

Wulfenite in Arizona



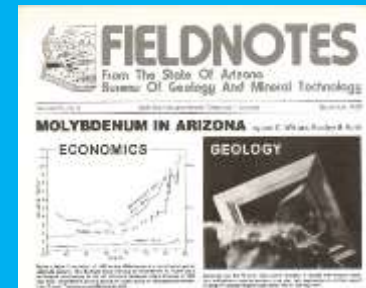
Glove Mine,
Santa Rita
Mts., donor
Lyda Hill

by Jan C. Rasmussen, R.G.

Wulfenite in Arizona

Sources of photos and information

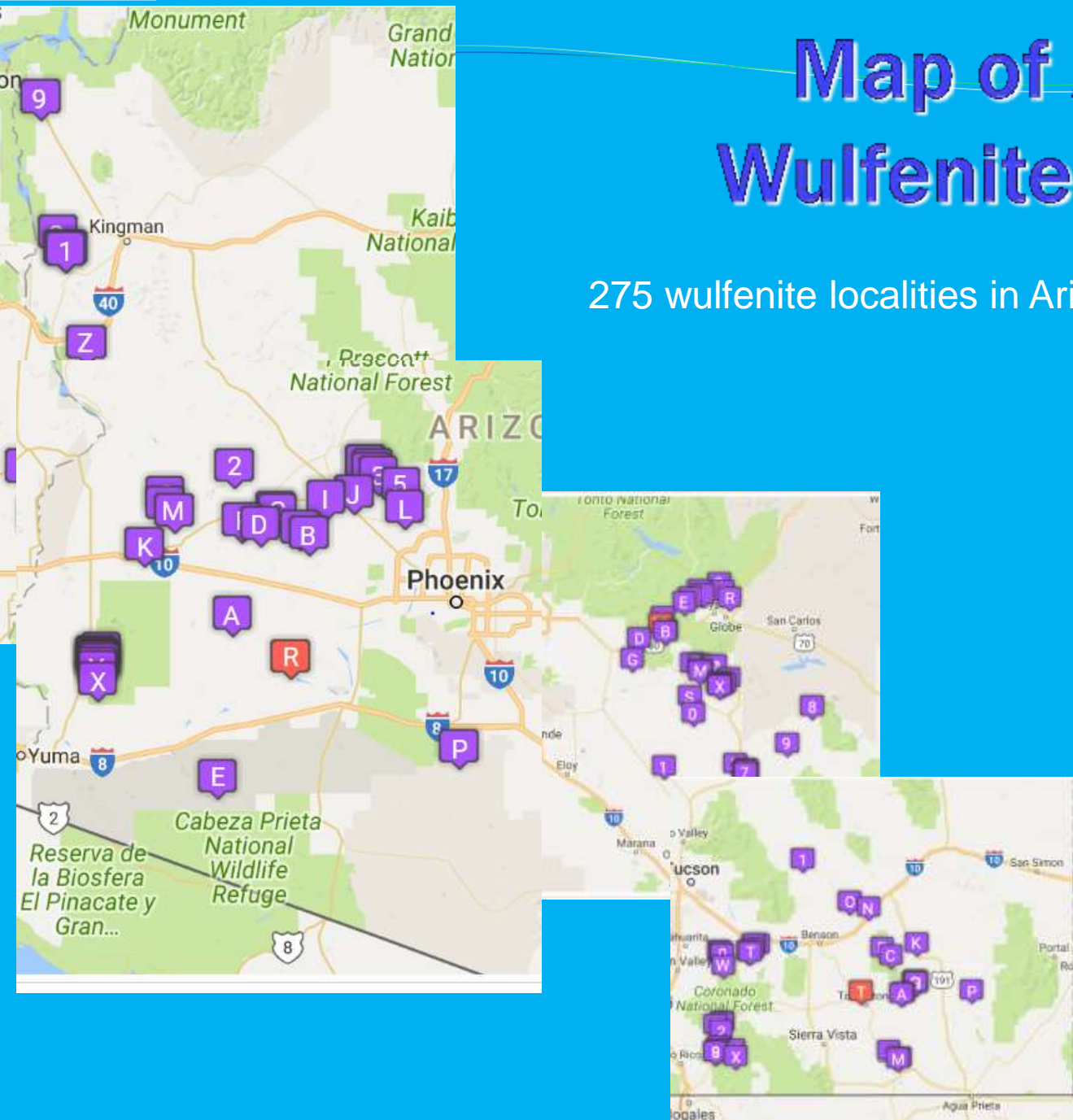
- Former Arizona Mining & Mineral Museum (467 wulfenite specimens)
- Tucson Gem & Mineral Society show 2012 “Arizona Mineral Treasures”
- www.mindat.org (approximately 275 localities, 1585 photos)
- Inventoried 150 localities from MRDS in 1980
- Flagg Mineral Foundation samples
- Based on 1980 compilation at Arizona Geological Survey for a USGS grant



Map of Arizona Wulfenite Localities

275 wulfenite localities in Arizona in www.mindat.org

Maps from
www.mindat.org



Wulfenite in Arizona

Mineralogy:

- Chemical & Physical Characteristics
- Mineralogical Associations

Geologic Setting: (age of primary deposit – wulfenite later)

- Alkali-calcic – lead-zinc-silver districts (Stage 3 and 4)
 - **Jurassic – 170-160 Ma – Defiance, Silver Bill**
 - **Laramide – 85 - 65 Ma - Glove**
 - **mid-Tertiary – 30-20 Ma – Red Cloud**
- Calc-alkalic – in later, outer Pb-Zn-Ag zones (Stage 4)
 - Laramide porphyry copper - 75-60 Ma – **79 Mine**
- Quartz alkalic – in Pb-Zn-Ag zones with stage 4 rhyolites
 - Jurassic - Bisbee
 - Laramide - **Old Yuma**
 - **mid-Tertiary - Tiger, Rowley**
- Peraluminous calcic
 - Laramide – Gold Basin
- Peraluminous calc-alkalic
 - Precambrian

Paragenesis - Oxidized zones , water courses



Wulfenite Mineralogy

- PbMoO_4
 - Lead Molybdate (molybdenum and oxygen)
- Colors
 - Orange-yellow, yellow, honey-yellow, reddish-orange, rarely colorless, grey, brown, olive-green and black
- Subadamantine to greasy luster

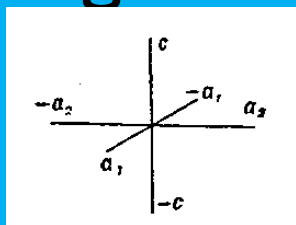


Defiance Mine, Gleeson (Turquoise) district, Cochise Co., AZ Mining & Mineral Museum, MM-M900, 18 cm, donor Les Presmyk

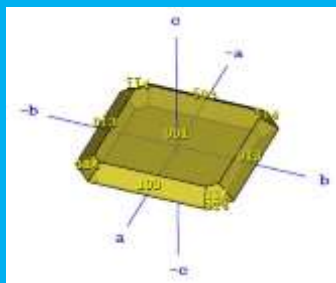
Common impurities: W, Ca, V, As, Cr (red), W, Ti

Wulfenite Crystallography

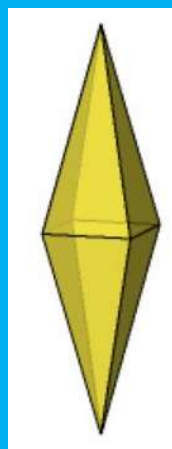
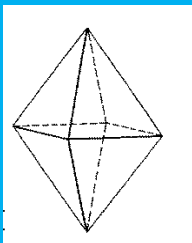
- Tetragonal



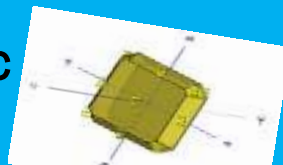
- usually tabular (flat square), thin plates



- rare dipyramidal



- rare pseudo-cubic



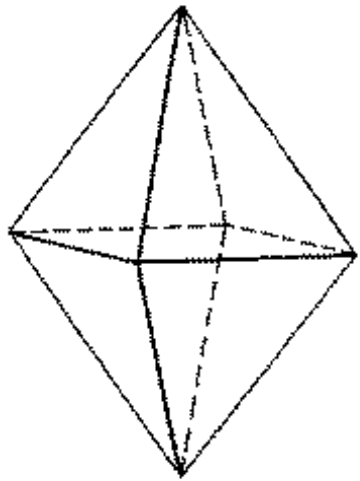
Glove Mine, Tyndall district, Santa Cruz Co.
AZ Mining & Mineral Museum MM-T554 14 cm

H = 2 ½-3

Streak white, brittle, cleavage on {011}, density 6.5-7.5

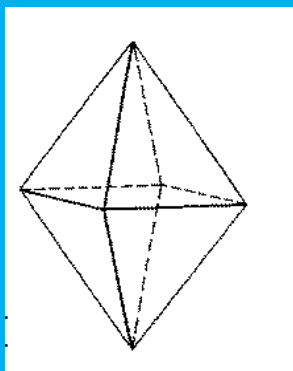
Unusual crystal forms - dipyramid

Truncated
dipyramid, San
Diego mine,
Tombstone district,
Cochise Co., 3 mm
FOV, Rolf Luetcke
photo, specimen,
www.mindat.org



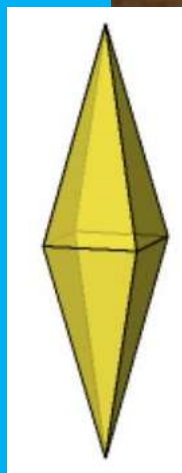
Unusual crystal forms - dipyramid

Wulfenite,
dipyramid, Melissa
Mine, Silver District,
La Paz Co., AZ, FOV
3 mm, Trevor Boyd
photo, specimen,
mindat.org



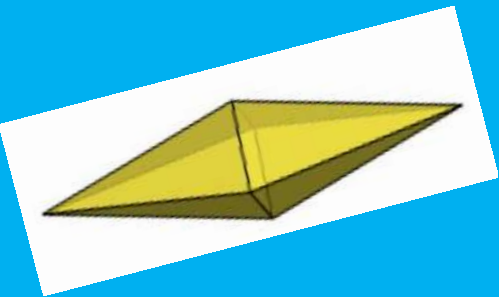
Unusual crystal forms - elongated dipyramid - acicular

Needle-like
dipyramid,
Heavy Weight
Mine, Helvetia-
Rosemont
district, Santa
Rita Mts.,
Pima Co., FOV
4 mm, Rolf
Luetcke photo,
specimen,
mindat.org



Unusual crystal forms - elongated dipyramid

Wulfenite, tall
dipyramid. Indiana-
Arizona Mine,
Waterman district,
Pima Co., FOV 0.75
mm, Bob
Rothenberg photo &
specimen,
mindat.org



Unusual crystal forms – pseudo cube = very thick plates

Wulfenite,
pseudo cube,
Gleeson Mine,
Turquoise
district,
Dragoon Mts.,
Cochise Co.,
FOV 1.46 mm,
Matteo
Chinellato
photo &
specimen,
mindat.org



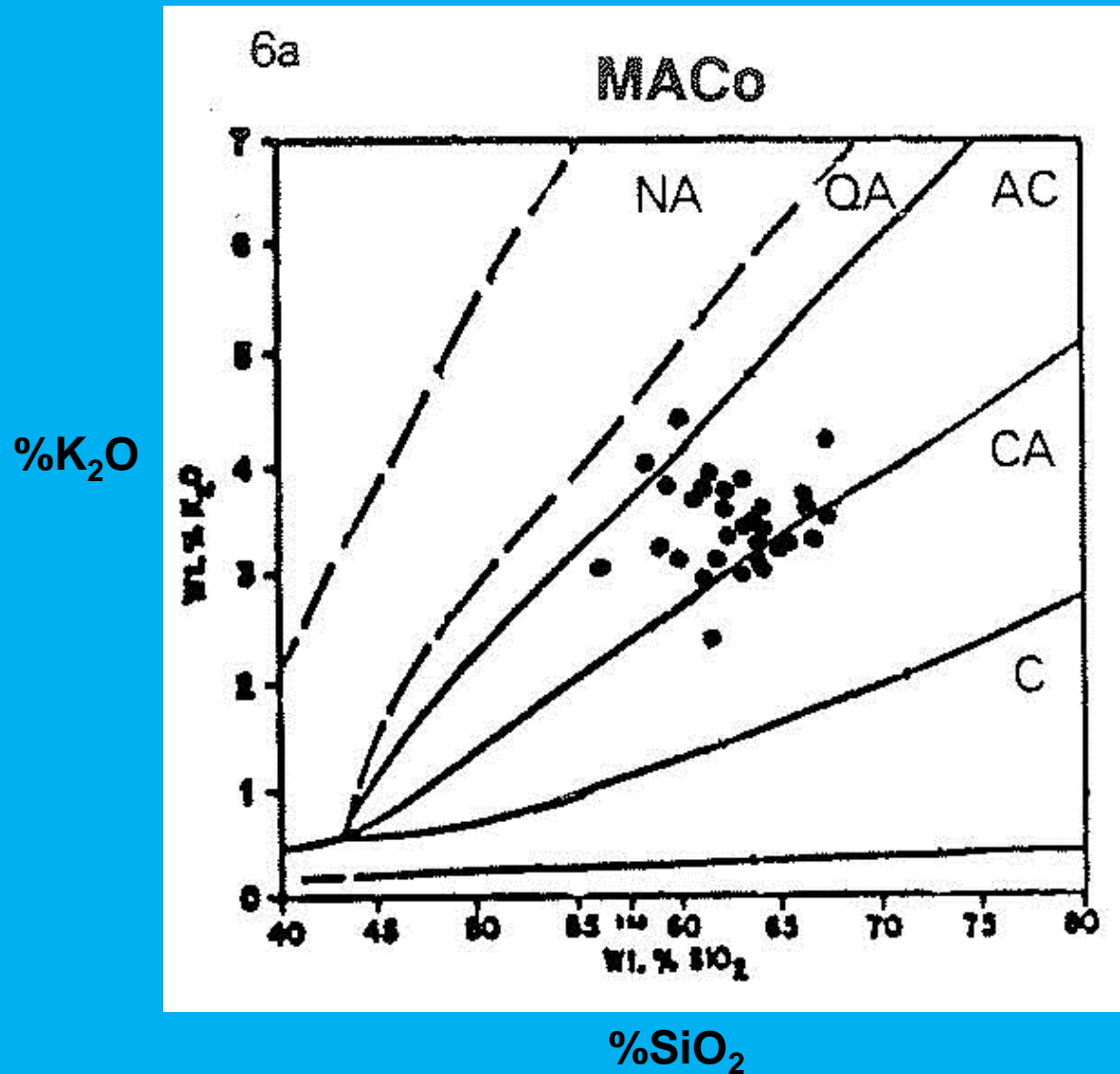
Wulfenite dipyramids on anglesite/galena

Wulfenite
dipyramids on relict
galena with
pseudocubic
wulfenite about 1
inch away from
galena.

Gorilla Mine,
Mineral Mountain,
Pinal County, AZ
Collected by Ken
Algier, Stan Keith
specimen & photo



Alkali-Calcic - Lead-Zinc-Silver



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

Keith & Wilt, 1986

www.JanRasmussen.com

Alkali-calcic - Lead-Zinc-Silver - Jurassic ~160 Ma

- Silver Bill, Defiance, Mystery, Tom Scott mines – Gleeson district (formerly part of Turquoise district) (on Gleeson Ridge), Cochise County

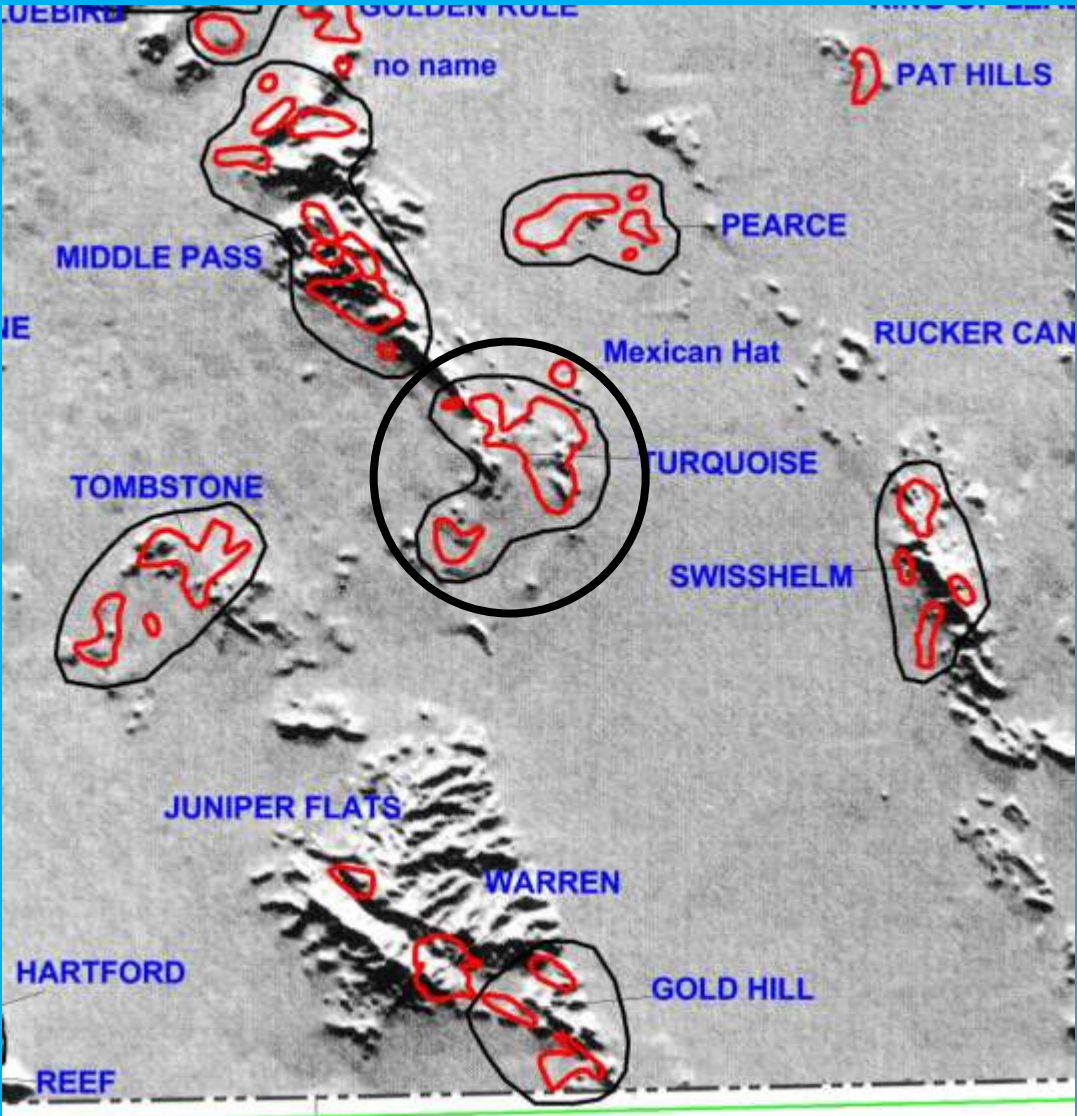


Silver Bill Mine, Turquoise dist, MM-T555



Defiance Mine, Gleeson district, owner Joe & Susan Kielbasa

Defiance & Silver Bill Mines, Turquoise district, Dragoon Mts., Cochise County - Jurassic



Wulfenite, Defiance Mine, ~2 in., owner Mark Hay

Silver Bill Mine, Gleeson Ridge (Turquoise district)

- Alkali-calcic, Jurassic
- 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



AZ Mining & Mineral Museum MM-T555, 8 cm

Defiance Mine, Gleeson dist.

- Alkali-calcic, Jurassic
- Cerussite, anglesite, malachite, smithsonite, cerargyrite, and pyrolusite
- Large amounts of magnificent wulfenite specimens lining solution cavities and in oxidized lead, manganese, and iron deposits
- Ore bodies 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 Jurassic age



AZ Mining & Mineral Museum MM-M900, Donor Les Presmyk, 18 cm

Alkali-calcic - Lead-Zinc-Silver - Early Laramide 80-75 Ma

- Glove mine - **Tyndall district** - Santa Rita Mountains
- Emerald-Silver Plume, Toughnut mines - **Tombstone district**
- Total Wreck mine - **Empire district** - Empire Mts.



Glove Mine, Flagg Mineral Foundation

Empire Mine,
Tombstone, Peter
Megaw

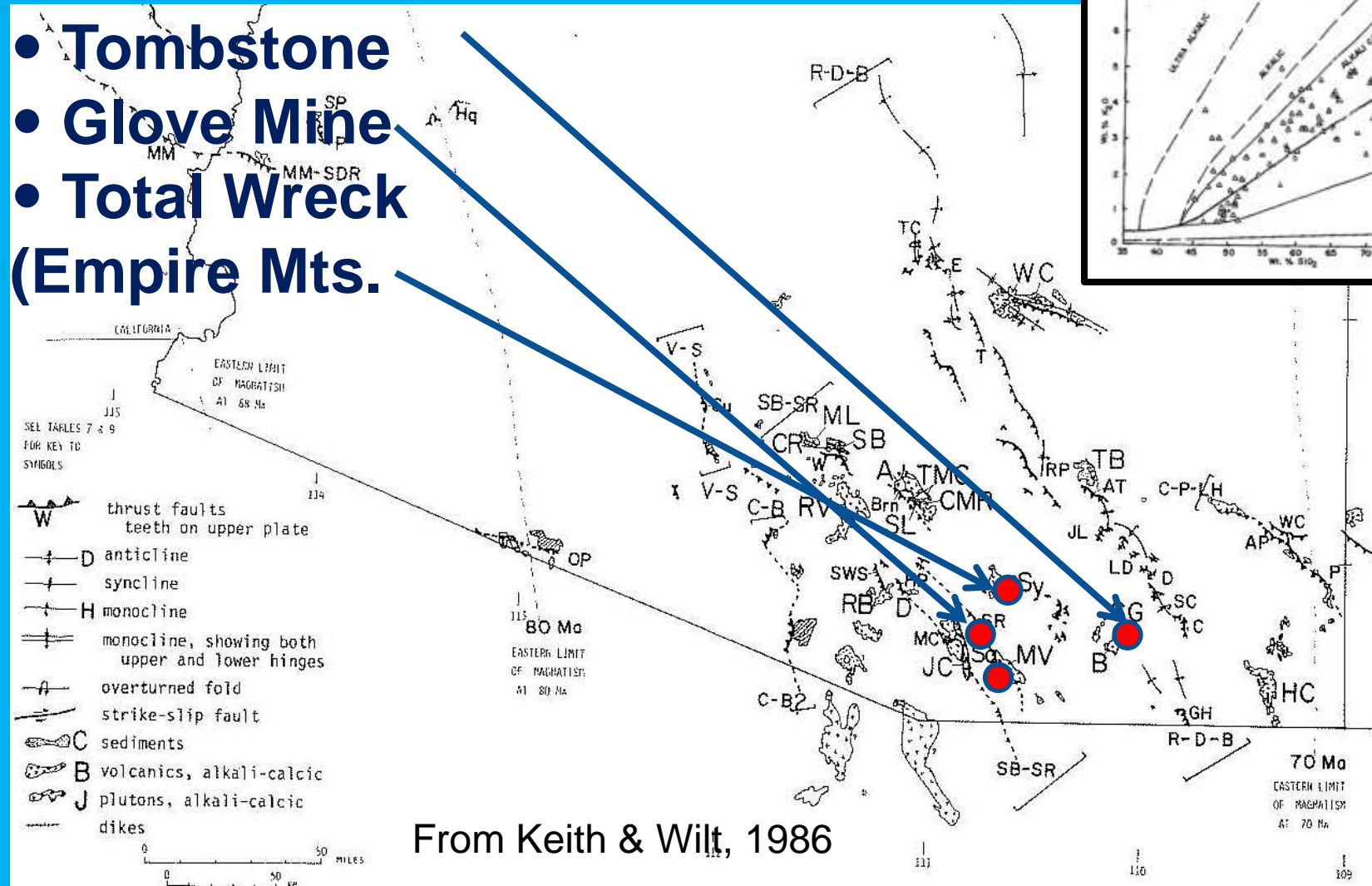


Total Wreck Mine,
Empire dist.



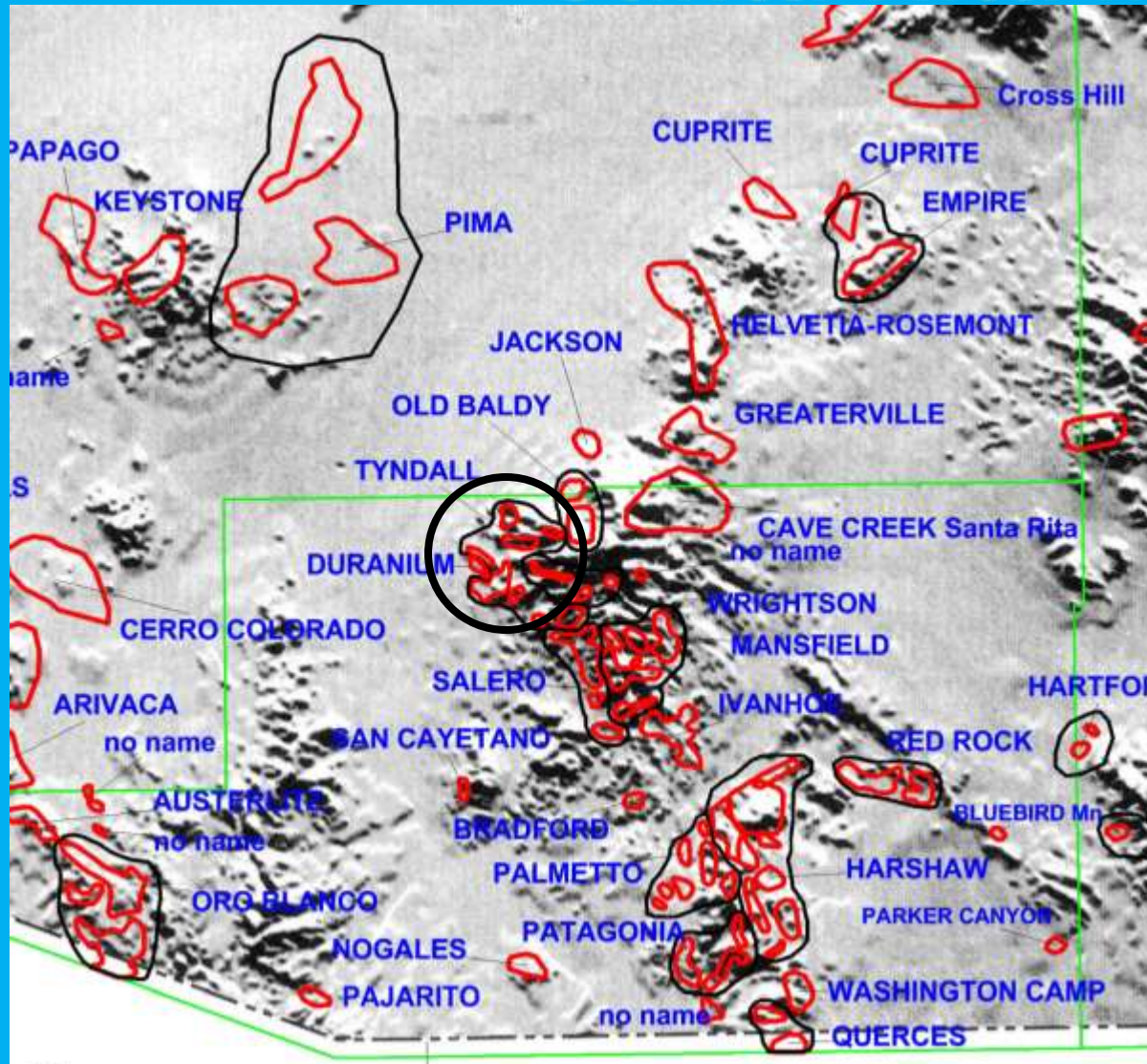
Laramide (80-75 Ma) Alkali-Calcic Lead-Zinc-Silver

- Tombstone
- Glove Mine
- Total Wreck (Empire Mts.)



From Keith & Wilt, 1986

Glove Mine, Tyndall district, Santa Rita Mts.



AZ Mining & Mineral
Museum MM-8564, 9 cm,
Arthur Bloyd donor

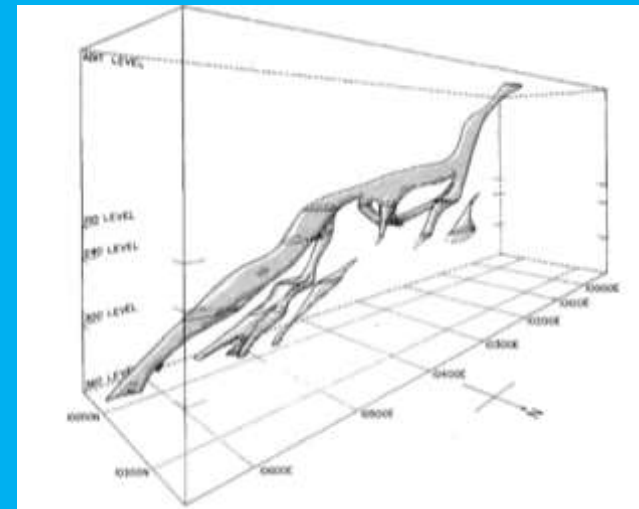
Glove Mine, Santa Rita Mts.

- Alkali-calcic, Lead-Zinc-Silver, Laramide
- 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, & smithsonite in the leached caverns as sand carbonate ore
- 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

diagram = Olson, 1966, Glove mine, Economic Geology, v. 61, p. 731-743.



AZ Mining &
Mineral Museum
MM-T554 14 cm

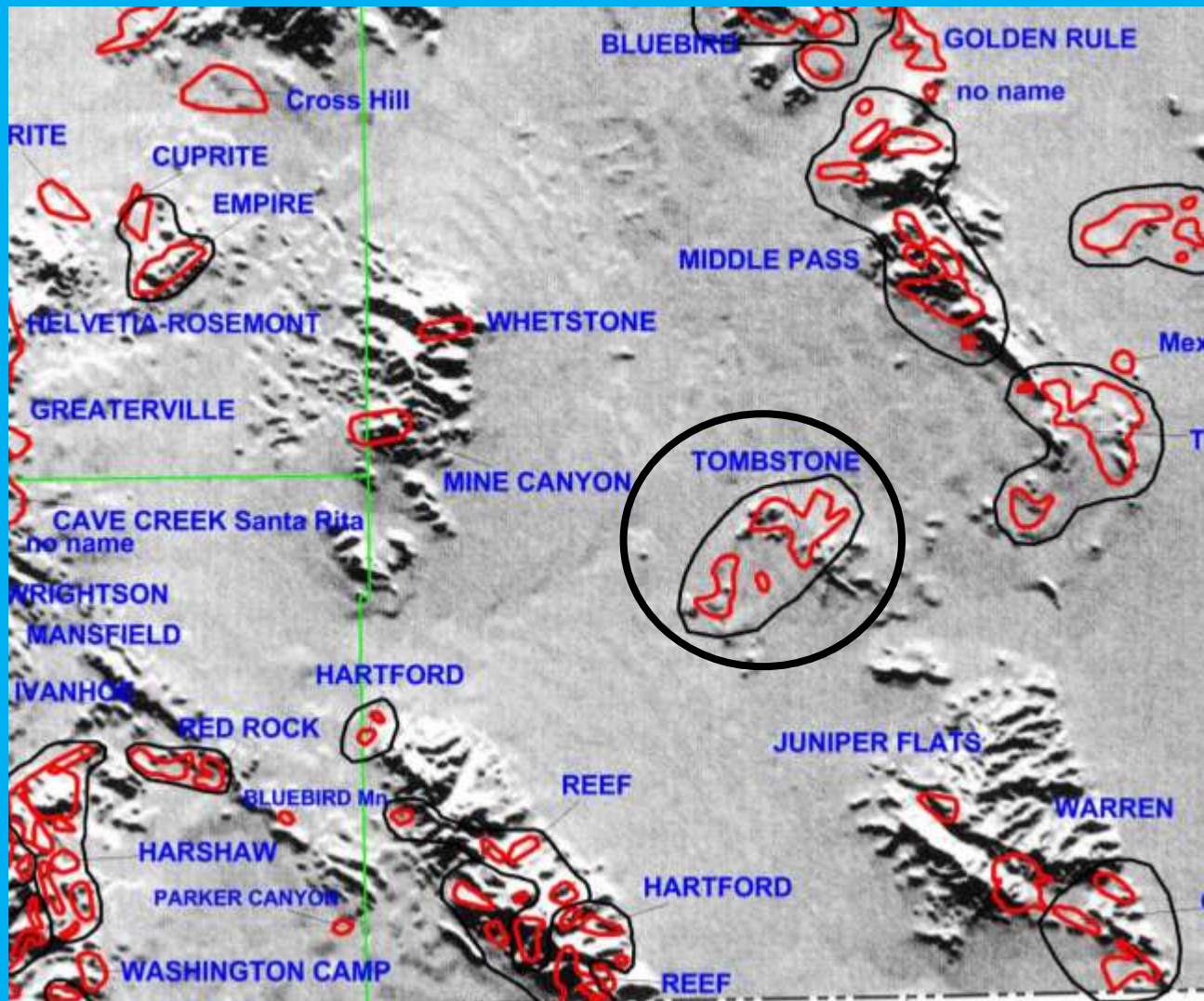


Glove Mine, Santa Rita Mts.



Flagg Mineral Foundation 3258 on loan to AZ Mining & Mineral Museum in 2010, 12 cm

Tombstone district, Tombstone Hills, Cochise County



Toughnut & Empire Mines

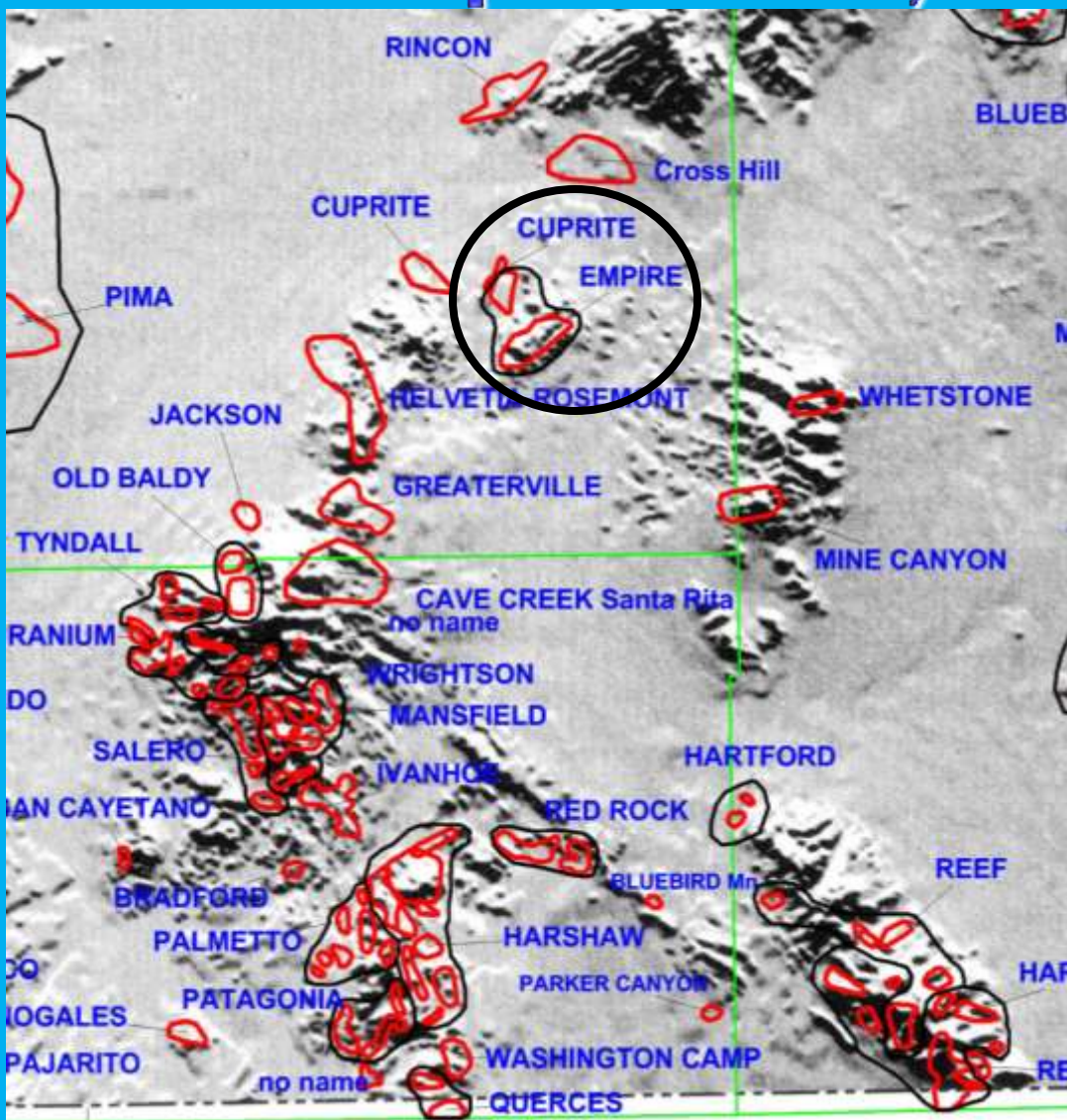
- Tombstone district
- Alkali-calcic - Laramide
- Lead-Zinc-Silver
- Oxidized, base metal sulfides in replacement ore bodies in lower Cretaceous Bisbee Group
- Along anticlinal rolls and in pipes where rolls are cut by faults
- In NE fissures
- Shaft workings
- Several thousand tons
- Produced Ag ore in late 1800s and early 1900s

Toughnut Mine, AZ
Mining & Mineral
Museum MM-T056,
donor John Weber, 4
cm



Wulfenite, Tombstone
district, Cochise Co.,
2-4 in., Arthur
Montgomery
collection, Rock
Currier photo,
www.mindat.org

Total Wreck Mine, Empire district, Empire Mts., Pima County



Wulfenite, Total
Wreck Mine,
Empire Mts., 2
in., Les Presmyk
sample, Flagg
show 2017



Wulfenite, mimetite, Total Wreck Mine,
Empire Mts., Pima Co., FOV 7 mm,
Michael Cline photo, specimen,
www.mindat.org

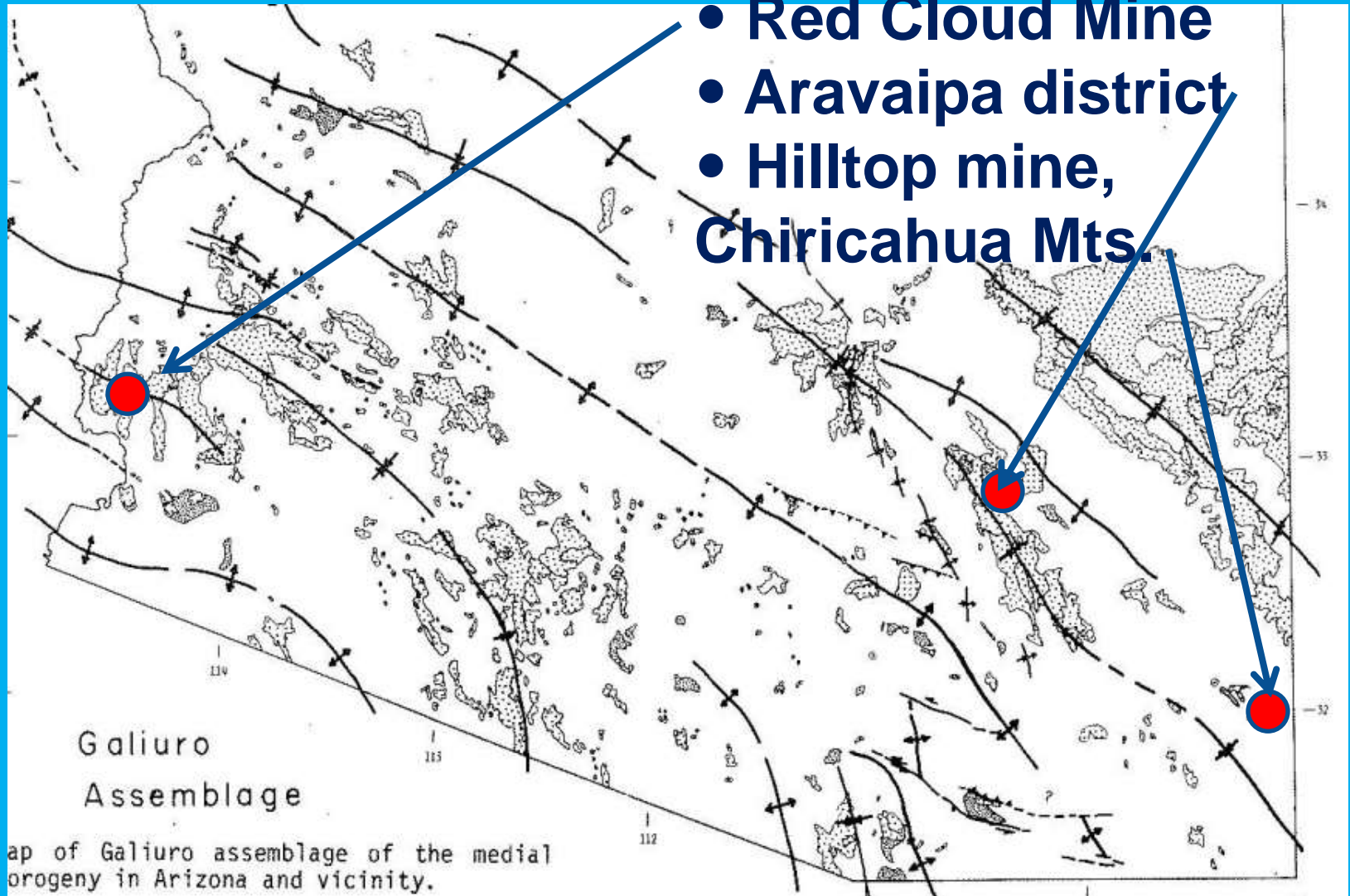
Total Wreck Mine, Empire Mts.

- Alkali-calcic Laramide
- Lead-Zinc-Silver
- Cerussite, wulfenite, vanadinite, cerargyrite, malachite, azurite, chrysocolla & minor copper & lead sulfides
- In irregular replacement ore bodies 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.



Wulfenite, Total Wreck Mine, Empire Mts., Pima Co., 2.5 cm, Dennis Tryon collection, www.mindat.org

Alkali-calcic Lead-Zinc-Silver – mid-Tertiary 25-15 Ma



Red Cloud Mine wulfenite



Red Cloud wulfenite, ~ 2 inches; collected by Rose from Edson-Rose pocket ~ 1972, photo and specimen in collection of Stan Keith

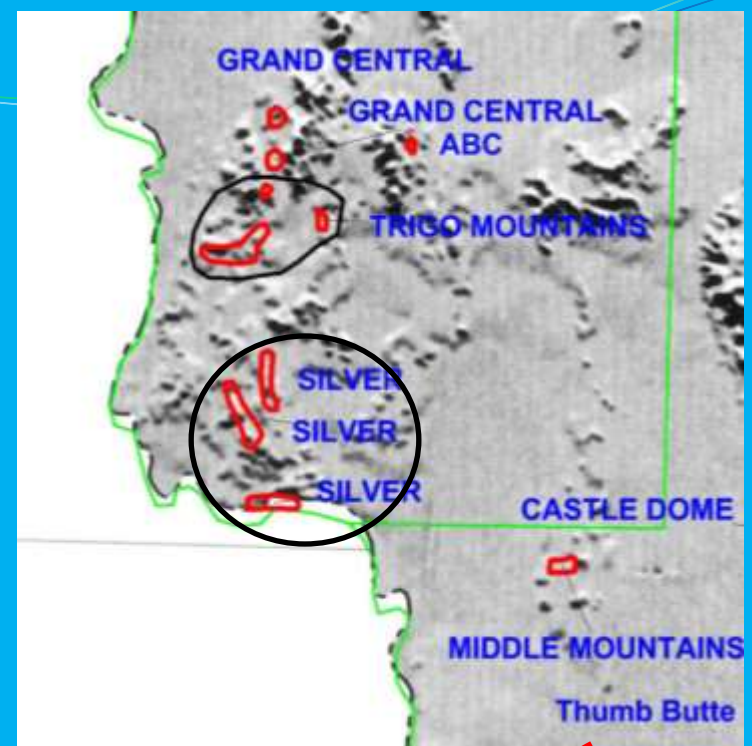
Red Cloud Mine

- 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



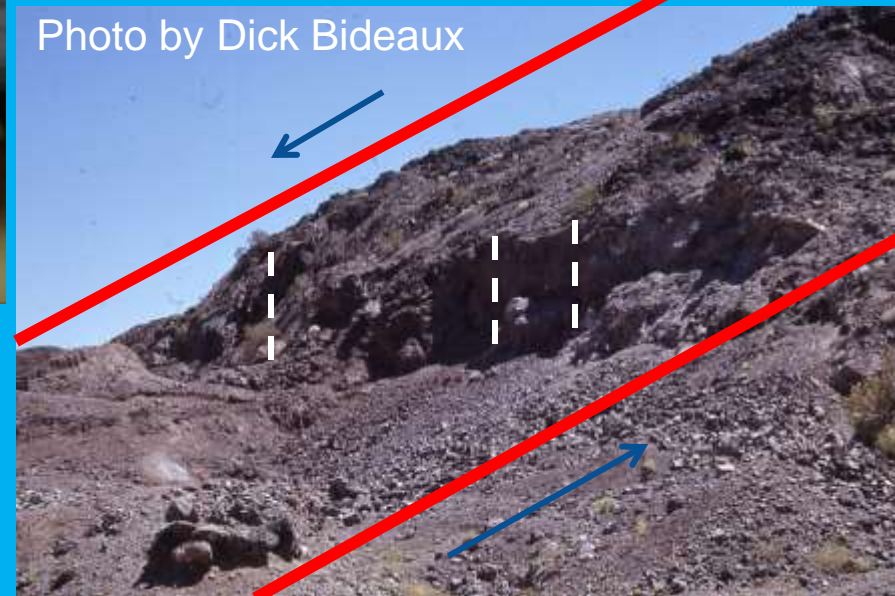
AZ Mining & Mineral Museum, MM-T565, 7 cm

Red Cloud Mine, Silver district



AZ Mining & Mineral Museum MM-T274, 9.3 cm,
Donors Les & Paula Presmyk

Red Cloud normal fault zone, vertical
channels containing wulfenite



Red Cloud Mine

Vanadinite, North Geronimo Mine, AZ Mining & Mineral Museum MM-T567, 9 cm

Vanadinite



- barrel shaped
- Soft, H=2.75-3
- hexagonal prisms
- Heavy, SG=6.8-7.1
- No cleavage

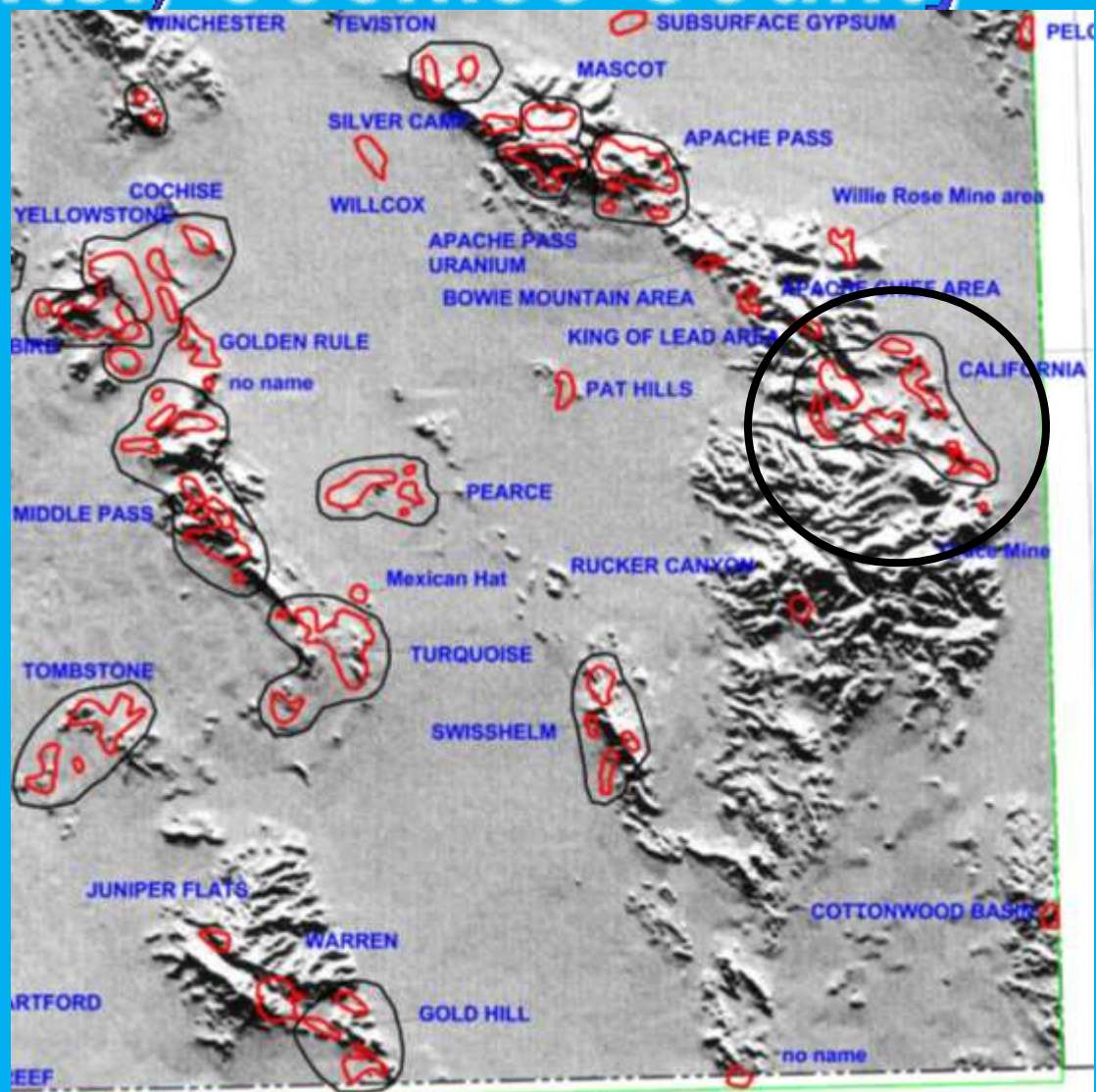
Table 1. Red Cloud mine wulfenite trace element semiquantitative analysis*

Si	0.028
As	ND 0.05
Mg	0.0052
Fe	0.0028
W	0.20
Ca	0.0031
Cr	0.0030
Sr	ND 0.001
V	ND 0.002
Other elements	nil



Edson

Hilltop Mine, California district, Chiricahua Mts., Cochise County



Wulfenite, Hilltop Mine, California district, Chiricahua Mts., Cochise Co., from Arthur Montgomery collection 1972, Rock Currier photo, www.mindat.org

Hilltop Mine, Chiricahua Mts.

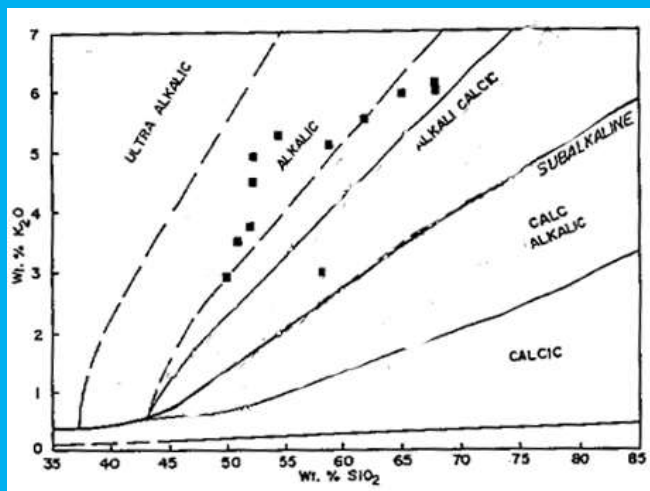
- Alkali-calcic
- Pb-Zn
- mid-Tertiary
- Galena, cerussite, sphalerite, wulfenite, & spotty copper oxides and scheelite
- In fissure veins and in irregular replacement lenses and bodies in banded and tilted, silicified Mississippian to Permian limestones and quartzites
- Extensive workings from several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



AZ Mining & Mineral Museum MM-T549, 11.5 cm

Quartz Alkalic - Laramide

- Old Yuma Mine
- ~ 72 Ma
- Amole pluton
- Amole district
- Tucson Mts.



Old Yuma Mine, Amole district, Jim & Gail Spann

Old Yuma Mine, Amole district, Tucson Mts.

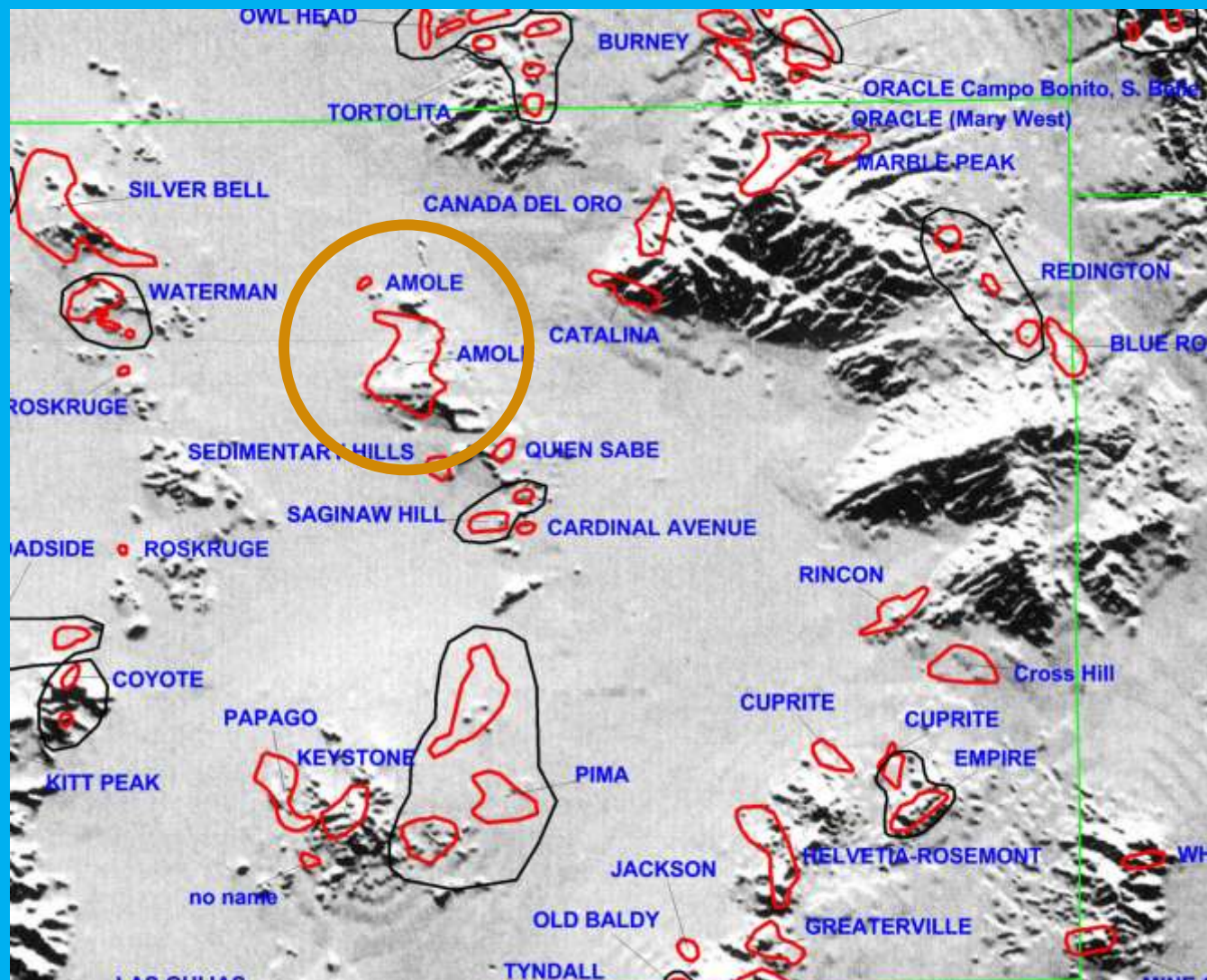
- Quartz Alkalic
- Laramide
- Au, Pb, Zn



Wulfenite, owners John & Karen Cesar

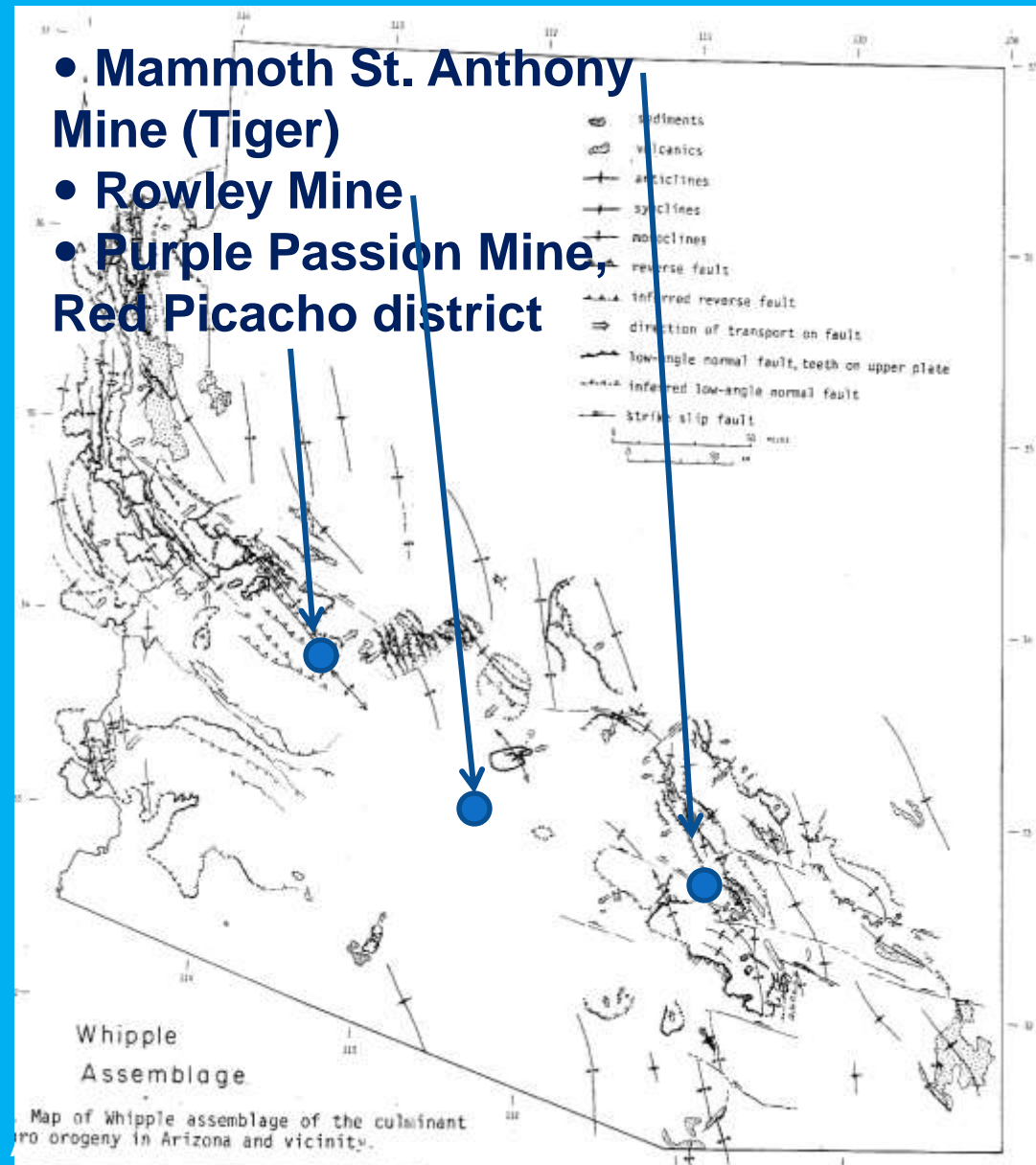


Vanadinite, owner Dick Morris



Quartz Alkalic - Mid-Tertiary

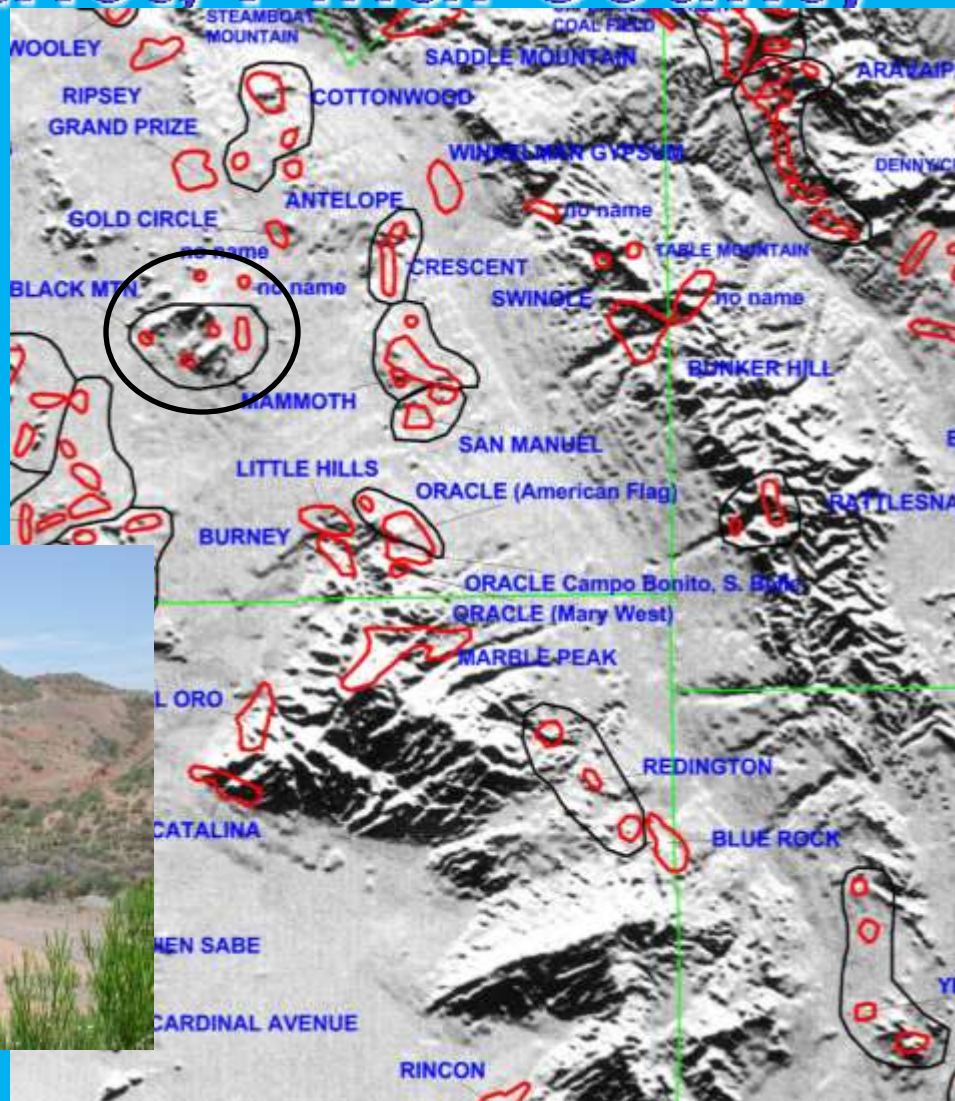
- 20-12 Ma
 - Tiger (Mammoth-St. Anthony Mine, Mammoth district, Pinal County)
 - Rowley Mine, Painted Rock district, Maricopa County
 - Red Picacho district (Purple Passion mine) – (date, etc. uncertain)



Mammoth-St. Anthony Mine, Mammoth district, Pinal County

- Quartz alkalic –
- Pb-Zn-Ag zones
- mid-Tertiary

Collins Cut, Tiger, AZ



Mohawk shaft, Tiger, Arizona

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) that was most intensely shattered and brecciated
- Deposit was oxidized and faulted, then wulfenite and vanadinite were deposited with later oxidation
- 6,314,822 pounds MoO_3 produced 1881-1947.



Wulfenite & cerussite, Flagg Mineral Foundation

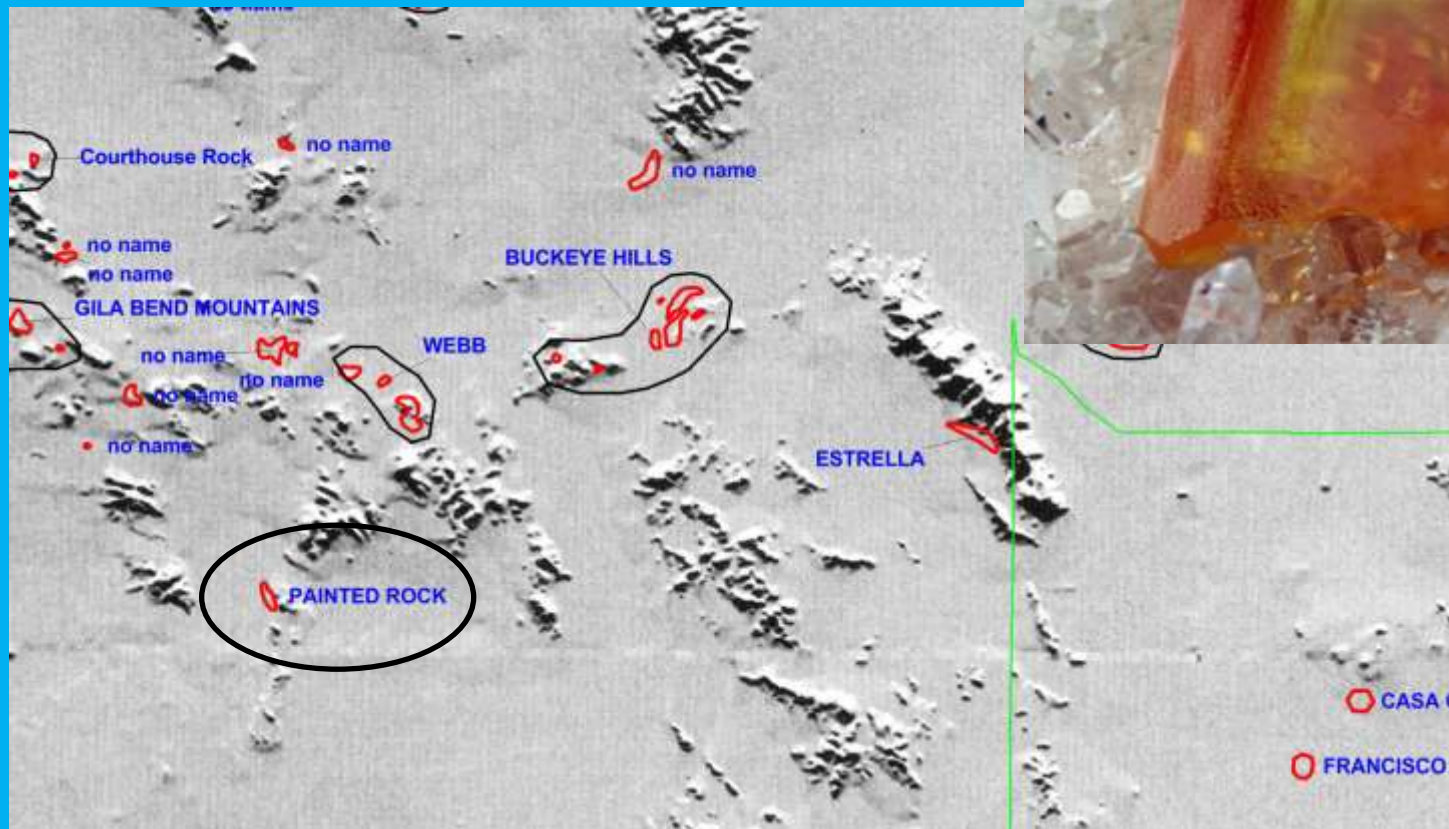
Mammoth-St. Anthony Mine (Tiger)



AZ Mining & Mineral Museum, MM-T553, 7 cm, Schultz Cut circa 1880s

Rowley Mine, Painted Rock district, Maricopa County

- Quartz alkalic
- Pb-Zn-Ag zones
- mid-Tertiary 25-13 Ma



Red dot wulfenite, 2.58 mm crystal, Domenico Priete collection, photo Matteo Chinellato, www.mindat.org

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),



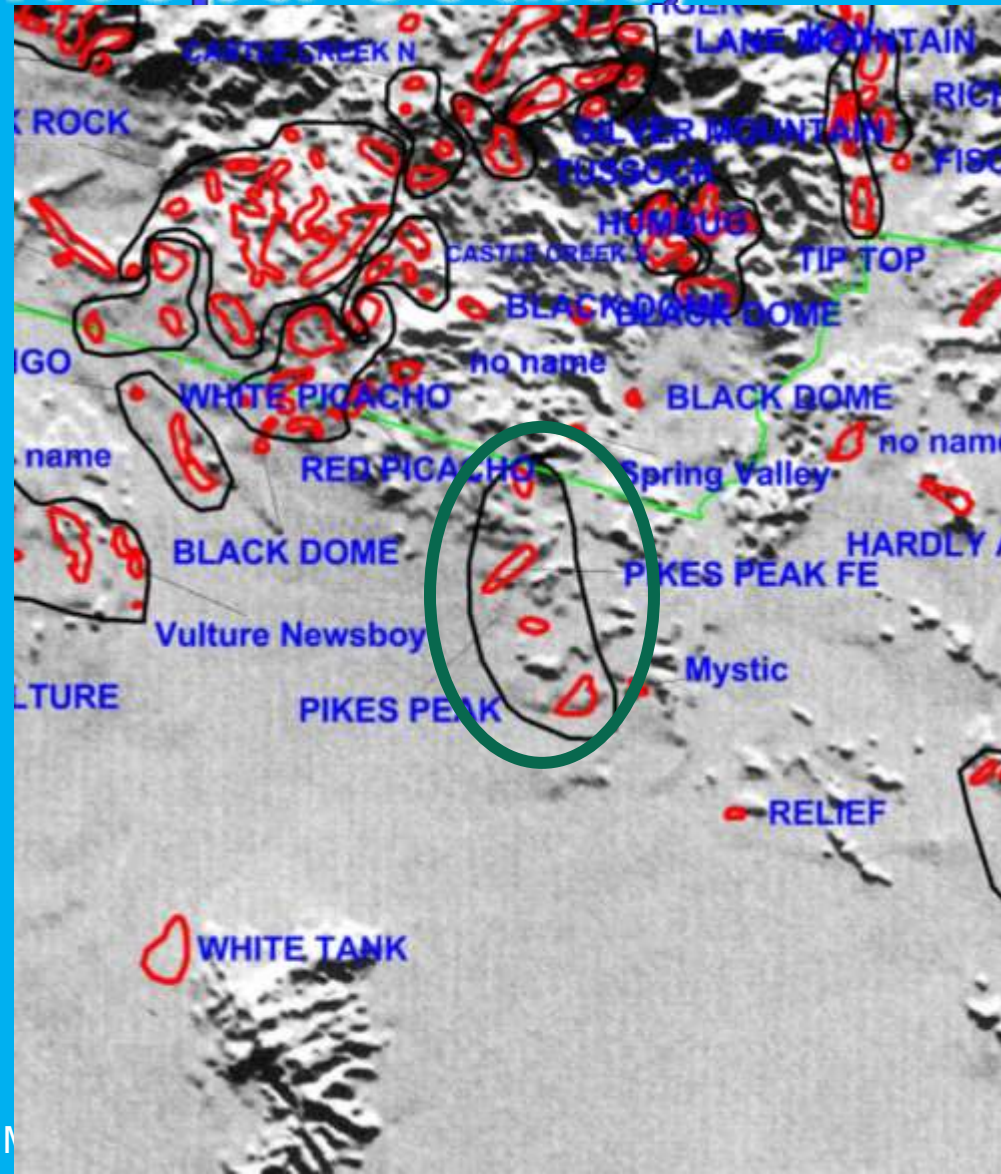
AZ Mining & Mineral Museum, MM-S201, 12.5 cm,
Donor James Horner

Purple Passion Mine, Red Picacho district, Maricopa County

- Quartz alkalic? In Pb-Zn-Ag zones
- on fluorite near galena
- mid-Tertiary?



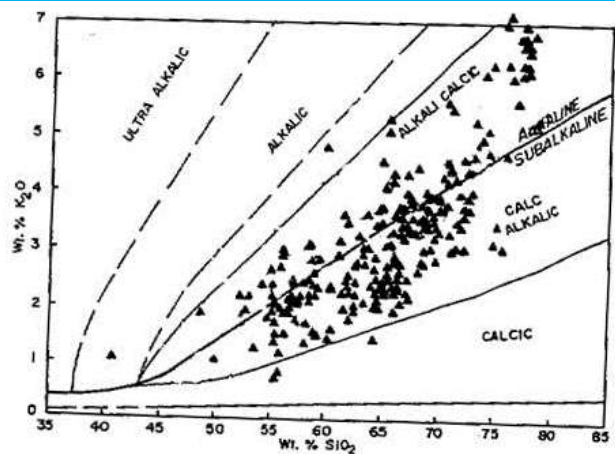
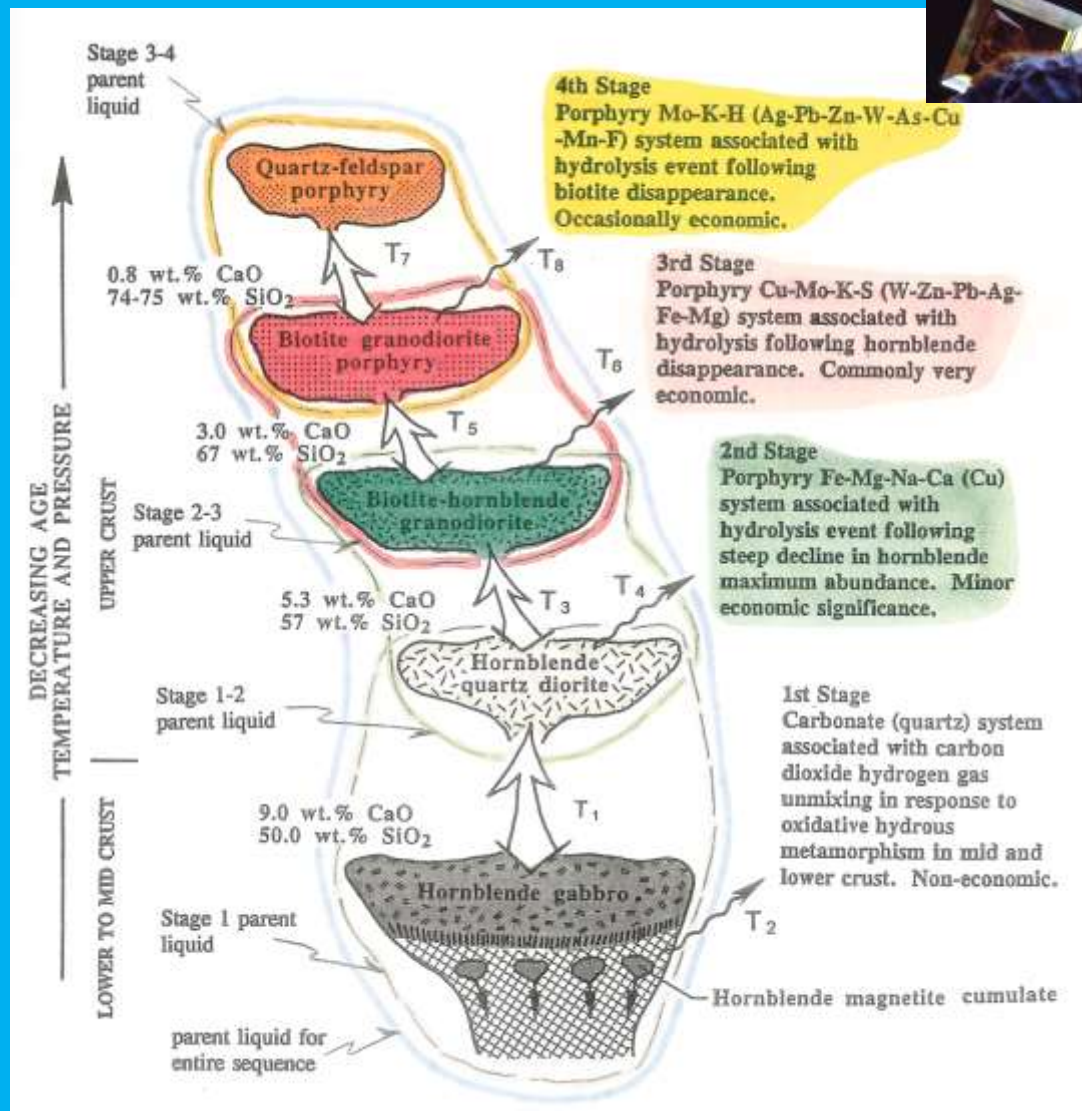
Wulfenite spicules, 2 mm long, Purple Passion mine, Red Picacho district; Steve Stuart, 2004, www.mindat.org



Calc-alkalic – Later 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

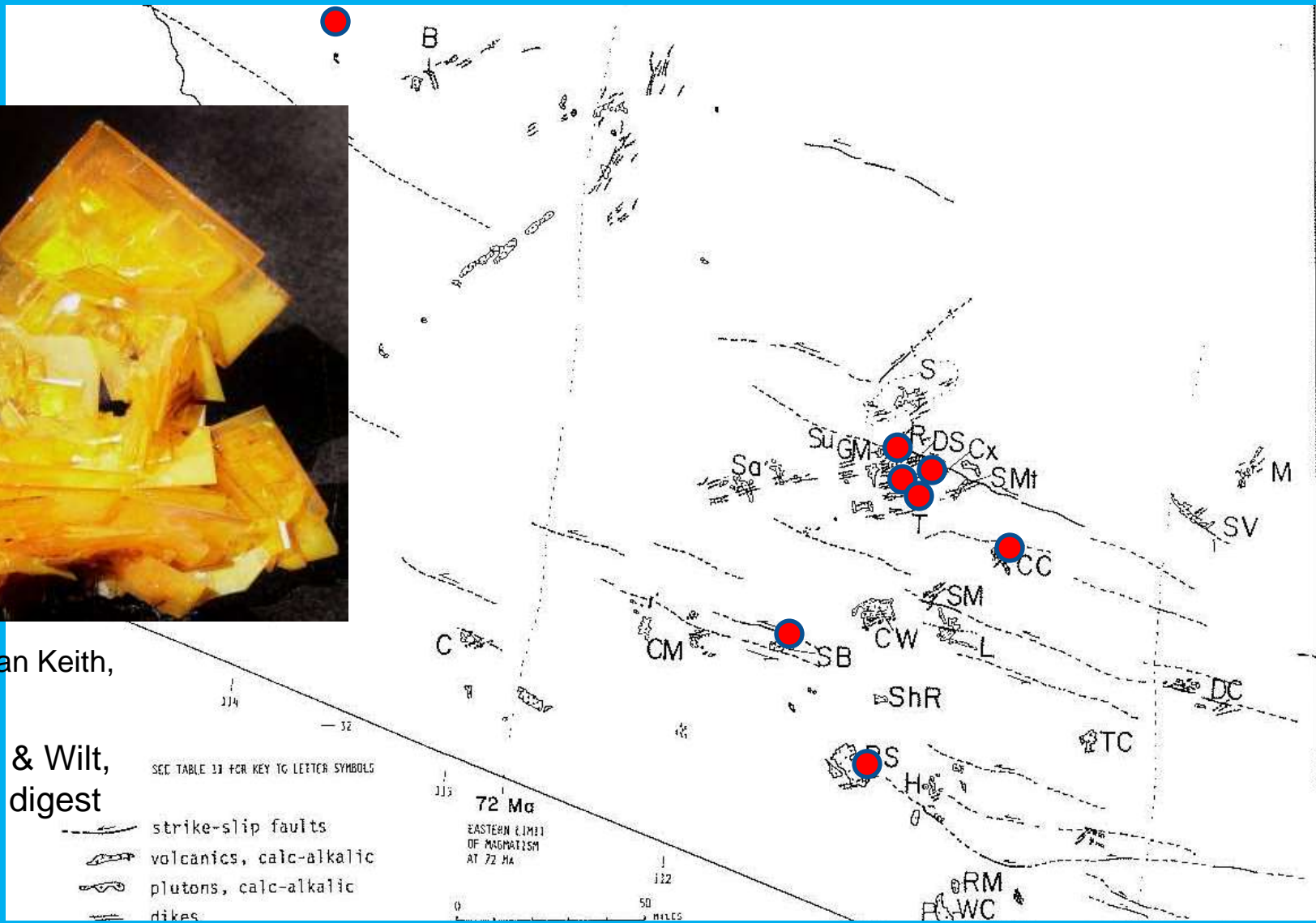
Stage 4 Oxidized Pb-Zn zones of Porphyry Copper deposits

Chilito Mine, Christmas Mine, 79 Mine, Banner district

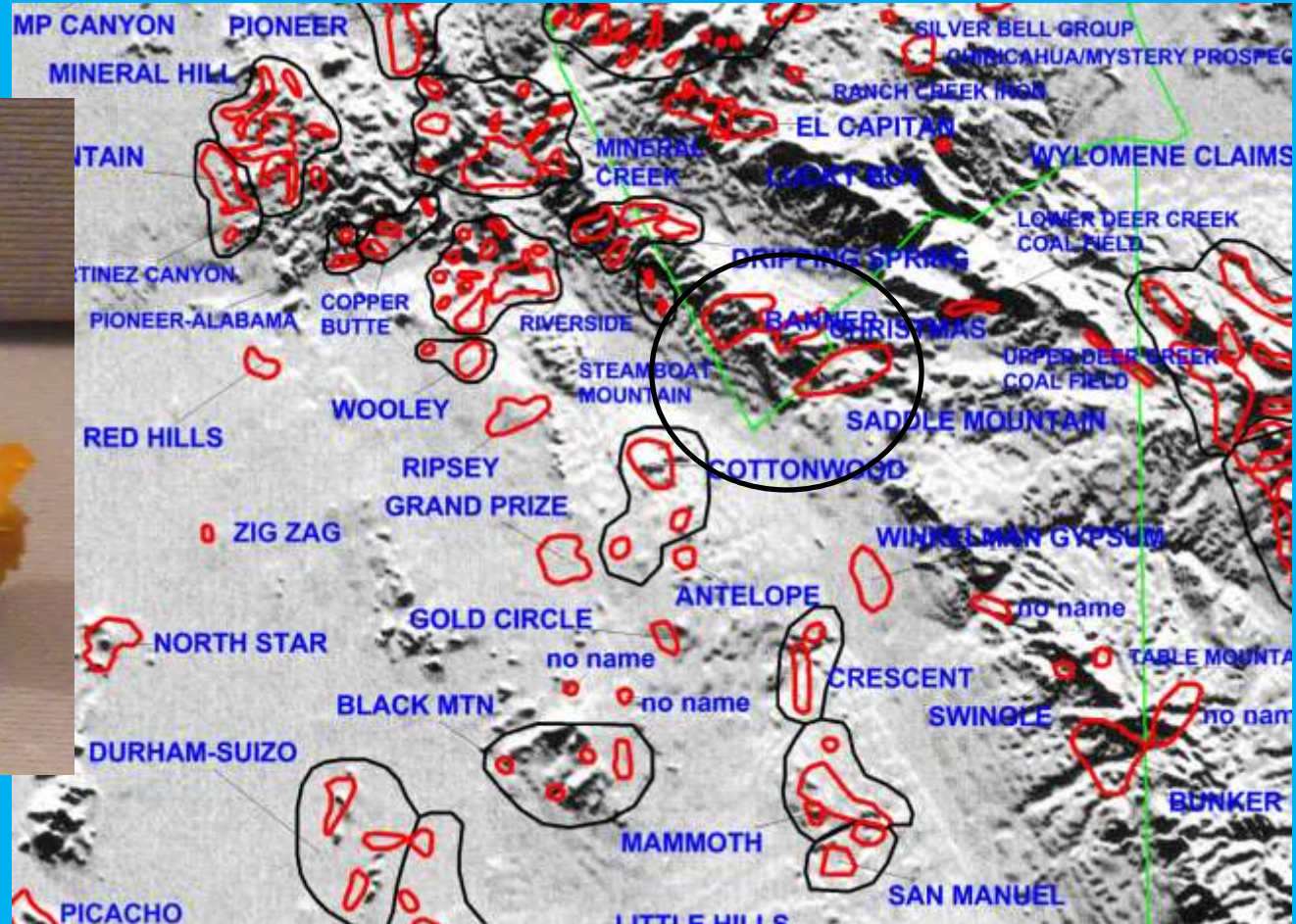


Owner Stan Keith,
1-2 in.

From Keith & Wilt,
1986, AGS digest



Banner district - Calc-alkalic - “outer”/ later (Stage 4) Pb-Zn zones



Owner Stan Keith,
1-2 in.

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



AZ Mining & Mineral Museum, MM-S698, 10.8 cm

79 Mine (Banner district)



Wulfenite, 79 mine, 4th level on main fault, large crystal 1.2 in. on edge, collected by Stan Espenshade, mid 1970s, photo and specimen by Stan Keith.

Finch Mine (Banner district)

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



AZ Mining & Mineral Museum, MM-T305, 8.2 cm, Donors Robert & Catherine Sanders

Queen Creek Mine (S of Superior)

- Good cabinet-sized specimens from the porphyry copper districts are not spectacular specimens that are attractive to most collectors



Wulfenite, Queen Creek/Belmont Mine, Pioneer/Superior district, Pinal Co., 3 in.

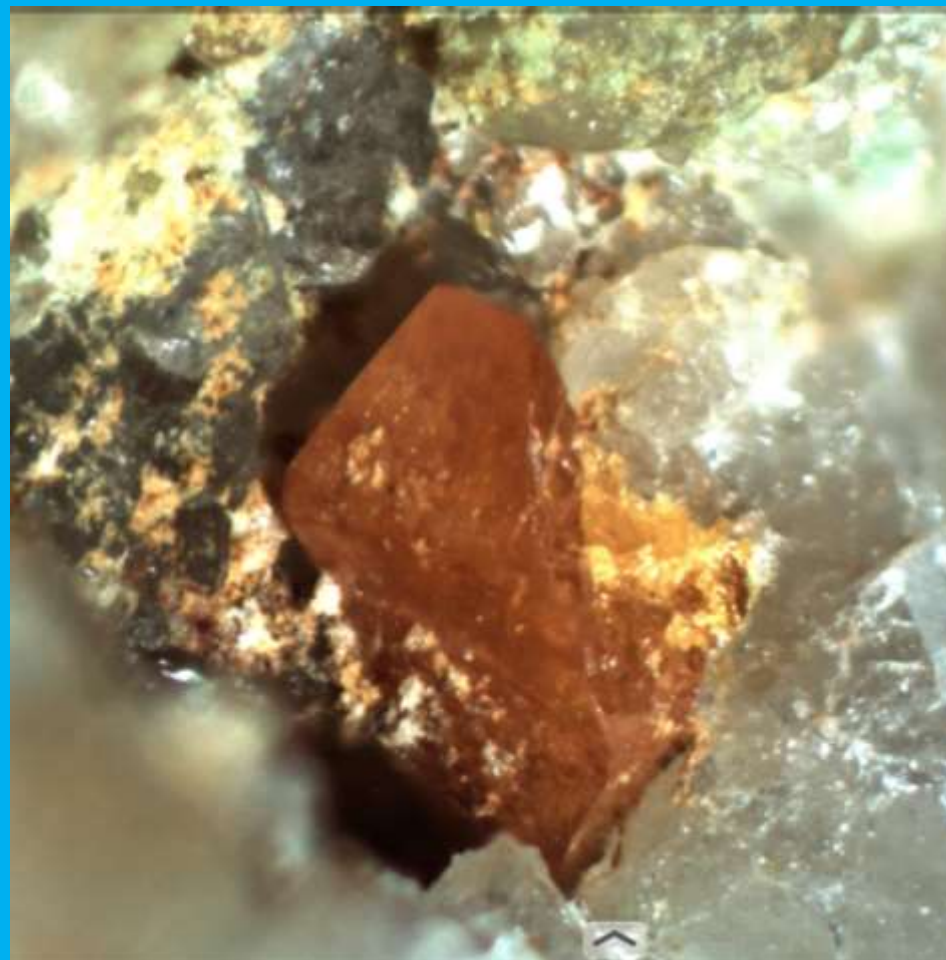
Silver Bell Mine, Pima County



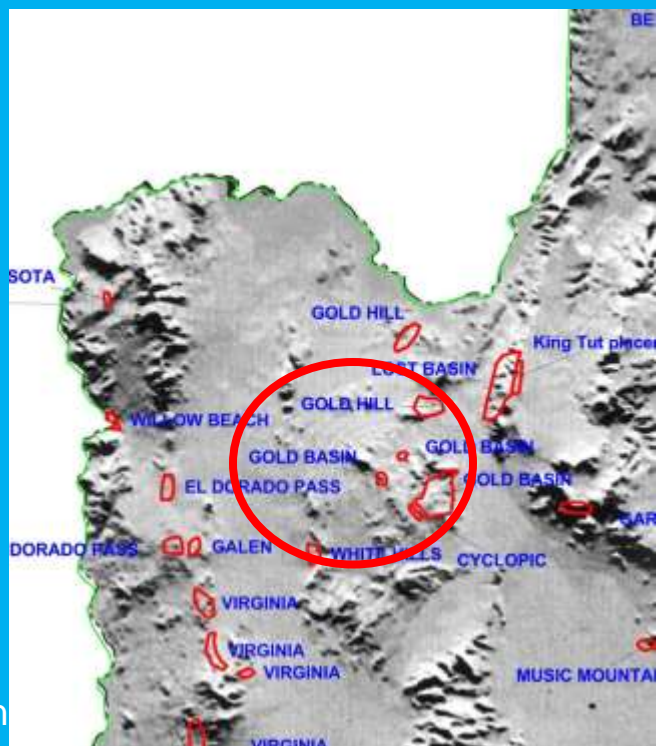
Wulfenite under calcite, Silver Bell district, Silver Bell Mts., Pima Co., 7 mm, ex Ray Grant Collection, Chris Whitney-Smith collection & photo, www.mindat.org

Peraluminous Calcic Wulfenite

- Jurassic or Laramide
 - Mildren mine, Cababi district
 - Vulture Mine
 - Gold Basin district
 - Shelby Mine
 - Junction Mine
 - Herradura, Mexico
 - Wulfenite is guide to gold



Dipyramidal wulfenite, Shelby Mine, Gold Basin District, Mohave Co., FOV 3 mm, former Phil Partington collection, Rolf Luetcke specimen & photo, www.mindat.org



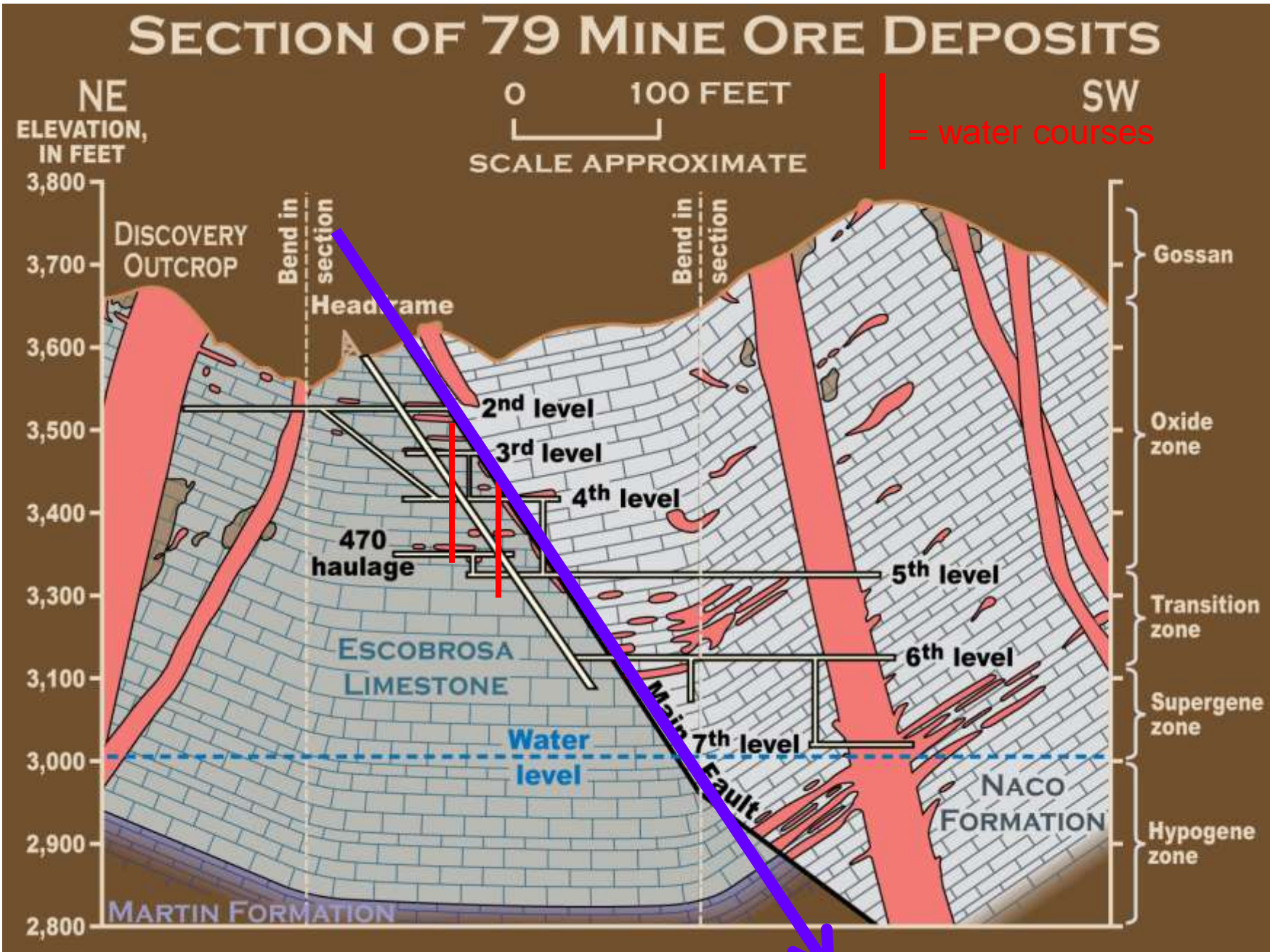
Wulfenite Formation

- Oxidized zones – supergene zones of Lead-Zinc deposits
- Largest, best specimens are formed in water courses
- Wulfenite is deposited away from the primary ores
 - Examples with thick tabular plates
 - Glove mine,
 - 79 mine,
 - Red Cloud mine
 - Defiance etc. Gleeson Ridge

79 Mine, Banner district



Wulfenite in open space watercourse near main fault, 79 mine, John Callahan photo



Water Courses

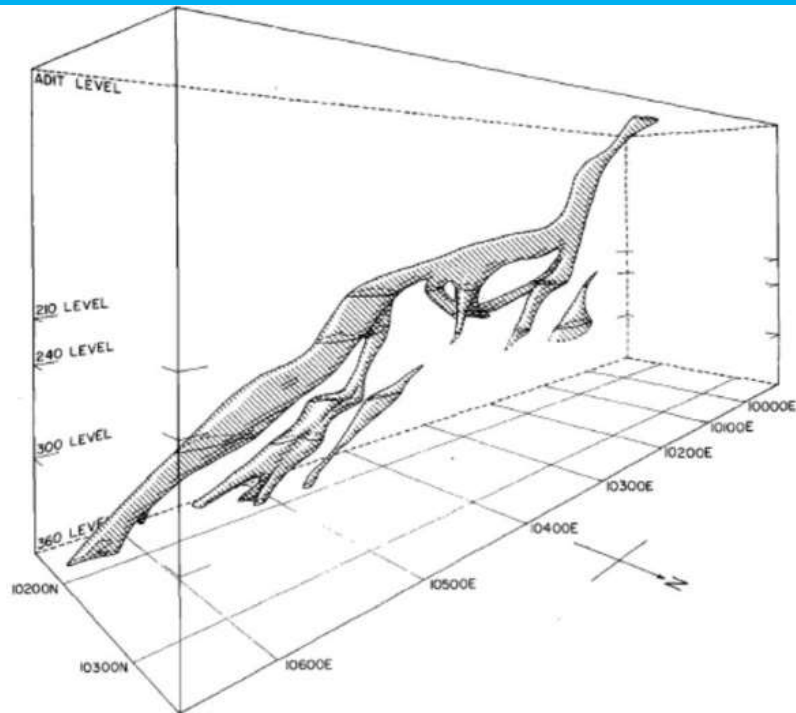


FIG. 5. Generalized view of the Glove ore body.

Olson, 1962, Glove mine



Main fault exposure in wulfenite room,
79 mine, Stan Keith photo

Wulfenite Colors

• Colors

- Colorless (no impurities)
- Red (Chromate)
- Orange-yellow (Arsenate)
- Yellow (Arsenate)
- Brown (iron?)
- Grey/black (Manganese?)
- Greenish (arsenic-manganese?)



Purple
Passion



Red Cloud



Glove



Hilltop



Defiance



Glove

Mineral Associations

- anglesite PbSO_4
- cerussite PbCO_3
- mimetite $\text{Pb}_5(\text{AsO}_4)_3\text{Cl}$
- vanadinite $\text{Pb}_5(\text{VO}_4)_3\text{Cl}$
- pyromorphite $\text{Pb}_5(\text{PO}_4)_3\text{Cl}$
- descloizite $\text{PbZnVO}_4(\text{OH})$
- limonite $\text{FeO} \cdot (\text{OH}) \cdot n\text{H}_2\text{O}$
- fornacite $\text{Pb}_2\text{Cu}(\text{AsO}_4)(\text{CrO}_4)(\text{OH})$
- hemimorphite $\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2 \cdot \text{H}_2\text{O}$
- smithsonite ZnCO_3
- aurichalcite $(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6$
- willemite Zn_2SiO_4
- diopside $\text{Cu}_6(\text{Si}_6\text{O}_{18}) \cdot 6 \text{H}_2\text{O}$
- rosasite $(\text{Cu,Zn})_2(\text{CO}_3)(\text{OH})_2$
- chrysocolla $(\text{Cu,Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$
- fluorite CaF_2



Cerussite, Mammoth-St. Anthony Mine (Tiger), Pinal County

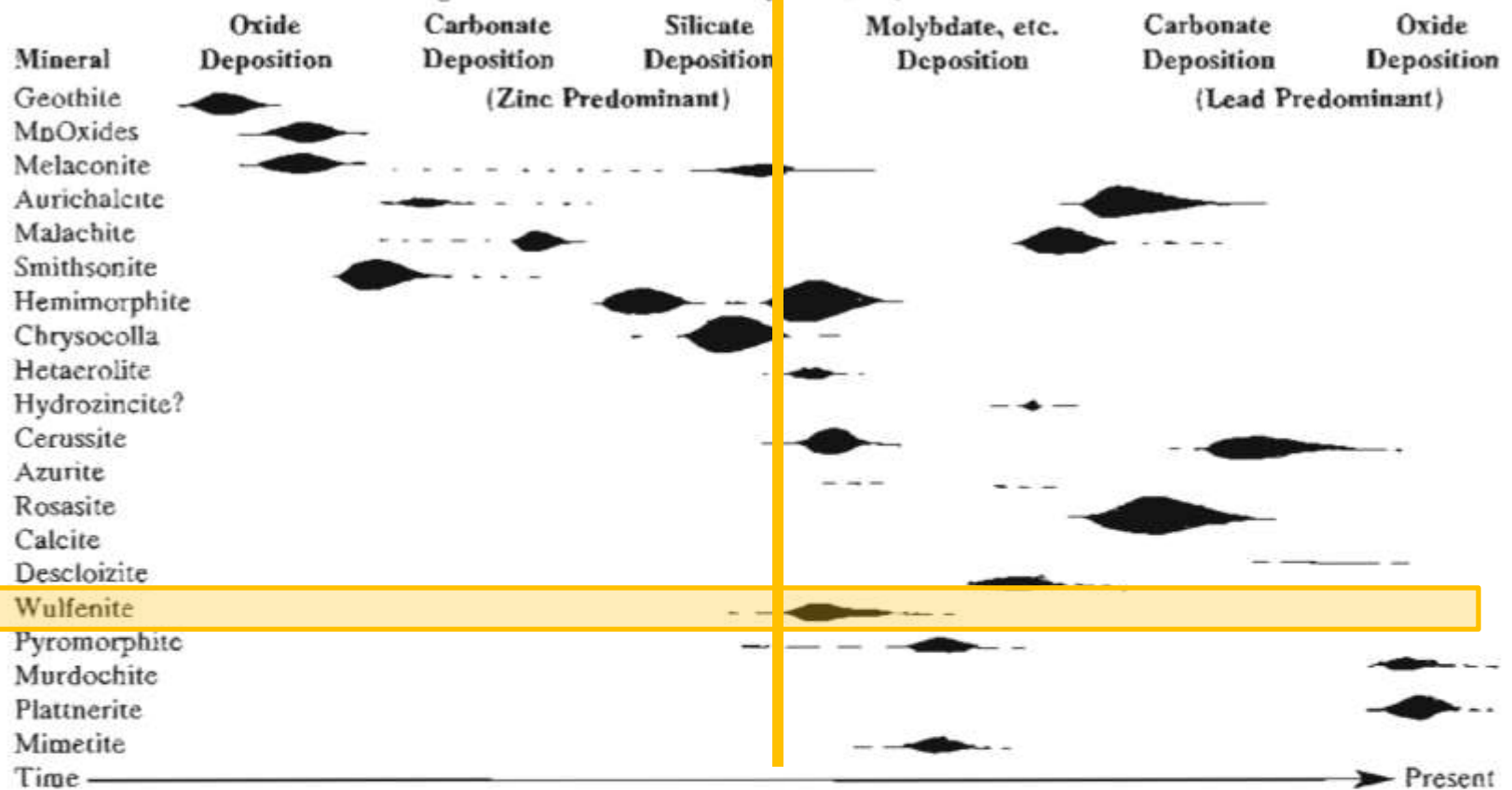
On loan to AZ Mining & Mineral Museum in 2010 from AMMMF (Flagg Mineral Foundation)

- calcite CaCO_3
- quartz SiO_2
- never on molybdenite MoS_2

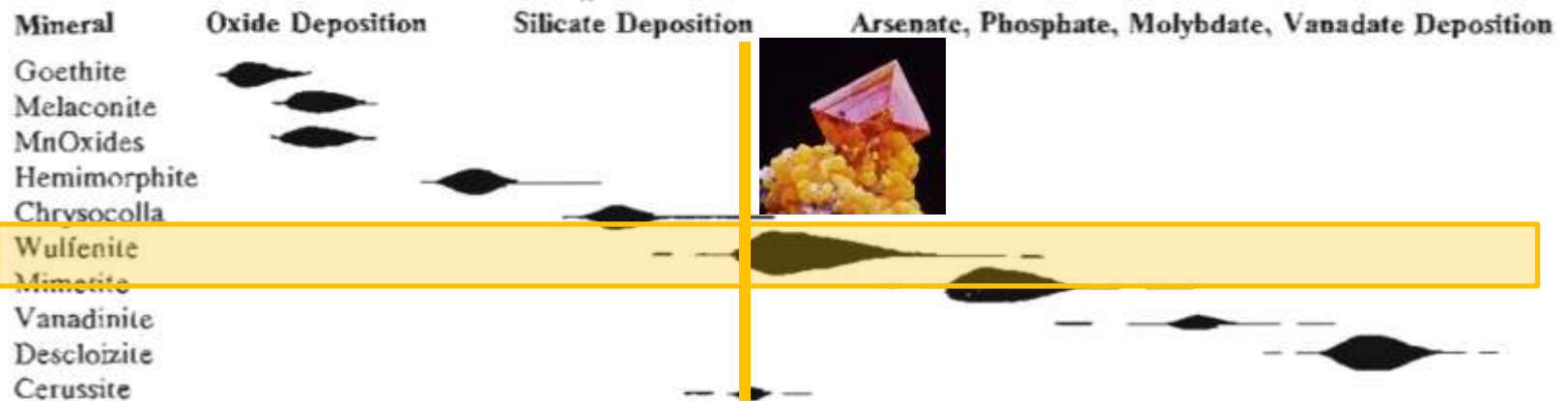
Mineral Paragenesis - 79 Mine

TABLE V OXIDATION OF TRANSPORTED IONS

Paragenesis in the 79 Breccia System (3rd, 4th and 470 Levels)



Paragenesis in the Main Fault (4th Level)



Conclusions

- 275 wulfenite occurrences in Arizona in www.mindat.org
- Nearly all wulfenite occurrences were oxidation products of deposits with primary galena
- No wulfenite found in any primary deposits that contained primary molybdenite (porphyry copper and porphyry molybdenum deposits)
- Color is related to impurities installed during early colloidal element/ion diffusion under meteoric conditions
- Best wulfenite specimens are in water courses/large open fillings in Alkali-Calcic and Quartz Alkalic districts away from immediate lead source
- Enough Mo is present as a chemical component of meteoric waters to stabilize wulfenite after oxidation of the lead source (typically after cerussite formation).



Wulfenite in Arizona

Mineralogy:

- Chemical & Physical Characteristics
- Mineralogical Associations

Geologic Setting: (age of primary deposit – wulfenite later)

- Alkali-calcic – lead-zinc-silver districts (Stage 3 and 4)
 - **Jurassic – 170-160 Ma – Defiance, Silver Bill**
 - **Laramide – 85 - 65 Ma - Glove**
 - **mid-Tertiary – 30-20 Ma – Red Cloud**
- Calc-alkalic – in later, outer Pb-Zn-Ag zones (Stage 4)
 - Laramide porphyry copper - 75-60 Ma – 79 Mine
- Quartz alkalic – in Pb-Zn-Ag zones with stage 4 rhyolites
 - Jurassic - Bisbee
 - Laramide - **Old Yuma**
 - **mid-Tertiary - Tiger, Rowley**
- Peraluminous calcic
 - Laramide – Gold Basin
- Peraluminous calc-alkalic
 - Precambrian

Paragenesis - Oxidized zones , water courses

