Geologic Settings of Wulfenite in Arizona

Jan C. Rasmussen, Curator

Arizona Mining & Mineral Museum

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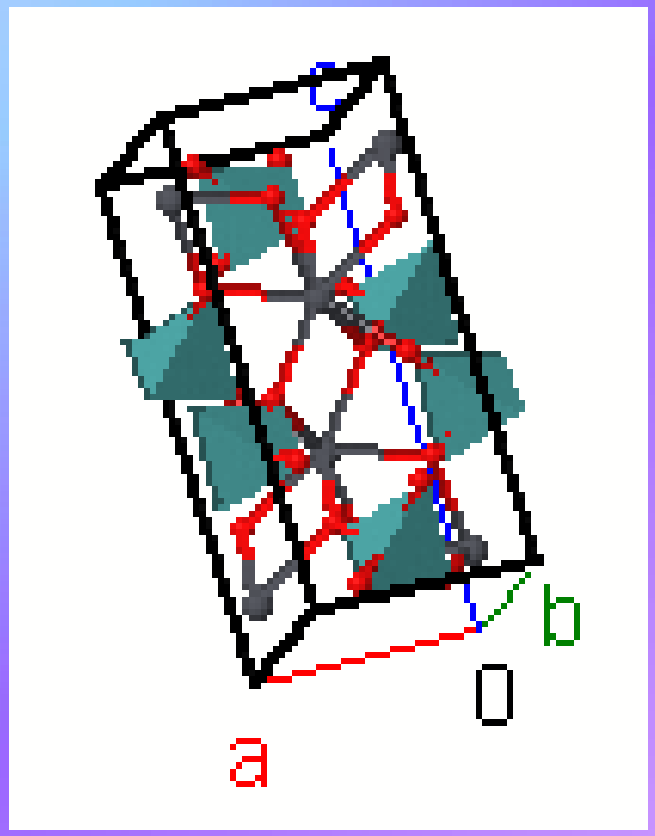
Wulfenite Mineralogy

- $PbMoO_4$



Los Lamentos, Mexico
Donor: Verna Lichleitner

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



Wulfenite Mineralogy

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

Toussit, Morocco
Donor: James Brown

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Geologic Settings, Arizona Wulfenite

Metaluminous:

- Alkali-calcic – lead-zinc-silver districts – best specimens
  - Laramide – 80 - 65 Ma - 15%
  - mid-Tertiary – 25-15 Ma – 30%
- Quartz alkalic – gold-base metal
  - Jurassic – 180-160 Ma
  - Laramide – 75-70 Ma
  - mid-Tertiary – 28-22 Ma
- Calc-alkalic – Stage 4 zones porphyry copper
  - Laramide - 75-60 Ma

Peraluminous

- Calcic (Au) - Precambrian, Jurassic, Late Laramide
- Calc-alkalic (W) – Precambrian, Jurassic, Late Laramide

Glove mine

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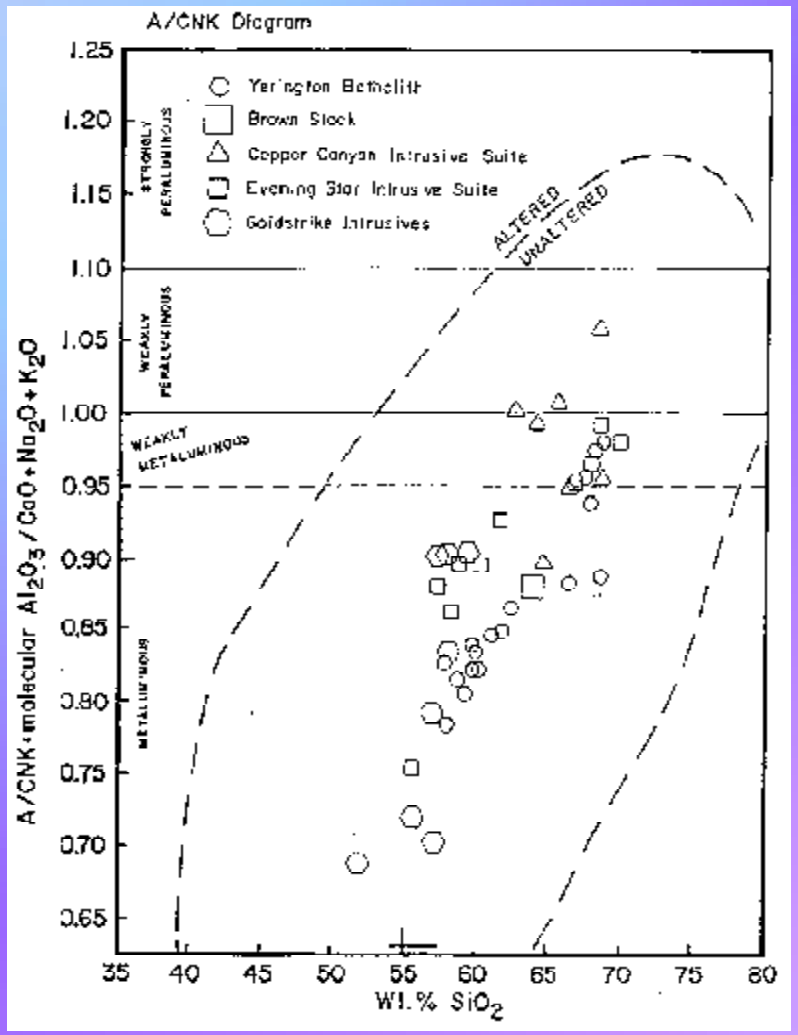
Al/Ca,Na,K content of assoc. igneous rocks

Metaluminous



Peraluminous

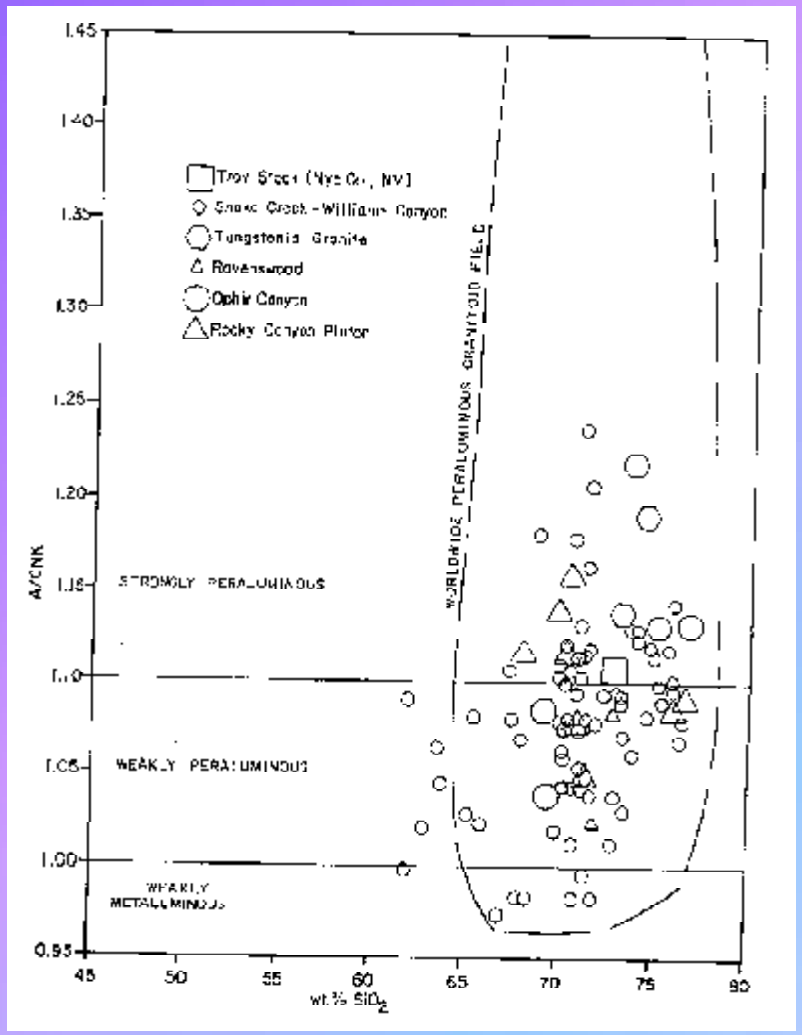


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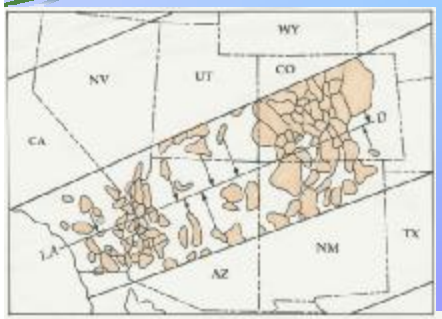
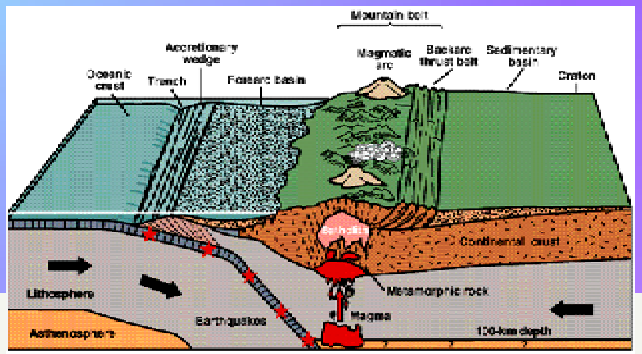
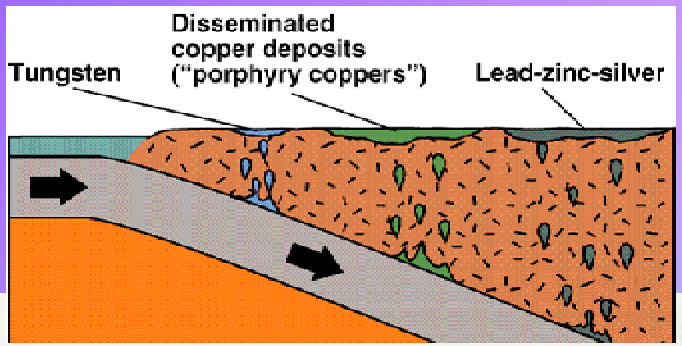
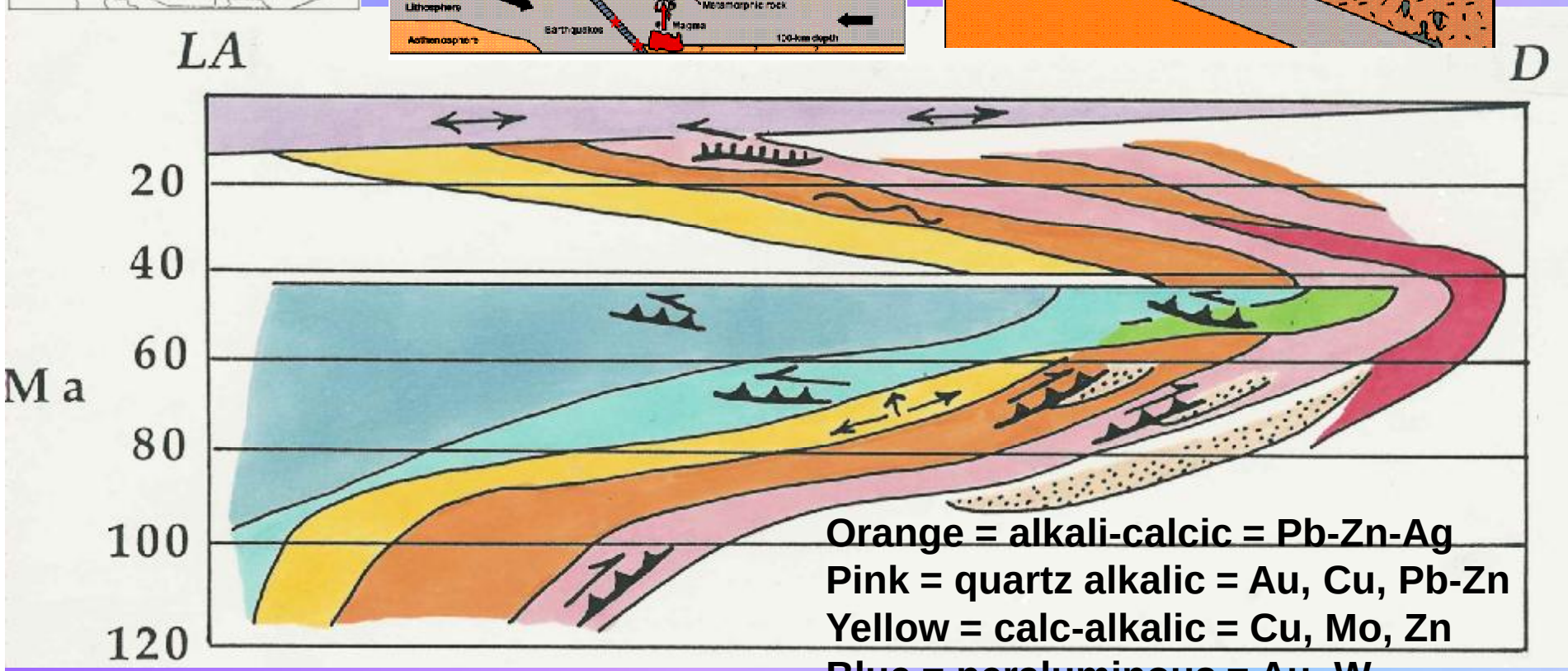
Plate Tectonics – slab flattening









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

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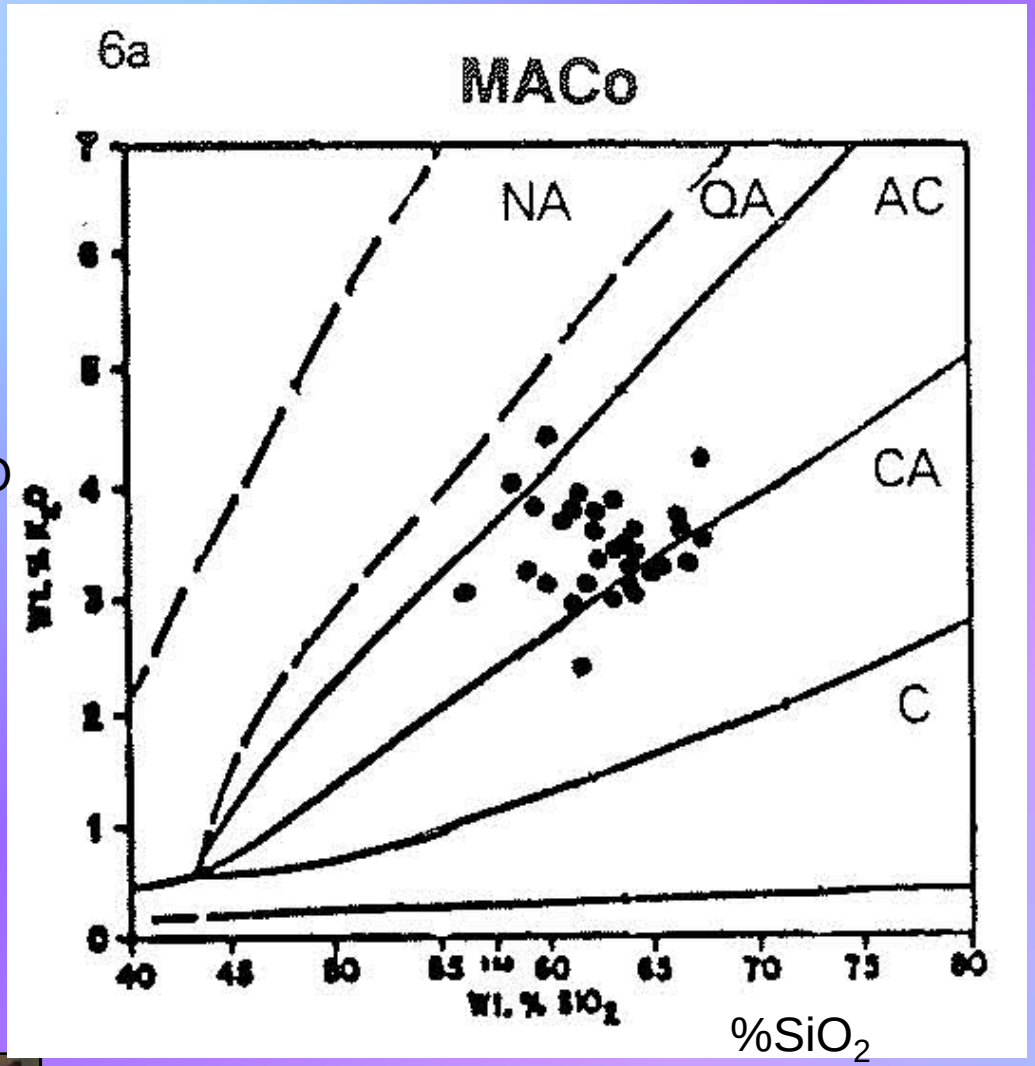
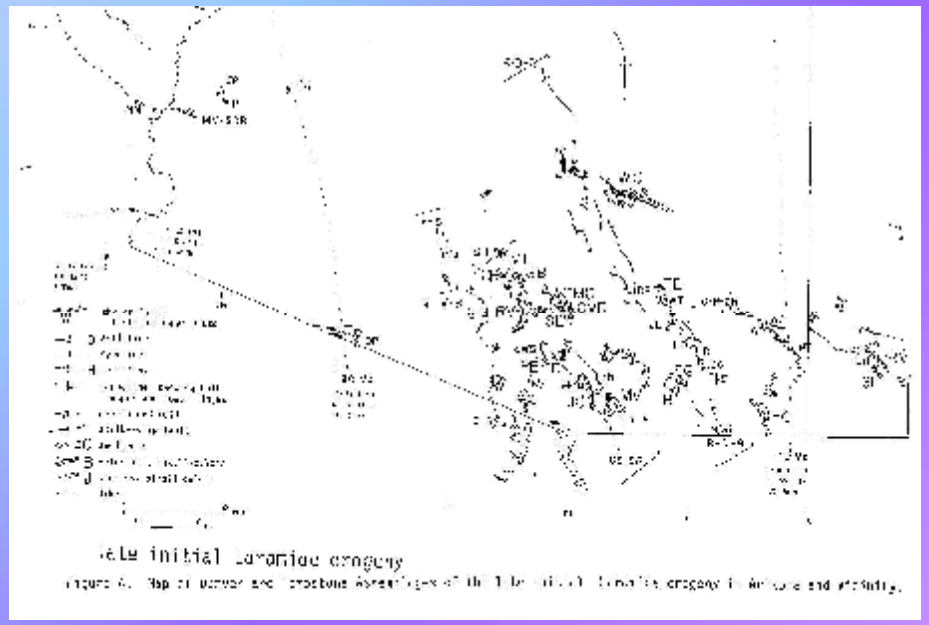
Alkali-calcic Lead-Zinc-Silver



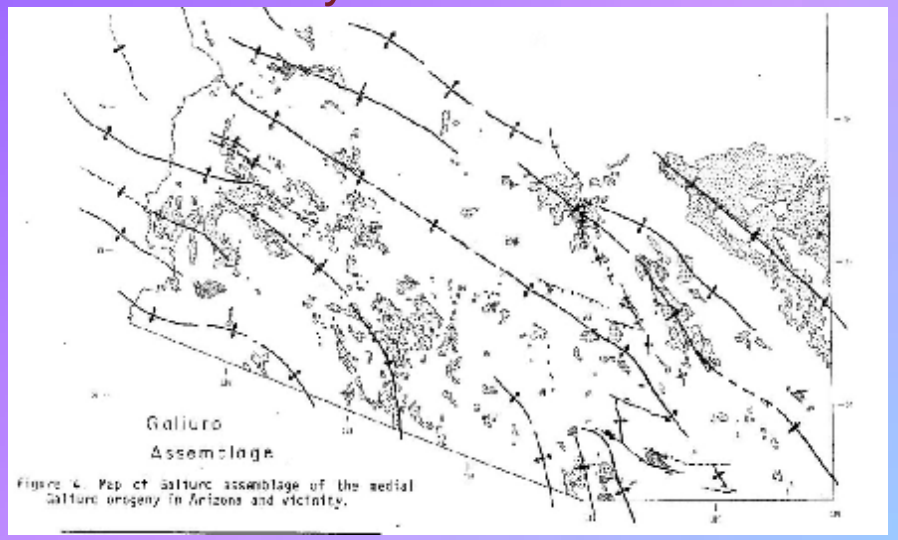
Whole rock geochemistry of associated plutonic rock (usually granite, quartz monzonite, or granodiorite)

Alkali-calcic Lead-Zinc-Silver

- Laramide – 80 - 65 Ma - 15%



mid-Tertiary – 25-15 Ma – 30%



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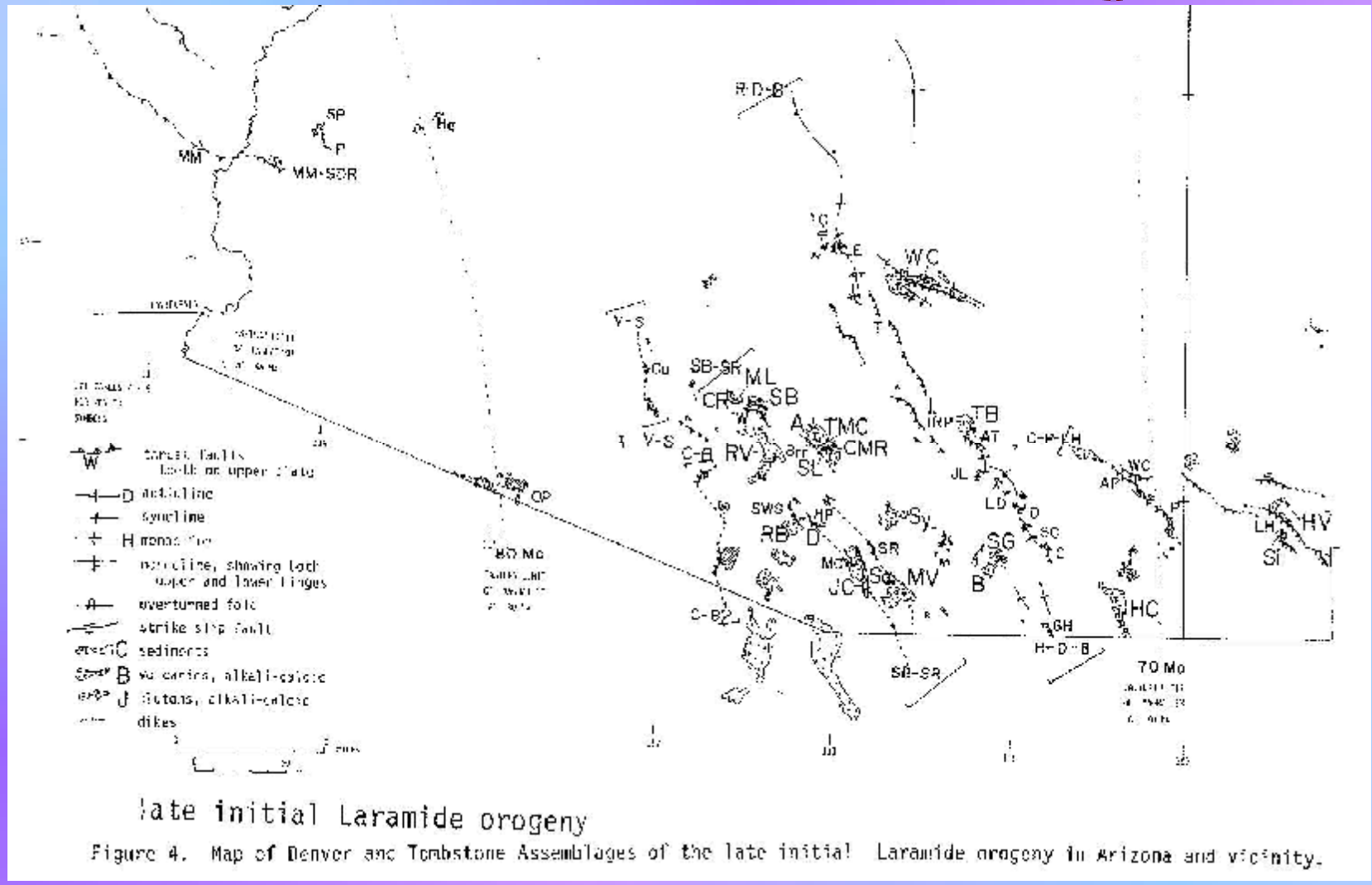
Laramide Alkali-calcic Pb-Zn-Ag

- Laramide – 80 - 65 Ma - 15% of wulfenite localities
  - 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 MAC - Pb-Zn-Ag - 15%



late initial Laramide orogeny

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.

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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 of Ag ore produced in late 1800s and early 1900s

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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: Les Presmyk

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Defiance mine, Turquoise dist.

- Alkali-calcic, Laramide, Pb-Zn-Ag
- Cerussite, anglesite, malachite, smithsonite, cerargyrite, and pyrolusite
- Large amounts of 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

Donor: Lorraine Kilpatrick

–Aplite dikes are probably related to Sugarloaf Quartz Latite Porphyry of Cretaceous (75 Ma) age

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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.

Photo from mindat.org

Mid-Tertiary MAC Pb-Zn-Ag – 30 %

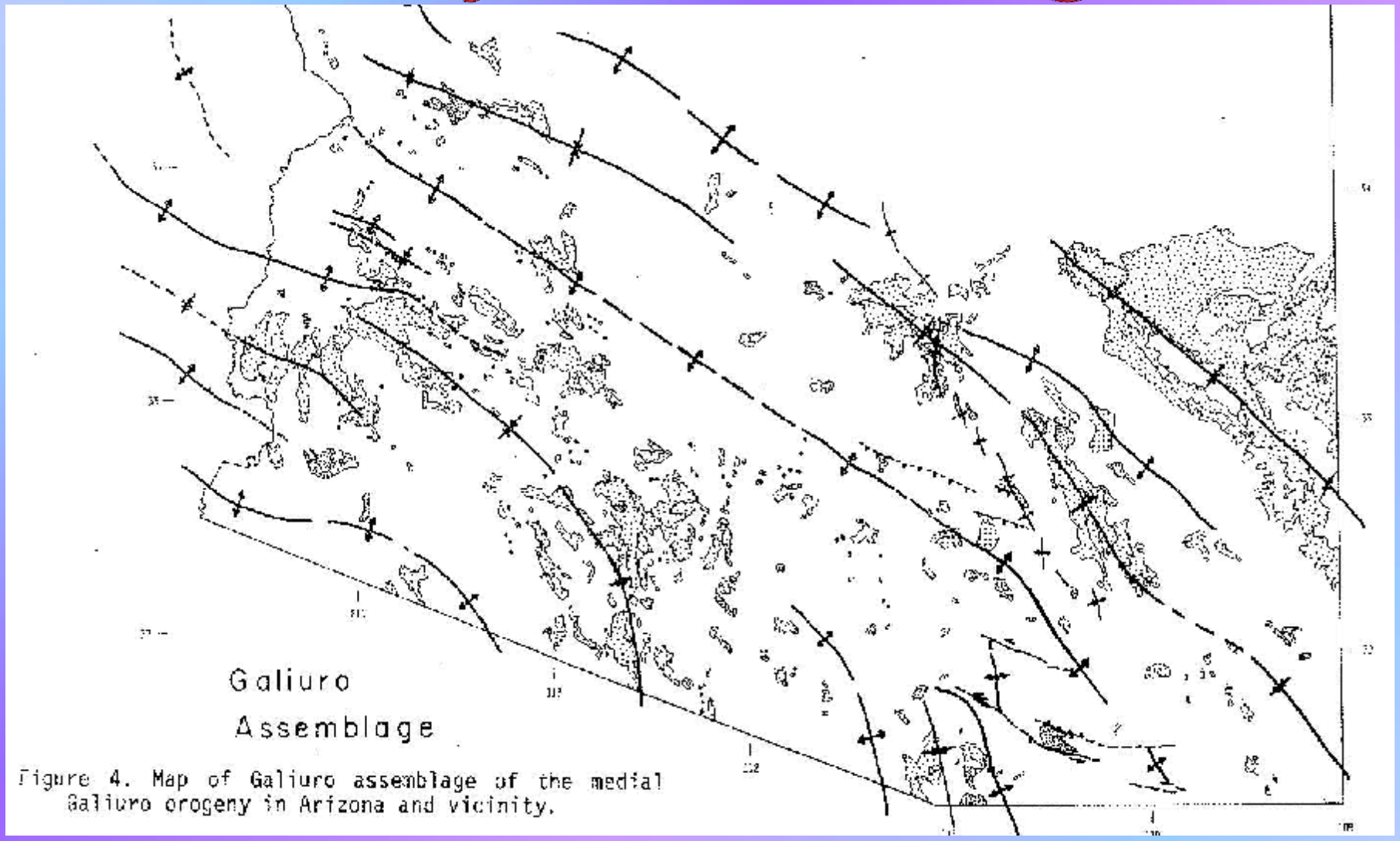

Figure 4. Map of Galiuro assemblage of the medial Galiuro orogeny in Arizona and vicinity.

From Keith & Wilt, 1986, SEPM Tertiary Rocky Mountains

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Mid-Tertiary - MAC -Pb-Zn-Ag

- Alkali-calcic - mid-Tertiary – 25-15 Ma – 30%
  - Red Cloud mine
  - Tonopah
  - Hull
  - Aravaipa
  - Ripsey
  - Grand Reef
  - Purple Passion
  - Hilltop mine, Chiricahua Mts.

Red Cloud Mine

- Alkali-calcic, mid-Tertiary, 25-15 Ma
- 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

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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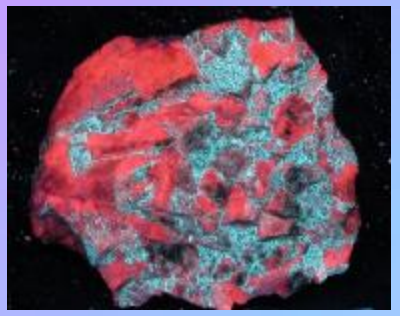
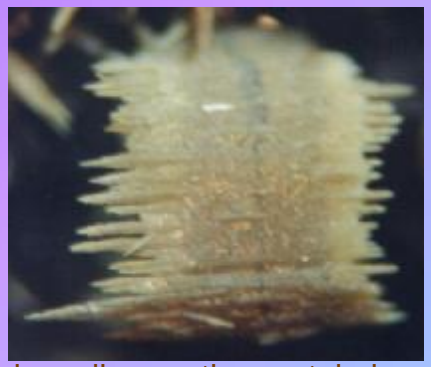
Purple Passion Mine, Maricopa Co.

mid-Tertiary?

- 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 are strongly fluorescent.

Photos courtesy of William Gardner





Epitaxial needle growth over tabular crystals of wulfenite, Purple Passion mine, Yavapai County (www.fluorescents.com/mr2001.htm).

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Los Lamentos, Chihuahua, Mexico

Alkali-calcic
mid-Tertiary
Pb-Zn-Ag

Donor: Verna Lichleitner in memory of Charlie Thornton

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Hilltop mine, Chiricahua Mts.

- Alkali-calcic, Pb-Zn
- 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 produced intermittently from early 1910s to 1954

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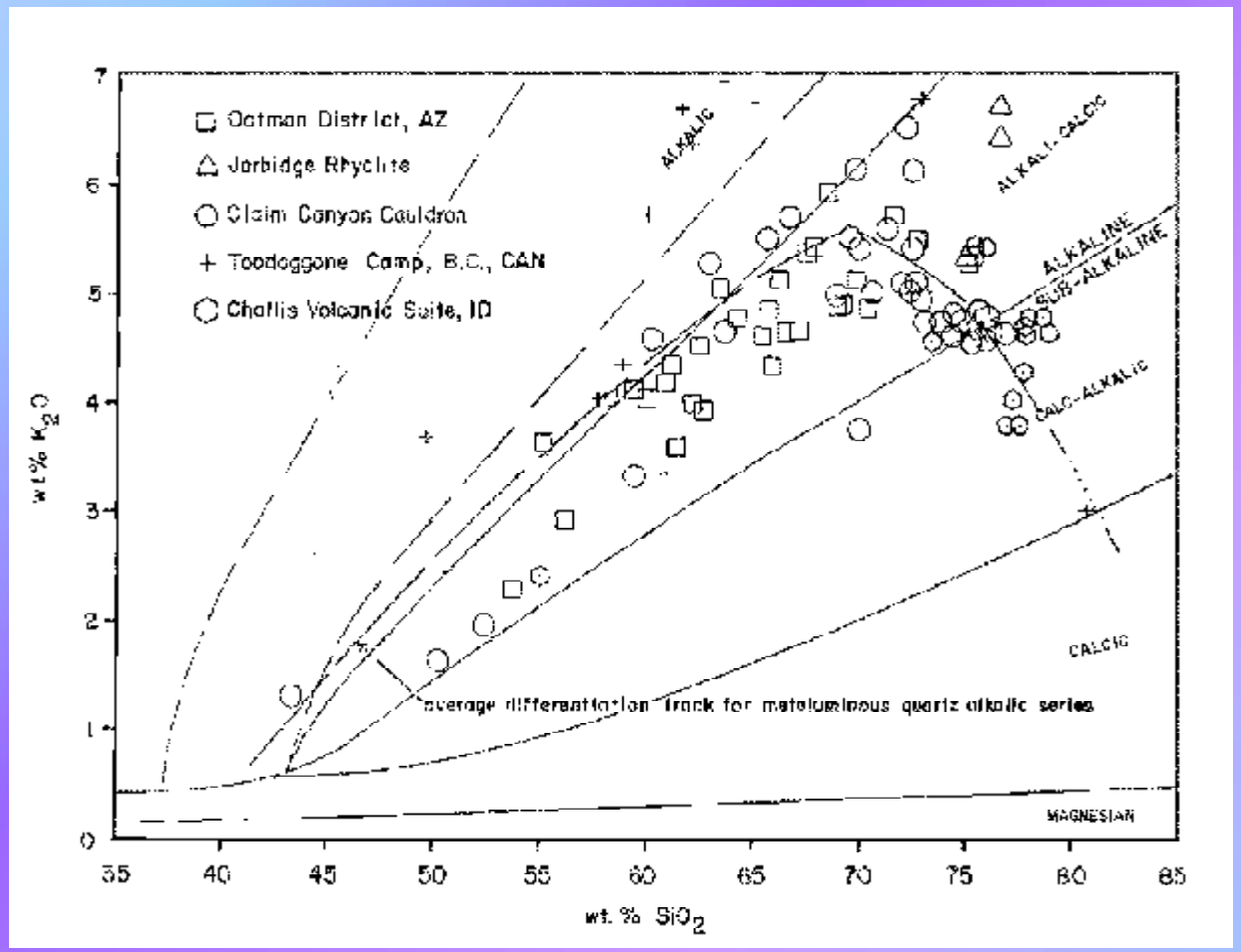
Quartz Alkalic Au-base metal



%K_2O

%SiO_2

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

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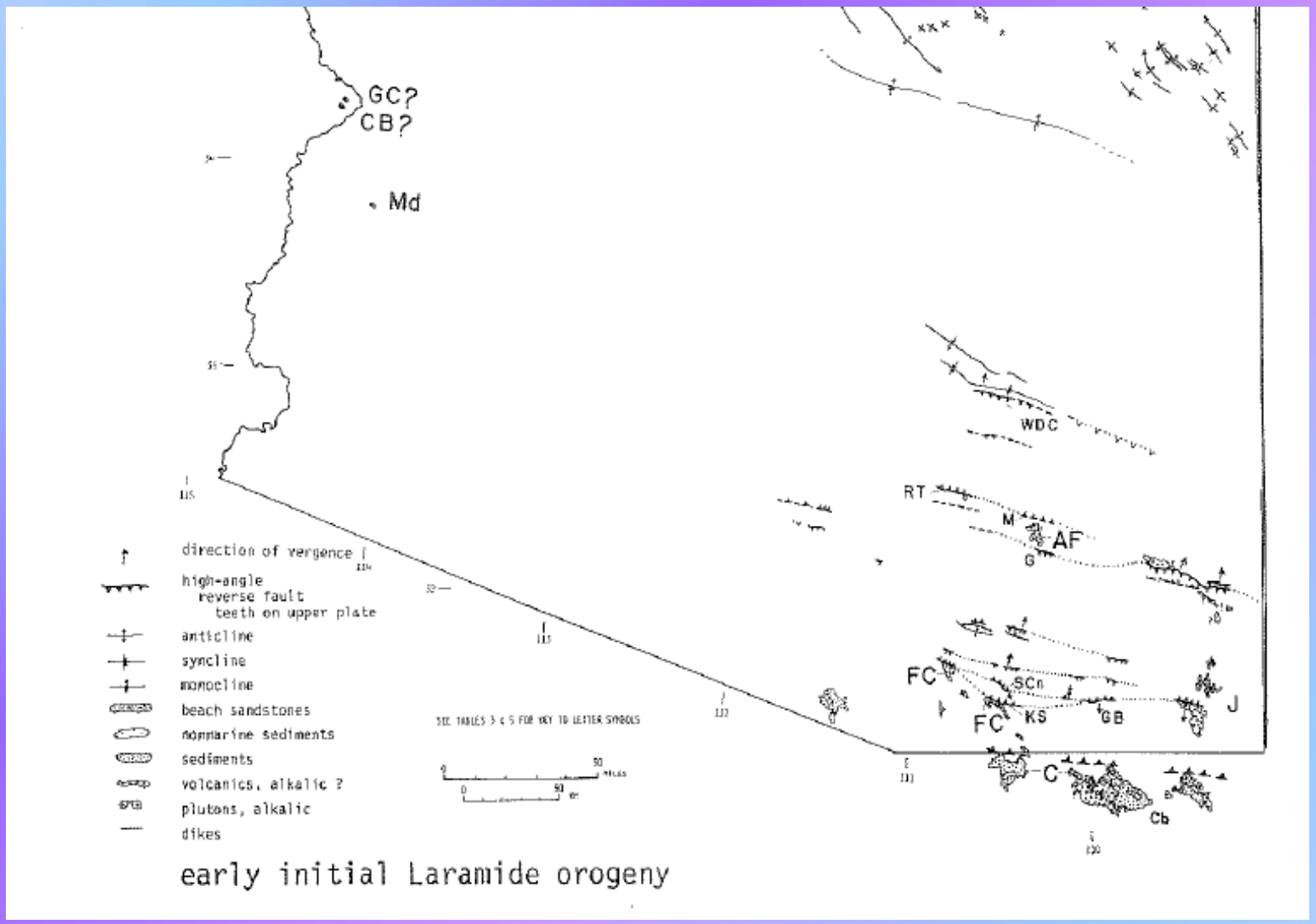
Quartz Alkalic - Pb-Zn-Ag zones

- Jurassic - MQA 45 model
  - Bisbee – Campbell ore body – minor occurrence
- Laramide MQA 42 model
  - Old Yuma mine – N. Tucson Mts.
- mid-Tertiary MQA 42 model
  - Mammoth-St. Anthony mine (Tiger town site)
  - Rowley mine (Painted Rock district, Maricopa Co.)

Laramide - MQA – Au-base metal



From Keith & Wilt, 1985, AGS Larmide

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Old Yuma mine, Tucson Mts.

- Quartz Alkalic - Laramide
- Au-Ag, Pb, Zn
- Partly oxidized base metal sulfides with spotty wulfenite & vanadinite, quartz & calcite gangue
- Steeply dipping, lensing & faulted orebody along a fracture zone cutting Cretaceous & assoc with Laramide porphyry intrusive (Amole Granite)

- **Shaft & underground workings**
- **Produced 1916-1947, total 5,700 tons ore 4% Pb, 1% Cu, 0.6% Zn, 0.3% Mo, 1 oz/Ag/T, 0.1 oz Au/T**

vanadinite

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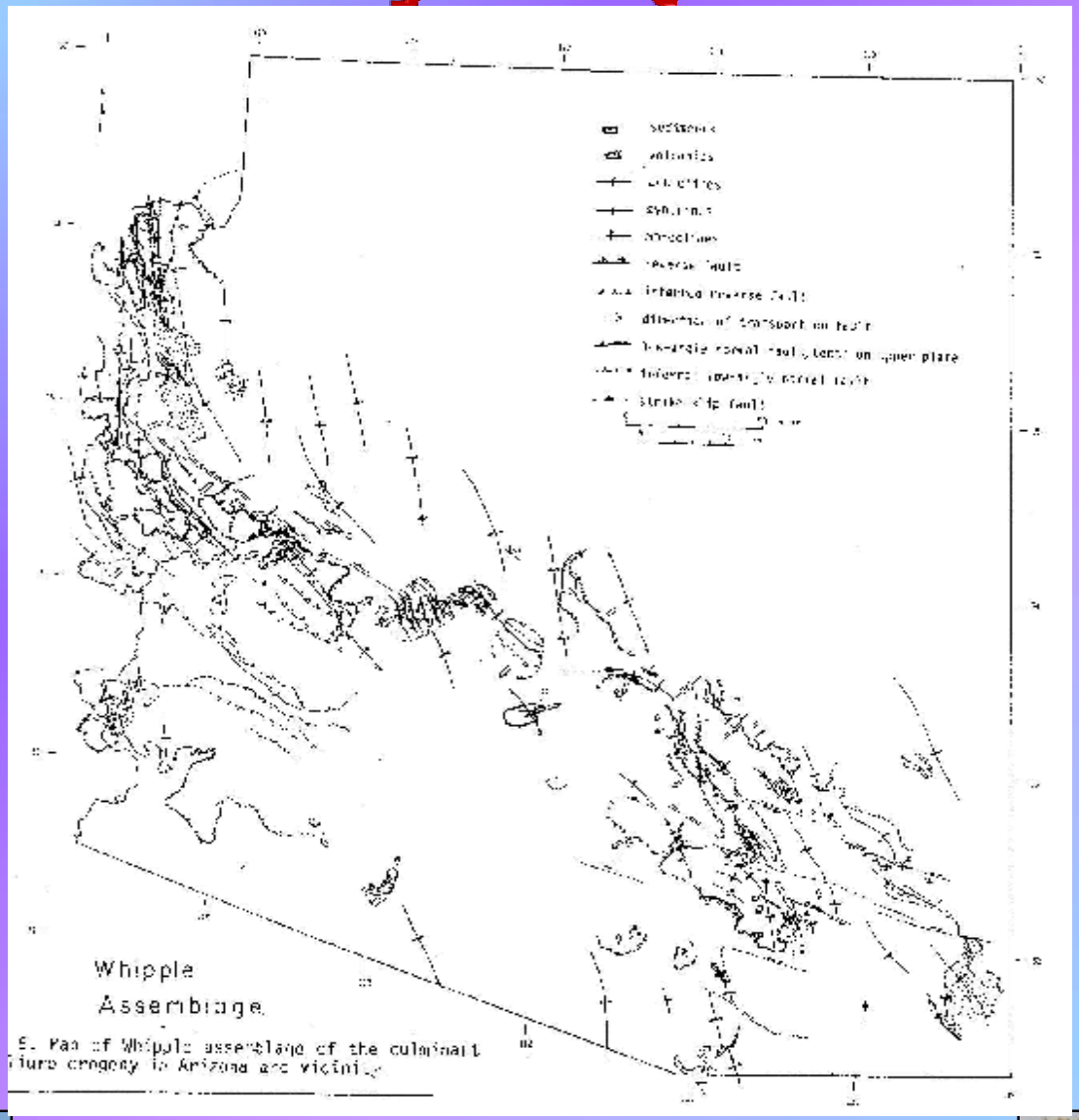
Mid-Tertiary MQA – Au-Cu

From Keith & Wilt, 1986, SEPM Tertiary Rocky Mountains



Mammoth-St. Anthony mine (Tiger)

- Quartz Alkalic – MQA 42
- mid-Tertiary – Au

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 flows 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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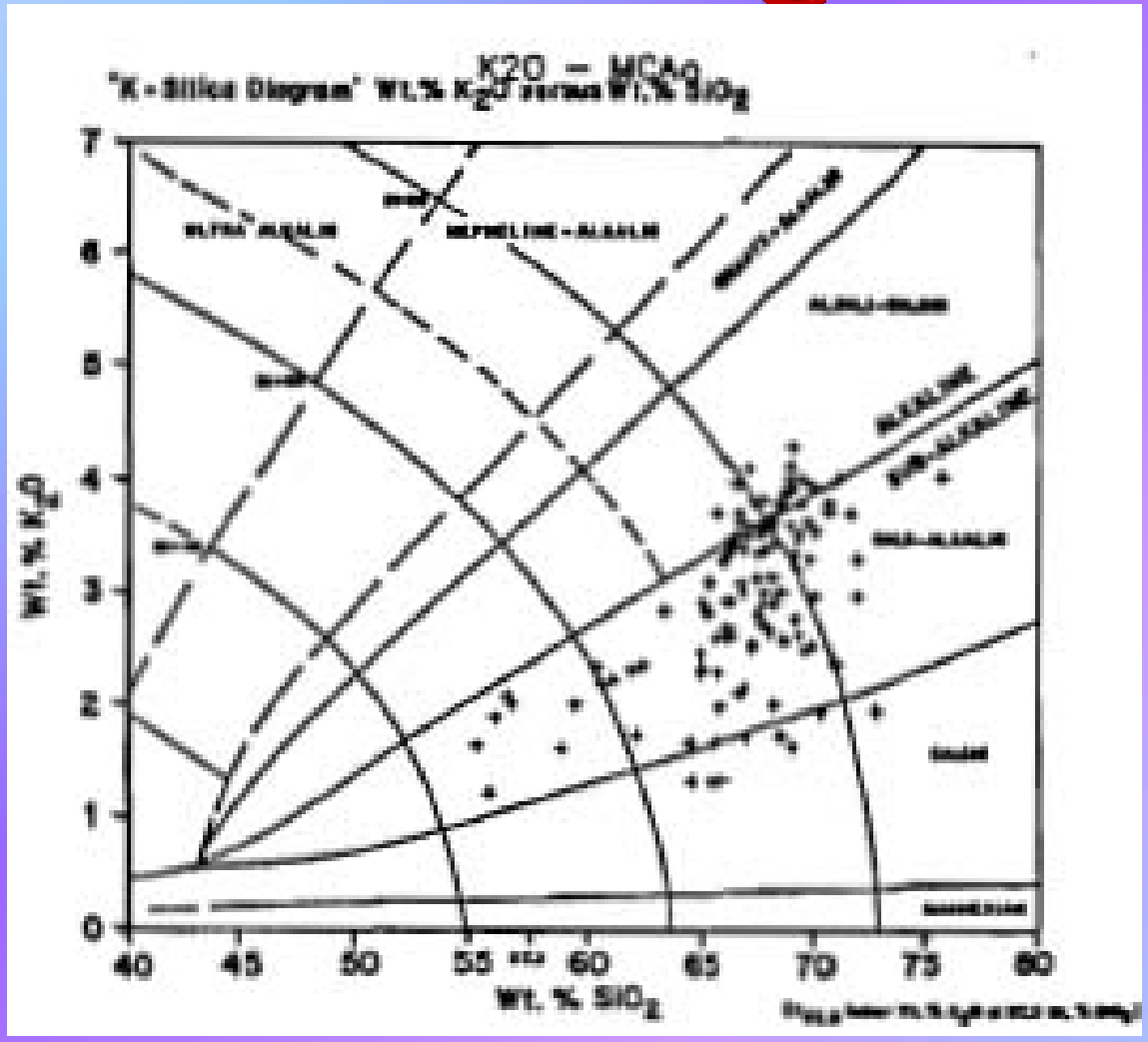
Calc-alkalic Stage 4 Porphyry Cu



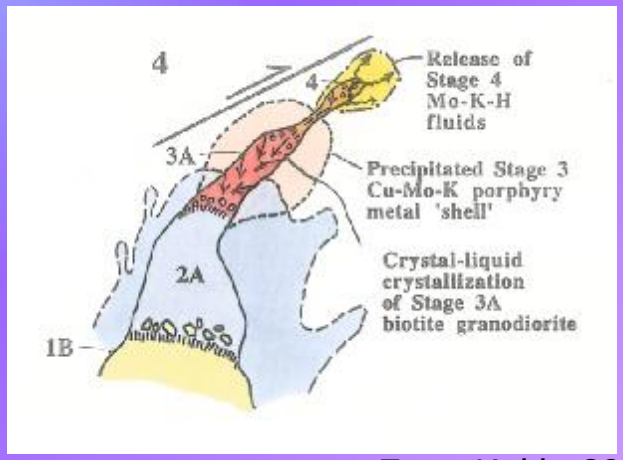
%K_2O

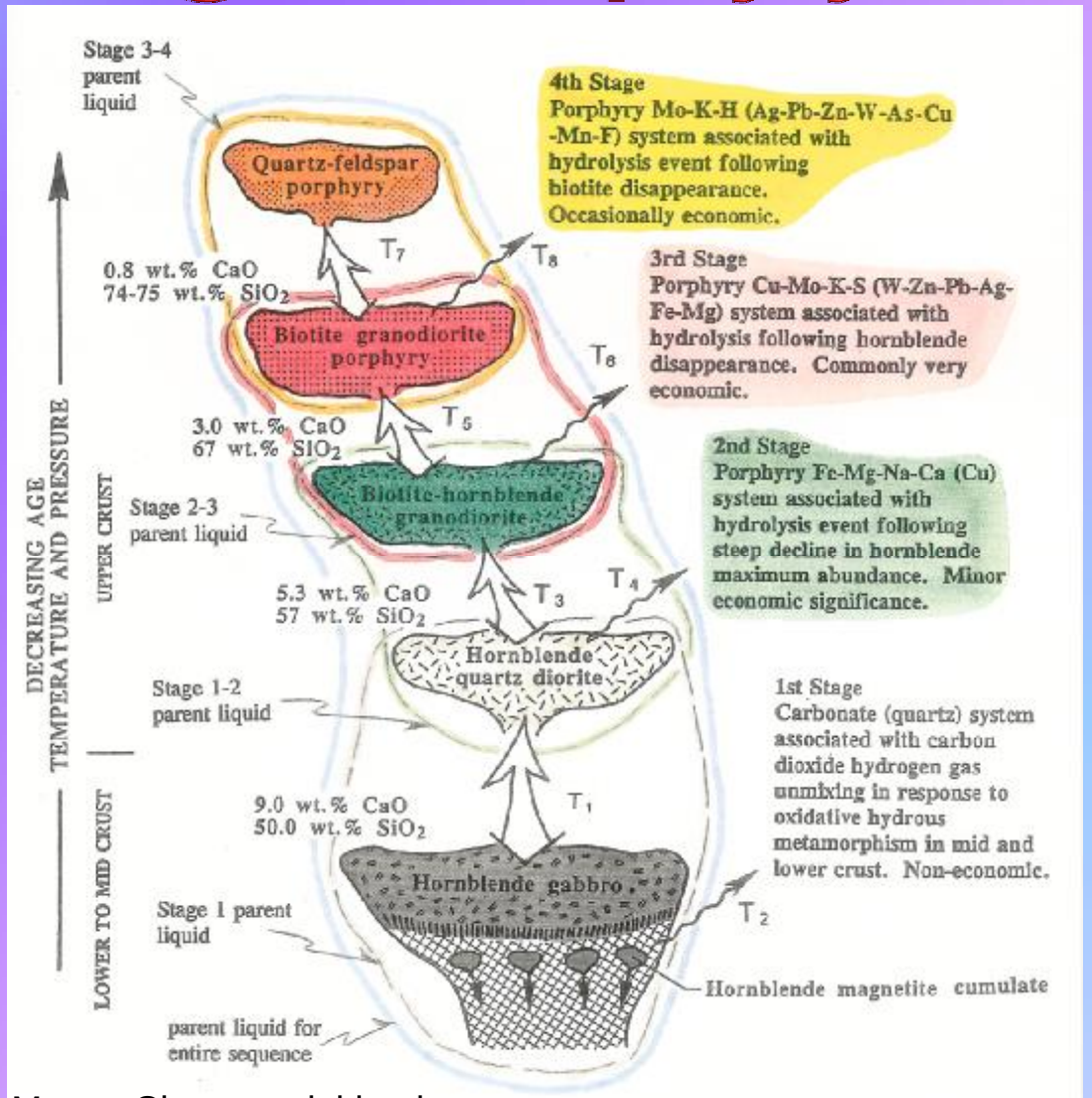
%SiO_2

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

Calc-alkalic – Stage 4 Porphyry Cu

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

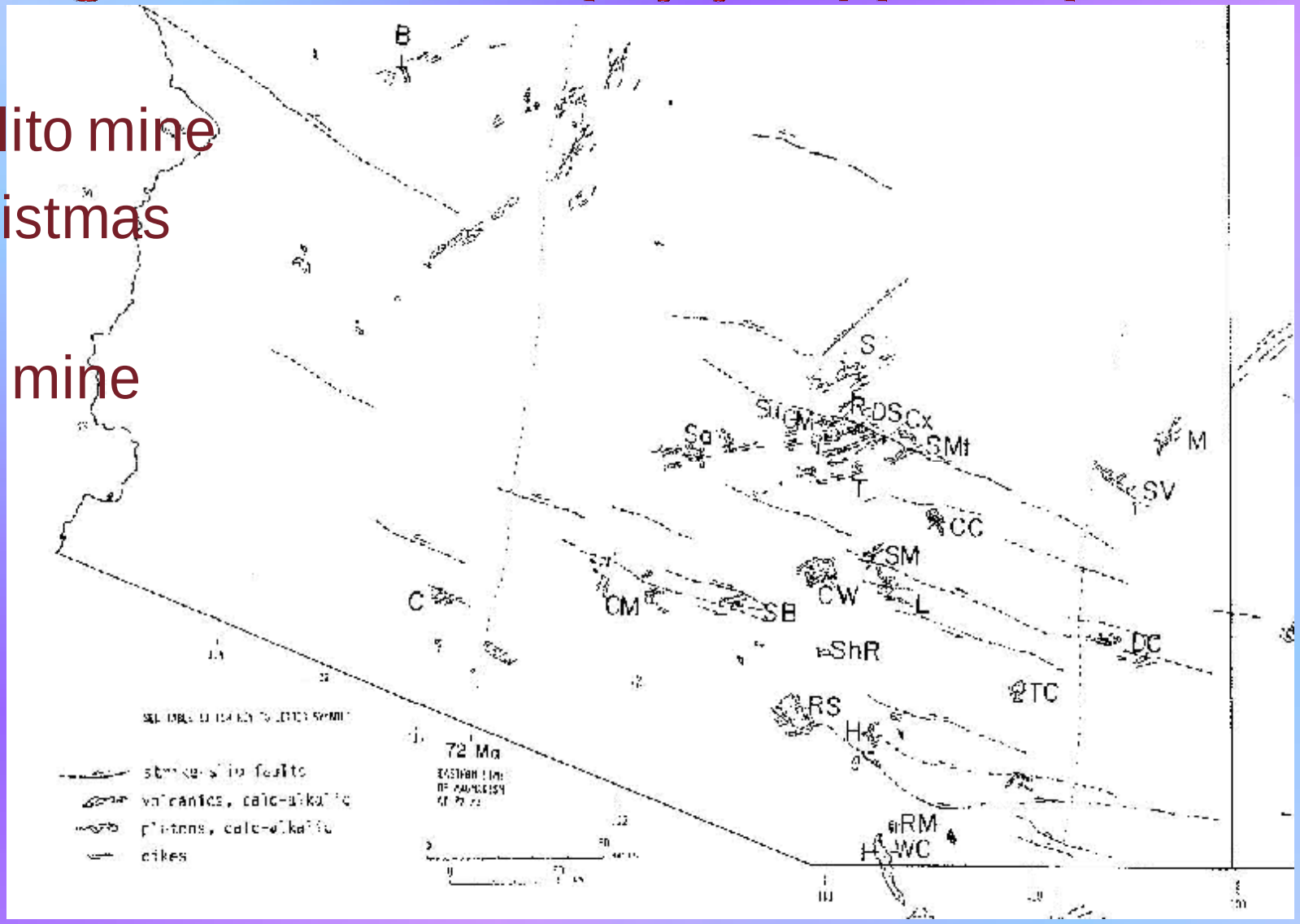




From Keith, 2003, MagmaChem model book

Stage 4 zones of Porphyry Copper deposits

- Chilito mine
- Christmas mine
- 79 mine



From Keith & Wilt, 1985, AGS digest

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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 metamorphosed Pennsylvanian Naco limestone and silicified rhyolite porphyry dikes of probable Tertiary (62 Ma) age

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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 stage 4 zones of porphyry copper districts are not spectacular cabinet specimens

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Geologic Settings, Arizona Wulfenite

Peraluminous

- Calcic (Au-base metal)
  - Precambrian
  - Jurassic
  - Late Laramide
- Calc-alkalic (W-base metal)
  - Precambrian
  - Jurassic
  - Late Laramide



Late Laramide – Peraluminous

- 80-45 Ma
- Calcic & Calc-alkalic

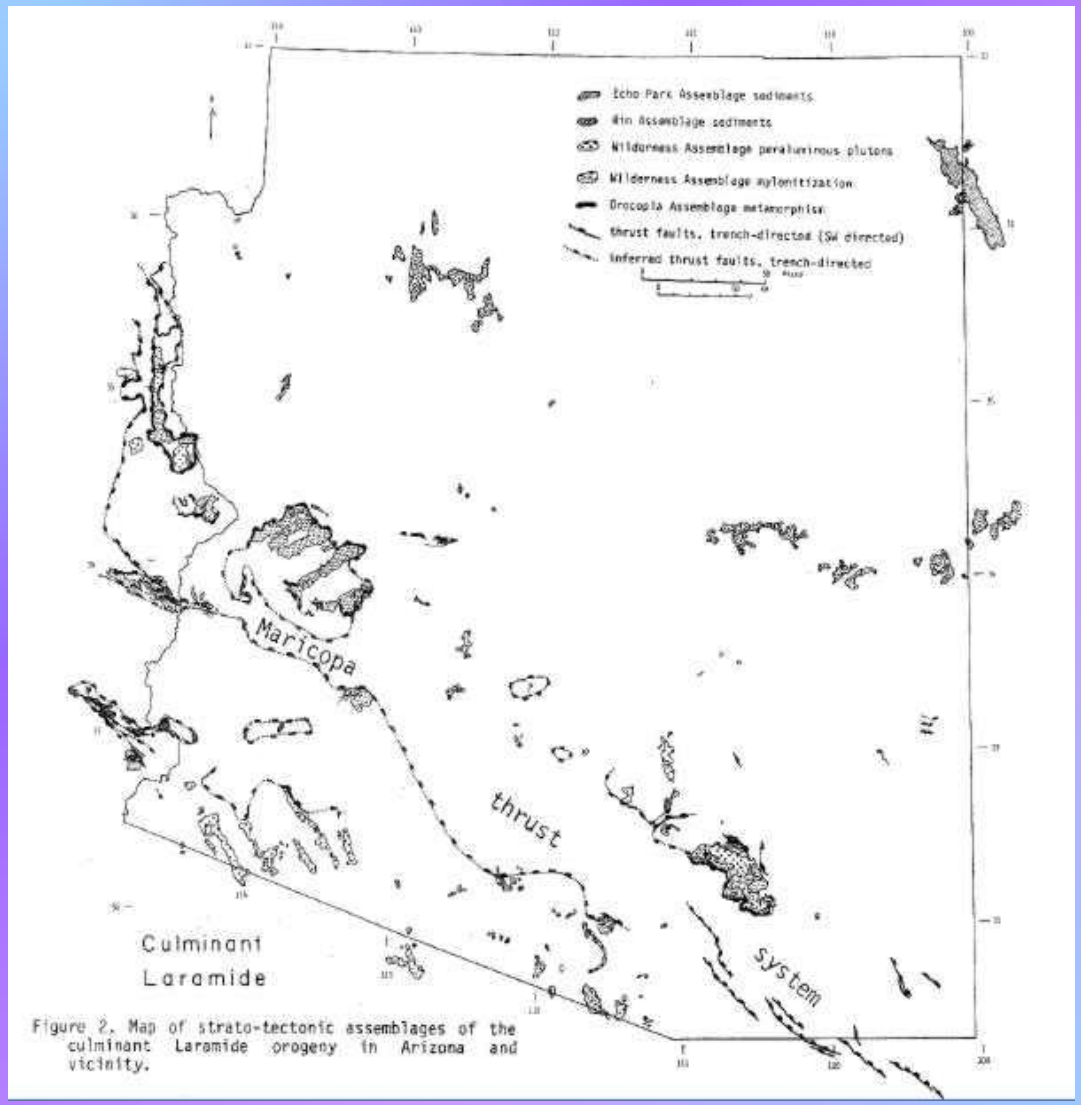

Figure 2. Map of strato-tectonic assemblages of the culminant Laramide orogeny in Arizona and vicinity.

From Keith & Wilt, 1985, AGS digest

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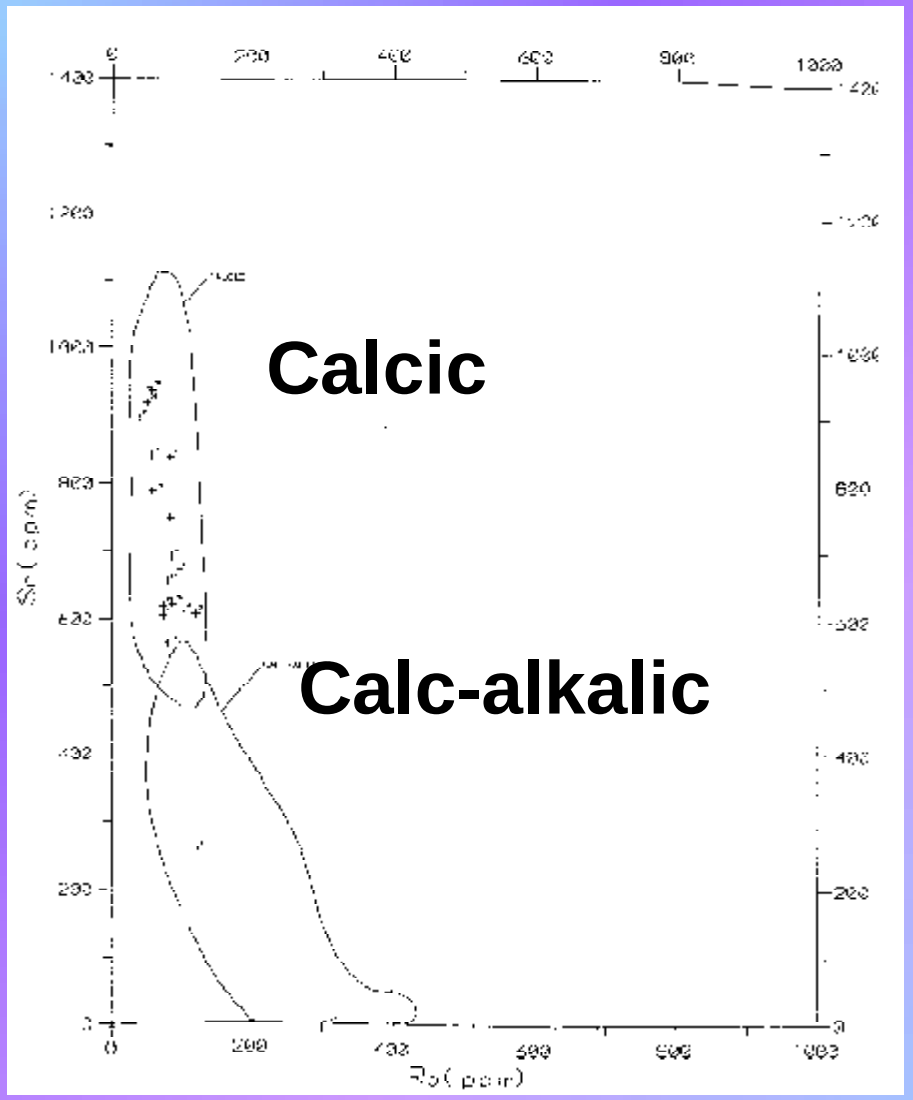
Peraluminous – Calcic or Calc-alkalic



Whole rock geochemical analysis of associated igneous rock (usually two-mica granite)

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Peraluminous Calcic (Au)

- Precambrian (~1700 Ma)
  - Cave Creek,
  - Hieroglyphic Mts.
- Jurassic (~175-150 Ma)
  - western Arizona
- Late Laramide (60-45 Ma)
  - Vulture mine

Vulture mine headframe (from http://www.jpc-training.com/vulture.htm

Peraluminous Calc-alkalic (W)

- Precambrian (~1700 Ma)
  - Tungstona mine
  - Picacho View mine
- Jurassic (~175-150 Ma)
  - Mildren mine, Cababi district
- Precambrian
  - Campo Bonito district
  - Three Musketeers

xxx



Mineral Associations

- Not molybdenite
- Always cerussite
- Sometimes:
  - mimetite
  - vanadinite

molybdenite

mimetite

vanadinite

galena

Vanadinite, Old Yuma mine

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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

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Geologic Settings, Arizona Wulfenite

Metaluminous:

- Alkali-calcic – lead-zinc-silver districts – best specimens
  - Laramide – 80 - 65 Ma - 15%
  - mid-Tertiary – 25-15 Ma – 30%
- Quartz alkalic – gold-base metal
  - Jurassic – 180-160 Ma
  - Laramide – 75-70 Ma
  - mid-Tertiary – 28-22 Ma
- Calc-alkalic – Stage 4 zones porphyry copper
  - Laramide - 75-60 Ma

Peraluminous

- Calcic (Au) - Precambrian, Jurassic, Late Laramide
- Calc-alkalic (W) – Precambrian, Jurassic, Late Laramide

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Geologic Settings of Wulfenite in Arizona

Jan Rasmussen, Curator,

Arizona Mining & Mineral Museum

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