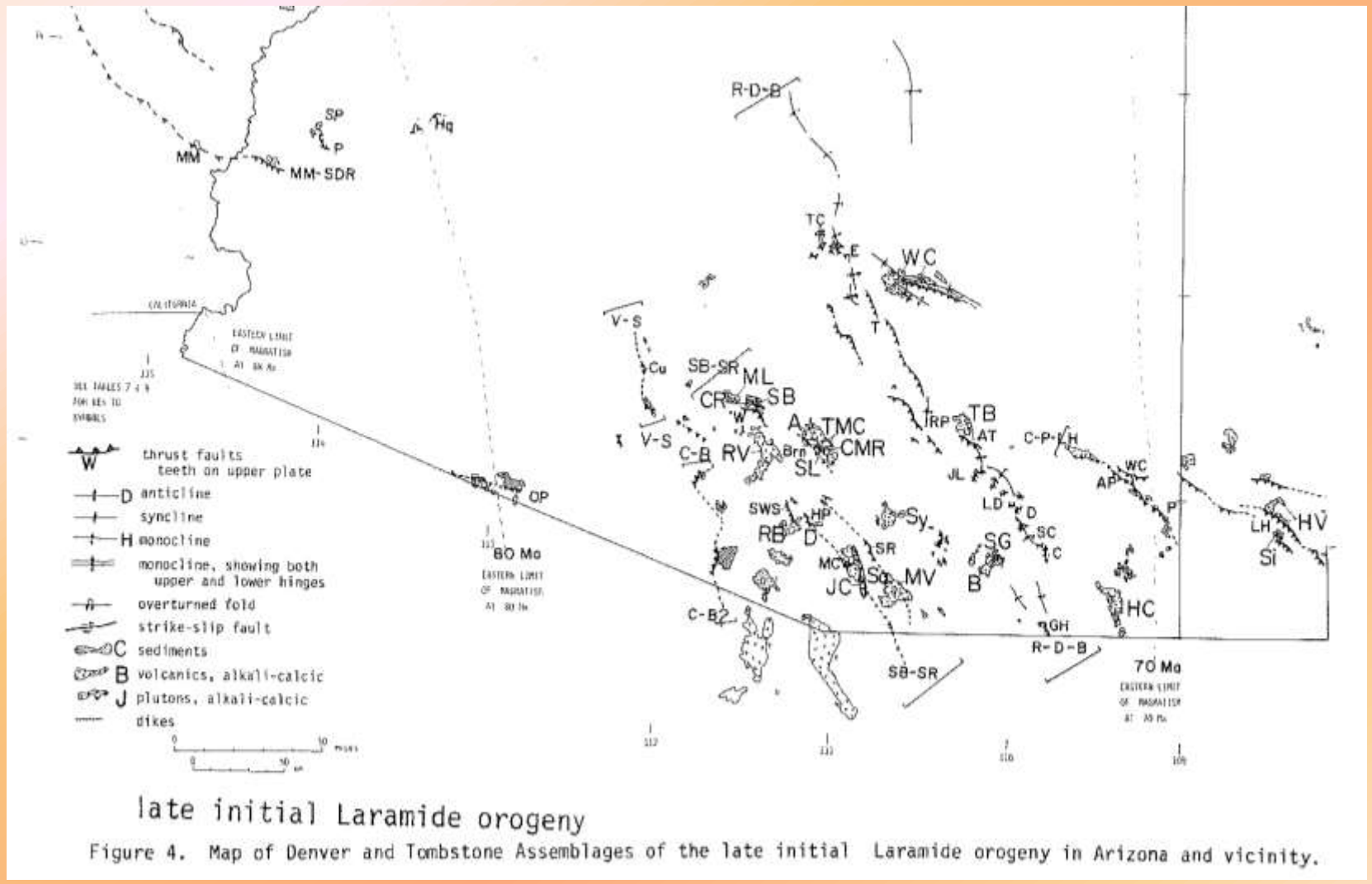


Figure 4. Map of Denver and Tombstone Assemblages of the late initial Laramide orogeny in Arizona and vicinity.

From Keith & Wilt, 1985, AGS digest

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# Glove mine, Santa Rita Mts.

- Alkali-calcic, Lead-Zinc-Silver, Laramide
- Donor Mark Hay
- Argentiferous galena, sphalerite, small amounts of pyrite, chalcopyrite & quartz
- Deposited in permeable zones at the intersection of a bedding plane fault and favorable beds in Permian Naco Limestone
- Extensive solution of the limestone and deep oxidation concentrated cerussite, anglesite, wulfenite, & smithhsonite in the leached caverns as sand carbonate ore
- Shaft & adit operations
- Worked various times 1911-1972
- Produced 29,260 tons of ore averaging about 22% Pb, 9% Zn, 7 oz Ag/T, 0.3% Cu, minor Au

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# Glove mine, Santa Rita Mts.

Donor: Mark Hay

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# Glove mine, Santa Rita Mts.

- Alkali-calcic - Laramide
- Lead-Zinc-Silver

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# Glove mine, Santa Rita Mts.

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# Toughnut mine, Tombstone district

- Alkali-calcic Laramide
- Lead-Zinc-Silver
- Oxidized, base metal sulfides in replacement orebodies in lower Cretaceous Bisbee Group along anticlinal rolls and in pipes where rolls are cut by faults
- donor: John Weber
- in NE fissures
- Shaft workings
- Several thousand tons produced in late 1800s and early 1900s



# Silver Bill mine,

## Turquoise district (Courtland-Gleeson)

- Alkali-calcic, Laramide
- Lead-Zinc-Silver
- Irregular small stringers, pockets, and replacement bodies of oxidized base metal sulfides in Pennsylvanian-Permian Naco Group Limestones adjacent to a quartz monzonite porphyry contact
- Shaft workings connected to the Mystery mine.
- Large tonnage mined during late 1800s; 6570 tons produced during 1922-30, 1938-41

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# Defiance mine, Turquoise dist.

- Alkali-calcic Laramide
- Lead-Zinc-Silver
-

Donor: Lorraine Kilpatrick

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# Defiance mine, Turquoise dist.

- Alkali-calcic, Laramide, Pb-Zn-Ag
- Cerussite, anglesite, malachite, smithsonite, cerargyrite, and pyrolusite
- Large amounts of magnificent wulfenite specimens lining solution cavities and in oxidized lead, manganese, and iron deposits
- Orebodies are in Pennsylvanian-Permian Naco Group limestones where fractures intersect or change dip or are parallel to bedding
- Aplite dikes are related to Sugarloaf Quartz Latite Porphyry of Cretaceous (75 Ma) age or Jurassic?

Donor: Les Presmyk

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# Total Wreck mine, Empire Mts.

- Alkali-calcic Laramide
- Lead-Zinc-Silver
- Cerussite, wulfenite, vanadinite, cerargyrite, malachite, azurite, chrysocolla & minor Copper & Lead sulfides
- in irregular replacement orebodies in badly faulted Permian limestone beds intruded by Laramide diorite stringers & dikes
- Shafts & tunnels
- Worked from 1880s to 1940, producing some 14,000 tons of ore averaging 8% Pb, 6 oz Ag/T, & minor Au & Cu
- shipped 8 tons of Mo concentrates in 1918.



# Mid-Tertiary Pb-Zn-Ag – 30 %

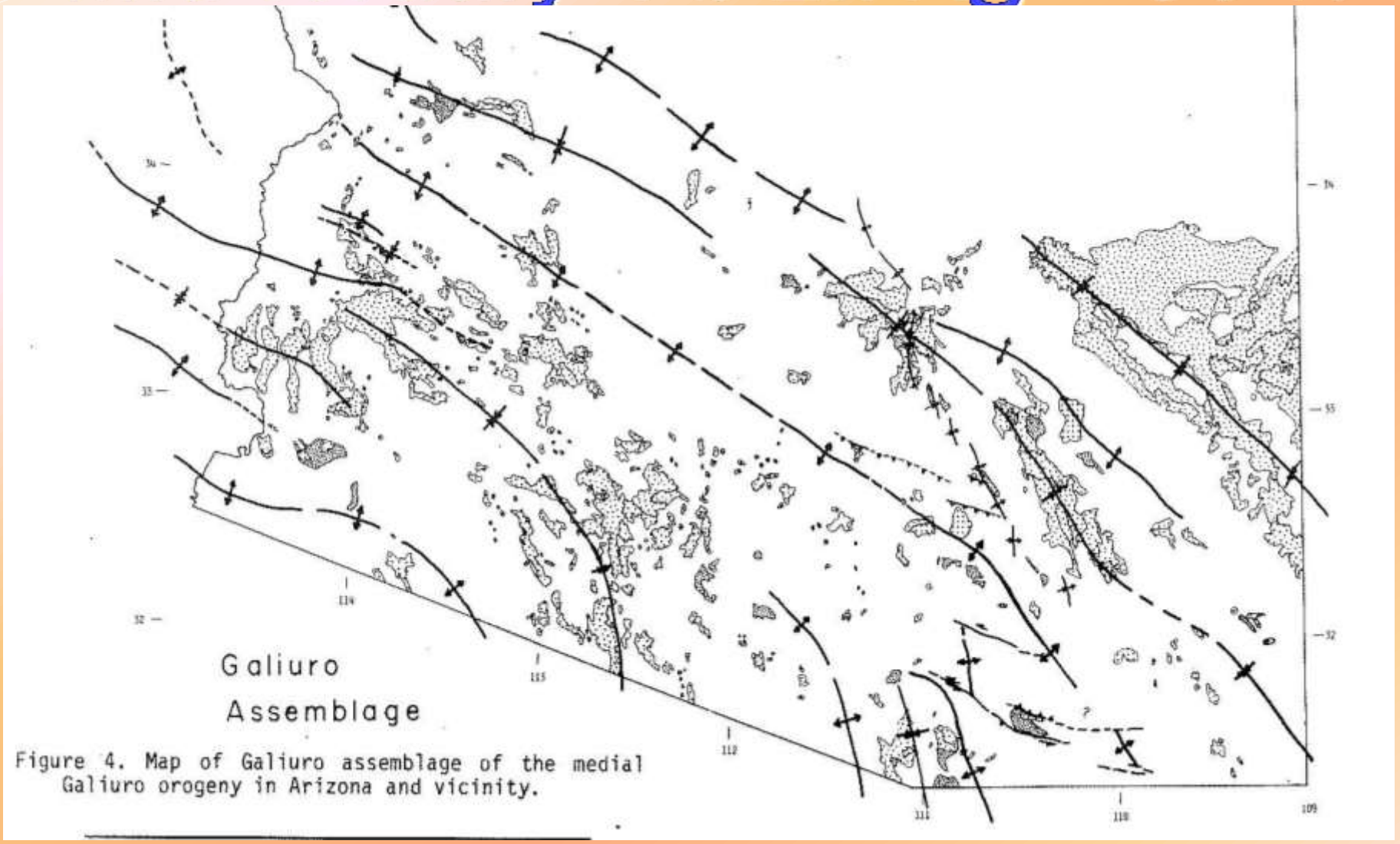


Figure 4. Map of Galiuro assemblage of the medial Galiuro orogeny in Arizona and vicinity.

From Keith & Wilt, 1986, SEPM Tertiary Rocky Mountains

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# Mid-Tertiary Lead-Zinc-Silver

- Alkali-calcic - mid-Tertiary – 25-15 Ma – 30%
  - Red Cloud mine
  - Tiger (Mammoth-St. Anthony mine)
  - Rowley mine
  - Aravaipa district
  - Hilltop mine, Chiricahua Mts.





# Red Cloud Mine

- Alkali-calcic, mid-Tertiary
- 25-15 Ma, Yuma Co.
- Irregular masses and vug linings of argentiferous lead and zinc carbonates with pyrolusite, vanadinite, wulfenite & minor malachite, nodules of partly altered argentiferous galena, & disseminated masses of silver chloride & bromide in a gangue of iron oxides, quartz, fluorite, calcite, gouge & brecciated wall rock
- Vein occurs in an irregular fault zone between Tertiary andesite breccia, dacite porphyry, rhyolite to dacitic tuffs & lapilli tuffs & Laramide granodiorite to quartz diorite intrusive
- Average grade 5-6% Pb, 10 oz Ag/T
- Shaft operations, 1880s
- total est. prod 21,000 tons ore ave. 18 oz Ag/T and 5.5% Pb and minor Au

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# Red Cloud Mine


Donor: Les & Paula Presmyk

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# Red Cloud Mine

Donor: Les & Paula Presmyk

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# N. Geronimo mine

- vanadinite
- Silver dist.
- La Paz Co.

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# Los Lamentos, Chihuahua, Mexico

Alkali-calcic

midTertiary

Pb-Zn-Ag

Donor: Verna Lichleitner in memory of Charlie Thornton

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# Hilltop mine, Chiricahua Mts.

- Alkali-calcic
- Pb-Zn
- mid-Tertiary
- Galena, cerussite, sphalerite, wulfenite, & spotty copper oxides and scheelite in fissure veins and in irregular replacement lenses and bodies in banded and tilted, silicified Mississippian to Permian limestones and quartzites
- Extensive workings from several tunnels
- Total of 30,000 tons ob base metal sulfide ore prodeced intermittently from early 1910s to 1954


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# Wulfenite - Quartz Alkalic

- Quartz alkalic – Pb-Zn-Ag zones – mid-Tertiary MQA 42 model
  - Mammoth-St. Anthony mine (Tiger townsite)
  - Rowley mine (Painted Rock district, Maricopa Co.)
- Quartz alkalic – Pb-Zn-Ag zones – Laramide MQA 42 model
  - Old Yuma mine – N. Tucson Mts.
- Quartz alkalic – Pb-Zn-Ag zones – Jurassic MQA 45 model
  - Bisbee – Campbell orebody – minor occurrence





# Mammoth-St. Anthony mine (Tiger)

- Quartz Alkalic – MQA 42
- mid-Tertiary

Donor: Leaverites

On loan from AMMMF (Flagg)

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# Mammoth-St. Anthony mine (Tiger)

- Wulfenite, vanadinite, gold in quartz, galena, sphalerite, anglesite, cerussite, and many oxidized minerals
- In west-northwest shear zones intruded by mid-Tertiary (22 Ma) rhyolite, with widest fissure veins occurring in quartz monzonite (Precambrian) most intensely shattered and brecciated
- Deposit was oxidized and faulted, thin wulfenite and vanadinite were deposited with later oxidation
- 6,314,822 pounds $MoO_3$ produced 1881-1947.


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# Mammoth-St. Anthony mine (Tiger)

On loan from AMMMF (Flagg)

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# Mammoth-St. Anthony mine (Tiger)

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# Rowley mine

- Quartz Alkalic - mid-Tertiary – 25-15 Ma – MQA 42

Donor: Floyd & Alice Getsinger

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# Rowley mine

- Barite, wulfenite, cerussite, base-metal sulfides, with secondary minerals of cerussite-anglesite suite, wulfenite suite, caledonite suite, and vanadinite suite.
- In northwest fissure veins in mid-Tertiary andesite and rhyolite flose and dikes
- Shipped 130 tons of wulfenite concentrate to California (18.26 % $MoO_3$),

Wulfenite and mimetite



# Rowley mine

Donor: James Horner

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# Old Yuma mine, Tucson Mts.

- Quartz Alkalic Laramide
- Au, Pb, Zn
  - Partly oxidized base metal sulfides with spotty wulfenite & vanadinte, quartz & calcite gangue
  - Steeply dipping, lensing & faulted orebody along a fracture zone cutting Cretaceous & assoc w/ Laramide porphyry intrusive (Amole Granite)
  - Shaft & underground workings
  - Produced 1916-1947, total 5700 tons ore 4% Pb, 1% Cu, 0.6% Zn, .3% Mo, 1 oz/Ag/T, 0.1 oz Au/T

vanadinite

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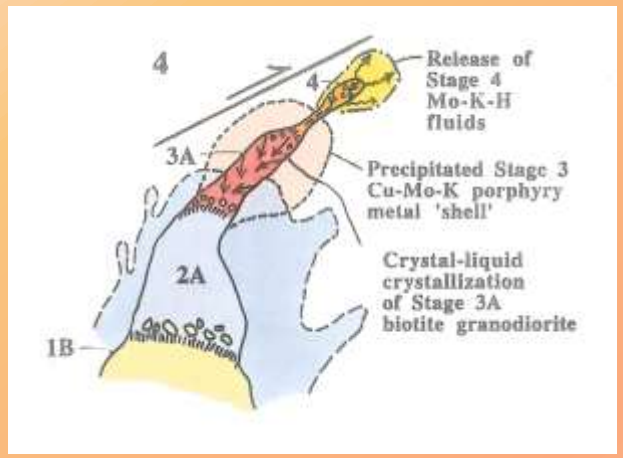
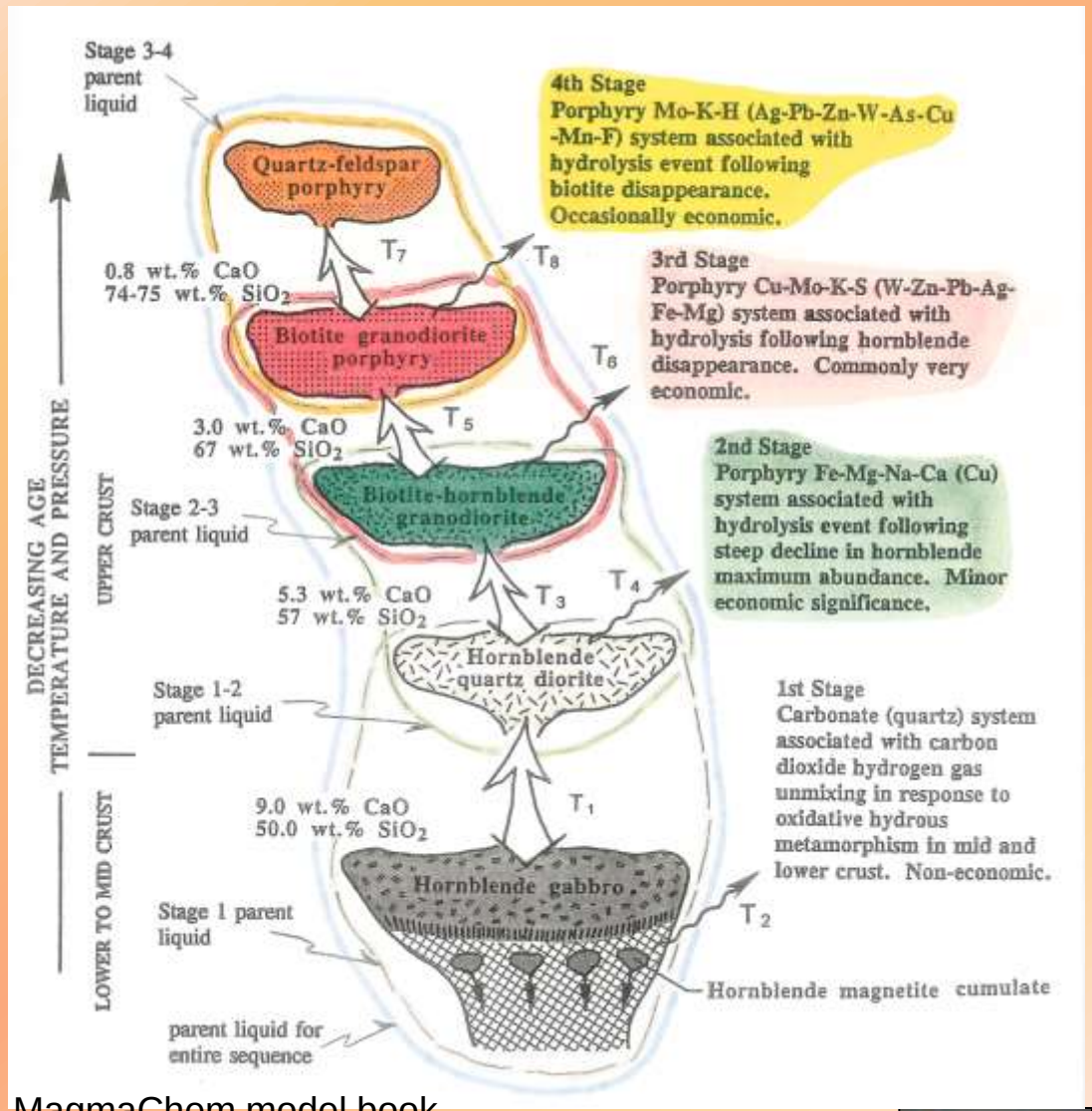
# Calc-alkalic – outer Pb-Zn zones

- Porphyry Copper deposits
  - Chilito, Christmas mine
  - 79 mine
  - Finch mine (S of 79 mine)
  - Grayhorse (Ray area)
  - Silver Bell
  - Twin Buttes
  - Mineral Park




From Keith, 2003, MagmaChem model book

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# Outer Pb-Zn zones of Porphyry Copper deposits

- Chilito mine
- Christmas mine
- 79 mine

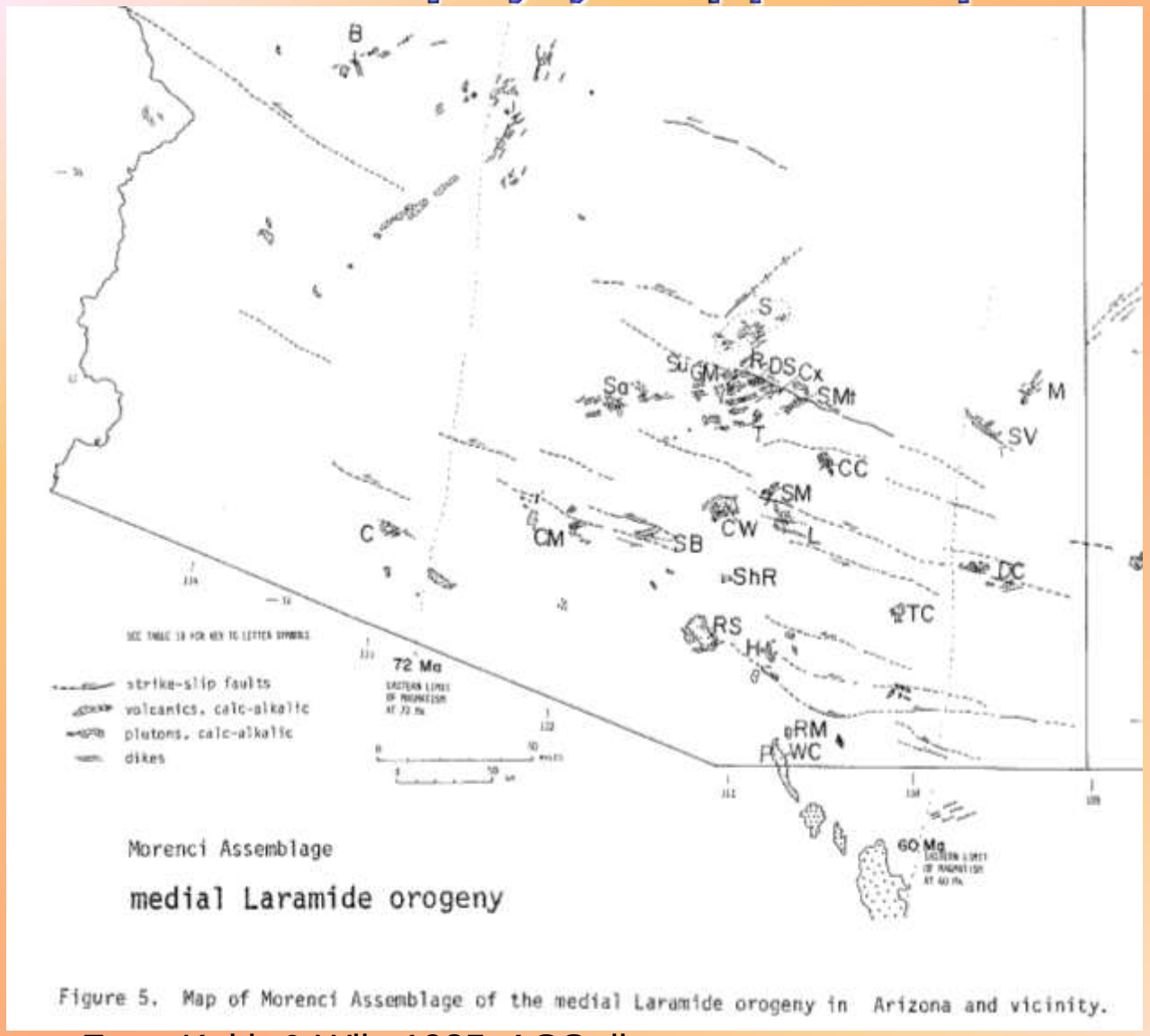


Figure 5. Map of Morenci Assemblage of the medial Laramide orogeny in Arizona and vicinity.

From Keith & Wilt, 1985, AGS digest



# 79 mine (Banner district)

- Galena, sphalerite, pyrite, cerussite, with a large variety of secondary minerals
- In permeable zones such as breccias, fractures, and shear zones
- Especially as bedded and vein replacements, in favorable rock types, such as contact metamrophosed Pennsylvanian Naco limestone and silicified rhyolite porphyry dikes of probable Tertiary 62 Ma) age



# 79 mine

Photo from John Callahan

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# Finch mine (Banner district)

- Galena, anglesite, cerussite, with vanadinite, descloizite, and copper carbonates
- In east-northeast striking fissure veins that juxtapose Willimason Canyon volcanics with Pennsylvanian Horquilla Formation
- 3 lots less than 1 ton of Molybdenum-vanadium concentrates produced in 1934


Donor Robert & Catherine Sanders


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# Superior mine

- Most specimens from the lead-zinc fringes of porphyry copper districts are not spectacular specimens

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# Peraluminous Wulfenite

- Jurassic
  - Mildren mine, Cababi district
  - San Francisco mine, Mexico
  - Kofa Mts. veins
- Precambrian
  - Maricopa mine, Cave Creek area, Maricopa Co.
  - Prince of Arizona mine, Hieroglyphic Mts.
  - White Picacho district, PCA
  - Red Picacho district (Purple Passion mine)

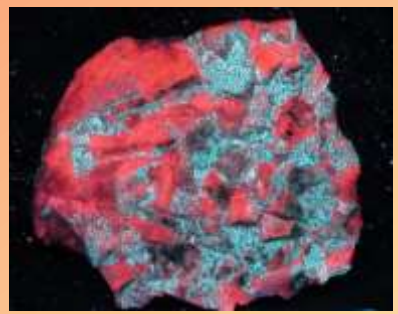
San Francisco Mine, Sonora, Mexico, donor Ed Davis



# Purple Passion Mine, Maricopa Co.

## Precambrian

- **Red Picacho district (Purple Passion mine)**
- Blades and unusual needle crystals. Some needles of wulfenite grow on the surfaces of wulfenite blades.
- 3 and 4 colored fluorescent material
- Wulfenite occurs on quartz (clear, smoky, milky and amethyst) and on fluorite, calcite or galena.
- Other associations include anglesite, cerussite, sulfur, chlorargyrite, smithsonite and willemite.
- Some specimens of calcite, fluorite, wulfenite and willemite strongly fluorescent.

Photos courtesy of William Gardmer





# Mineral Association

- Never molybdenite
- Always cerussite
- Sometimes:
  - mimetite
  - vanadinite

molybdenite

galena

mimetite

vanadinite

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  - Jurassic
  - Mid-Tertiary
- Calc-alkalic – outer Pb-Zn-Ag zones of Laramide porphyry copper deposits - 25%
- Peraluminous
  - Precambrian
  - Jurassic
  - Laramide





# Gift Shop Supports Museum

- Profits from gift shop supply Tour Guide salaries and other expenses
- State only supplies one salary and rent
- All other museum expenses paid by donations

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# Arizona Mining & Mineral Museum

- 1502 W. Washington (NW corner Washington & 15th Ave.)
- Phoenix, Arizona - M-F 8-5, Sat. 11-4
- 25,000 school children and 20,000 visitors annually


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