Arizona Geological Society – Fall Field Trip 2023

South 32 Hermosa Zn – Mn – Ag Deposit

Field Trip Guide compiled by South 32 staff
Organized by AGS VP Field Trips Paul Jensen

Photos: AGS members examining core; Core box contents; Peter Megaw speaking with Stan Keith on deck; Stone wall; AGS members walking the ourcrop.

AGS Hermosa Tour Agenda

8:00am – Meet at Patagonia South32 office. Collect lunches?

8:30am – get site safety intro, PPE, and visitor check in

8:45-9:15am – drive to site

9:15-10:00am – site overlook review and district overview by

10:00-10:15am – drive to Mowry stop

10:15-11:15am – Mowry Stop

11:15-11:45am – drive to Hardshell stop

11:45-12:30pm – Hardshell stop

12:45-1:15pm – Lunch and Peter Megaw talk (Safety conference room)

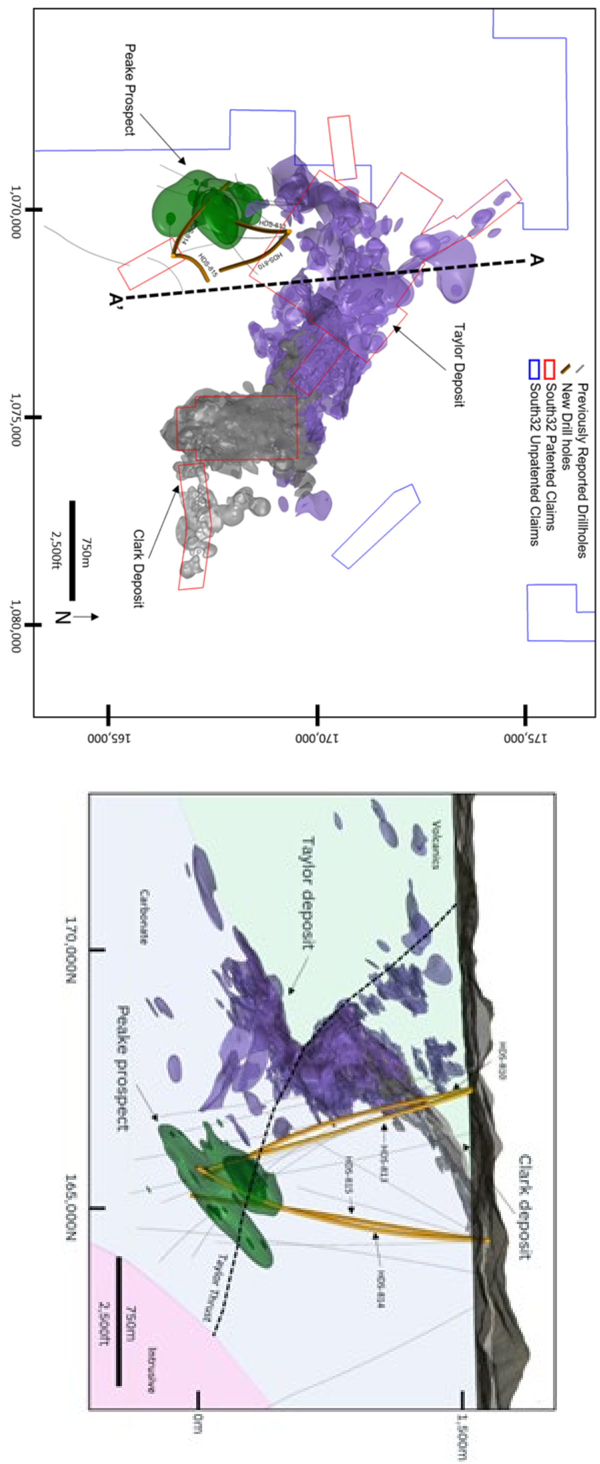
1:15-2:30pm – core shed with “show core”

2:30-3:00pm – return to Patagonia office

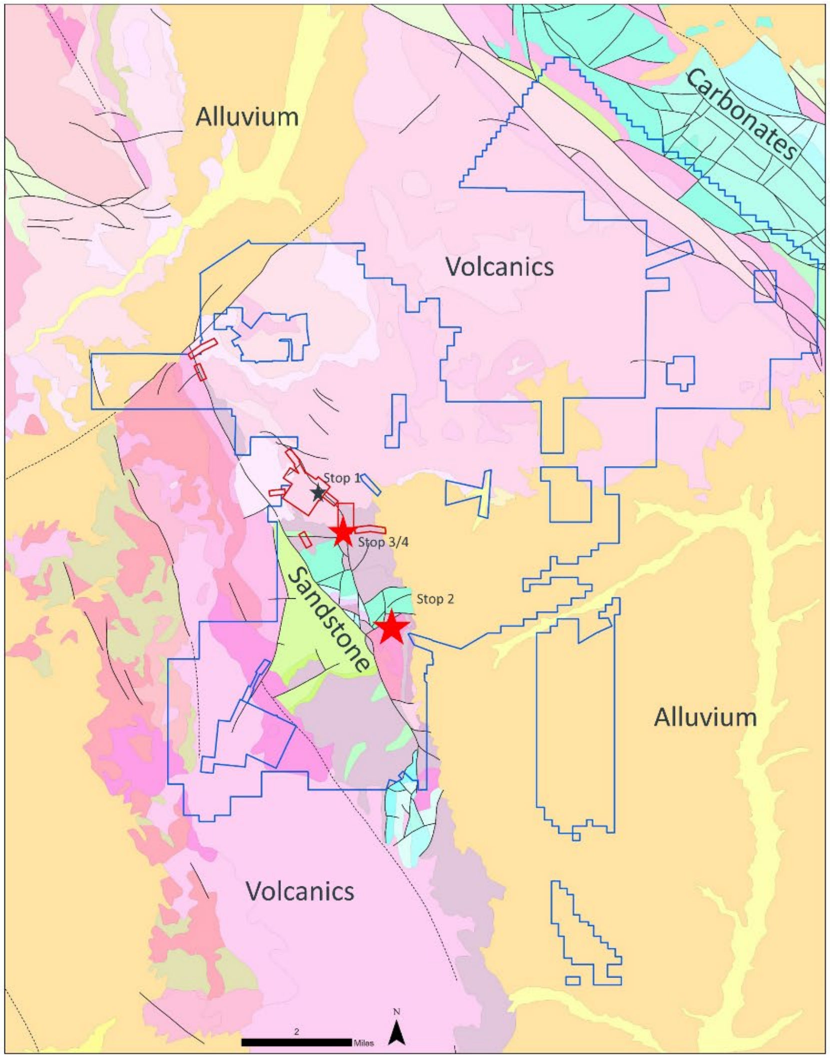
3:00-4:00pm – drive back to Tucson

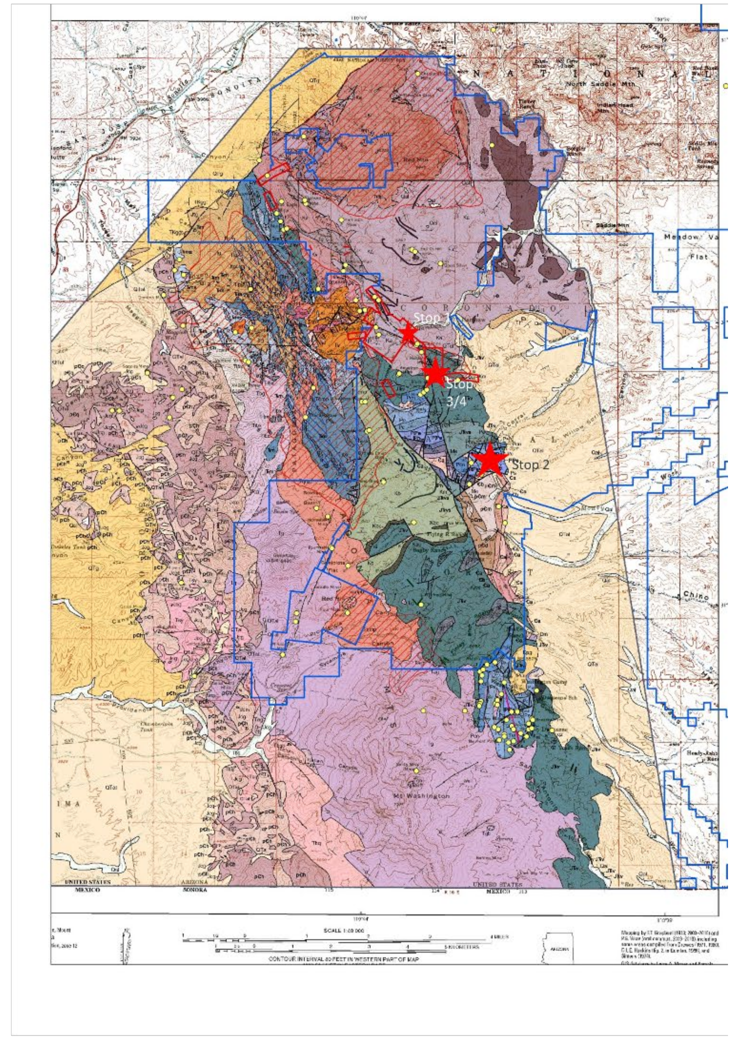
Stop 1: Hermosa Site Overlook and District Overview

After going through security gates, park at overlook. High-level summary of the deposits, site progress, and regional overview.



Hermosa Mineral Domains in plan view and cross section


Alluvium
Carbonates
Volcanics
Stop 1
Stop 3/4
Sandstone
Stop 2
Alluvium
Volcanics
2
Miles
N

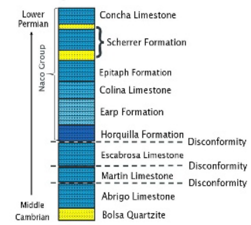

Stop 1
Stop 3/4
Stop 2

History of the Patagonia Mountains and Related Ore Deposits

A summary of the geologic history that formed the Patagonia mountains and associated ore deposits.

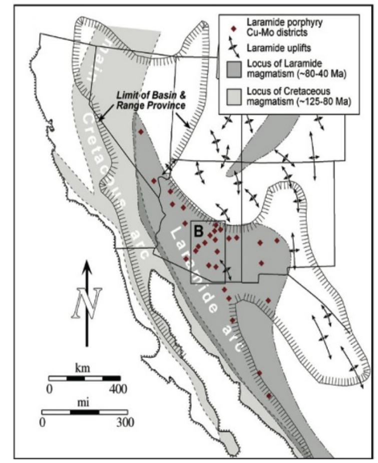
Proterozoic rocks consisting of the Pinal Schist, the sedimentary Apache Group as well as various basalt flows and intrusive units form the basement for which the Paleozoic sediments were deposited on.

Sedimentation occurred throughout the Paleozoic



Volcanic activity during the early Jurassic period produced the Older Volcanic unit and the quartz feldspar dike that intrudes into the Naco group. Clasts of limestone and Older Volcanics in the Hardshell volcanics indicate that the Hardshell unit is younger than both units. It's not clear if the Hardshell is a separate volcanic sequence or is the youngest portion of the Older volcanic unit.

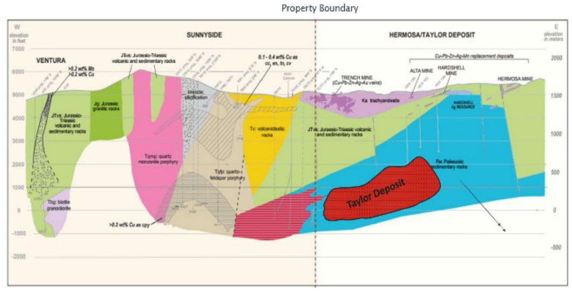
Extension during the Cretaceous period created the Bisbee rift in southern Arizona and New Mexico. The sedimentary rocks deposited within the rift are recognized as the Bisbee Formation and outcrop south of site. Crustal shortening during the beginning of the Laramide Orogeny likely resulted in the Taylor Thrust. The thrust was formed sometime after the deposition of the Hardshell volcanic unit but prior to the andesite as no evidence for the thrust is found in the andesite.



The Laramide arc formed during the Laramide orogeny and is responsible for most of the intruding plutons that form the famous porphyry copper deposits of the southwest. Beginning approximately 74 Ma and lasting for 16 Ma multiple intrusive events formed the Patagonia batholith. Common igneous rocks that can be found are granodiorite, quartz feldspar porphyry, quartz monzonites, and syenodiorite.

General Timeline of Intrusive and alteration events in the Patagonia Mountains

1) Washington camp-Duquesne granodiorite intrusion and subsequent Cu-Pb-Zn-Ag Replacement deposit 74Ma
2) Intrusion into Mesozoic volcanics and sedimentary rocks formed the Flux Cu-Pb-Zn-Ag replacement deposit 70 Ma
3) Small volume intrusions formed the Ventura Mo-Cu breccia deposit 64 M.a
4) Additional small volume intrusions possibly formed the Blue Nose and Morning Glory Mine 62 Ma
5) The Red Mountain granodiorite intruded shortly after the small volume intrusions and formed the porphyry Cu-Mo system about 61-60 Ma. Concurrently, another large volume intrusion formed Red Hill and the Red Hill Cu-Mo Breccia deposit (Four Metals Mine) 61-60 Ma
6) The Sunnyside porphyry (Quartz feldspar Porphyry) intruded 60-59 Ma with the Porphyry Cu-Mo system forming between 61-58 Ma.

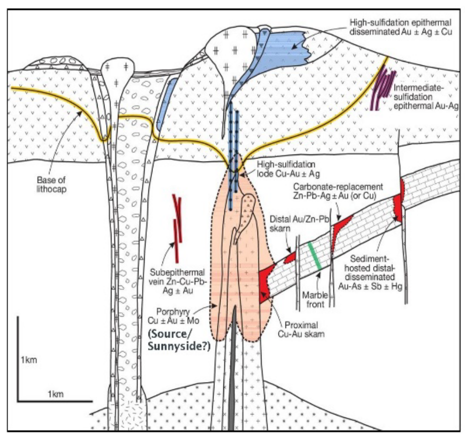


Where does our Deposit fit in?

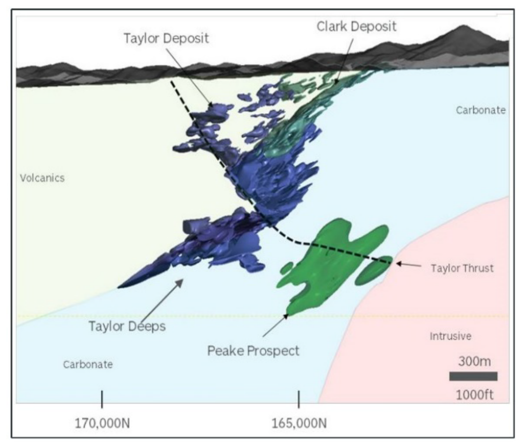
The Taylor deposit was discovered in 2014 after the academic studies were concluded and thus its genesis has not been rigorously studied. This type of deposit is typically distal from intrusions, so Red Mountain and Sunnyside are both potential sources for the Taylor deposit. The general skarn zonation associated with Taylor and the Peake prospect would suggest Sunnyside as the causative intrusive.

The Taylor mineralization is hosted in the Concha, Scherrer, and epitaph units but is most prevalent in the Concha where the Clark deposit is also hosted. The style of mineralization is massive galena and sphalerite (Taylor) and massive MnOx (Clark). The Peake prospect also has galena and sphalerite with chalcopyrite.

The Clark deposit is an up-dip extension of the Taylor deposit. The introduction of an external fluid oxidized the Taylor deposit (similar to iron rusting) leaving only MnOx.



Type Deposit Model



Actual Deposit Model

Sources:

Geologic Map of the Patagonia Mountains, Santa Cruz County, Arizona, Frederick T. Graybeal, Lorre A. Moyer, Peter G. Vikre, Pamela Dunlap, and John C. Wallis.

Succession of Laramide Magmatic and Magmatic-Hydrothermal Events in the Patagonia Mountains, Santa Cruz County, Arizona, Peter G. Vikre, Frederick T. Graybeal, Robert J. Fleck, Mark D. Barton, Eric Seedorff. *Economic Geology.* 2014.

Root Zones of Porphyry Systems: Extending the Porphyry Model to Depth, Eric Seedorf, Mark D. Barton, William J.A. Stavast, David, J. Maher, *Economic Geology*. 2008.

Porphyry Copper Systems, Richard H. Sillitoe, 2010. *Economic Geology*, 2010.

Hermosa Project Update Presentation by South32 on January 17, 2022.

Stop 2: Historic Mowry Mine and Townsite

The Mowry Mine is part of the Harshaw Mining District's lead-zinc-silver rich carbonate replacement tend within the Patagonia Mountains. Rooted deep in Arizona history, one goal for the Arizona Geological Society stop will be to visit remnants of the historical mining and point out some of the local geology. After turning off Apache road near the ruins of the old townsite, we will drive uphill to the smelter's slag pile, park, then walk up along the mined Mowry Fault and the old powder house, then over to the grated No. 3 shaft.

Dr. Titley (1992) summarizes the Mowry Mine's history well. See below.

Overall, intermittent mining occurred from the 1850's-62, 1864, 1893, 1901, 1905-07, 1918-20, 1922, 1924-31, 1936-37, 1941-44, 1947-52. The USBM totals production (from 1860's-1952's) of ore treated at 145,647 tons yielding 8,228,879 pounds of lead, 374,656 ounces of silver, 21,250 pounds of zinc, 100 ounces of gold, and 9,505 pounds of copper. The mill is estimated to have produced approximately 100tpd. The 1950's saw an increased interest at Mowry and in the Patagonia mountains with manganese by the Federal DMEA (Defense Minerals Exploration Administration). Exploration programs continued in the 1960's and 1970's but no major developments occurred.

Mining extended to depths of 500' with the oxide mineralization occurring dominantly around 300-400'. Below the oxide mineralization, the sulfides had been noted to see a reduction of silver and mining predominantly stopped (a similar story seen at other mines in the area).

Mowry's dominant mineralization occurs along the 350-400m east-northeast trending Mowry fault located along Paleozoic carbonates and an intrusive body in oxidized argentiferous Pb-Ag. Dominant minerals include cerussite [$PbCO_3$], anglesite [PbSO4], psilomelane [$Ba(Mn^{2+})(Mn^{4+})_8O_{16}(OH)_4$] or [$Ba, H_2O)_2Mn_5O_{10}$], and pyrolusite [$MnO_2$]. There is some speculation on the age of the intrusive body along the shear zone. Early maps age the intrusive bodies as pre-Cambrian while more recent USGS age dating in the area date many intrusive rocks as Tertiary-Cretaceous. Vikre et al. (2014) took a sample within the intrusive monzonites at Washington Camp to the south determined those rocks date to ~74Ma and notes a consistency to Tertiary granites (Tg) and the Cu-Pb-Zn-Ag deposits in the area although is Cretaceous in age. Another sample at the Morning Glory mine to the east aged its intrusive at ~61.5Ma which sits within the Tertiary.

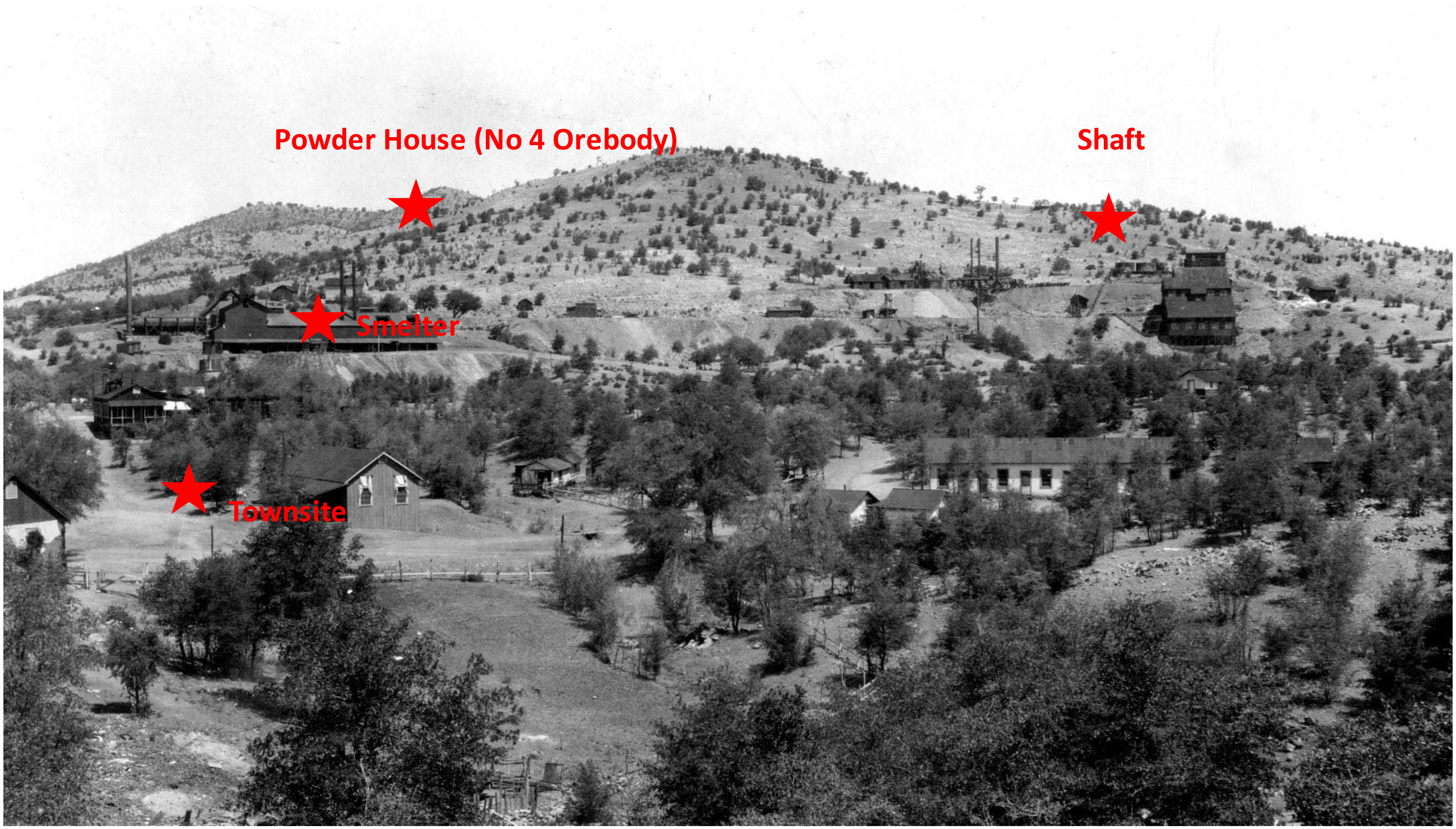
Sources:

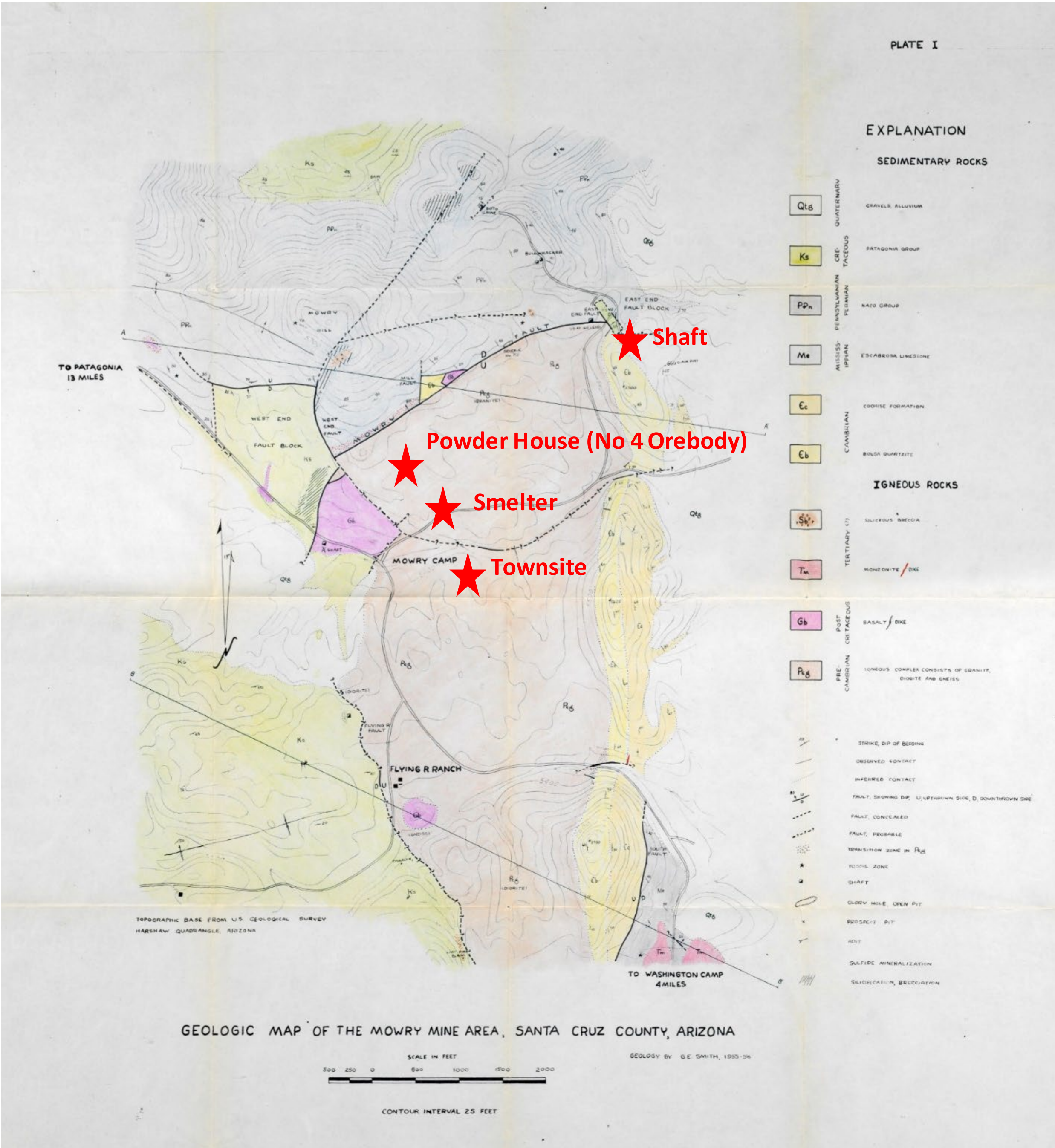
Vikre P, Graybeal F, Fleck R, Barton M, Seedorf E. 2014. Succession of Laramide Magmatic and Magmatic-Hydrothermal Events in the Patagonia Moutnains, Santa Cruz County, Arizona. Economic Geology. 109: 1667-1704.

Titley's summary is from: MowrymineSantacruz44c-1-0001 (az.gov)
http://docs.azgs.az.gov/OnlineAccessMineFiles/M-R/MowrymineSantacruz44c.pdf

USGS Photographic Library Explorer
https://library.usgs.gov/photo/#/?terms=Mowry%20mine

Smith, G.E., 1956, The Geology and Ore Deposits of the Mowry Mine Area, Santa Cruz County, Arizona: M.S. Thesis, University of Arizona, 44p.
https://repository.arizona.edu/handle/10150/551265


Powder House (No 4 Orebody)
Shaft
Smelter
Townsite



GEOLOGIC MAP OF THE MOWRY MINE AREA, SANTA CRUZ COUNTY, ARIZONA

MOWRY MINE NOTES, OCT 1992

S.R.Titley

The old workings of this mine may be viewed from the surface as a linear group of caved stopes along the ENE-striking vein. The observer should be extremely careful at this site because of this caving and stay away from any opening - and do not get near the fences that protect these openings. There are plenty of samples in rock piles along the vein trace. At this writing, remnants of some adobe buildings at the old town site of Mowry are still present and the "stone-masoned" powder building still stands near the outcrop of the No. 4 orebody.

The actual date of discovery of the Mowry vein is unknown and it may have occurred some time in the 18th Century by unknown prospectors who left behind a number of shallow pits and trenches. But it was "rediscovered" by a Mexican prospector at about the time of the Gadsden Purchase and sold for virtually nothing to a group of investors headed by Lt. Sylvester Mowry about 1858. The mine evolved from the presence of exposed rich, (enriched) silver-lead ores, the dominant metal production through some 50 years of intermittent mining. Elsing and Heinemann (1936) report a production value from 1858 to 1930 of about $1,000,000 in currency of the time - derived from 10,000,000# of Pb at about $0.05/# average and from about $500,000 worth of Ag. Granger (1960) reports a production of $1,500,000. Through much of its significant mining life, the Mowry is said to have been geared to production of about 100tpd.

The mine has a storied history, some of which is described by Granger (1960) and Schrader (1915). Important points of this history stem from its discovery to the imprisonment of Lt. Mowry for some 6 months after the U.S. Government seized the workings in 1862, for ostensibly selling Pb to the confederacy. (Mowry was unsuccessful in regenerating interest in the mine after the Civil war and is said to have died penniless in London a few years later (Granger, 1960). Raphael Pumpelly, at the time a chemist/metallurgist with the "Santa Rita Mining Co." is said to have known and visited the property during early years of its operation.

Withdrawal of troops from Ft. Crittenden during the Civil War resulted in renewed dangers from Apaches and mining stagnated until the 1870s during and following which mining was carried out intermittently until the early part of the Century. Mining of Mn ores took place for a brief period of time during the mid 1950s under DMEA encouragement, and Ventures Ltd. is said to have had an interest in the property at that time. Schrader states that the property consists of 20 patented mining claims.

Rich silver ores were processed both on site where bullion and local coinage was produced, and in Europe by way of wagon transit of Ag and Pb bars to Yuma. Some specimen quality material is said to have been shipped to London during this early period. Lead ores at Mowry, as well as from other mines in the Patagonia and Santa Rita Mountains were smelted locally during the late decades of the 19th century in Alum Canyon, Patagonia, and Duquesne. The ores at Mowry during the late 1800s are said to have yielded more than $100/ton at prevailing prices, an ore-grade value cut-off that was commonplace in this region at this time.

The mine comprises a group of fault-controlled ore shoots of veins and carbonate replacement ores in a 75m wide shear zone marking the fault boundary between Precambrian granitic rocks (to the south) and the Paleozoic-Mesozoic section to the north. This structure, the Mowry Fault, is known to be mineralized along a strike length of some 350-400m, representing only a small fraction of the composite length of the fault as shown in the accompanying section extracted from Smith (1956), compared with the fault as mapped by Simons (1974). Development, all of which is old, extended to the 500ft (160m) level. Exploration of the early 1980s is said to have attempted to discover mineralization, by geophysics,along the fault trace to the east and to further trace it beneath cover beyond outcrop. Results of this work have not been disclosed to the public.

Ores mined consisted, in the main, of oxidized, argentiferous primary lead-silver mineralization. Principal minerals were cerussite, and anglesite in a dark wad of various manganese (psilomelane and pyrolusite) and iron (hematite) oxides. A secondary Sb mineral "bindheimite" ($Pb_2Sb_2O_6[O,OH]$) and a member of the stibiconite group, is present and possibly derived from stibnite or a Ag-bearing sulfosalt such as miargyrite or andorites. Galena is reported to have been sparingly present and, although accounts differ between authors, oxidation of the ores was present to a depth of between 300 and 400. Primary sulphides are present in the lowest levels at about 500 feet, but Ag grades are reported to have fallen. Where galena was associated with pyrolusite it is said to have been rich (several 1000s of ounces/t) in silver.

The south wall of the vein is Precambrian "granite", the north wall a complex of Paleozoic strata with incorporation of horses of a pyroxene monzonite of likely younger age. Replacement of carbonate rocks has taken place in various strata along the vein with a dominance of mineralization in the Escabrosa limestone (See attached map.). The longitudinal section of the vein by Smith (1956) is attached and shows the structure cutting a deep exposure of "porphyry" interpreted in Schrader as "gabbro". This is possibly the pyroxene monzonite of Cretaceous age mapped by Simons (1974).

Age of the mineralization is unknown and may only be inferred as Laramide owing to the manifestation of a (dated) widespread thermal event of such an age (Simons, 1972,1974) in this region. Laramide trachytic volcanic rocks and intrusions of the Patagonia mountains are widespread, the most significant manifestation of which is Red Mountain flanking the town of Patagonia to the east. However, owing to increasing recognition in some mining districts in southern Arizona of a mid-Tertiary thermal overprint, the age of the event at Mowry remains open. Mineralization is manifestly related to the margins of a significant block fault whose age would set an oldest limit but an age which is presently unconstrained. It could be as old as Triassic and related to widespread volcanic activity of that age (ca. 200Ma), or as young as some time in the Tertiary. No evidence links mineralization with or precludes its development synchronous with faulting.

Tucson, 20th Oct. 1992.

REFERENCES

Brinsmade, R.B., 1907, Lead-silver deposits of Mowry Arizona: Mines and Minerals, v.27, #12, p.529-531.

Elsing, M.J. and Heineman, R.E.S. 1936, Arizona metal production: Arizona Bureau of Mines Bulletin no. 140, 112p.

Granger, Bird H., 1960, Will C. Barnes' Arizona Place Names Revised: Tucson, University of Arizona Press, 519p.

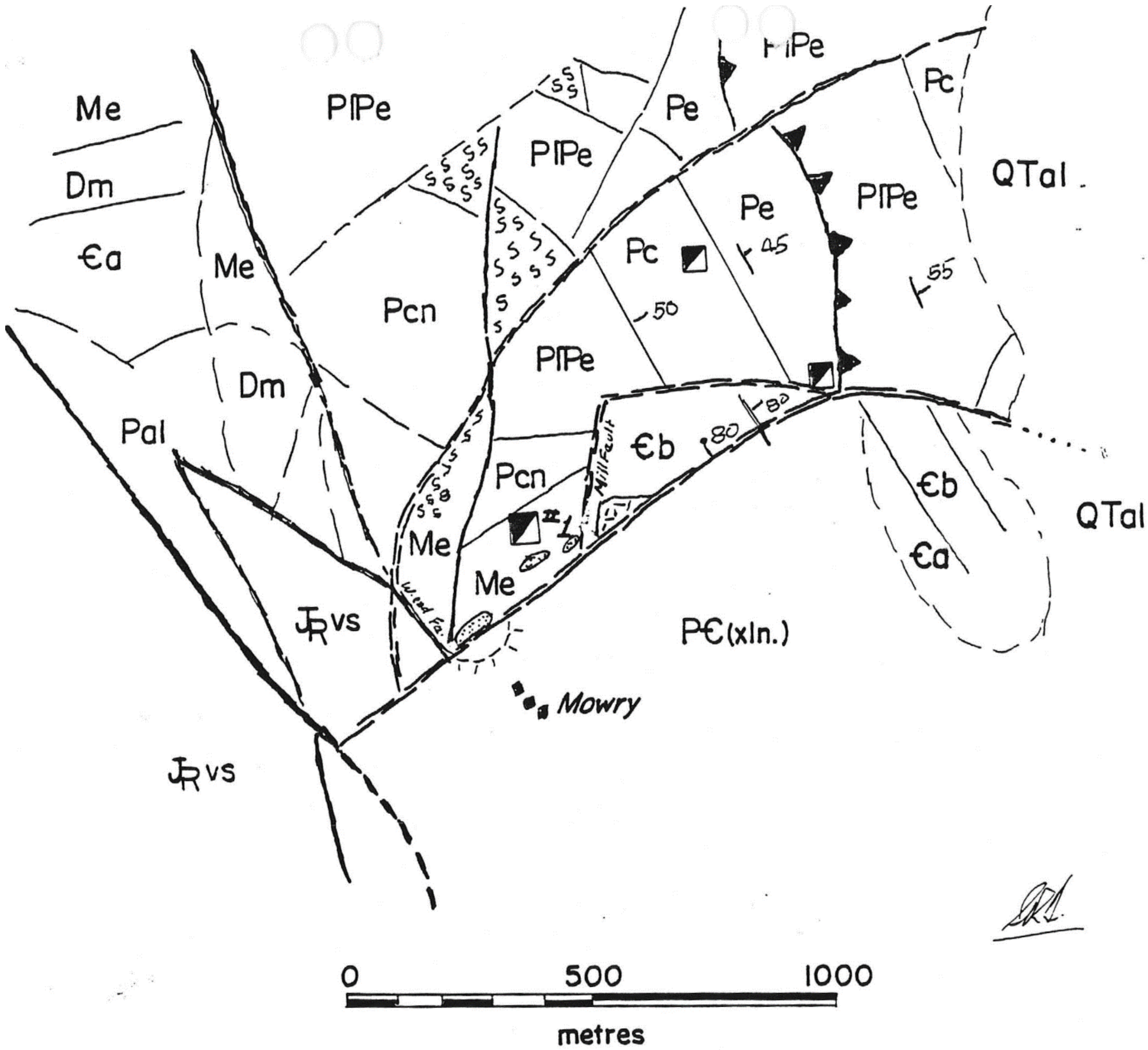
Prouty, J.W., 1907, The silver lead deposits of the Mowry Mine, Mowry, Santa Cruz County, Arizona: Univ. of Arizona unpub. M.S. thesis, 18p.

Schrader, F.C. 1915, Mineral deposits of the Santa Rita and Patagonia Mountains Arizona: U.S.Geological Survey Bull. 582, 373p. (Especially, p.296-306).

Simons, F.S., 1972, Mesozoic stratigraphy of the Patagonia Mountains and adjoining areas, Santa Cruz County, Arizona: U.S.Geological Survey Prof.Paper 658E, 23p.

Simons, F.S., 1974, Geologic map and sections of the Nogales and Lochiel Quadrangles, Santa Cruz County, Arizona: U.S.Geological Survey Misc. Investigations Series, Map I-762, (1:48,000).

Smith, G.E., 1956, The geology and ore deposits of the Mowry mine area, Santa Cruz County, Arizona: Univ. of Arizona unpub. M.S. thesis, 44p.



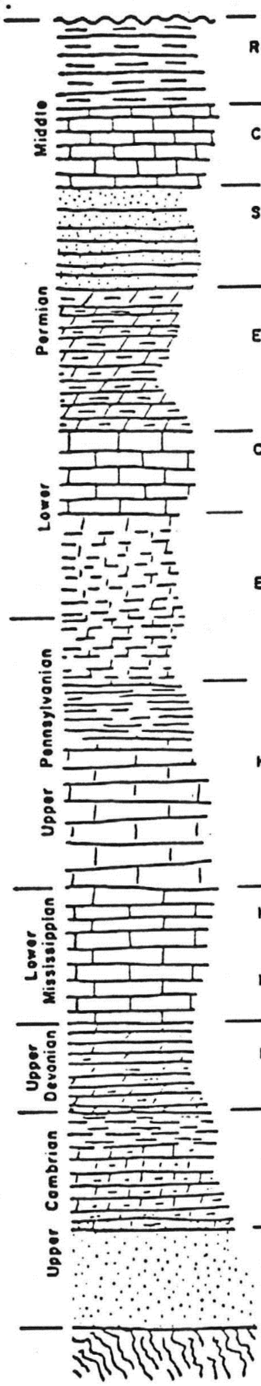
GEOLOGICAL SKETCH MAP – MOWRY MINE AREA

(Adapted from Simons (1974) & Smith (1956))

(Unsurveyed)

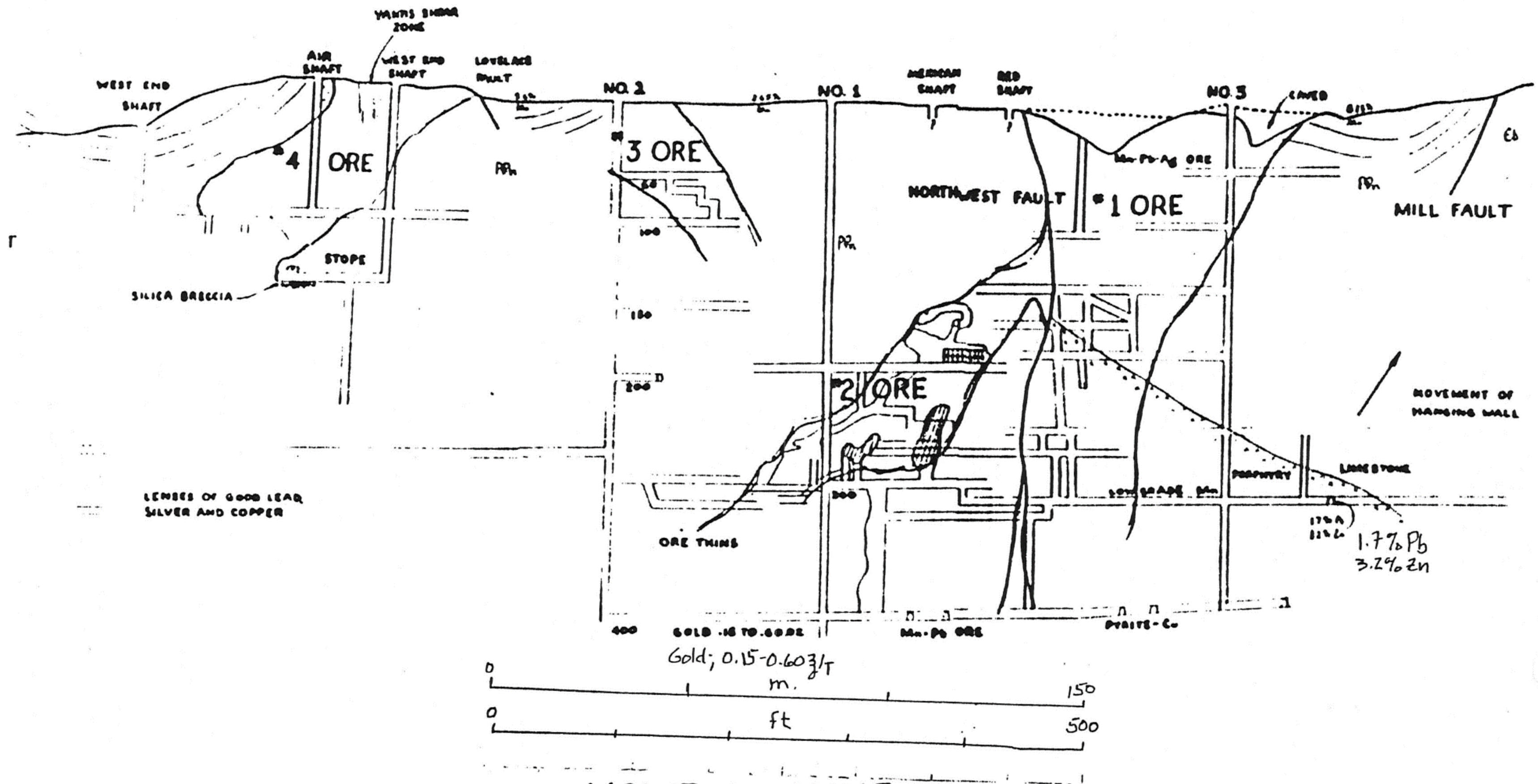
Generalized Paleozoic Column for southeastern Arizona. Not included are units of local occurrence such as the El Paso Limestone, Portal Formation, and Black Prince Limestone.

Map not.



Prv	Rainvalley fm. ~ 500'	variable thin to thick-bedded limestone - 80% limestone
Pcn	Concha fm. ~ 500'	thick-bedded clean limestone ~ 90% carbonate (with some chert)
Ps	Scherrer fm. ~ 500 - 600' thinning to west	lower and upper silt-sandstone units (~ 200' total) sandwich 300-400' of silty sandstone carbonate ~ 40% carbonate, 60% clastic
Pe	Epitaph fm. 750' (Tombstone) to 1500' (SW N. Mex.)	extremely variable unit with evaporite facies, in west is 1/3 dolomite and in east is 3/4 dolomite, locally includes gypsum, chiefly to northeast - thin-bedded with chert
Pc	Colina fm. 200' (Silver Bell) to 600' (Tombstone)	thick-bedded relatively pure $CO_3^{=}$, low dolomite content but widely variable
PIPe	Earp fm. ~ 1000'	ferruginous (pink) silty limestone and dolomite, ~ 65-35 carbonate to siltstone, thin-bedded
		formation boundary @ 50-50 carbonate-shale
IPh	Horquilla fm. 600' (Silver Bell) to 1600' (Chiricahuas)	upper 1/2 ~ 40% shale and silt, 60% carbonate; lower 1/2 increasing from 40-60 to 5-95% clastic to carbonate
Me	Escabrosa Gp. 600 - 750' (Hachita fm., Keating fm.)	upper massive and lower thin-bedded limestone clean ~ 97% carbonate (< 5% $CaMg(CO_3)_2$)
Dm	Martin fm. 300 - 400'	50% carbonate (1/2 dolomite) 50% silty carbonates (shales, thin sands)
€a	Abrigo l. s. 600 - 800'	50% limestone, 50% shale, thinly laminated micaceous, locally
€b	Bolsa Quartzite 400 - 700'	37% quartzite, 60% arkose, 3% shale

(from Norton, et al., 1975, U. of A.



MOWRY MINE

SANTA CRUZ COUNTY, ARIZONA

LONGITUDINAL SECTION THROUGH ORE BODIES

Stop 3 and 4: Hardshell Mine Historical working and mineralization

About 400' to the northwest of this stop is the main entrance of the historical Hardshell Mine. The large void opening is visible on your left when driving from call points 10 to 11, along with several other small workings. The deposit was originally discovered in 1879 and mined from 1896 through 1964. The Hardshell was a primarily underground, Pb-Ag-Mn-Cu-Zn mine. Workings include a 600-foot-deep inclined shaft and several levels of drifts. Workings sum to about 3,000 feet of opening. The deepest workings reach a vertical depth of 250 feet. In total about 35,000 tons of ore was produced averaging 6% Pb, 8 oz/ton Ag, 0.5% Cu, with minor Zn, Mn, and Au.

Mineralization occurred in irregular oxidized veins hosted in fault gouge and breccias, striking roughly E-W along the fault zone. Minor sulfide ore was recorded deeper in the mine. The host lithologies are Jurassic-Triassic volcanic rocks and Cretaceous Andesite. We will see some of the same lithologies at the stop.

Geology Overview

Lithology

Outcropping lithologies include two subunits of the Hardshell Volcanics formation (approx. 145 Ma), these subunits are the rhyolite lithic tuff and the lower tuff, in stratigraphical order (**Figure 1**). At this outcrop we can observe a contact between these two units. The rhyolite lithic tuff is characterized by its porphyritic texture with abundant plagioclase phenocrysts, as well as common 1-50 mm angular rhyolite lithic clasts, sometimes accompanied by a eutaxitic texture.

The lower unit, the lower tuff, is characterized as being light gray, massive, and fine grained with rare plagioclase phenocrysts and < 10 mm lithic clasts. We also find sparse weak hematite-limonite liesegang banding.

In the creek bed are a number of float pieces from the lower Paleozoic-age limestones.

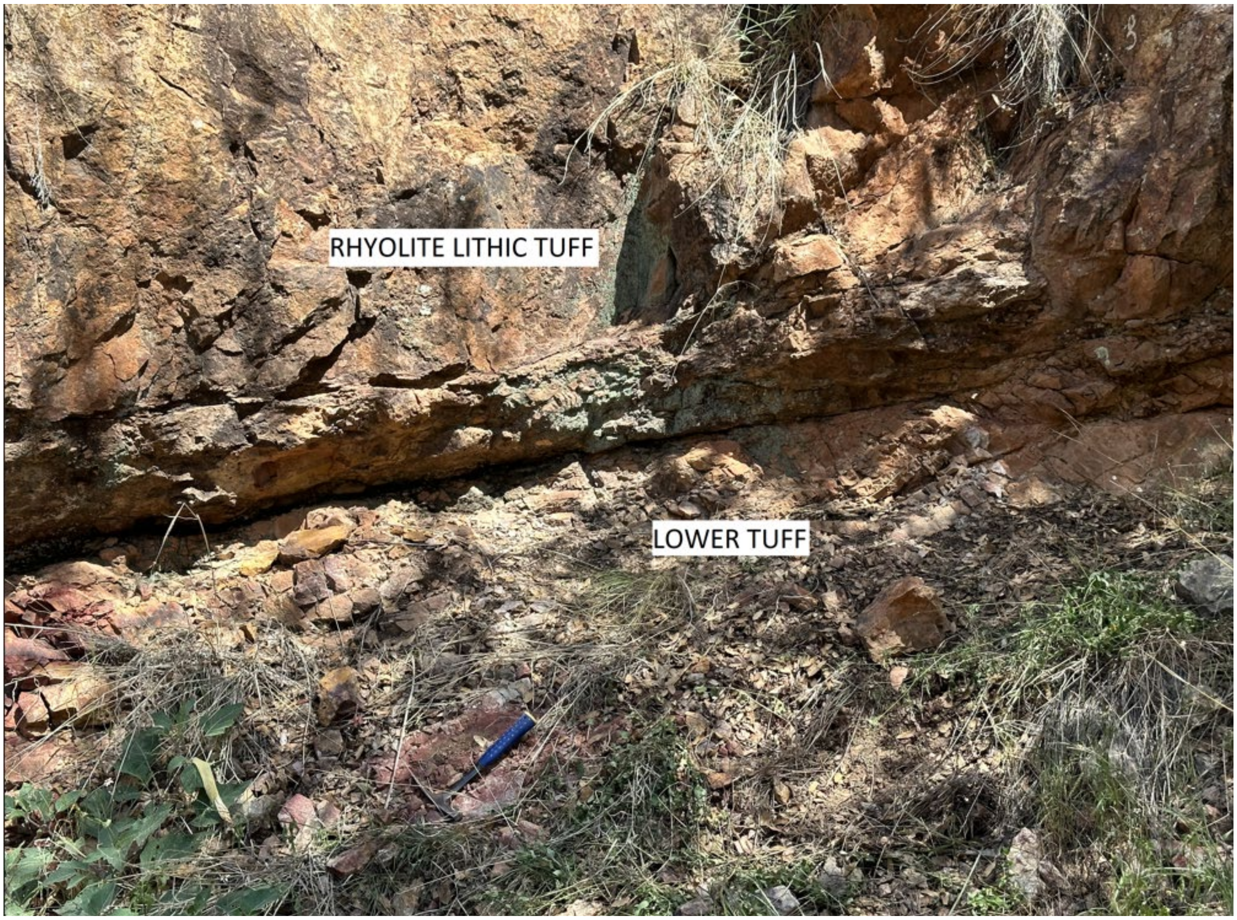


Figure 1: Lithological contact between lithic tuff and lower tuff subunits, rock hammer for scale.

Alteration and Mineralization

On the surface of several outcrops at this stop, alteration is evident in the form of black manganese oxide from supergene alteration, primarily in the mineral form cryptomelane $K(Mn^{4+},Mn^{2+})_8O_{16}$. The manganese mineralization is preferentially located in the lithic tuff unit, along with additional silicification, and minor propylitic alteration. Some of the supergene altered outcrops exhibit significant vuggy textures.

Structure

Our stop is located between the American fault and the Hogan fault. The American fault has a stratigraphic displacement of over 4,000 feet. One of the outcrops shows evidence of faulting through slickensides (**Figure 2**). It is unclear how it is structurally related to the nearby regional faults.

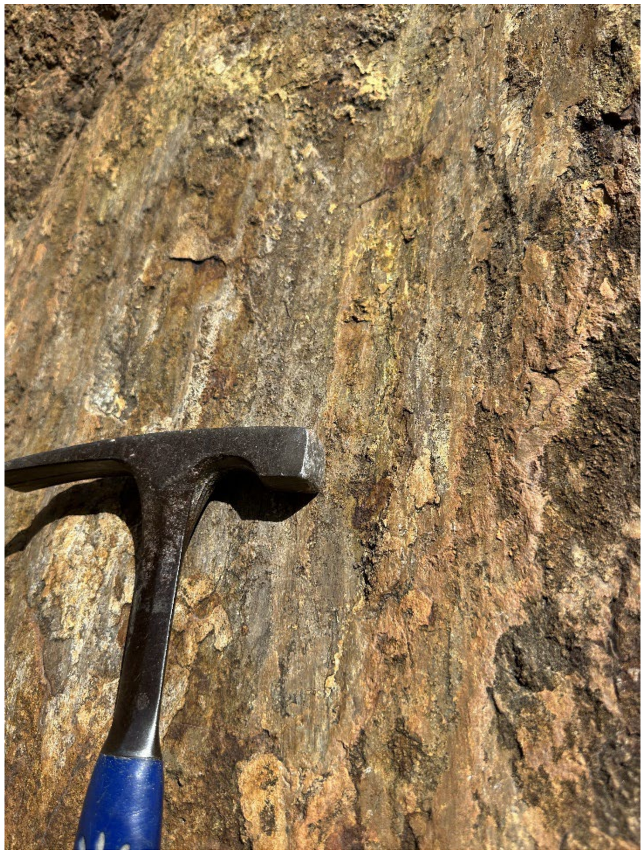


Figure 2: Slickensides, rock hammer for scale.