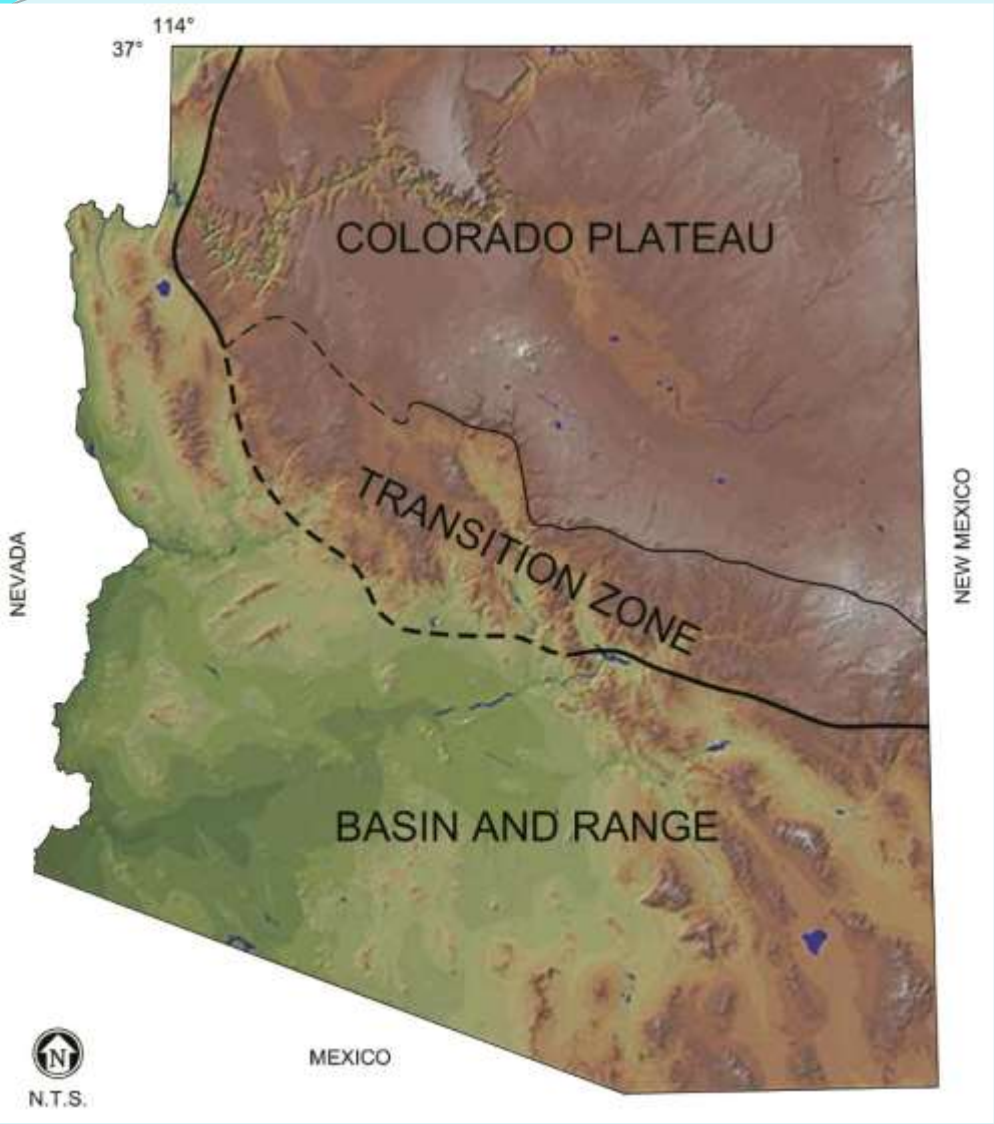
Geology, Mines, & Minerals, Tombstone, Arizona

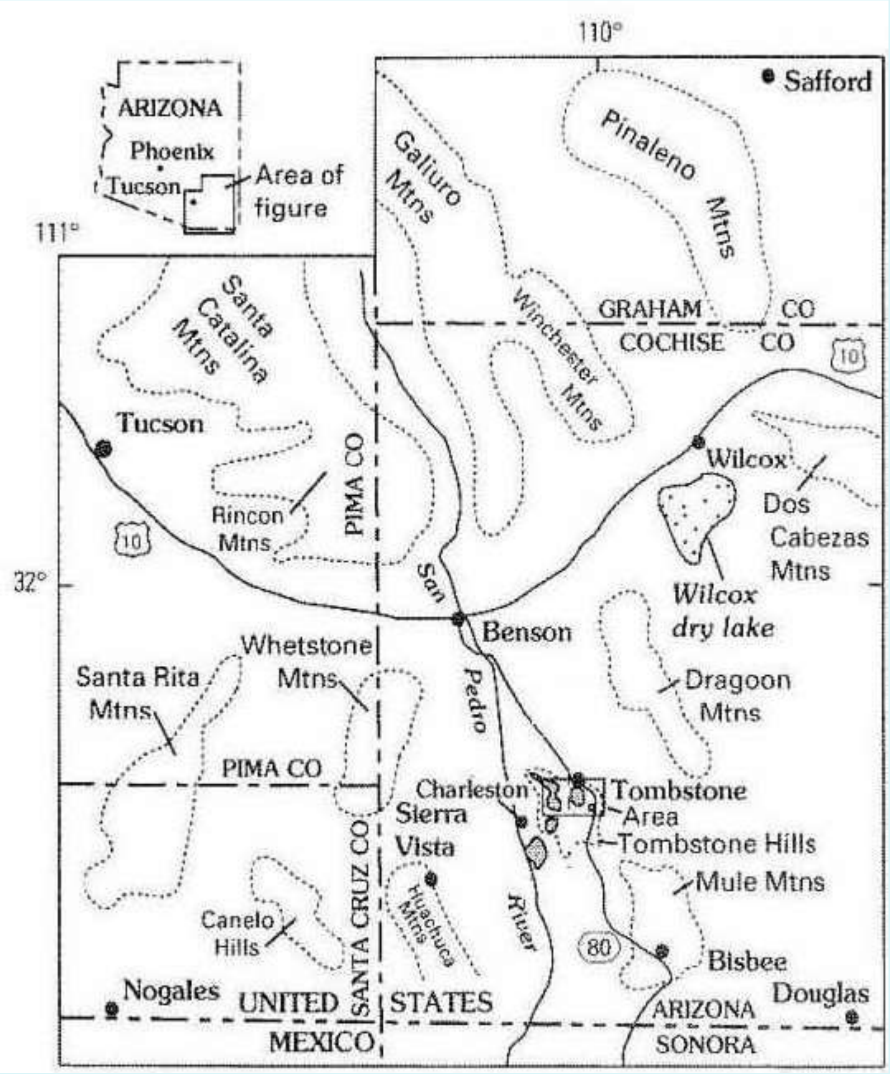
by Jan C. Rasmussen

Acknowledgements

- SRK Consulting, Tucson
- Burton Devere – Bonanzas to Borrascas
- Peter Megaw – photomicrograph specimens
- Sugar White – photography of Megaw specimens
- TGMS 2012 show displays
- Mindat.org
- Jim Briscoe

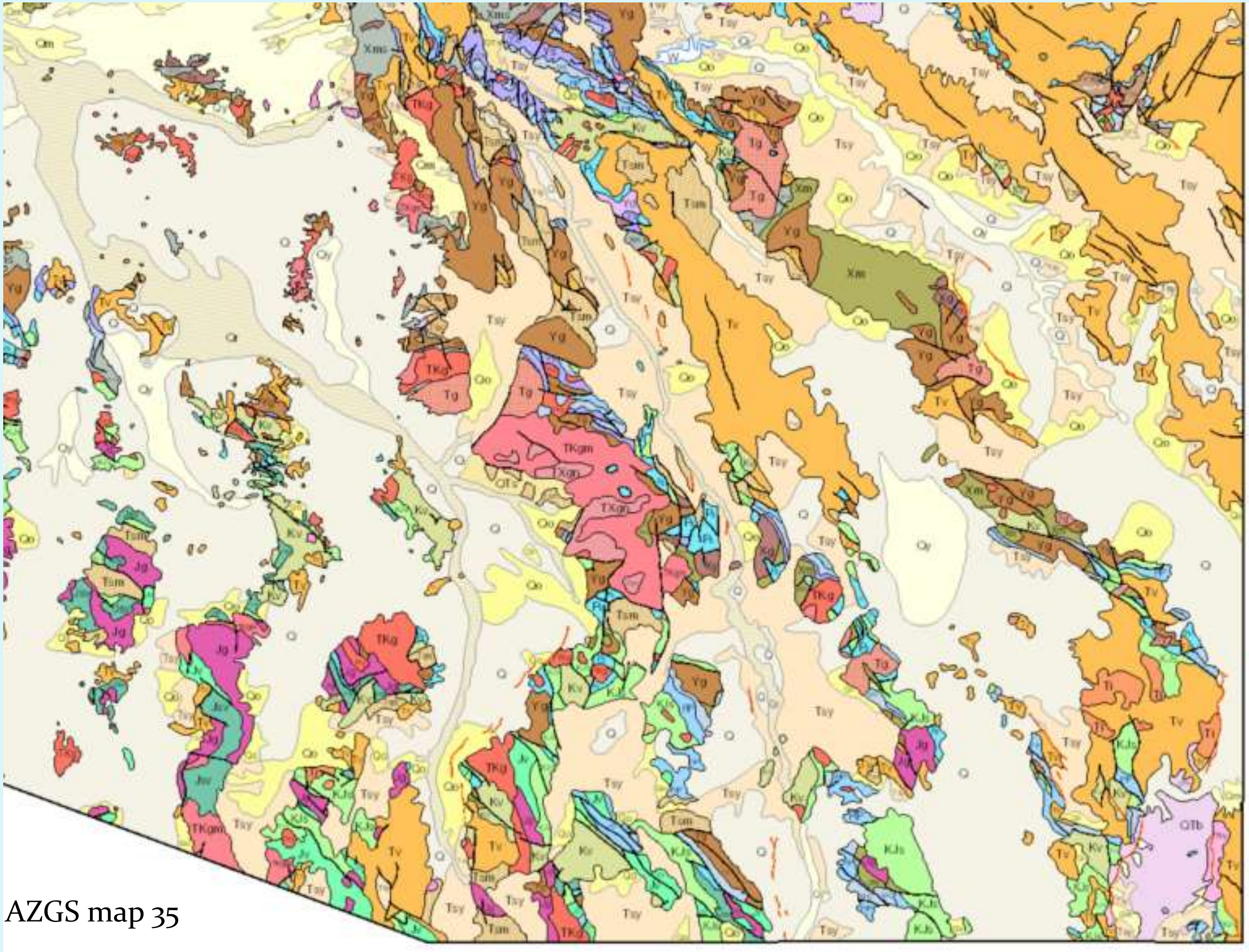
Location: Cochise Co., SE Arizona





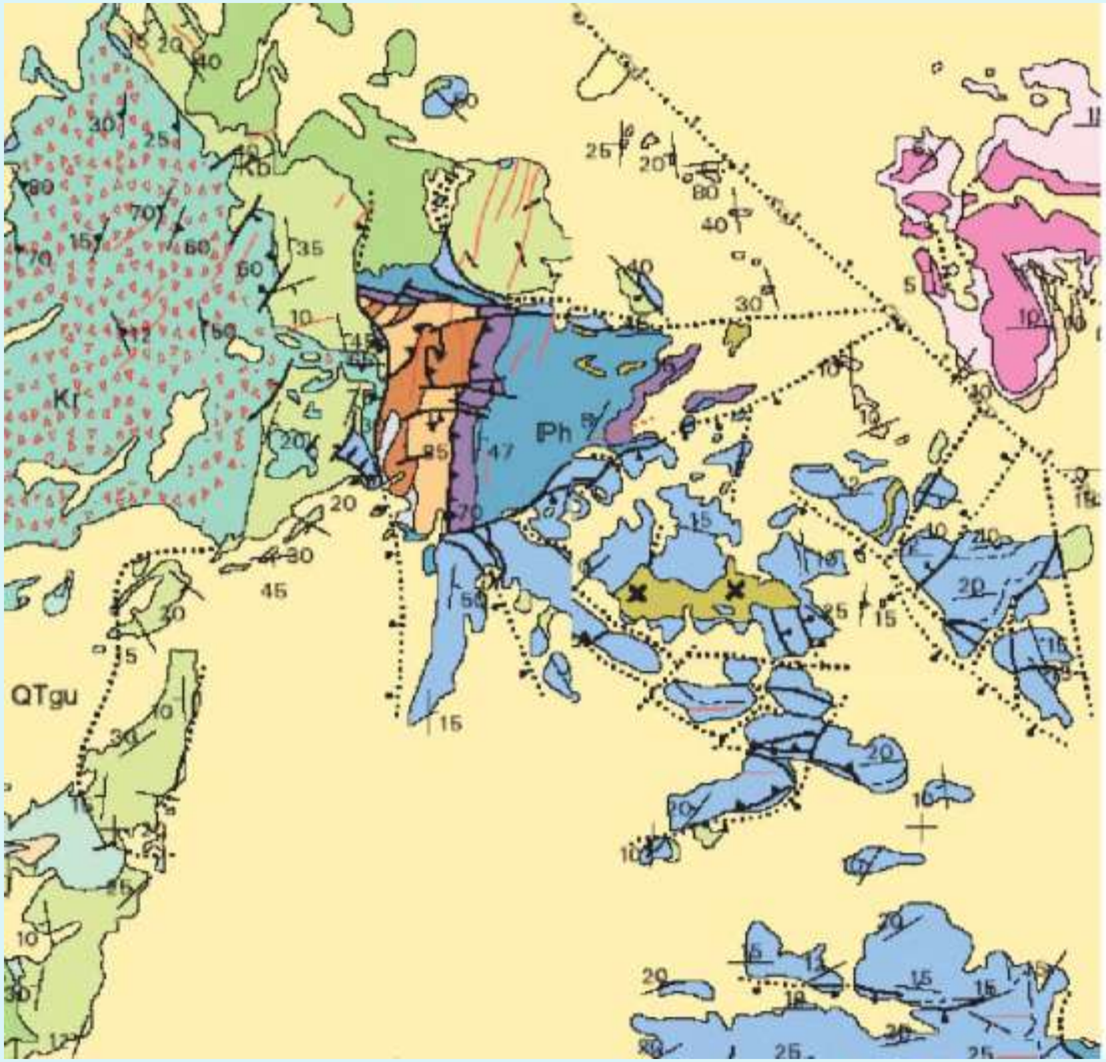
Source: SRK Consulting

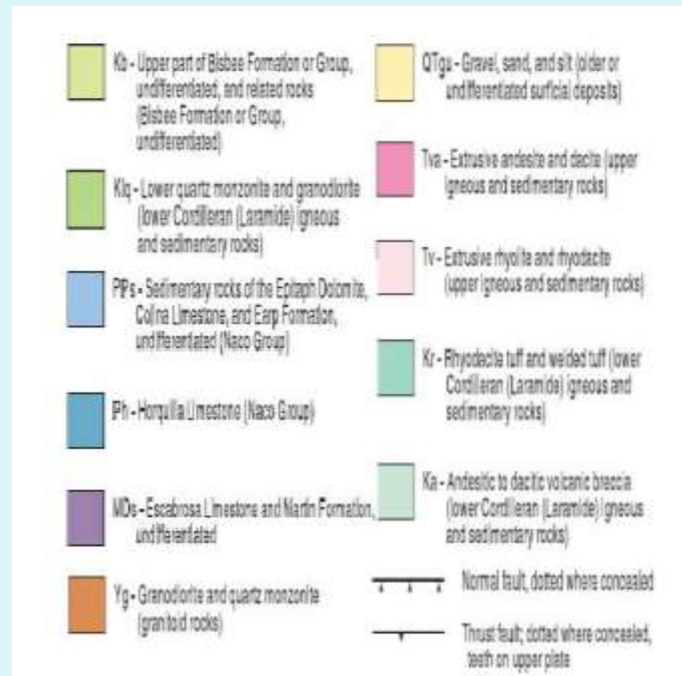
Geologic map, Cochise County



Source: AZGS map 35

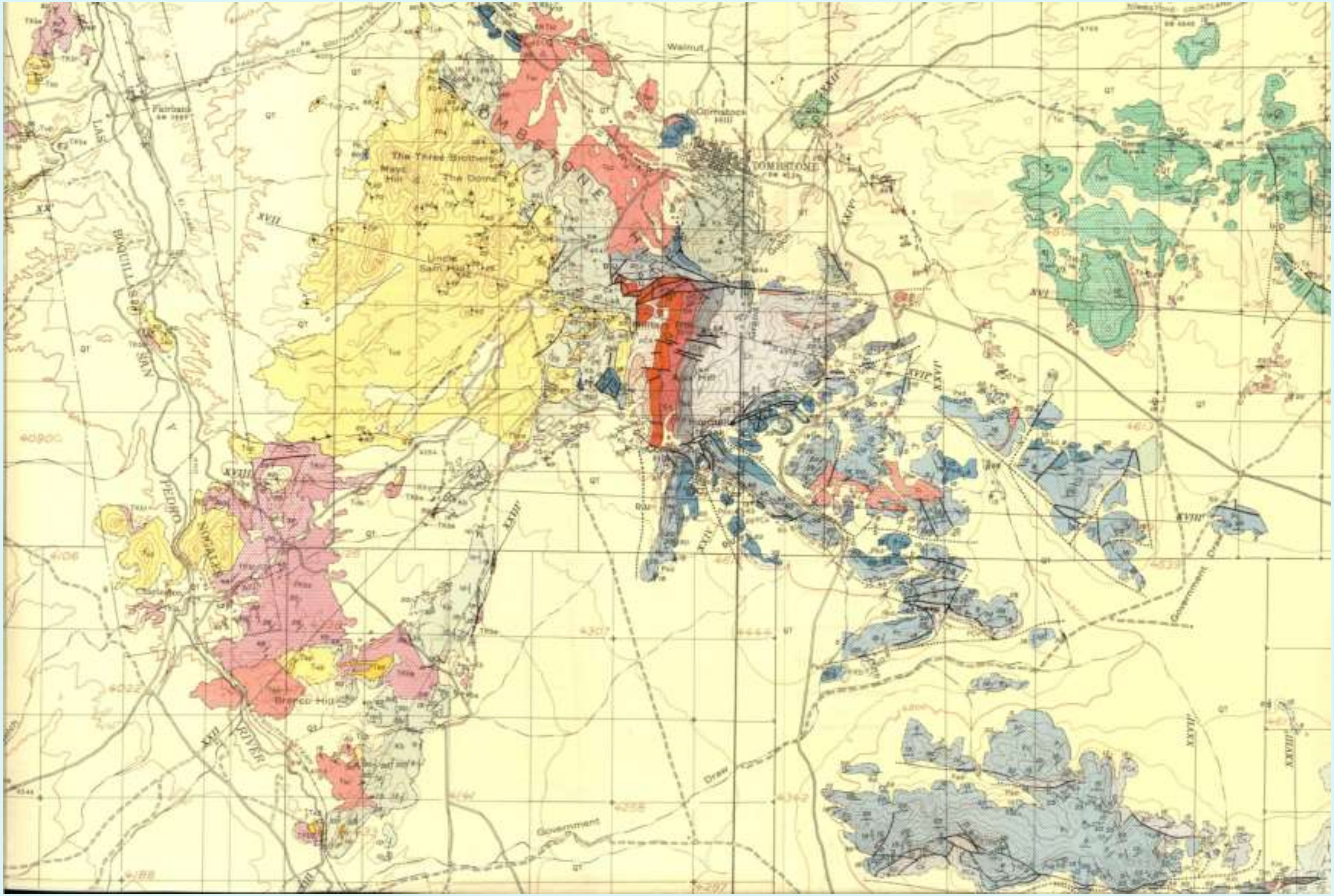
Geologic map, Tombstone Hills





Source: Drewes, USGS geologic map

Gilluly geologic map



Tombstone Hills, looking north

Paleozoic

Jan and Colina Limestone (Permian)

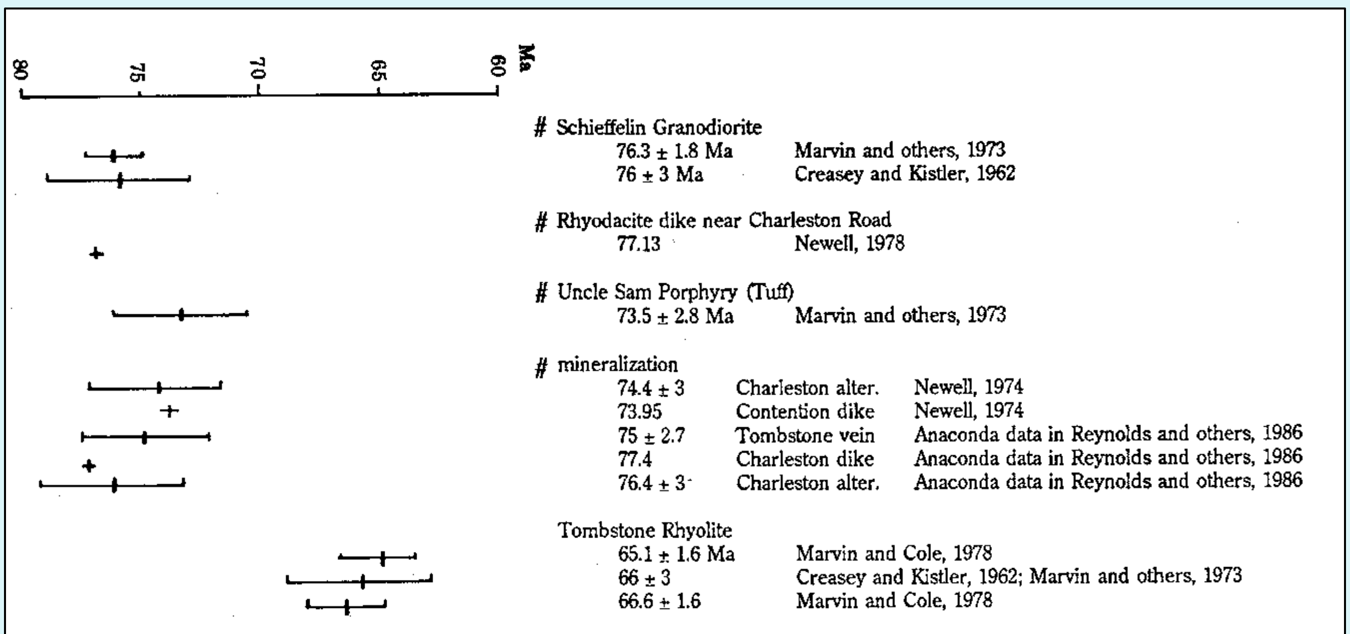
Bisbee Group – Lower Cretaceous

Laramide orogeny

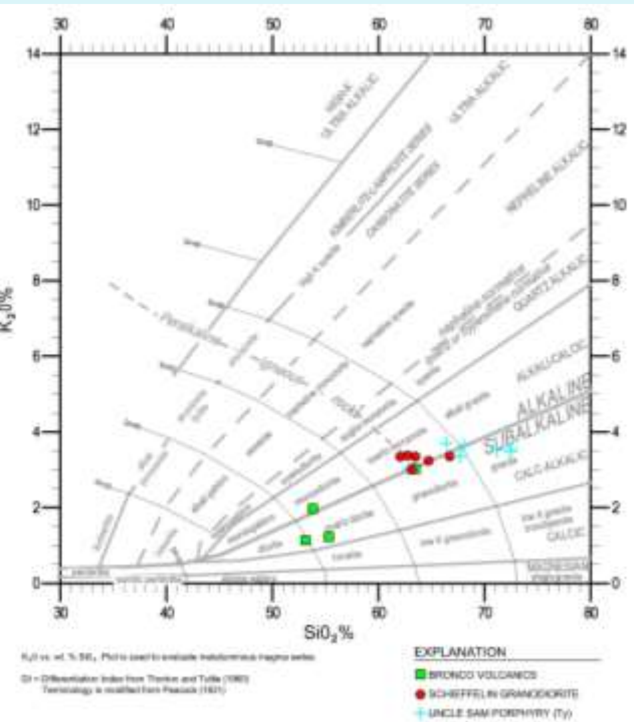
Orogenic Phase	Age (Ma)	Sedimentation	Magmatism	Structures	Resources
Late	55-43	none	widespread, 2-mica, garnet-muscovite granitoid stocks, batholithic sills, aplo-pegmatite dikes, peraluminous, calc-alkalic	SW-directed, low-angle thrusts widespread, shallowly dipping mylonitic zones, general SW shear	mesothermal, Pb-Zn-Ag veins, minor Cu-Au veins, Au in quartz veins, kyanite, tungsten
Middle	65-55	none	calc-alkalic hydrous, numerous epizonal stocks & small batholiths, local sporadically preserved volcanics, widespread regional NE to ENE-striking dike swarms	widespread NE- to ENE-striking regional dike swarms between E-W to ENE striking structural elements of the Texas Zone that moved in left-slip	large disseminated porphyry Cu systems, locally containing skarns & veins; Cu-Zn-Ag veins; Pb-Zn-Ag veins, skarns or replacement marginal to plutons; Cu-Zn skarns adjacent to epizonal porphyritic plutons; composite, epigenetic, mesothermal, zoned disseminated porphyry Cu systems, with several zones in a large system
Early	85-65	continental clastics; large exotic blocks interbedded volcani-clastics	alkali-calcic, hydrous plutonism & pyroclastics, volcanism, some epizonal quartz monzonite porphyritic stocks; lower= andesite dacite breccia; upper= dacite-rhyolite ignimbrite flows & ash flows	NW-striking, NE-directed folds & thrusts with 1-10 km shortening	mesothermal, Pb-Zn-Ag veins & replacement deposits
Earliest	89-85	coarse continental clastics; generally lacking volcanic components, except in upper parts; angular unconformity over mid-Cretaceous; accumulated in E-W trending basins adjacent to block uplifts; conglomerate & alluvial fans	quartz alkalic hydrous, volcanics 7 small stocks, small volcanic centers, small epizonal porphyritic stocks; volcanics highly brecciated; latites & monzonites	E-W block uplifts; E-W to WNW-ESE striking high-angle reverse faults (60 degrees) with shortening 5-7 km vertical throw, 1-3 km horizontal throw; bidirectional transport N- or S-directed or NNE= or SSW-directed either side of block uplifts	epigentic Cu-Au hydrothermal

Laramide – Government Butte

Cretaceous Schieffelin Granodiorite



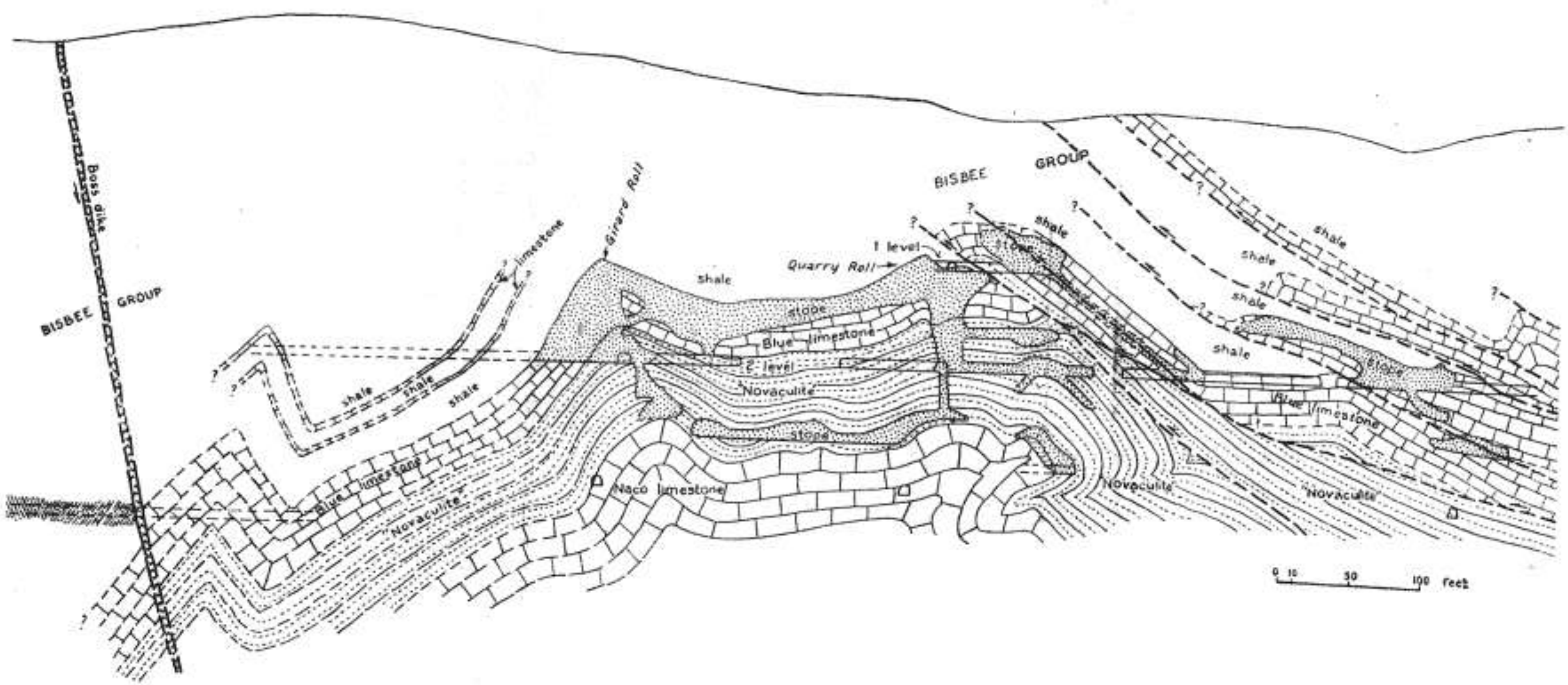
Cretaceous Schieffelin Granodiorite, Uncle Sam Tuff



MC Type	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MACo
SAMPLE NO.	T11	T12	T13	M	A1, 1, p. 99	A2, 2 p. 99	T25	T2a2	T2a3	T2a5
reference	Lang 1991	Lang 1991	Lang 1991	Clarke 1915	Gilluly 1956	Gilluly 1956	Lang 1991	Lang 1991	Lang 1991	Lang 1991
Rock name	Bronco Volcanics	Bronco Volcanics	Bronco Volcanics	Uncle Sam rhyolite	Uncle Sam quartz latite	Uncle Sam quartz latite	Uncle Sam	Uncle Sam	Uncle Sam	Uncle Sam
SiO_2	53.2	55.1	53.9	68.04	66.59	68.16	62.9	72.4	72.3	71.5
TiO_2	1.3	0.7	1	0.42	0.38	0.43	0.85	0.37	0.38	0.39
Al_2O_3	18.5	16.2	15	15.82	16.77	16.07	16.1	15.1	14.7	14.5
Fe_2O_3	8.54	5.78	4	2.34	1.94	1.75	6.35	2.12	2.9	0.97
FeO	0.52	1.68	3.33	0.84	1.26	1.15	0.26	0.78	0	1.55
MgO	3.6	3.5	5.07	0.8	1.04	0.9	2.6	0.93	0.92	0.87
MnO	0.13	0.1	0.14	0.07	0.11	0.11	0.11	0.09	0.1	0.1
CaO	8.5	7	5.02	3.26	2.86	2.61	5.5	2.8	2.7	2.5
Na_2O	3.1	2.8	4.2	3.93	3.66	3.79	3	3.7	3.4	3.5
K_2O	1.1	1.2	2	3.32	3.77	3.64	3	3.5	3.5	3.5
P_2O_5	0.11	0.16	0.22	0.15	0.26	0.16	0.11	0.06	0.05	0.04
LOI	1.9	6.6	4.64	1.17	1.19	1.26	0.5	0.8	1.1	1
TOTAL	100.5	100.82	98.62	100.24	99.83	100.03	101.28	102.65	102.05	100.42
Plutonic/ volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic
Altered?		Altered LOI	Altered LOI						Altered AI Alteration Index high	

Uncle Sam Tuff

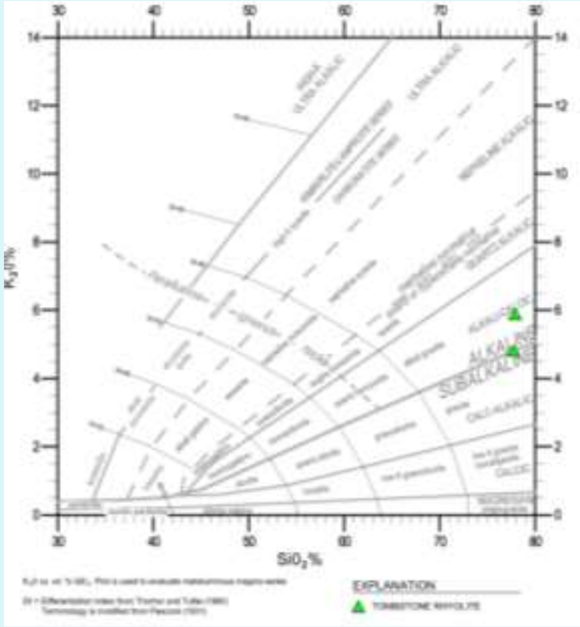
Silver mineralization



Cross-section along West Side fissure, looking northwest.
(From Butler & others, 1938)

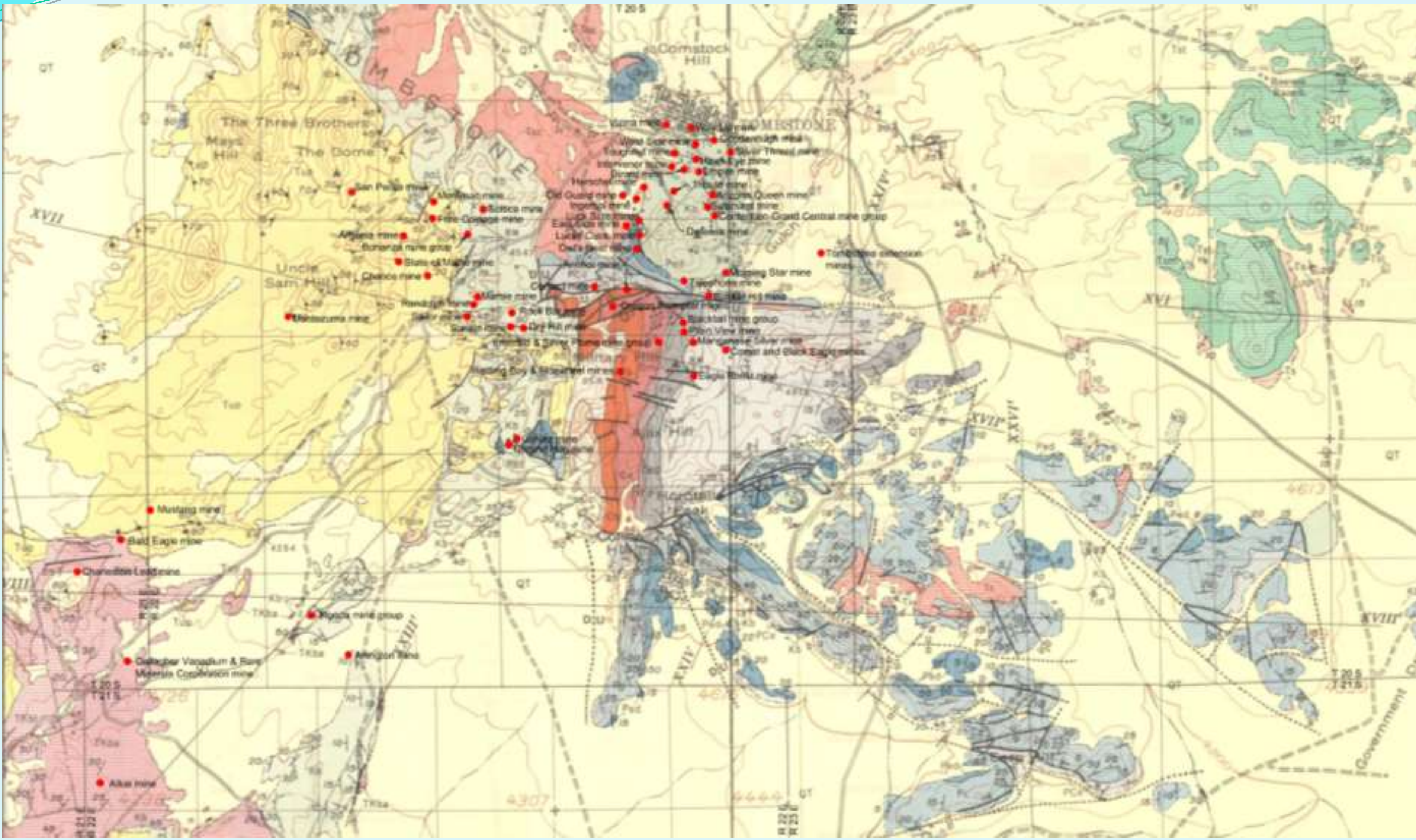
Laramide (Tertiary) Rhyolite

Laramide (Tertiary) Rhyolite



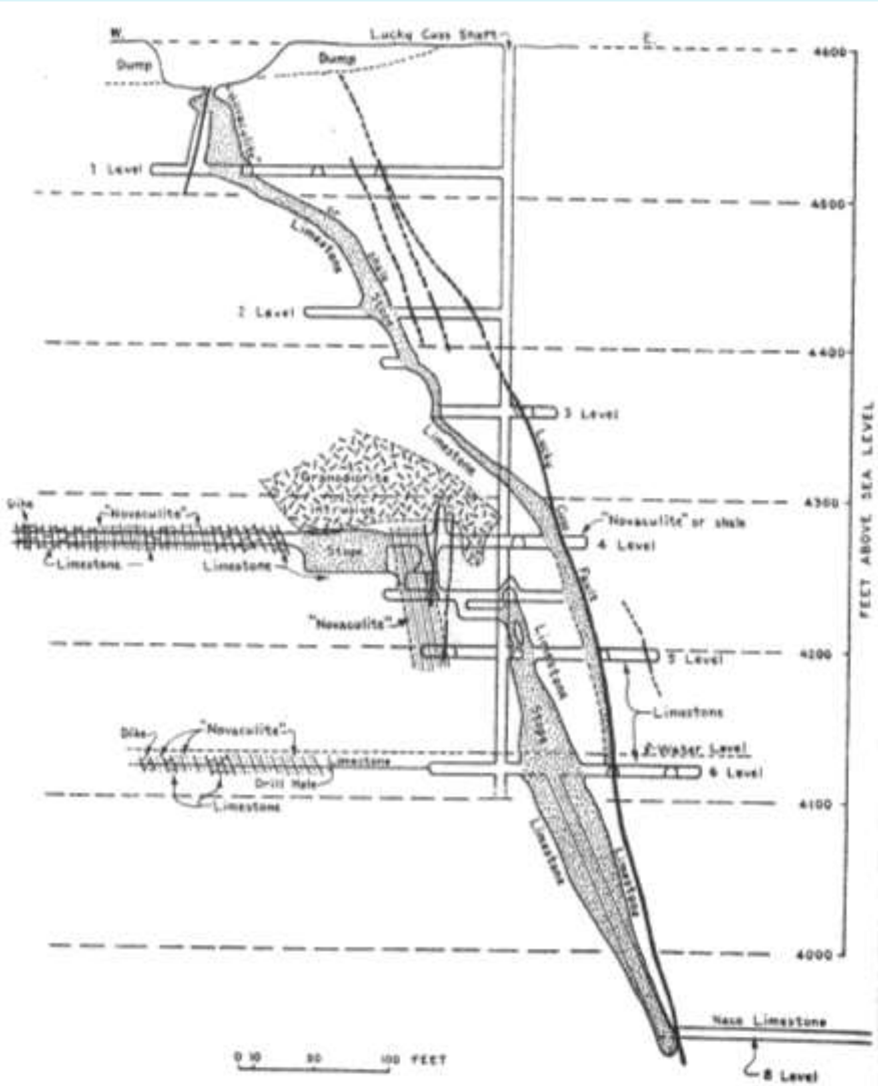
MC Type	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MCAo	MCAo
SAMPLE NO.	N	JD-19	JD-20	T21	T22	T23	T24	T43	T44
reference	Clarke 1915	Dewhurst	Dewhurst	Lang 1991	Lang 1991	Lang 1991	Lang 1991	Lang 1991	Lang 1991
Rock name	Schieffelin Granodiorite	Schieffelin	Schieffelin	Schieffelin	Schieffelin	Schieffelin	Schieffelin	rhyolite porphyry	rhyolite porphyry
SiO_2	62.33	63.87	63.03	66.6	64.8	63.7	63.2	78.1	78.9
TiO_2	0.63	0.83	0.87	0.66	0.7	0.61	0.85	0.06	0.06
Al_2O_3	16.92	16.2	15.93	15.7	15.4	15.6	16.2	13.3	13.2
Fe_2O_3	3.95	NA	NA	3.73	2.63	3.04	5.91	0.62	0.63
FeO	1.24	4.16	4.48	1.29	2.65	2.46	0.39	0	0
MgO	1.97	2.21	2.89	1.9	2.2	2.2	2.5	0.24	0.23
MnO	0.07	NA	NA	0.08	0.09	0.09	0.1	0.08	0.06
CaO	4.48	4.06	3.85	4.5	4.5	4.7	5.4	0.6	0.15
Na_2O	3.62	3.44	3.78	3	2.9	2.9	3.1	0.13	0.18
K_2O	3.36	3.37	3.42	3.3	3.2	3.3	3	5	5.9
P_2O_5	0.17	NA	NA	0.1	0.11	0.11	0.11	0.02	0.02
LOI	1.42	NA	NA	0.8	1.3	1.3	0.4	3.2	2.6
TOTAL	100.38	98.14	98.25	101.66	100.48	100	101.16	101.35	101.93
Plutonic/ volcanic	plutonic	plutonic	plutonic	plutonic	plutonic	plutonic	plutonic	volcanic	volcanic
Altered?								Altered LOI	Altered LOI

Mine map (from Cochise County mines, Keith, 1973)

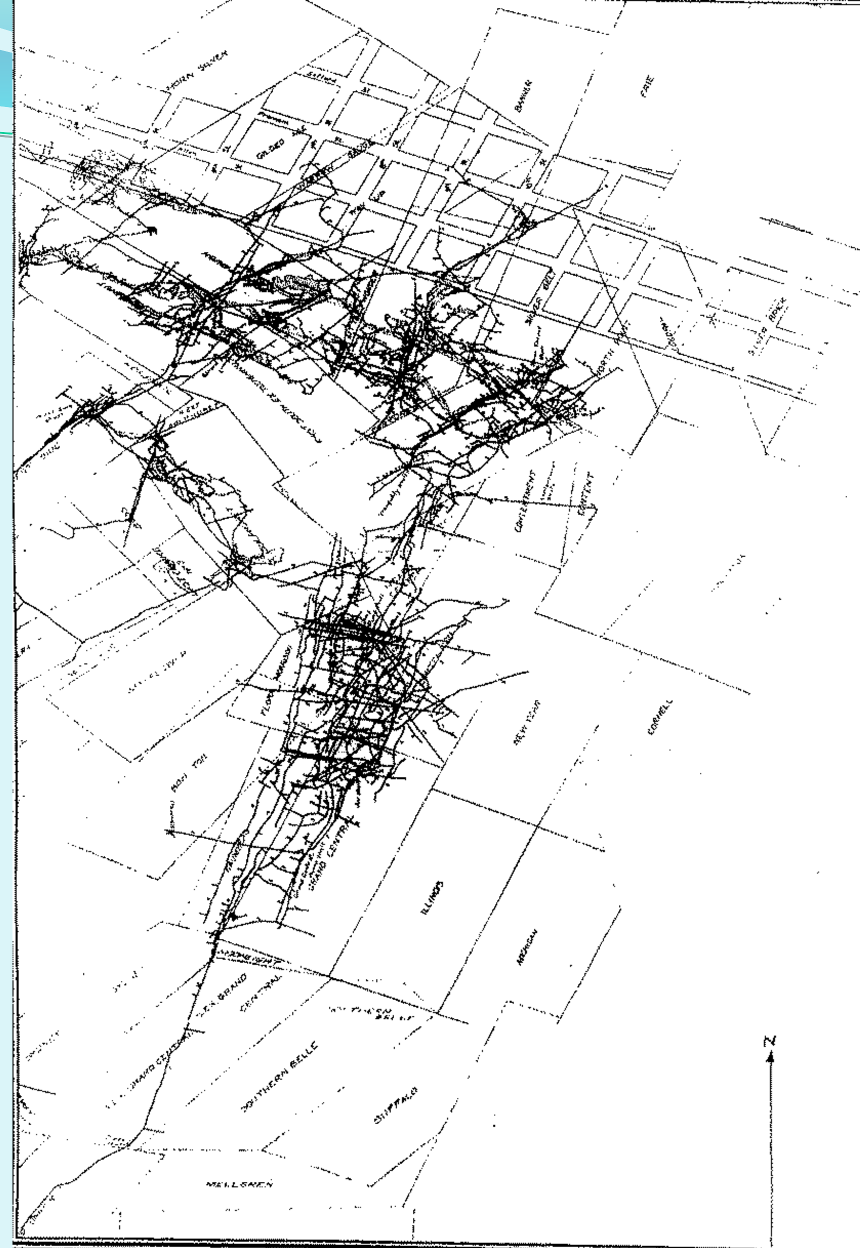


Source: Gilluly map, Keith data, SRK Consulting map

Butler mine map

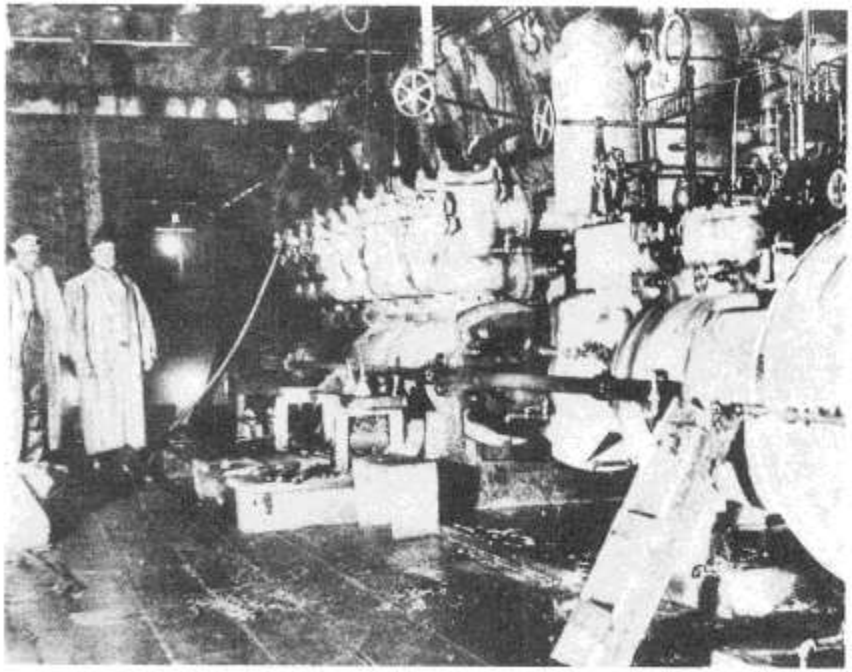


Cross-section through Lucky Cuss workings at main shaft, looking North.
(From Butler & others, 1938)

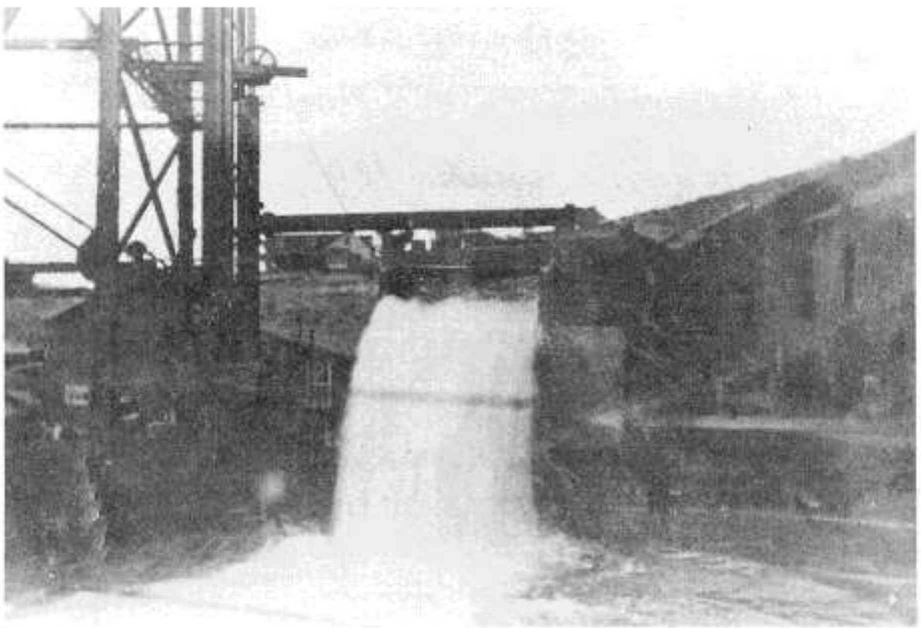


Plan of mine workings. Toughnut-Goodenough mineral zone to north;
Contention-Grand Central mineral zone in south center.
(From Butler & others, 1938)

Water pumping



Pumps on 1000-foot level of the Boom Shaft.
J. H. Macia is on the right.
Macia-Devere Collection

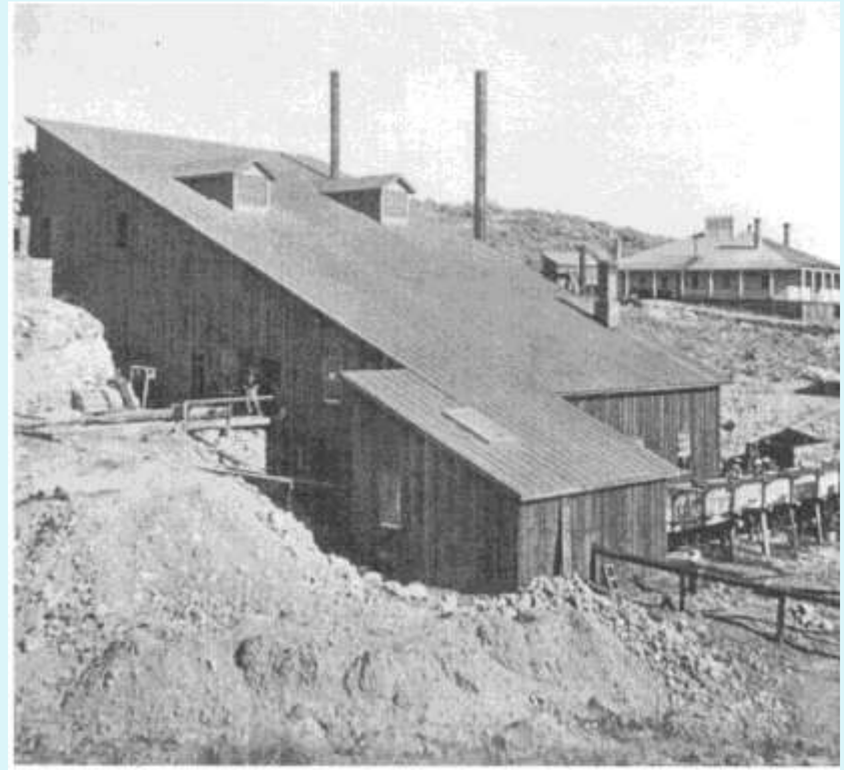


Water discharge from the Boom Shaft; 4,000,000 gallons per day, 1908.
Macia-Devere Collection

Mills along San Pedro River

A pair of ore wagons pulled by five teams.
Macia-Devere Collection

Hand sorted, sacked ore heading to the mill.
Macia-Devere Collection



Gird's Mill at Millville on the east bank of the San Pedro River. Gird's bur galow sits in background at upper right. (From Bailey, *Too Tough to Die*)

- High transportation costs

Tombstone Consolidated Mines

Tombstone Consolidated Mines Company, Ltd. main production and pump shaft, "The Boom shaft," 1906. Macia-Devere Collection

In 1900, E. B. Gage, Frank Murphy, and William Staunton consolidated Tombstone's mining properties and formed the Tombstone Consolidated Mines Company. Water was drained out of the mines, and a rail spur was laid. For a few years, precious metals were retrieved from below the water level. However, the pumps failed in 1909. The company went bankrupt, and its mines were passed to the Phelps-Dodge Corporation. (David Snell.)

Tombstone Consolidated Mines Company, Ltd.
Boom Shaft complex, 1908.
Macia-Devere Collection

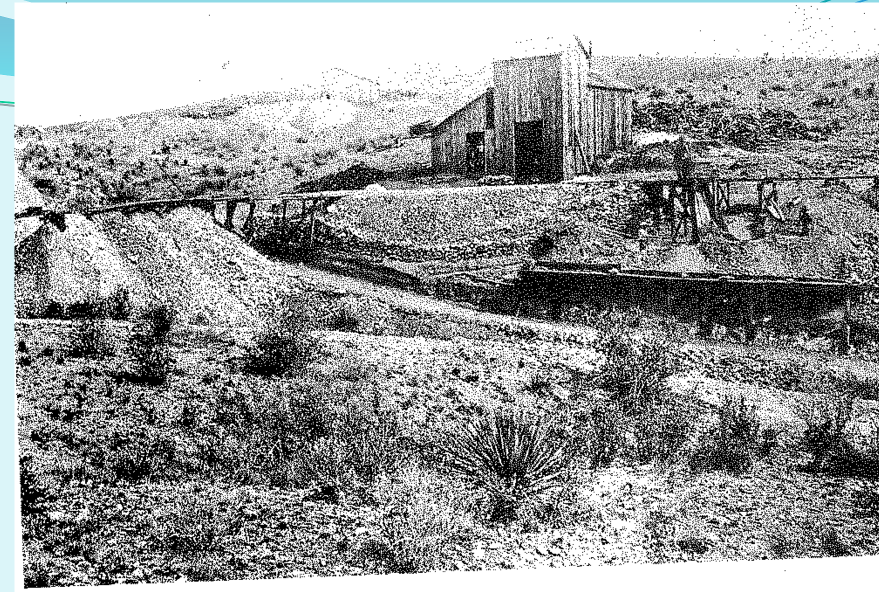
1900 - 1908

Various Mining companies

- Early individual miners - 1879 – 1900
- Tombstone Consolidated Mines – 1900-1914
- Bunker Hill Mines (Phelps Dodge) - 1914 – 1933
- Tombstone Development Co. – 1933 – 1937
  - Newmont & other lessees – 1954 – late 1950s
- Cyanide dump leach - 1970s
- Contention open cut – 1979-1983 (cyanide spill)
- Numerous copper exploration companies (ASARCO, Phelps Dodge, Newmont, Placer-Amex, Anaconda, BHP, JABA
- Current claims & exploration
  - Tombstone Exploration Corp.
  - Liberty Star Uranium & Metals
  - Other major companies

Lucky Cuss

After the first silver strike, Schieffelin found two more rich silver claims, which he registered as the "Lucky Cuss" and the "Toughnut." Word spread that silver had been discovered, and other prospectors began to search the area. Before long, more mines began to open, including the Grand Central, the Charleston, and the Contention Mines, and a mining camp was born named after Ed's first claim—Tombstone. (Don Taylor.)



Lucky Cuss Mine, 1880.
Macia-Devere Collection

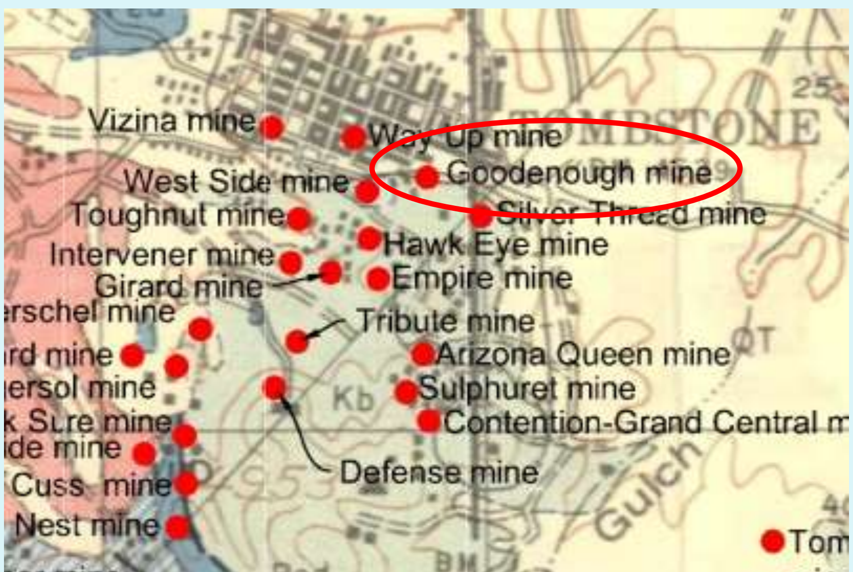
Toughnut

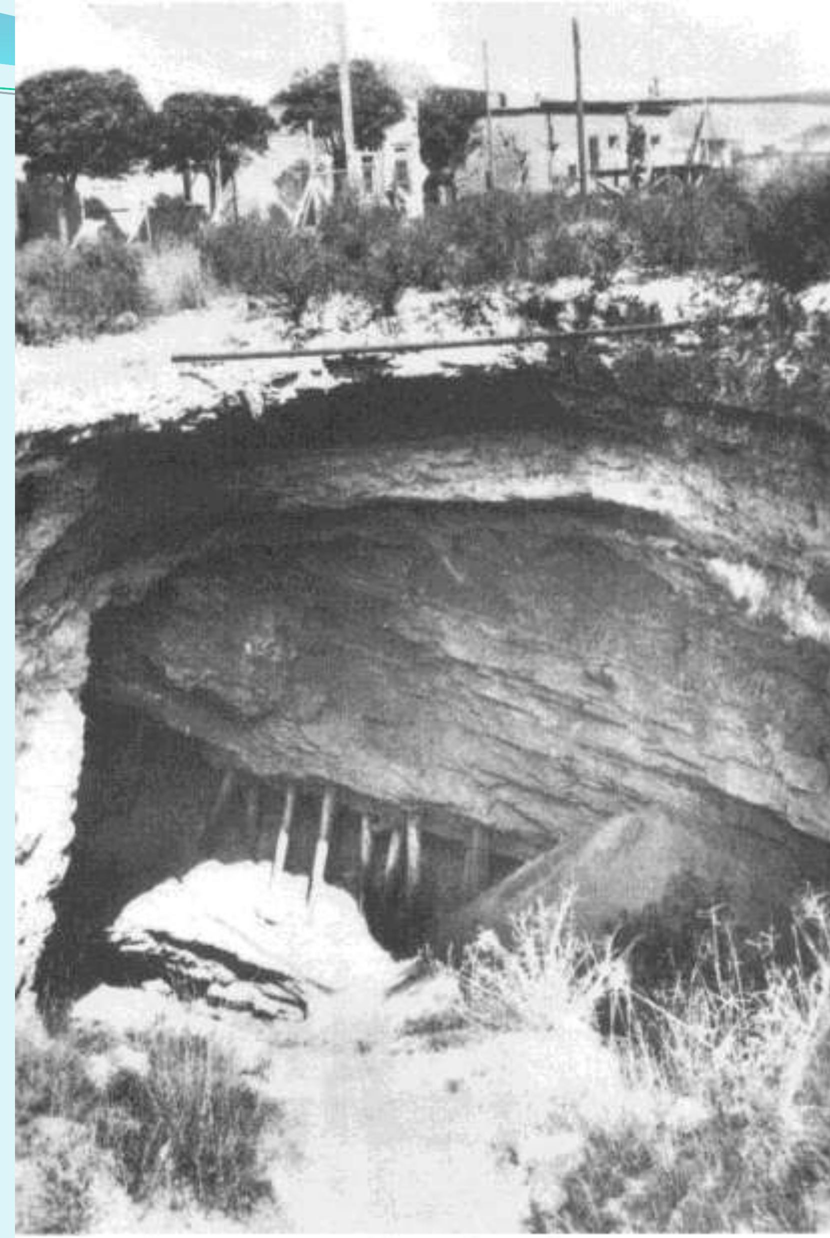
Toughnut Mine, circa 1882. Macia-Devere Collection

Toughnut shaft and headframe, circa 1934.
Macia-Devere Collection

Goodenough mine

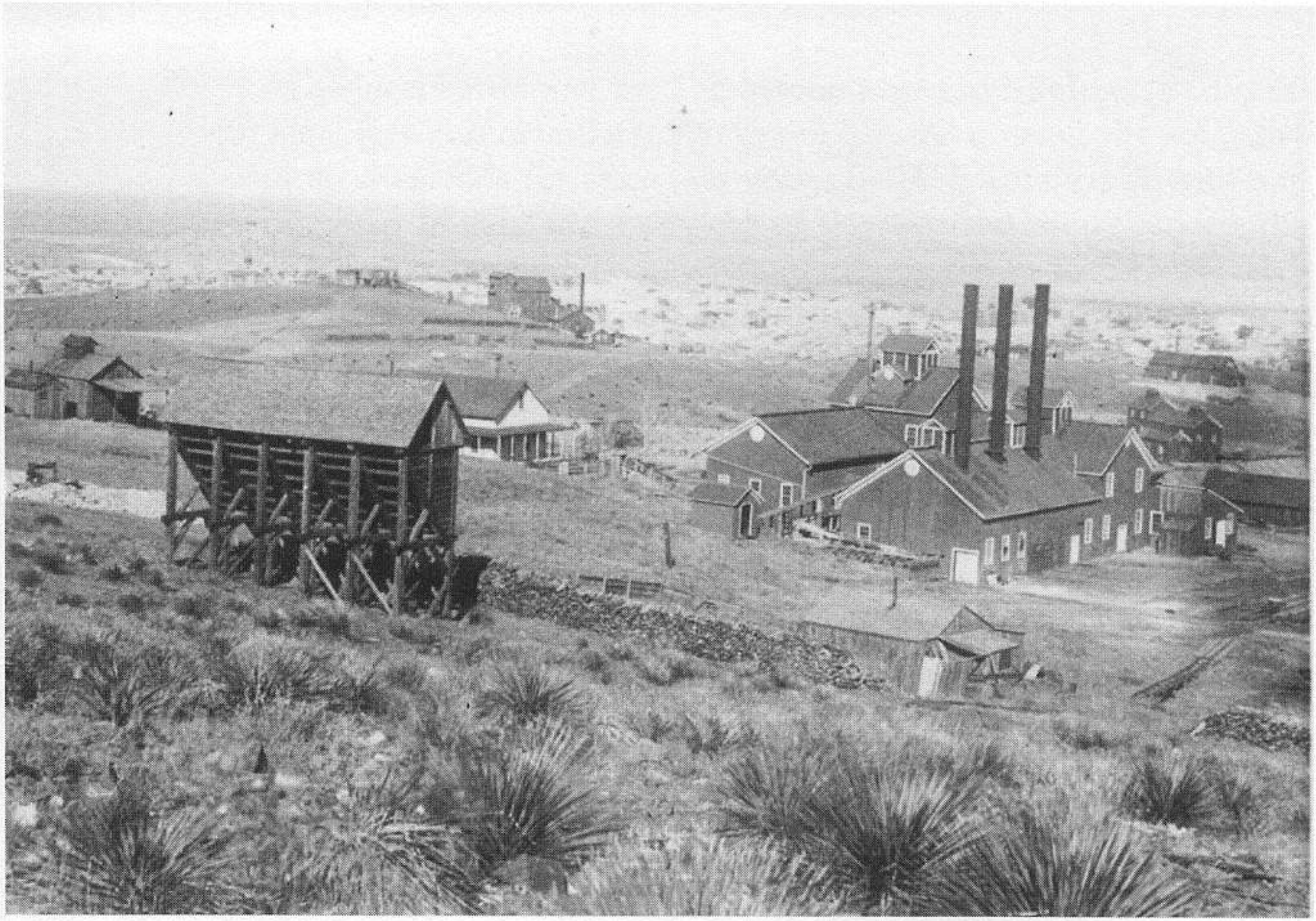
Single jackers working in a stope in the Goodenough Mine, circa 1880.
Macia-Devere Collection





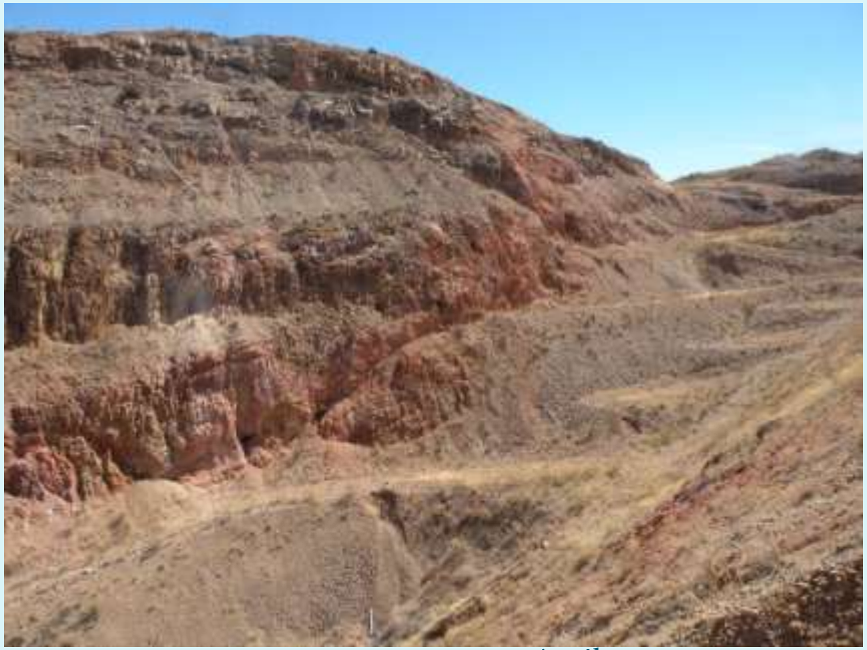
Million Dollar Stope of the Goodenough Mine, circa 1950.
Old West Research & Publishing.

Contention Mine - 1883



Contention Mine, 1883. White house is Superintendent White's residence. Girard mill is in upper center background. Macia-Devere Collection

Contention vein – open cut 1980-1985



Production history

Period	Price of Silver (USD)	Production $	Remarks
1877–80	1.15 – 1.20	$2,318,567	Discovery and early development. Mills built on San Pedro River.
1881–86	0.99 – 1.14	16,877,175	Active development and large production. Water encountered in mines in 1882, and mills built at Tombstone.
1887–96	0.63 – 1.05	4,564,650	Decreased production due to depletion of many of the large ore bodies above water level.
1897–1911	0.52 – 0.68	5,575,900	Consolidation of principal properties and attempted de-watering of district by a 1,000-foot pump shaft.
1912–14	0.553 – 0.615	379,917	Lessee operations.
1915–17	0.507 – 0.824	1,117,687	War period. Considerable production of manganiferous silver ore and concentrates.
1918–32	0.282 – 1.12	5,150,789	Mainly lessee operations. Production of silver during 1918 –22 stimulated by Pittman Act.
1933–36	0.35 – 0.77	1,118,325	Production stimulated by increased price of gold and silver.

Estimated Production

Mineral System/ Synonym (Mineral Zone)	Production Period (years)	Ore (short tons)	Au (oz)	Ag (oz)	Cu (lb)	Pb (lb)	Zn (lb)
Argenta	1922-1924	184	10	3,539	1,225	206	
Bunker Hill	1889-1931	382,330	32,404	4,407,706	2,963,902	7,461,919	45,192
Contention	1880-1885	98,252		5,240,721			
Contention/ Grand Central	1881-1950	306,090	7,815	5,377,798	286,771	6,345,686	
Galvez	1910-1924	295	81	4,382	2,149	1,796,733	
Good Enough	1884-1913	174,603	7,560	5,367,114	21,109	1,560,100	
Herschel	1905-1935	11,430	2,060	320,085	48,068	1,167,270	
Ingersol	1922-1932	1,359	378	39,273	11,689	227,393	
Lucksure	1905-1918	2,324		24,817	1,445		
Old Guard	1905-1935	2,644	383	59,516	61,574	186,887	
Rocky Bar	1920-1924	510	7	17,954	2,497	91	
Soltice	1914-1940	475	107	20,761	841	133,865	
State of Maine	1921-1950	30,343	9	104,696		2,667	
Sunset	1919-1927	419	3	11,443	5,644	10,458	
Tombstone Extension	1930-1954	26,680	1,308	222,106	90,930	14,304,882	
Tombstone Group	1903-1957	451,927	64,302	4,907,169	3,879,915	13,566,470	214,517
Toughnut-Empire	1879-1936	108,697	4,006	4,260,112	32,850	1,222,400	
Vizina	1880-1891	12,726		517,079			
Tombstone (combined)[1]		2,677,138	240,844	25,926,156	5,354,277	107,085,538	2,141,711
Tombstone (combined)[2]	1879-1981	2,953,296	131,468	32,076,966	7,763,447	49,854,350	555,527

Tombstone, 1879 - 2012

- Not large producers
- Early high grade
- Small orebodies
- Mining costs high
- Price of silver low
- Too much water, too expensive to pump, burned out pumps
- Government regulations

Minerals

Native elements	Sulfides	Haloids	Oxides	Carbonates	Sulfates
sulfur	galena	cerargyrite	quartz	calcite	barite
tellurium	argentite	bromargyrite	cuprite	rhodochrosite	anglesite
gold	chalcocite	embolite	tenorite	cerussite	jarosite
silver	sphalerite	fluorite	hematite		plumbojarosite
copper	alabandite		magnetite		
	covellite		hetaerolite		
	bornite		polianite & pyrolusite		
	chalcopyrite		manganite		
	pyrite		psilomelane		

Silver-bearing hypogene minerals

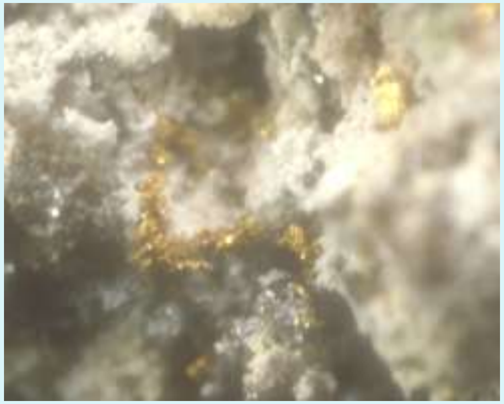
- Tetrahedrite
- Galena
- Tellurium bearing minerals
  - Empressite: AgTe
  - Hessite: Ag_2Te
  - Krennerite: $AuTe_2$
  - Tellurium: Te
  - Rickardite: Cu_7Te_5
  - Altaite: PbTe (probable)

Supergene minerals

- Bromargyrite AgBr
- Chlorargyrite AgCl
- Gold Au
- Miersite (Ag,Cu)I
- Te-Oxysalts

Chlorargyrite Megaw specimen, Sugar White photo

Elements



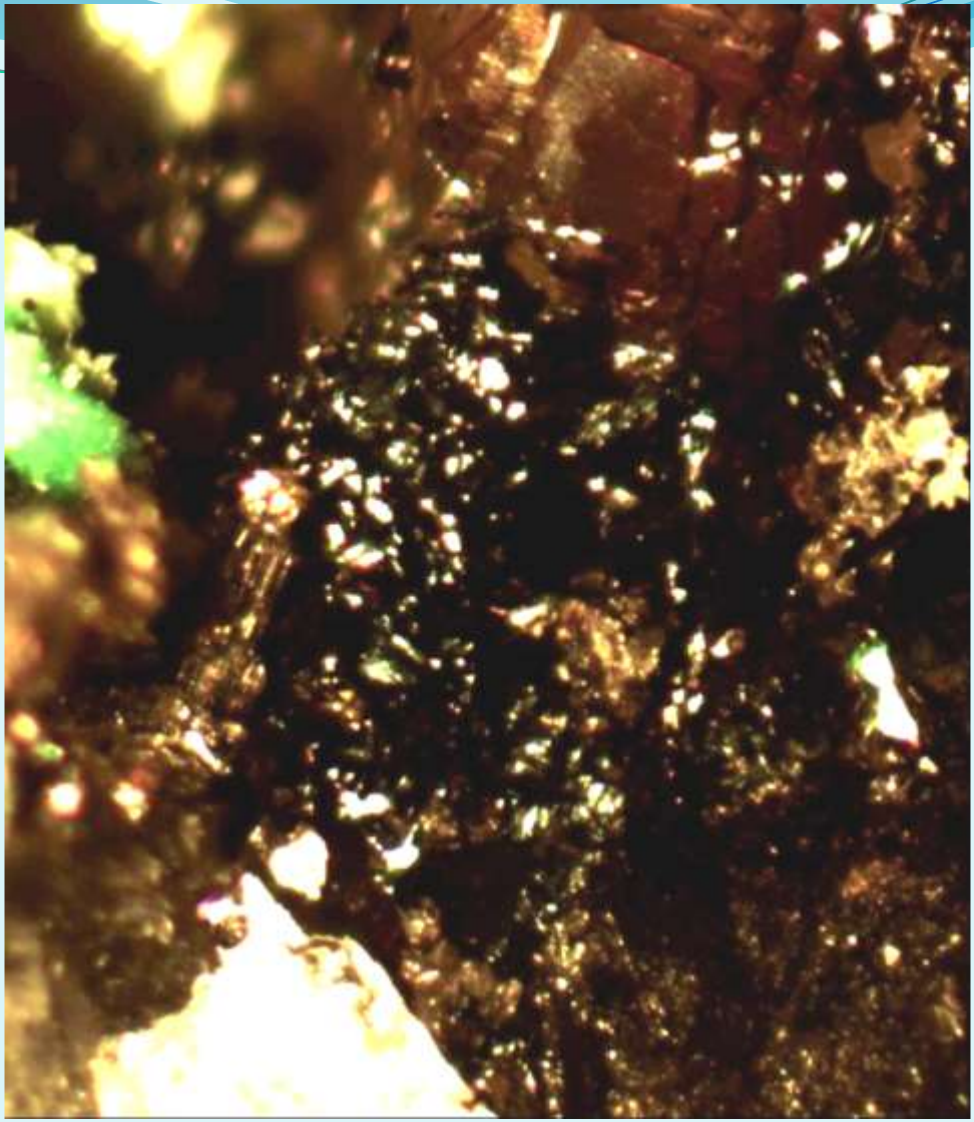
Gold

Megaw specimen,
Sugar White photo

Native Silver

Sulfides

- Galena PbS
- Argentite Ag_2S
- Chalcocite Cu_2S
- Stromeyerite ($Ag_2S.Cu_2S$)
- Sphalerite ZnS
- Alabandite MnS
- Covellite CuS
- Bornite Ci_5FeS_4
- Chalcopyrite $CuFeS_2$
- Pyrite FeS_2



Stromeyerite Rolf Luetcke specimen and photo – Mindat.org

Halides

- Chlorargyrite - AgCl
- Embolite - Ag(Br,Cl)
- Bromargyrite – AgBr
- Fluorite – CaF_2

Chlorargyrite – John Betts photo & specimen MinDat.org

Oxides

- Cuprite Cu_2O
- Tenorite CuO
- Hematite Fe_2O_3
- Magnetite Fe_3O_4
- Hetaerolite $ZnMn_2O_4$
- Polianite and pyrolusite MnO_2
- Manganite $Mn_2O_3.H_2$)
- Limonite $2Fe_2O_3.3H_2O$
- Psilomelane H_4MnO_5

Sulfo-salts

- Bournonite $PbCuSbS_3$
- Tetrahedrite $Cu_6Cu_4(Fe,Zn)_2)(Sb,As)_4S_{13})$
- Famatinite (Cu_2CuSbS_4)

Pyrolusite - Rolf Luetcke specimen and photo. MinDat.org

Phosphates

- Fluorapatite $Ca_5(PO_4)_3F$
- Pyromorphite $Pb_5(PO_4)_3Cl$

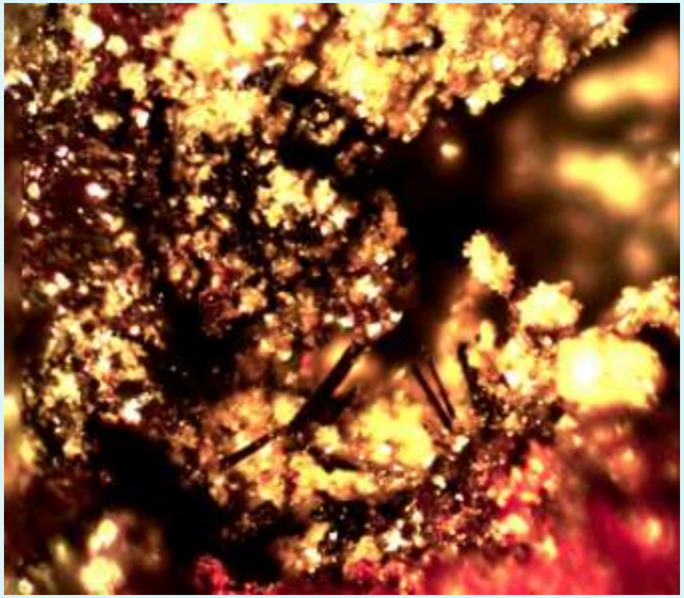
Carbonates

- Calcite $CaCO_3$
- Rhodochrosite $MnCO_3$
- Smithsonite $ZnCO_3$
- Cerussite $PbCO_3$
- Malachite $Cu_2(CO_3)(OH)_2$
- Azurite $Cu_3^{2+}(CO_3)_2(OH)_2$
- Rosasite $(Cu,Zn)_2(CO_3)(OH)_2$
- Aurichalcite $(Zn,Cu)_3(CO_3)_2(OH)_6$
- Hydrozincite $Zn_5(CO_3)_2(OH)_6$

Megaw specimen, S. White photo

Vanadates

- Vanadinite $Pb_5(VO_4)_3Cl$
- Descloizite $PbZnVO_4(OH)$
- Mottramite $PbCuVO_4(OH)$



Mottramite - Rolf Luetcke specimen and photo. Mindat.org

Vanadinite – Jesse Crawford photo Mindat.org

Sulfates

- Barite
- Anglesite
- Connellite
- Brochantite
- Gypsum
- Beaverite
- Jarosite
- Plumbojarosite
- Ettringite

Brochantite, Empire Mine, Brent Thomas photo MinData.com

Molybdates

Wulfenite $PbMO_4$

Manganese minerals

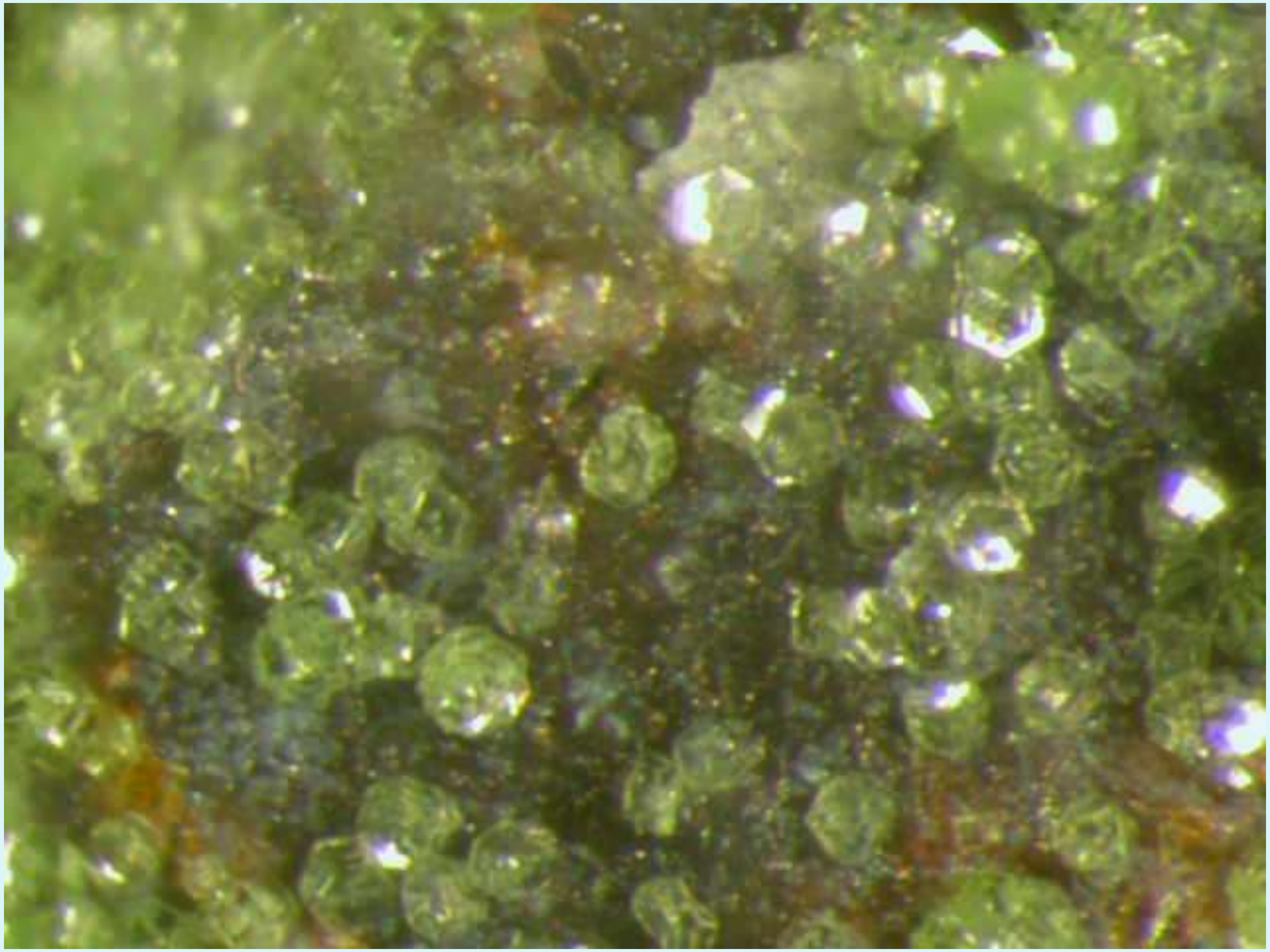
Tombstone Secondary Tellurium species: type locality

- Cesbronite
- Choloalite
- Dugganite
- Emmonsite
- Fairbankite
- Frohbergite
- Girdite
- Khinite
- Mackayite
- Mroseite
- Oboyerite
- Parakhinite
- Paratellurite
- Quetzalcoatlite
- Rodalquilarite
- Schieffelinite
- Sonoraite
- Tlapallite
- Utahite
- Winstanleyite
- Xocomecatlite
- Yafsoanite

Source: Peter Megaw

Tellurates (TeO_4), Tellurites (TeO_3)

- Dugganite
- Emmonsite
- Fairbankite
- Khinite
- Girdite
- Parakhinite (discredited)
- Schieffelinite
- Winstanleyite



Dugganite – Empire mine. Brent Thorne specimen and photograph. MinDat.org

Emmonsite

$Fe_2^{3+}Te_3^{4+}O_9.2H_2O$

Dugganite $Pb_3Zn_3Te^{6+}O_6(AsO_4)_2$

Megaw specimen,
Sugar White photo

Fairbankite $PbTe^{4+}O_3$

Megaw specimen,
Sugar White photo

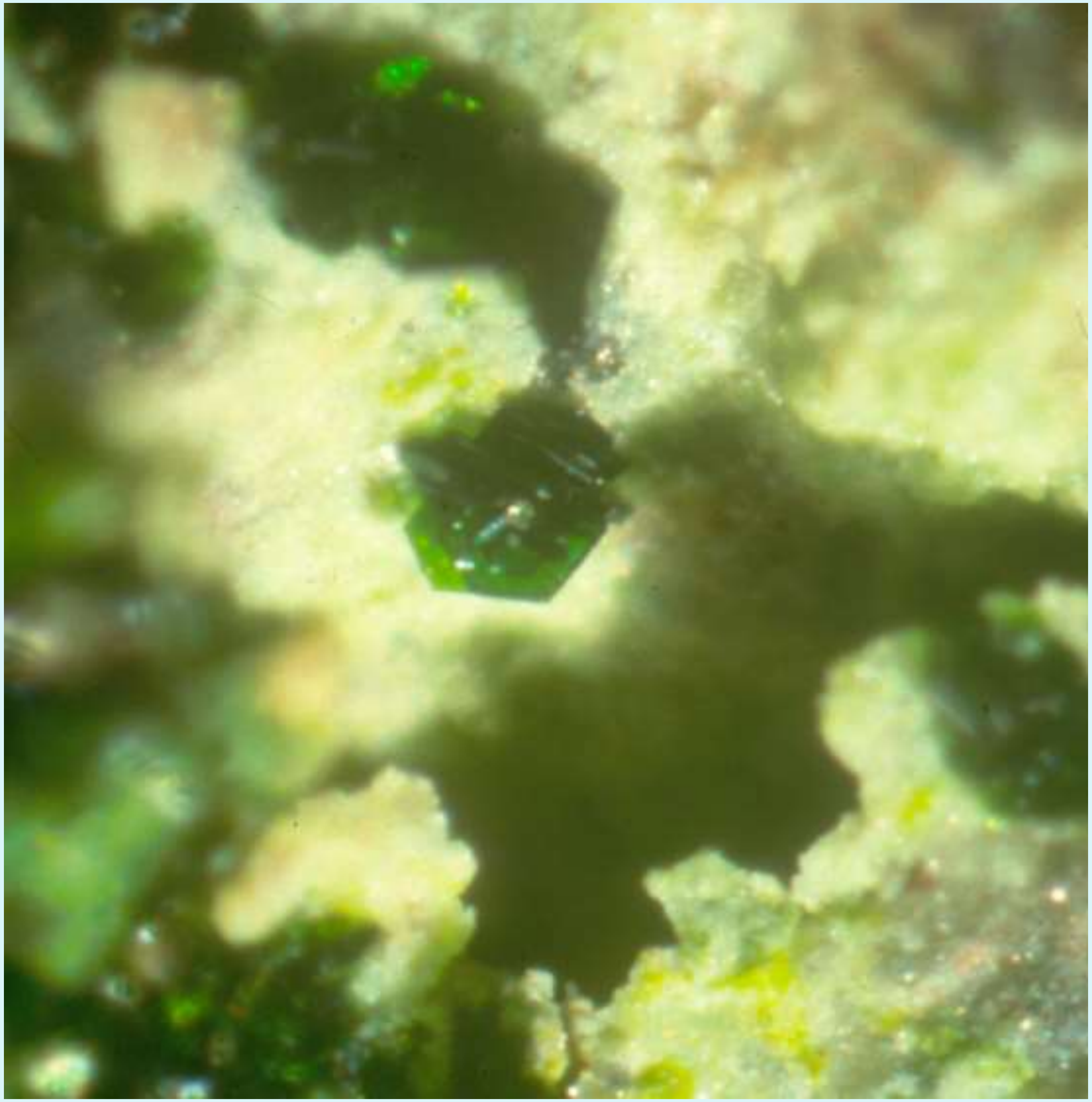
Girdite $Pb_3H_2(Te^{4+}O_3)(Te^{6+}O_6)$

Megaw specimen,
Sugar White photo

Khinite $PbCu_3^{2+}Te^{6+}O_4(OH)_6$

Megaw specimen,
Sugar White photo

Parakhinite $Cu_3^{2+}PbTe^{6+}O_6(OH)_2$

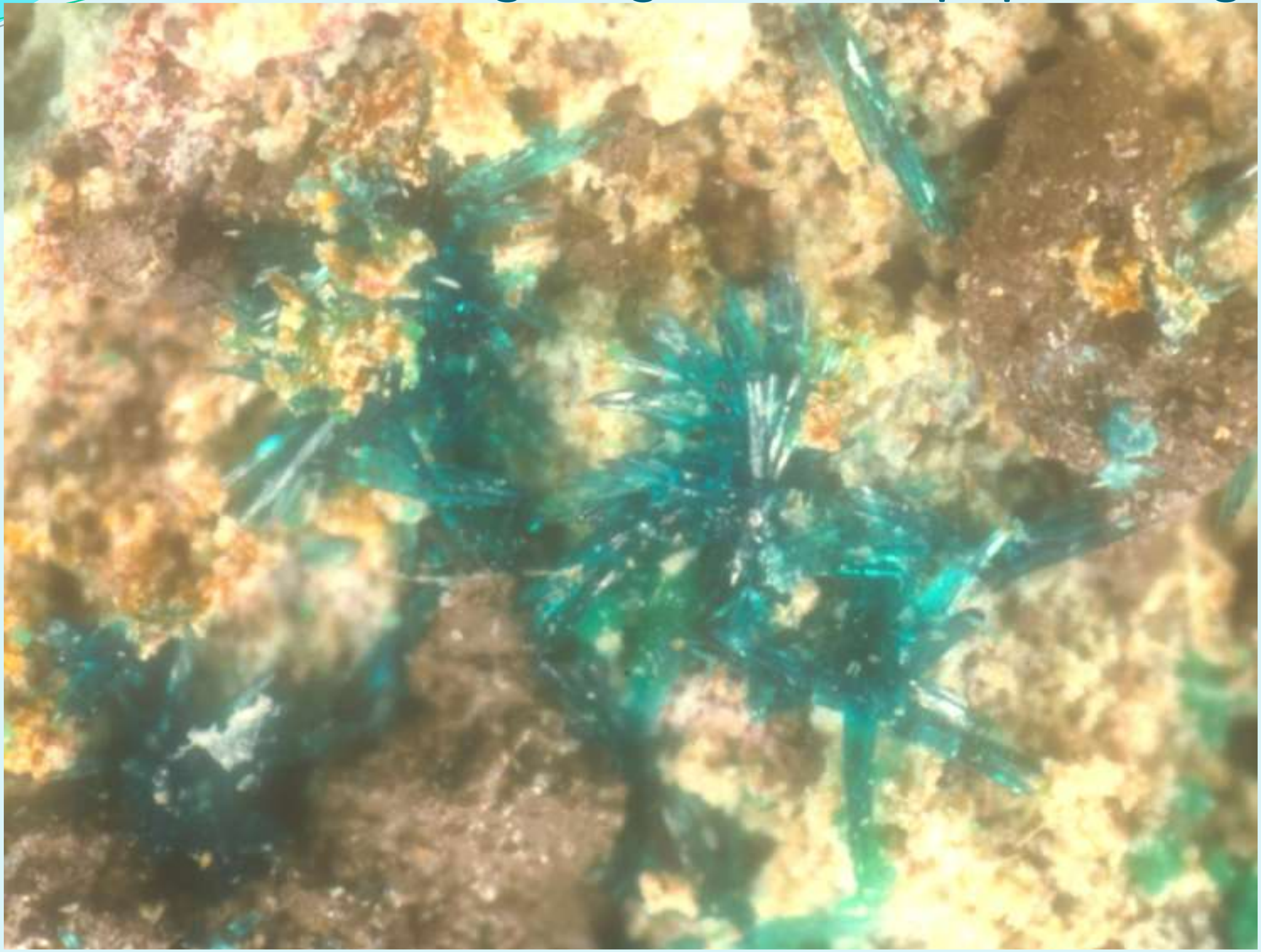


Megaw specimen,
Sugar White photo

Schieffelinite $Pb(Te^{6+},S)O_4.H_2O$

Megaw specimen,
Sugar White photo

Utahite $Cu_5Zn_3(Te^{6+}O_4)_4(OH)_8.7H_2O$



Megaw specimen,
Sugar White photo

Winstanleyite $TiTe_3^{4+}O_8$

Megaw specimen, Sugar White photo

Yafsoanite $Ca_3Zn_3(Te^{6+}O_6)_2$

Megaw specimen,
Sugar White photo

Geology, Mines, & Minerals, Tombstone, Arizona by Jan C. Rasmussen