GOLD AND SILVER DEPOSITS IN COLORADO SYMPOSIUM

FIELD TRIP GUIDEBOOK

BERTHOUD HALL, COLORADO SCHOOL OF MINES
GOLDEN, COLORADO
JULY 20-24, 2017

GOLD AND SILVER DEPOSITS IN COLORADO SYMPOSIUM

FIELD TRIP GUIDEBOOK

Principal Editors:

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Sponsors:

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Front Cover: Gregory Vein and mines (1898). View is looking south from Bates Hill, across what is now casino-filled Black Hawk (previously Mountain City) and down the North Fork of Clear Creek (left center). The Gregory Vein passes through the steep, black, diagonal "open cut" or "surface stope" at right center. The vein was discovered on May 6, 1859, and was the first "lode" gold discovery in the Rockies (and Colorado), or in what at the time was referred to as the Snowy Range of the Kansas Territory. The photo also shows the daily passenger train to Central City. Photo courtesy of Denver Public Library, Western History Collection – Call No. 584. Design by Lew Kleinhans, Brian Alers. See Trip G for additional information.

Back Cover: The Mineral Industry Timeline – *Exploration* (old gold panner); *Discovery* (Cresson "Vug" from Cresson Mine, Cripple Creek); *Development* (Cripple Creek Open Pit Mine); *Production* (gold bullion refined from AngloGold Ashanti Cripple Creek dore and used to produce the gold leaf that was applied to the top of the Colorado Capital Building. Design by Lew Kleinhans and Jim Paschis.

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Field Trips &
Field Trip Leaders / Organizers

Trip A (Fri.): Hoosier Hill, Emmett Mine and Rip Van Dam Mine in the Gold Hill and Jamestown Areas
Jim A. Paschis

Trip B (Mon.): Cross & Caribou Mines Area
Steve Zahony

Trip C (Fri.): Georgetown / Empire Area
Steve Zahony

Trip D (Mon.): Leadville Area
Tommy Thompson

Trip E (Fri.): Alma / Fairplay Area
L.J. Karr,
Dean Misantoni

Trip F (Mon.): Cripple Creek/Victor Area
Robert Carnein,
Steven W. Veatch

Trip G (Fri.): Central City / Blackhawk / Idaho Springs Area
Laurence P. James,
James Piper,
Brian Alers,
Jesse Peterson,
Don McCoy,
Alex Gysi,
Lee Alford,
Lewis C. Kleinhans

Trip H (Mon.): Aspen/Smuggler Mine Area
Ralph Stegen

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Additional assistance was provided by Bill Rehrig, James Piper, and Bob Carnein.

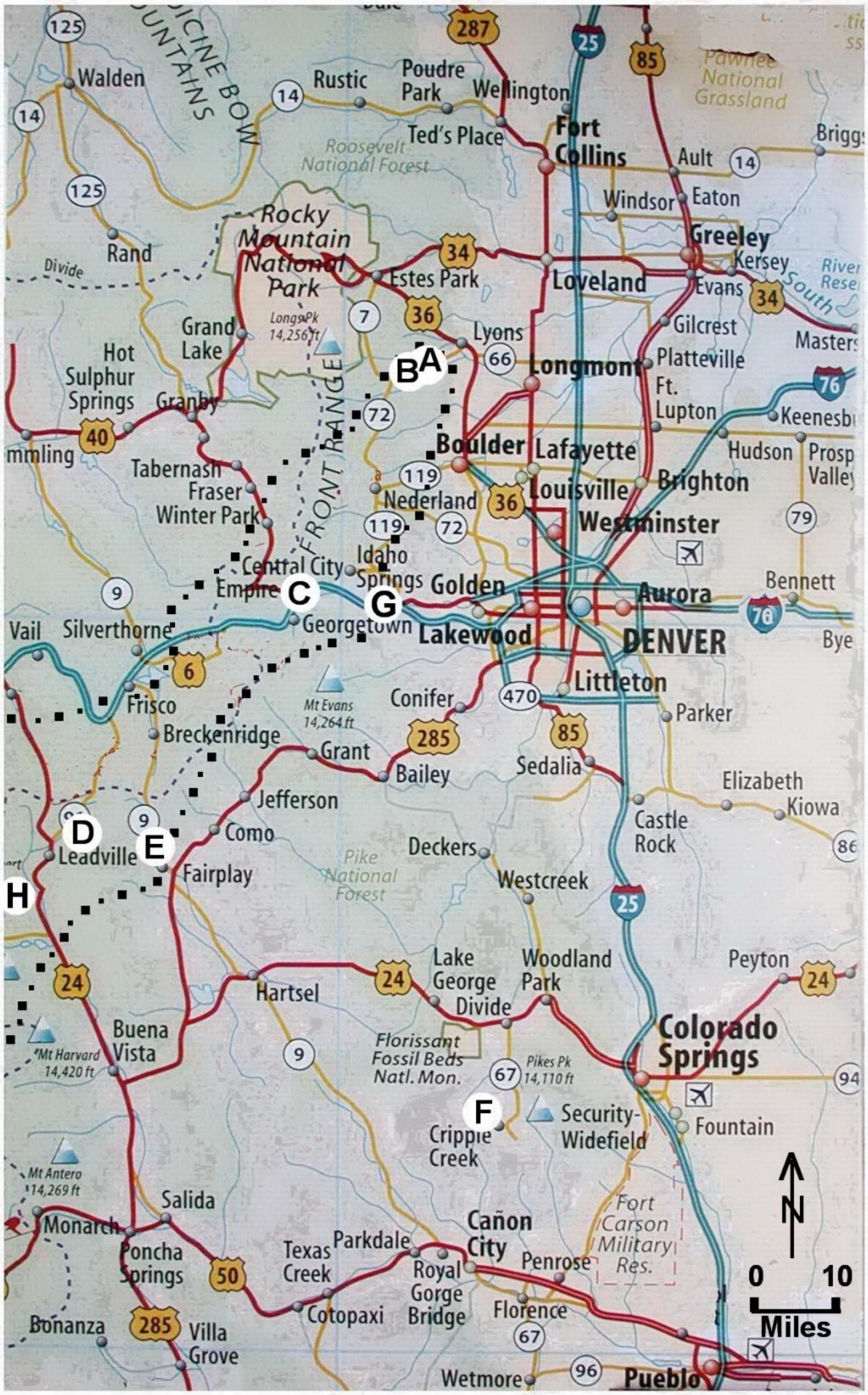
Acknowledgements

Far too many contributors participated in the making of this symposium than can be mentioned here. Notwithstanding, the Planning Committee would like to acknowledge and express appreciation for endorsements from the Colorado Geological Survey, the Colorado Mining Association, the Colorado Department of Natural Resources and the Colorado Division of Mine Safety and Reclamation.

Field trip leaders and organizers would also like to acknowledge the following for their contributions to the field trip efforts: Pat Farr, Dick Nielsen, Matt Collins, Matt Schreiner, and Jay Parker.

Contents

Field Trip Location Map



Field trip mining districts

A Gold Hill
B Grand Island
C Empire & Georgetown
D Leadville
E Alma & Fairplay
F Cripple Creek & Victor
G Central City, Blackhawk, Idaho Springs
H Aspen

Colorado Mineral Belt

Map showing field trip locations and the northern end of the Colorado Mineral Belt

Field Trip A: Hoosier Hill, Emmett Mine and Rip Van Dam Mine; Gold Hill and Jamestown Areas

July 21, 2017

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Summary Itinerary and Instructions

We will begin this trip in *Golden* at North Table Mountain with an overview. We will then proceed through *Boulder* to the Hoosier breccia reef near *Gold Hill*, followed with a stop below the Cash Mine for another overview and panning demonstration, and then on to *Jamestown* for an examination of Emmett Mine fluorite. We'll finish with an underground examination of the Rip Van Dam Mine and microscopy of gold telluride ore and then return to the Colorado School of Mines campus.

For reference, a stratigraphic column for the area is included (Figure 1).

Participants should carpool using four-wheel drive vehicles and make a contribution for fuel to their driver for this approximately 90-mile round trip. This trip will include a Mine Safety Training Class at the Rip Van Dam Mine by certified instructor, Matt Collins, Mining Engineer, CPE. Bring geologic field equipment, ultraviolet light (optional), sun screen, long pants, gloves for underground, and required hard hat, eye ware, and boots for mud in the RVD. RVD is dry, but the entry has 4" deep mud. Mine light, belt and self-rescuer will be provided. Do not open the self-rescuer unless you desire to purchase it for $300. Bring a lunch; AM and PM drinks and snacks will be provided. Places for "Pit Stops" are listed. Park off street in the Golden snow dump at 11th and Maple Street by 8 AM. The estimated return time is 7PM. The lead vehicle will be a white Suburban with a CSM plate: AU DORE with a yellow-flagged antenna. The tail vehicle should keep their headlights ON.

Road Log

MILE FIELD TRIP WITH FEATURES DEMARCATED ENROUTE

0.0 Highway 93 at U.S. 6 over Clear Creek, Golden, Colorado. Drivers may set their odometer here. Placer gold is in Clear Creek and may be panned as far east as Indiana Street, about 6 miles toward Lakewood. The gold originates upstream west especially from the ore deposits originating in the vicinity of Black Hawk, Central City, and Nevadaville.

1.7 Bennett clay mines are at steep dipping open cuts with clays valuable to blend in brick building products. These industrial minerals were originally accessed by adits and later by open-cuts with shipment to Denver by railroad; the old rail bed may be seen west of the highway. The clays are interbeds in the Cretaceous Dakota Group. The Golden Gate Canyon road is just west from here. Depending on vegetation and sun angle, it is possible to discern the east-west texture of the Precambrian gneiss. This is the southern limb of an antiform with the northern limb about four miles north. At that location, important lithologic and structural changes lead to essential controls

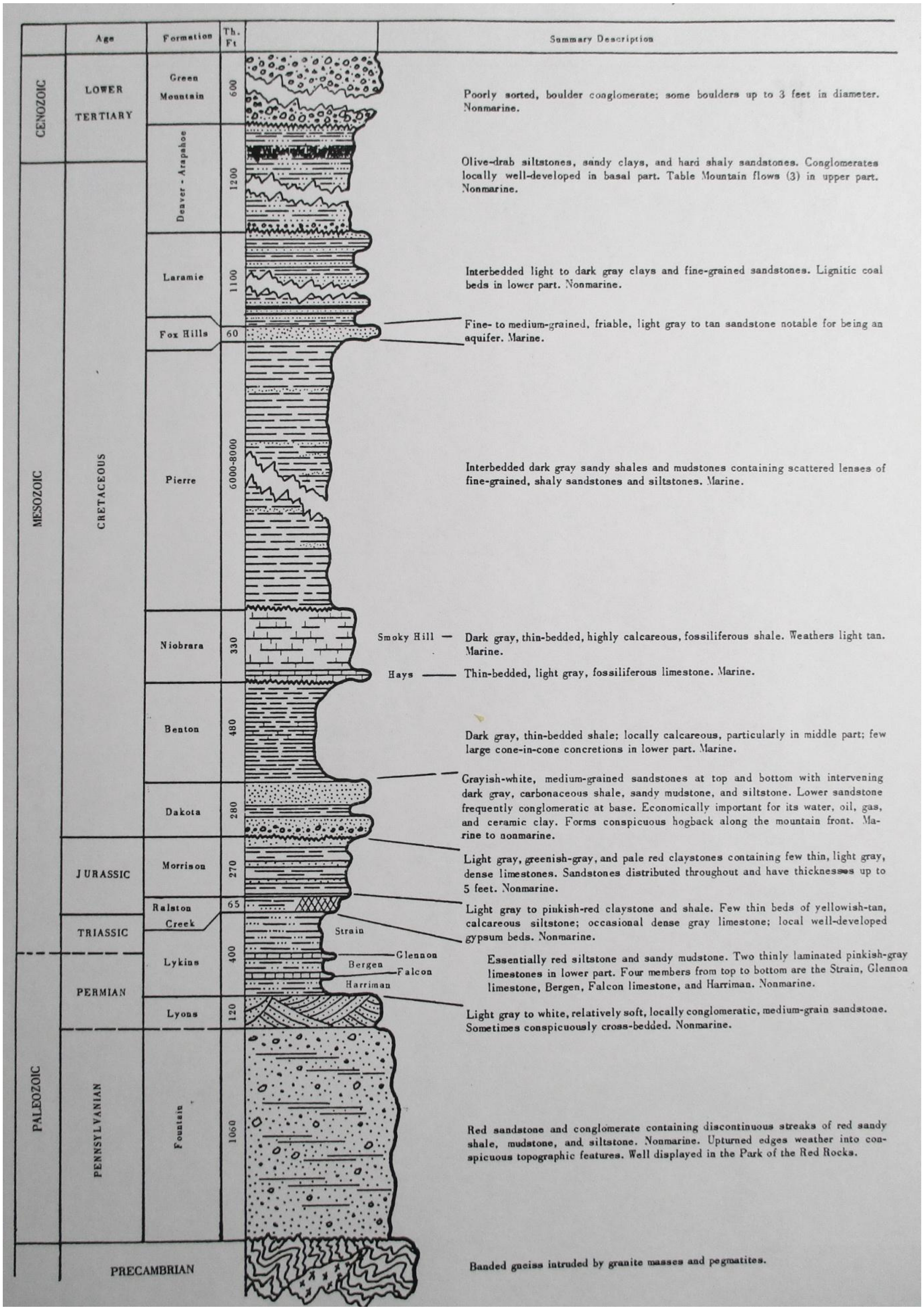


Figure 1: Generalized Stratigraphic Column – Golden, Colorado

hosting uranium mineralization at the Schwartzwalder Mine. The mine closed in 2000, after producing 20,000,000 pounds of uraninite in veins and breccias mined as deep as one-half mile.

2.0 **North Table Mountain Park:** The view to the northwest and the distant parts of this trip will be pointed out from here. Beginning from the west around and looking northward, the following points of interest may be seen: 1. Bennett clay mines. 2. East Rogers breccia reef (fault); note the offset in the red cliffs of the Pennsylvanian Fountain Formation. The highest ridge is Ralston Buttes and the Schwartzwalder Mine lies near the Ralston Creek valley bottom beneath the dense Ponderosa pine forest. Ralston Creek, being of lower gradient than Clear Creek, was the early route to the Gilpin County gold mines. The Mena Mine at Ralston creek with its singular vein cuts ankeritic-altered rock containing visible bismuth and silver in addition to uraninite. 3. Coal Creek Quartzite, the youngest of the Precambrian formations, is exposed in a synform. It has been interpreted as a drag fold formed by the Colorado Lineament. 4. Mining infrastructure at the Ralston Quarry mine of hornblende latite from the Ralston dike. It is the intrusive equivalent of the Table Mountain volcanic flows above. 5. Fountain Formation Flatirons just west of Boulder. 6. Knolls of covered latite intrusives trending toward the Table Mountain flows. 7. The landslide block of Dakota Group sandstone just west of the farm with two brick silos. At this stop samples of the main rock formations, along with ores of uranium, gold and tungsten will be available for viewing. Included will be a diagram of the Schwartzwalder orebody where the total mineral value at the highest price for uraninite ($42/pound) would have been nearly $800,000,000.

Pit stop (?)

2.4 Re-enter highway 93 turning north ***Take great caution here as there is no merge lane!***

3.2 Pass the farm buildings to the west with the Dakota sandstone just behind. This block most likely is a severed slump from the bedrock sandstone farther west. There it is adjacent to the high angle Golden mountain front fault with a structural offset of 8,000 to 10,000 feet separating the Front Range from the yoked Denver Basin to the east.

4.5 The left turn is the entrance to the Ralston Quarry. It provides quality aggregate for concrete products.

4.8 Pass 64th avenue leading to the Schwartzwalder and Black Forest mines and White Ranch Park.

5.5 Pass over Ralston Creek. Reservoirs to the east and west provide water supplies to Denver and Arvada. The lead vehicle (white Suburban) will drive in the right lane slowly to re-group the vehicles of the field trip, which should try to remain assembled for the remainder of the trip.

6.1 Pioneer Sand facility is on the right. To the west small open cuts produced clay from the Dakota Group. This formation was the transgressive unit for the Cretaceous seaway through Colorado. The comparable regressive sequence is represented by the Fox Hills Formation due north with vertical dip and was also mined for clay. The obscured 8,000-foot thick marine unit between the Dakota and Fox Hills is the Pierre Formation shale.

8.5 The high flat surface entered is the Rocky Flats alluvium and is composed of detritus from the Coal Creek Quartzite. Ahead on the east side, aggregate quarry operations exposed cross-beds up to 18 feet high. The alluvium was a result of glacial outwash and has been mapped over 16 square miles reaching as far south as Green Mountain. Highway 72 westbound leads to Coal Creek Canyon.

9.8 The entrance to right was for the former Rocky Flats Plant which was a U.S. Department of Energy facility. Its mission was to make plutonium triggers for nuclear warheads and is now decommissioned. Viewing to the west, several of the 28 tunnels for the Union Pacific Railroad continue beneath the Continental Divide to the west. Below us, the interpreted section (Figure 2) comprises sedimentary formations younger than 270,000,000 years (270 Ma), unconformably overlying basement crystalline rocks older than 1,710,000,000 years (1,710 Ma). The time gap separating the crystalline rocks (1,710 Ma) and the next overlying rocks (270 Ma) is 1,440 Ma, which is approximately one-third the Earth's age!

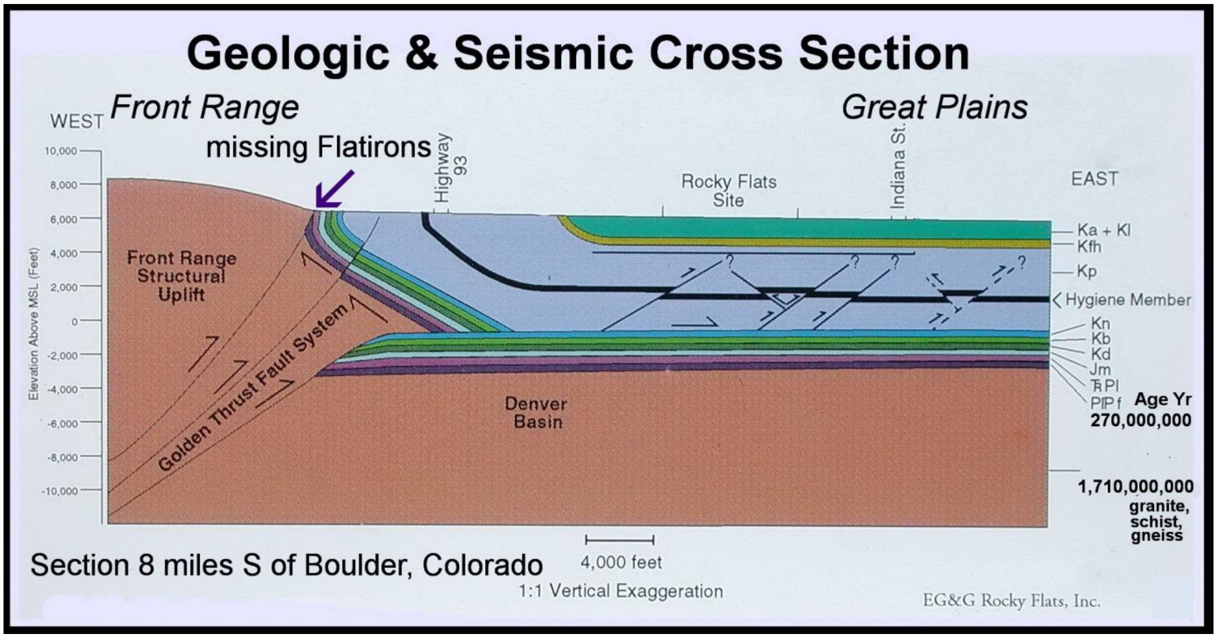


Figure 2: Geologic and seismic cross-section used to assess the potential for recent faults beneath Rocky Flats site; none were found that post-dated (cross-cut) Kfh (Fox Hills).

11.3 The Trinity engineered aggregates infrastructure is in view on the right. Their 180-foot deep open pit mine in Pierre shale is to the west. The shale is rotary kiln roasted making light-weight aggregate and baseball infield products. NREL wind-powered generators are ahead.

13.2 The descent into the Boulder valley begins here as the Pennsylvanian Fountain Formation to the west is in prominent view. To the east the Fox Hills and overlying Laramie Formations show prominently decreased dip. The Laramie here contained a very extensive, shallow coal field mined from 1859 to 1979 producing 107,000,000 tons of coal.

15.0 As South Boulder Creek is crossed, 14,255-foot high Longs Peak in Rocky Mountain National Park and the burned north canyon over Jamestown may be seen. The Emmett and Rip Van Dam mines are at the base. What is your estimate on the dip of the Flatirons: 45º, 55º, 65º?

18.2 Highway 93 is now Broadway in the city of Boulder as the west-east baseline is intersected on the latitude of 40º 00'. Our vehicles should be in the median side as a left turn will be soon.

19.7 Cross over Boulder Creek and turn left at the light to enter Canyon Blvd. (Highway 119). At 9th Street, look left (south) to see the truer dip on the Flatirons which is 45º.

20.0 Enter Boulder Canyon (Highway 119) which is walled with Boulder Creek Granite. This coarse grained catazonal batholith assimilated bordering Precambrian gneiss and schist. On the perimeter it is granodiorite, at its core where assimilation was minimal it is granite. There is no readily seen Pennsylvanian-Precambrian unconformity here in contrast to the classic locality at the upper amphitheater parking area of Red Rocks Park north of Morrison, Colorado.

22.4 Leave Boulder Canyon and turn right to Four Mile Canyon. ***Caution for bicycles!***

25.4 At the 3-mile marker note the 2010 forest fire devastation of the Four Mile Fire which at the time was Colorado's most costly wildfire. The fire was inadvertently started by a retired fireman. Although devastating, it does permit less obscured geological views.

26.2 Logan Mill road is on the left, but stay right as the village of Salina is entered. Gold Run begins here as we follow the right turn. Records are indefinite, but historical research suggests that this was the area in which placer gold was first discovered in Boulder County in 1859.

27.8 Stay left at the Ingram Gulch turnoff.

28.8 Enter the village of Summerville and stay straight, not turning right to climb. This narrow road passes a blocked road on the right to the Rex Mine which is said to have a gold grade twice that of the Cash ore but less tonnage. Continuing straight will lead to the Hoosier Hill site of the Hoosier breccia reef. The structure to be examined is shown in the SE corner the geologic map by D.J. Gable (Figure 3). Four-wheel drive is suggested for this climb.

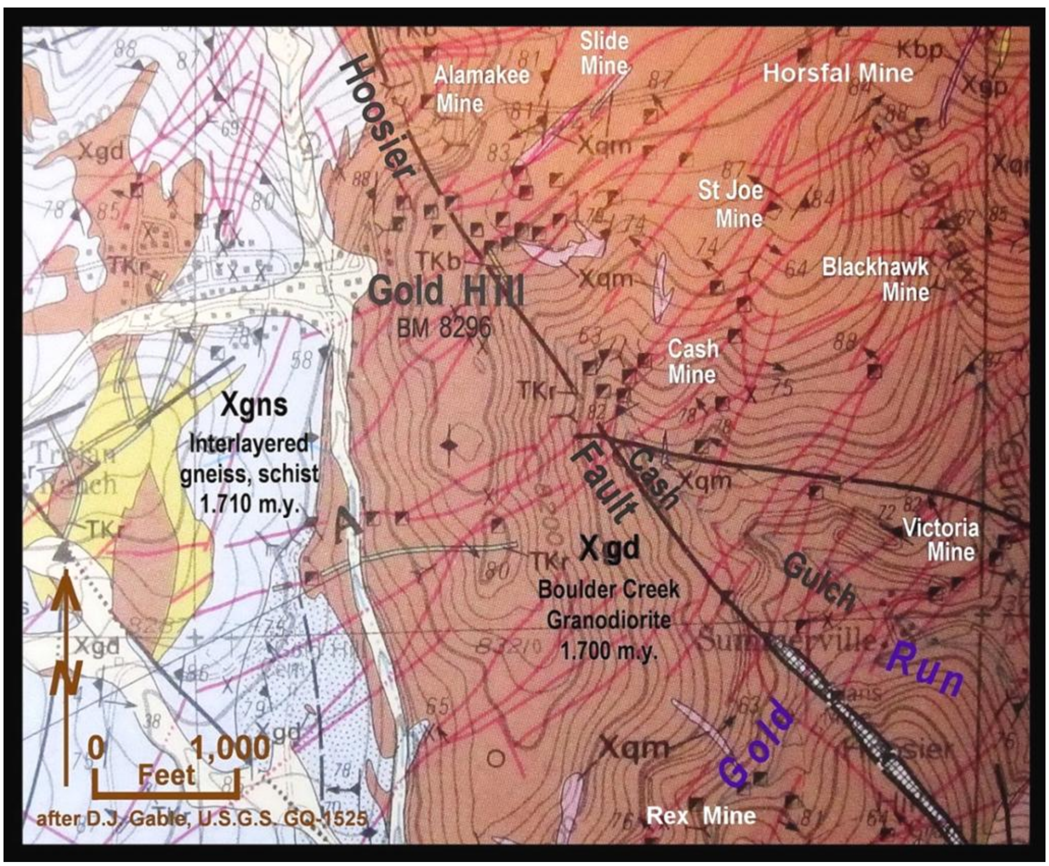


Figure 3: Geologic Map of Gold Hill area by D.J. Gable.

29.5 **Hoosier breccia reef.** Park at the level area in the road and allow clearance for possible traffic. Walk to top of ridge to examine the Hoosier breccia reef. Note the strike trending NNW to the far valley wall. Examine the sequences of brecciation and white quartz. Grates over shafts here suggest mineralization was in and on both sides of the reef.

Note the higher structural relief of the white quartz compared to the flanking lower relief of the granite. Granite in this area weathers approximately 1”/1000 years. Massive, fine grained quartz would take longer. There is reef top quartz here that is extremely smooth, what might that suggest?[1] The Cash Mine workings, including mill, hoist house, dump and 3rd level adit are 4,000 +/- feet to the north northwest.

30.3 Pass through Summerville again and continue upward on the road toward Gold Hill. The view to the southeast across the valley to the Hoosier breccia reef shows outcrop of the fault in the third dimension with an undulatory dip of the hanging wall and footwall.

30.7 Pass the closed lower road to the Cash Mine. Samples of sediment were collected during high meltwater after heavy snow in mid-May at the base of the Cash gulch. Pull off on the right side with flashers operating. A panning demonstration using sediments from the gulch will make a heavy mineral concentrate. A visual check for gold will be made. Gold (native) and tellurides, such as petzite, Ag_3AuTe_2, were mined at the Cash 1,200 feet upslope and approximately to a depth of 300 feet lower than our elevation here.

32.5 Enter Gold Hill and intersect Boulder County Road 52 which is called Main Street.

32.7 Turn right (east) and note the Hoosier breccia reef outcrop is not apparent and is possibly only a shear zone.

32.9 Entrance to the Cash Mine property. The Gold Hill Mill facility is housed in the large building. Milled tailings are collected in the adjacent lined pond. At this time the owner is preparing to use flotation and gravity methods to check for feasibility of gold recovery from the prior mine development materials seen from the Hoosier Hill view. Turn left back to Gold Hill.

33.2 Place transmission to lowest gear after right turn to descend the very steep Lickskillet Road.

33.4 Dumps to the right are the tailings of the initial telluride vein discoveries in Boulder County made in 1872. The assayer B.N. Sanford first noted telluride ores brought in by prospectors for assaying. He subsequently located some of the earliest lode claims in the Gold Hill vicinity.

34.2 Turn right at the pavement to Left Hand Canyon County Road 106.

38.0 Turn left in James Canyon west bound on County Road 94. ***Caution for bicycles!***

40.1 Continue past the entry to the Rip Van Dam Mine toward Jamestown.

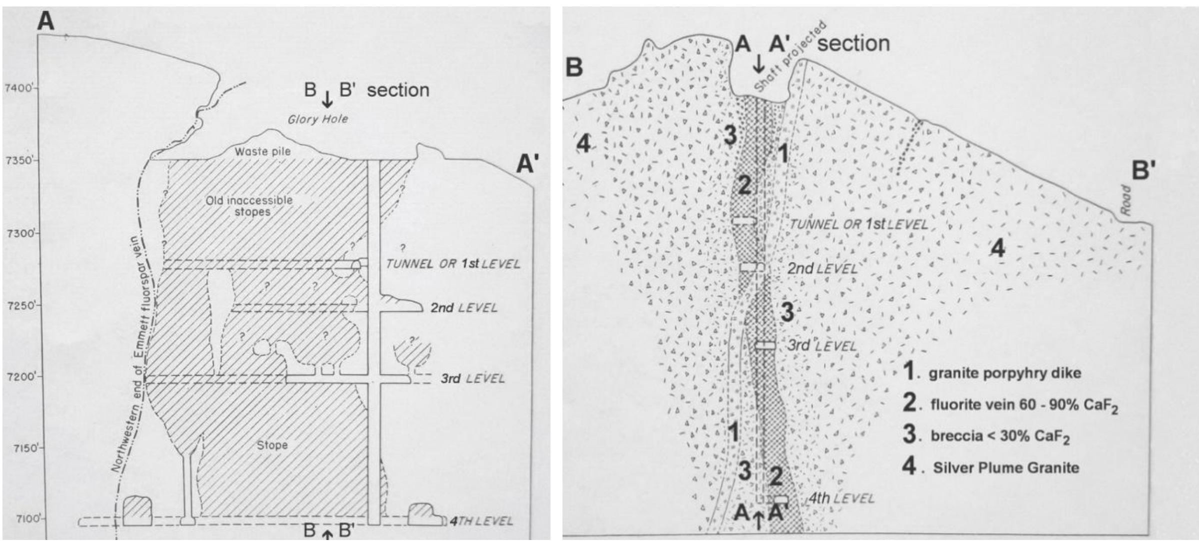
43.2 **Emmett Mine.** Turn right and park at base of County Road 87 & Balarat Road. The Buckhorn Mine was nearby at the James Creek bed, now obscure, and produced gold, silver and lead ore by shaft. It is the type locality for buckhornite, $AuPb_2BiTe_2S_3$. Walk across the highway to review the Emmett Mine. We will walk to the collapsed head frame on the eastern side of the mine then descend into the open pit. ***Be careful of possible high wall failures!***

[1] The field trip guide interprets the Hoosier quartz surface to have been locally glacial polished.

Two cross sections are shown below and based upon U.S. Geological Survey Prof. Paper 223.

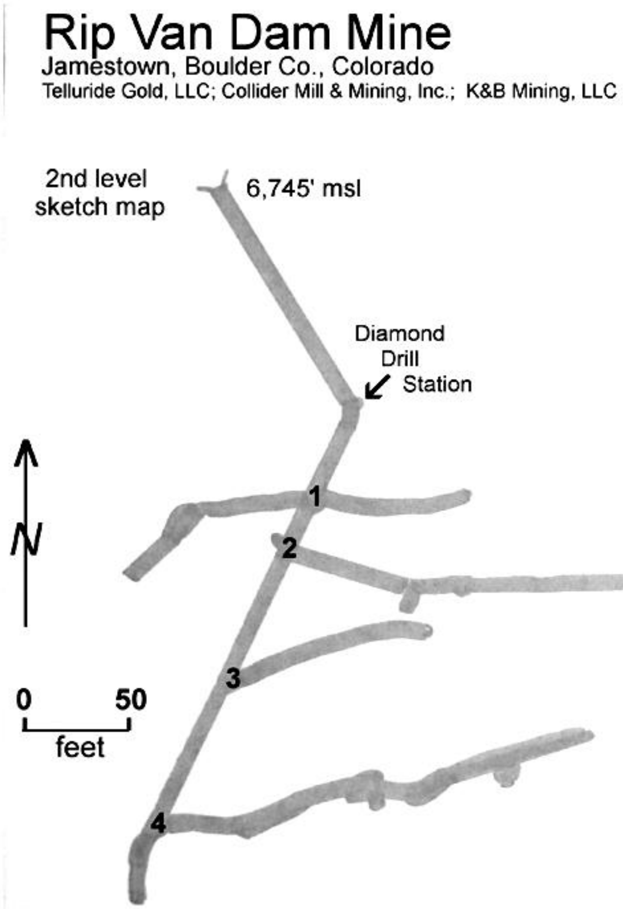
Figure 4a, A-A’ is viewed toward the 030º azimuth and shows the mine development with stopes in the plane of the fluorite breccia vein. Figure 4b, B-B’ is viewed toward the 298º azimuth and shows the geology with flanking hanging wall and footwall. The vein is cut by a granite porphyry dike. The mine was initially developed by adit which is visible in the high western wall of the open pit. The decision was made to continue mine development by shaft. The fluorite ore (Figure 5) grade production was about 65% CaF_2. The non-fluorescent purple mineral ranged

Return to Jamestown. ***Pit stop? Parking area is on right; go to the stone building ahead left.***



Figures 4a (left) and 4b (right): Emmett Mine longitudinal (A-A’) and cross (B-B’) sections.

Figure 5: Examples of fluorite ore from the Emmett Mine.



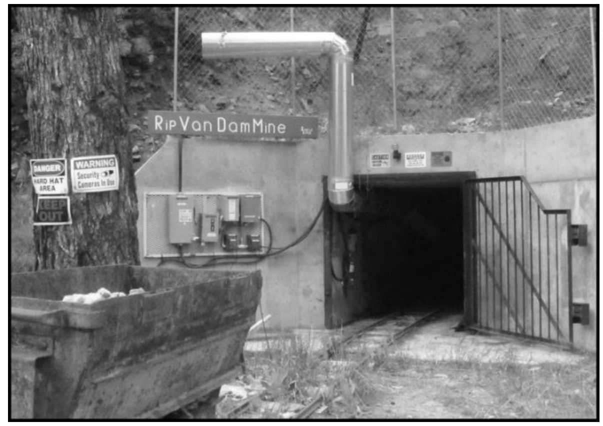


Figure 6: Sketch map of 2nd level underground workings at the Rip Van Dam Mine

from sand size up to 2 feet in diameter. In addition to wall rock breccia fragments and quartz other minerals noted in small amounts are: pyrite, galena, chalcopyrite, sphalerite and tetrahedrite. The grade was consistent with depth and likely continues below the developed shaft at 480 feet below collar.

46.2 **Rip Van Dam Mine** road entrance is just below the green residence. **Drivers take care at narrow road sections!** The intention is to first drive to the 2nd level portal shown in Figure 7 for the underground portion of the trip. We will have underground safety training here from Matt Collins and advice on use of the self-rescuer essential for donning in cases if mine fires or carbon monoxide is present. Depending on the current level of exploration we may drive to the 1st level first to observe the exploration diamond core drilling. Be sure to sign the waiver and return it to your field trip leader.

Secondly, an opportunity will be available to view with a reflected light microscope, a high grade ore sample found near the 1st level area and prepared as a polished section. Our group will be divided in two, an underground group and an ore viewing group. The groups will be reversed so all may participate in both presentations. Underground, several narrow structures will be seen in the host rock of Precambrian Silver Plume Granite. Small locally mineralized areas may be observed where marked and include: white horn quartz, black ferberite, $FeWO_4$, purple fluorite, CaF_2, and a pegmatite of green beryl, $Be_3Al_2Si_6O_{18}$. The yellow secondary mineral, probably

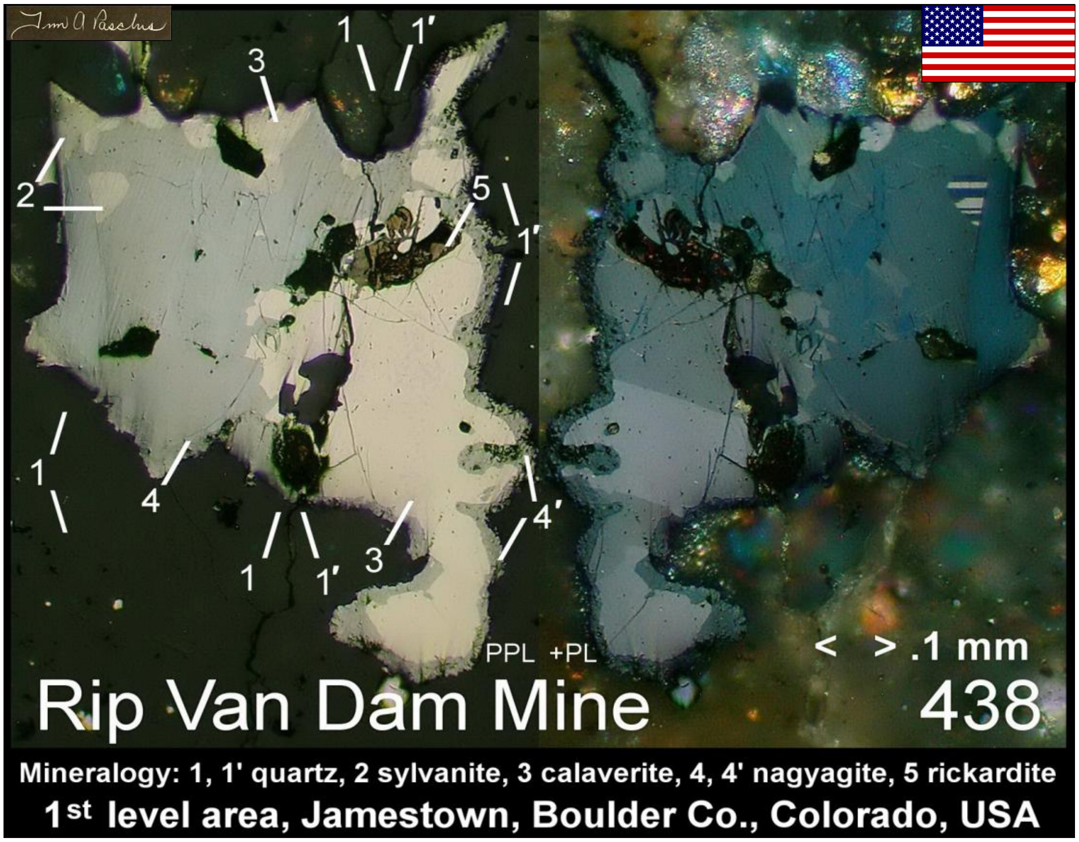


Figure 7: Photomicrographs from a polished section prepared from a high-grade sample found near the near the 1st level area of the Rip Van Dam Mine showing three primary gold tellurides and a secondary copper telluride

andersonite, $Na_2Ca(UO_2)(CO_3)_3.6H_2O$, formed locally on the ribs since mine development decades ago. It is also vividly fluorescent under ultraviolet illumination. It likely originated from the relatively high average U content (12 ppm) of Silver Plume Granite, highest of the three (Pikes Peak Granite and Boulder Creek Granite batholiths) Front Range intrusives.
An area of polished section 438 is shown above in Figure 7 with three primary gold tellurides and a secondary copper telluride species. The gold tellurides are: calaverite, $AuTe_2$; sylvanite,

$AuAgTe_4$; and nagyagite, $Au(Pb,Sb,Fe)_8(S,Te)_{11}$(?). The copper telluride is rickardite, Cu_7Te_5. Other minerals out of this view shown are: gold, Au; petzite, Ag_3AuTe_2; and weissite, $Cu_{2-x}Te$. Historical mine production data will be available as published in U.S. Geological Survey Professional Paper 223. A sample prepared from the Cash Mine may also be viewed. Printed images of the photomicrographs will also be available for viewing.

Following these activities, return the underground gear: self-rescuer, mine light and mine belt to your field trip leader and receive a bag for muddy boots. When departing the mine road take care upon exiting at the tight left turn back to the pavement of County Road 94. **Caution for bicycles!** Stay left at 2 miles as this road will join Left Hand Canyon, which should be followed east to meet Highway 36. Turn right on 36, proceeding south entering Boulder via the first right turn on to Broadway and return to Golden.

Thanks to all drivers and participants!!!!

Field Trip B: Boulder County – Cross and Caribou Mines
July 24, 2017

Steve Zahony, Consulting Mining Geologist
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Introduction

The trip will start in Golden, CO at the designated CSM parking lot at 8AM. We will travel via Highway 93 to Boulder, CO and on to Nederland via Highway 119. For whom it is more convenient to meet in Nederland CO, a second rallying point will be at the Sinclair gasoline station at 9:15AM at the roundabout in Nederland where Highway 119 meets Highway 72.

For a road log for the leg of the trip from Golden to Boulder and part of the way up Boulder Canyon, please turn to the road log of Field Trip A: Hoosier Hill, Emmett Mine and Rip Van Dam Mine field excursion in this booklet. That road log will be followed from the CSM campus to mile 22.4. From that point, we will continue on Highway 119 up Boulder Canyon to Nederland.

From the Nederland roundabout, we will travel west on Highway 72 for 0.4 mile and take the Caribou Rd., which follows the North Beaver Creek drainage. Stay on the main gravel road to the settlement of Cardinal, which is 2 miles west-northwest of Nederland. The main road loops back to the east at Cardinal and then loops back to the northwest paralleling Coon Track Cr. At 2.4 miles beyond Cardinal, the road reaches the Cross Mine road that is clearly marked.

At the Cross Mine we will meet Thomas Hendricks, the mine operator, who will brief us on mine safety, be our guide underground and give us a tour of the Caribou silver district following the underground trip. We will supply miner's lights and self-rescuers for each participant. If you own a hard hat, please bring it with you. Please bring your own lunch as we plan to eat lunch at Caribou.

Figure 1 is a topographic map of the Caribou-Grand Island Silver District, together with its major veins and property boundaries. Figure 2 is a diorama of the Cross and Caribou Mines together with their associated underground workings.

Caribou – Grand Island Silver District

Silver was discovered here in 1869 and hand-sorted, rich ores were shipped by wagon for treatment at Blackhawk by 1870. The major silver producing veins were the Caribou and the No-Name, both located west of the settlement of Caribou, which is near the drainage divide at an elevation just below 10,000 feet. East of the town, gold-bearing veins are more prevalent. The Cross Mine is developed on a system of gold-bearing pyritic vein.

The Caribou-Grand Island district is centered about a 62.6 million year old (Ma), Laramide, composite augite-bearing monzonite stock containing unusual mafic phases that include gabbroic units and titanium-bearing magnetite bodies. These Tertiary bodies intrude Proterozoic Idaho Springs formation schist and gneiss. A mass of Boulder Creek granite underlies Boulder County Hill east of Caribou.

Silver and gold-bearing veins crosscut the Tertiary and Precambrian crystalline rocks. The major vein trend in the district is east-west but the most silver-productive vein, the No-Name vein, strikes northeasterly and crosscuts and offsets or terminates all other veins. Its junction with the east-trending Caribou vein is the locus of the main silver orebody exploited to date. Most of the other productive veins of the district west of Caribou persisted with rich ores, probably secondarily enriched, to depths of only 100 feet. Few of the veins had mineable ore below 300-400 feet depth. Ore shoot seem to develop where vein dips become flatter.

Total silver production in the Caribou district is poorly documented but is between 5-10 million ounces, the bulk of which came from the shoot at the No-Name-Caribou vein junction. This orebody persisted from surface to the lowest level of the mine at the 1,230-foot down-shaft level. When in production, the Caribou Mine was serviced by an inclined shaft. The mine was allowed to flood in 1928 but was reactivated in1948 for its uranium potential. An adit, the Idaho Tunnel, was driven to intersect the No-Name vein at the 500 Level and the Caribou shaft was revitalized. Economic uranium resources did not materialize. The target pitchblende-bearing shoot averaged only 0.12% U_3O_8 and had limited strike length. In that period of uranium exploration, the lowest level of the mine was deepened 190 feet to the 1230 Level. This lowest level was developed and extensively sampled for uranium, gold, and silver, and an underground diamond drilling program ensued. Prof. Ernest E. Wahlstrom of CU conducted a detailed channel sampling program on the 1230 Level that outlined a block of ore 170 feet long with an average width of 37 inches assaying 0.11 opt Au, 31.37 opt Ag and 3.24% Pb. A vein parallel with the No-Name vein, the Nelson vein, was also channel sampled by Wahlstrom, and over a 212.5 feet drift distance averaged 30 inches in width at 0.072 opt Au, 34.97 opt Ag, and 1.18% Pb. Galena, tetrahedrite, native silver and silver-bearing sulfosalts are responsible for the elevated silver grades.

Because of problems ventilating the lowest levels of the mine, low metal prices, and safety issues, the mine was allowed to flood in 1956. Bonanza grades persist and seem to proliferate at the bottom of the mine. Drilling below the 1230 Level confirmed this.

Cross Mine

The Cross Mine portal is located about ¼ mile southeast of the ghost town of Caribou. The Cross vein system was discovered in 1873 and is primarily gold bearing with lesser amounts of silver. Including the adit entry level, the mine is developed on four levels with winzes connecting the levels below the haulage level. Tom Hendricks has been operating the mine since 1974. During the period 1977 to 1983 the mine produced 5,000 ounces of gold and 125,000 ounces of silver from 27,000 tons of development ore. Much drilling (over 63,000 feet) and exploration drifting has been done underground that has outlined probable resources of about 350,000 tons grading 0.32 opt Au and 2.3 opt Ag.

The Cross Mine exposes a series of auriferous sulfide veins along a contact zone between Precambrian

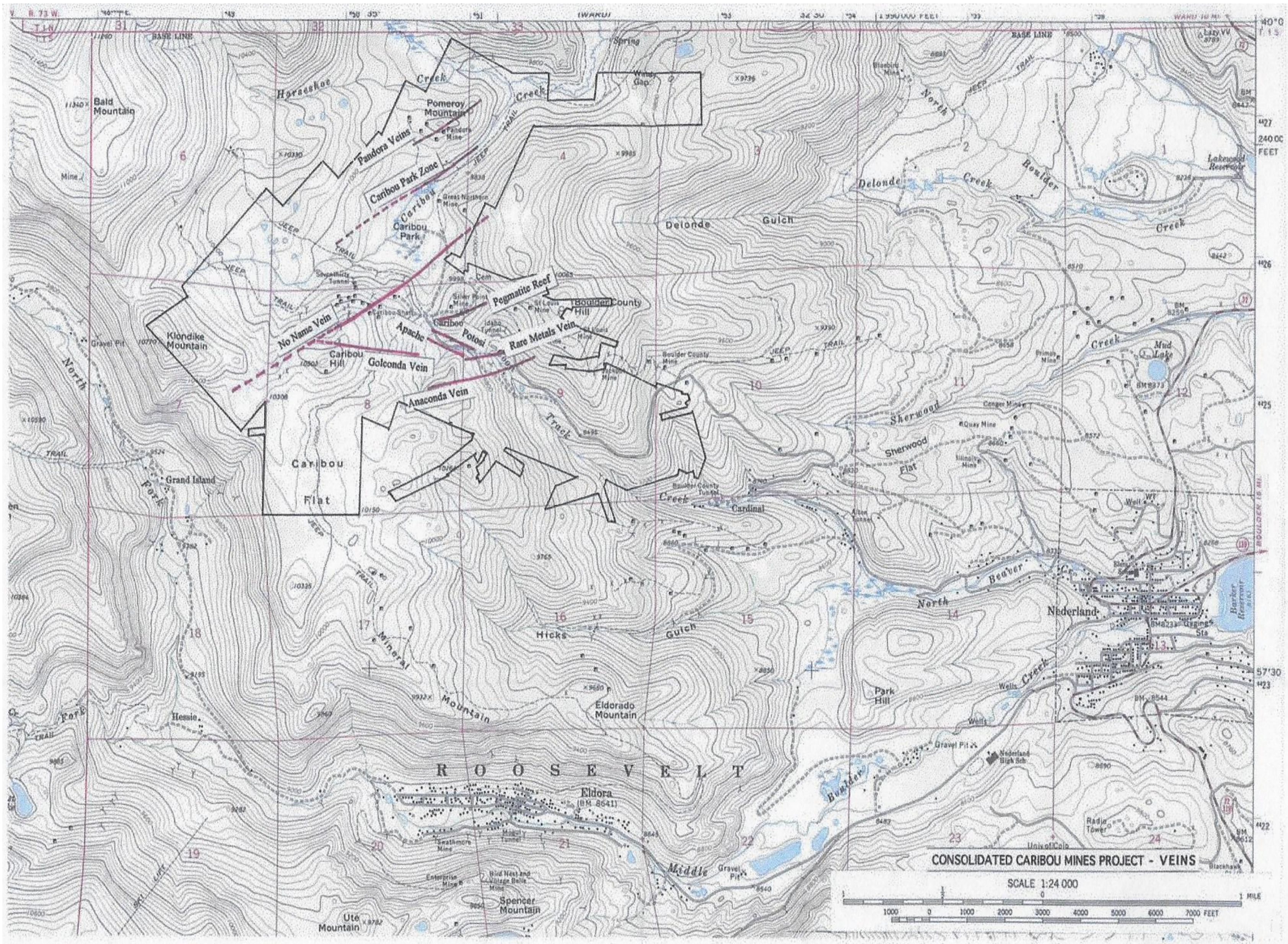

Figure 1: Topographic map of the Caribou-Grand Island Silver District, together with major veins and property boundaries.

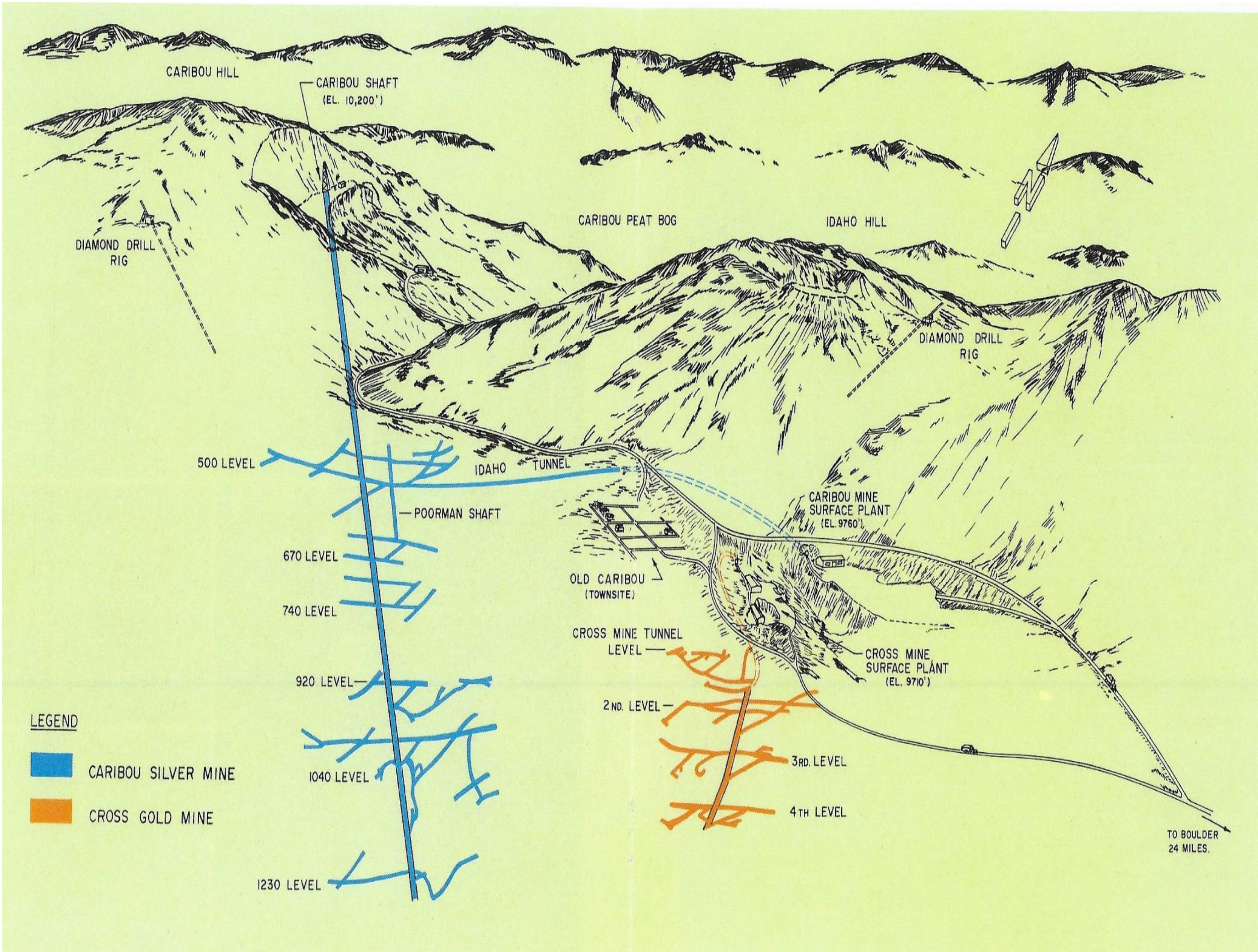

Figure 2: Diorama of the Cross and Caribou Mines and associated underground workings.

gneiss and a Laramide monzonite intrusive. A myriad of veins form a stockwork-like zone of gold mineralization. Some of the veins are persistent and form the identified resource. Most veins, however, are discontinuous but are part of a broad zone of gold mineralization, which has been described as a possible bulk-mineable resource.

A 1994 masters thesis by Kerry Holland proposed that the gold-containing structural zone is at the junction of the Arapahoe Pass and Junction Ranch fault zones. He believes that ore-bearing fluids were derived either from a deeper magmatic sources than the rocks exposed at the surface or were derived from Laramide metamorphic processes. He defined seven distinct sequential stages of mineralization: 1) fine grained quartz-pyrite with trace molybdenite, 2) coarser grained quartz pyrite with hematite, sericite, and base metal sulfides, 3) calcite and dolomite, 4) main stage gold, silver, and base metals, 5) sulfosalt stage, 6) dolomite stage, and 7) supergene stage with iron oxides. The common sulfosalts are stromeyerite, tetrahedrite, and pyrargyrite. Silver is most abundant in electrum and argentite of Stage 4 and in sulfosalts of Stage 5.

Boulder County Tungsten District

The Caribou district is located just beyond the western boundary of the Boulder Tungsten district. Tungsten-bearing veins in the Boulder mining region are temporally and in their physical appearance close relatives of the gold-silver telluride veins. The areal extent of the tungsten-rich veins overlaps the telluride veins and in the rare case tungsten-bearing veins contain telluride minerals and native gold.

The Boulder County tungsten district extends from about one mile west of the community of Nederland towards the northeast for a distance of ten miles. Like the majority of the telluride veins, the tungsten-bearing veins follow the main northeasterly Tertiary structural trend, and indeed the majority of the tungsten-bearing veins have a northeasterly strike direction. Overall, the outline of the tungsten zone resembles the shape of a butternut squash with its bulge at the southwest end in the vicinity of Nederland.

In their mineralogy, the veins are relatively simple, dominated by chalcedonic quartz (horn quartz) that is the host to fine-grained ferberite, the iron-rich end member of the wolframite series. Like its cousins the gold-telluride veins, ore shoots tend to be short both vertically and horizontally but high in grade. Viable shoots occur along changes in fissure direction and at fissure intersections. Wallrock alteration resembles that of the telluride veins in having relatively thin zones of sericitization and silicification next to the vein with broader outboard zones of argillation.

Host rocks to the tungsten-bearing veins can be the variety Precambrian crystalline units and early-Tertiary intrusive rocks but there is a close relationship between the tungsten veins and biotite latite dikes and breccias some of which contain tungsten minerals.

Ferberite in the veins of the Boulder gold region was not identified until 1900. In quick succession the Boulder district became the prime tungsten-producing district of the United States, producing the majority of the tungsten metal needed in World War I. After the war, scheelite-producing districts overshadowed the Boulder district but tungsten mining continued on a greatly reduced scale. In 1942, when gold mining was shut down during the war effort, many gold miners switched to tungsten mining.

Whatever time is remaining after the excursion to the Caribou area will be spent in discussing and stopping at tungsten occurrences. Returning to Nederland from Caribou, we will turn north onto paved Highway 72. At 2.0 miles from reentering Highway 72, a stop will be made near the Clyde tungsten mine. At 3.0 miles from entering Highway 72, we will turn east on the Sugarloaf Rd. and continue for another 3 miles and stop at the large Oregon Mine dump along the Sugarloaf Rd., where ferberite-bearing vein material is abundant on the mine dump.

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Field Trip C: Empire – Georgetown Area
July 21, 2017

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Introduction

There will be two assembly locations for this field trip: one at 8 AM, at the unpaved parking area along Clear Creek at the junction of 11th St. and Maple St., and a second at 9 AM in Empire, CO, at the intersection of Highway 40 and Main St., just west of the Hard Rock Cafe. Carpool arrangements will be transmitted to each participant by phone and e-mail prior to the trip.

The trip and road log will start at the intersection of US Highway 40 and Main St. in Empire. We will head north on Main St., which becomes the road of Empire Creek. At 0.8 miles, a gated road splits to the left that reaches the Minnesota Mine. Make a sharp right at this split, staying on the main road. The off-limits flat area to the left is the reclaimed Empire waste disposal facility, last operated in 1990. Our first stop and parking spot will be at 1.8 mi. from Empire.

Empire District

The Empire Mining District was first worked in the early 1860's as a placer operation by ground sluicing of wide zones of oxidized, gold-bearing, pyritic veins. A water ditch was constructed from Mill Creek, located over three miles to the northeast, and about 75,000 ounces of gold were recovered in the first fifteen years of sluicing. Wide trench-like, deep, surface cuts may in part be remnants of this initial mining activity, although much trenching was conducted in modern times. Sporadic underground mining activity overlapped with and followed ground sluicing in the subsequent decades with variable success. In 1934, Minnesota Mining, Inc. began mining underground at the north end of the district, recovering 100,000 ounces of gold before the wartime edict L-208 shut down the operation in early 1943.

A generalized geological map of the Empire district, copied from USGS Professional Paper 223, is duplicated on the following page (Figure 1). Wide but discontinuous, gold-bearing, pyritic quartz veins surround a Tertiary hornblende monzonite porphyry intrusive that is more of a dike swarm at the surface, unlike the solid body show on the attached map. The dominant vein trend strikes northeasterly with steep angles of dip towards the porphyry mass. Precambrian Boulder Creek granodiorite and gneisses of the Idaho Springs formation host the majority of the pyritic veins, although some veins cross into the monzonite porphyry. Other Tertiary intrusives, common in the mining districts of the Front Range, like bostonite and alaskite dikes, also occur here.

Veins are dominated by pyrite, quartz, and chalcopyrite. Gold prefers to be associated with chalcopyrite, but productive veins also contain lesser amounts of galena and sphalerite. Veins tend to make sheeted zones with individual veins being less than 5 feet wide. Complete oxidation of sulfides extended to a maximum depth of 40 feet, but in most cases gold-liberating oxidation was shallower. Unoxidized pyritic ore typically contains about 0.3 ounce/ton Au. Wallrocks are silicified with disseminated pyrite and sericite.

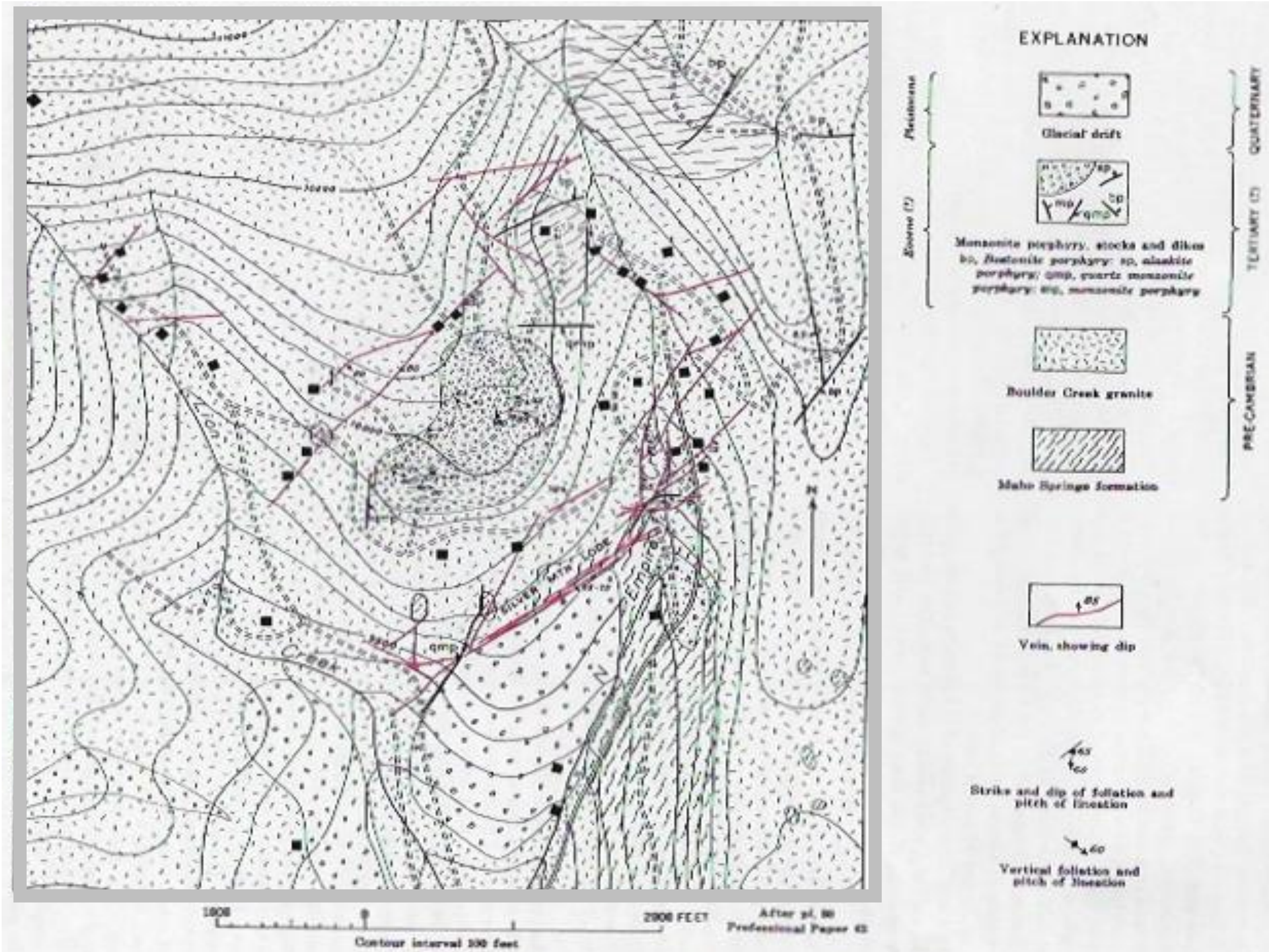

Figure 1: Map showing relationship of veins to porphyry stocks in the Empire District.

In the 1970's, the bulk tonnage potential of the district was recognized. Close-spaced drilling was conducted at the Silver Mountain Lode and the Minnesota Mine areas by a number of companies, including Noranda Mines. About 60,000 tons were removed for bulk testing in 1984, resulting in the benched topography that we will examine at the Silver Mountain area. By 1989, 270 holes had been drilled that showed a resource of 458,000 tons grading 3.95 grams Au/ton. The resource was not mined.

From Empire, we will proceed to the train depot in Georgetown by returning to Interstate 25 via Highway 40. At 1.2 miles east of the center of Empire, if time permits a stop, we will examine an exposure of a pegmatite along the south side of Highway 40 that contains sulfide minerals. This pegmatite is most likely related to the intrusion of the Silver Plume granite, but due to the abundance of coarse biotite, the pegmatite may be an apophysis of the older Boulder Creek granite. However, a poorly documented specimen of molybdenite, supposedly obtained from this pegmatite, returned a Laramide age by the Re/Os isotopic dating method.

Railroad Trip

We will assemble at the railroad station located at the southwestern edge of Georgetown. Our train departs at 12:10 PM. There is ample parking at the station. Following the train ride we will examine the mineral collection from local mines at the Clear Creek County Assessor and Treasurer's office in Georgetown. Depending on the interest of participants, we can visit the Pelton wheel-driven hydroelectric plant, also in Georgetown, that was built to generate electricity for the nearby mines and the city.

The original Georgetown Loop was completed in 1884 to service the thriving mines of the Silver Plume area. Railroads reached Denver in 1870 and a narrow-gauge railroad was completed to Idaho Springs in 1877 and later the same year to Georgetown. In 1879, the silver stampede to Leadville took its toll on the Georgetown-Silver Plume district but mining activities continued in the district and reached their peak in 1896. During both world wars, mining was rejuvenated in the Georgetown-Silver Plume district for lead and zinc production. Except for sporadic mining promotions, sustained mining has not occurred since the end of World War II. Past mining had reached depths of over 1,000 feet in the strongest vein systems during the most active time of the district's exploitation. It would be a major undertaking to revitalize the district today.

Georgetown Silver Plume District

This prominent silver district (Figure 2) covers a large area of steep topography from Leavenworth Creek, the mouth of which is located one mile south of Georgetown, to Lincoln Mountain, about a mile southwest of Empire. To the northeast, the district merges with the southwestern extension of the greater Idaho Springs Mining District. The most productive part of the district is located along the precipitous southern slopes of the twin peaks of Sherman Mountain and Republican Mountain, immediately north of the town of Silver Plume.

Oxidized veins were discovered in the district in 1859 and initially worked for their gold content. Within a decade, rich silver ores were discovered in these same veins. Total oxidation of veins of the entire district only extended to shallow depths of 40 feet maximum, and usually shallower. Pleistocene glaciation was effective in removing the partially weathered upper parts of veins of the district. The effects of glaciation are evident from the U-shapes of major valleys and the sporadic presence of till and morainal debris.

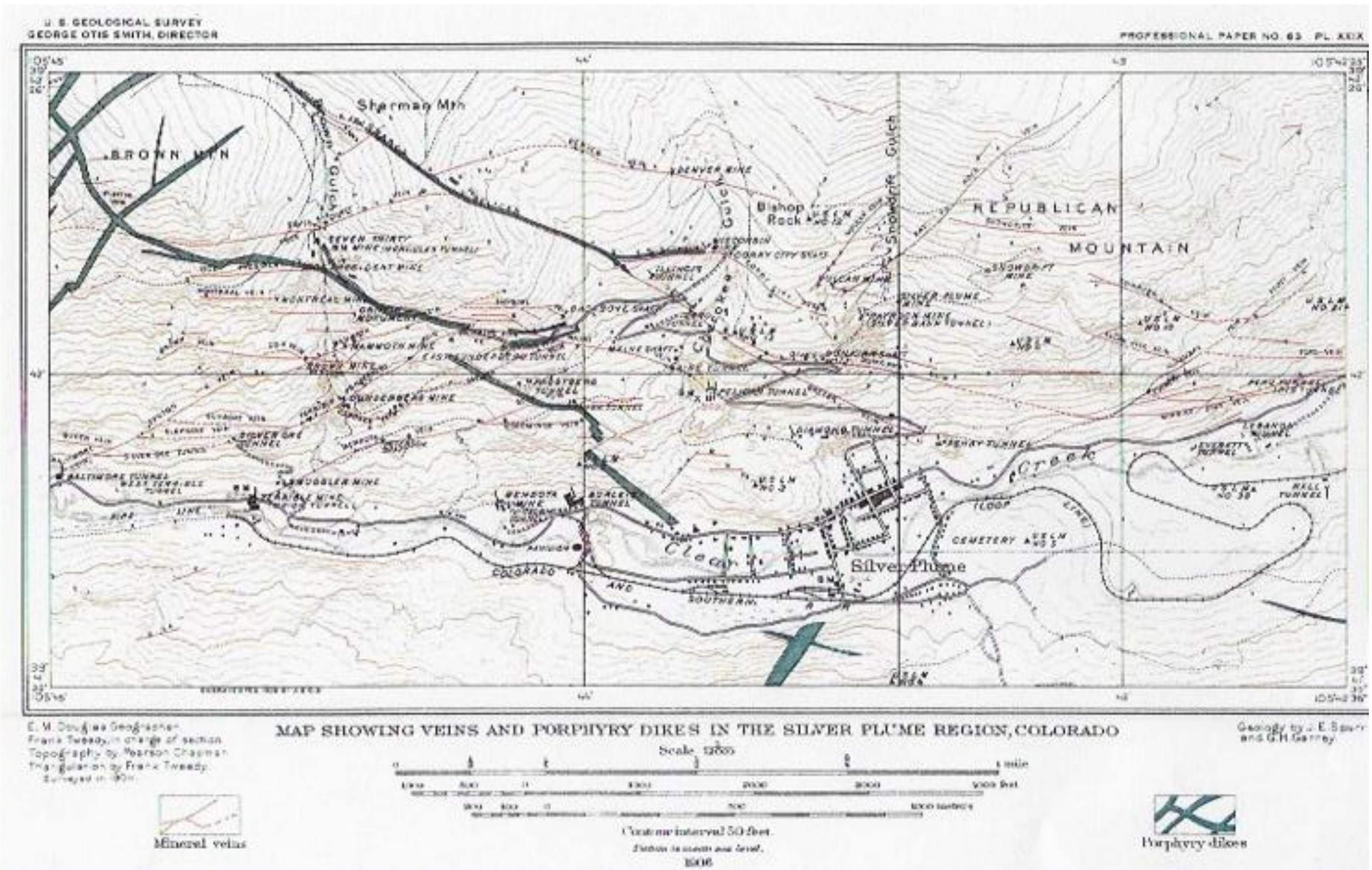

Figure 2: Map showing veins and porphyry dikes in the Silver Plume Region, Colorado.

The various schists and gneisses of the Idaho Springs formation and the Proterozoic Silver Plume granite host the veins of the district. There are several granitic stocks of Tertiary age within the district and dikes of quartz monzonite and rhyolite porphyry are in many places intricately associated with productive veins. Dikes of rhyolite appear to be genetically related to the silver- and base metal-bearing veins. A stock of rhyolite porphyry along the east margin of Leavenworth Creek, about two miles south of Georgetown, was explored for molybdenum.

Productive veins of the district tend to strike in an east-northeasterly direction, although the most productive vein in the Silver Plume district, the Pelican-Bismarck, strikes in a west-northwesterly direction. Many of the other northeasterly veins appear to be splays of this vein. Productive structures are persistent and have been mined for horizontal distances up to 7,000 feet. Ore shoots make up about 20 to 50 percent of the veins. The most productive vein of the district, the Pelican-Bismarck vein, produced ore to depths exceeding 1000 feet. The Colorado Central vein at the mouth of Leavenworth Creek also was productive to depths of over 1000 feet.

Below the shallow gold and silver-enriched zones, powdery high-grade ore occurred in the upper 200-300 feet of the surface that commonly contained several hundred ounces of silver to the ton. Ore rich in polybasite, tetrahedrite, and ruby silver were abundant in this zone and persisted in rare cases to depths of 800 feet, below which galena and sphalerite prevailed with typical silver contents of several ounces of silver per percent lead. Ore shipped to smelters from the Silver Plume-Georgetown district were considered some of the highest-grade silver ores of Colorado. The Colorado Central Mine produced ore averaging over 200 ounces silver per ton over a sixteen-year period.

Vein widths are hardly ever described in the published literature. Judging from museum hand specimens, it appears that ore shoots generally consisted of a high-grade sulfide leader vein of about 4-6 inches thickness surrounded by a sulfide-veined zone of up to several feet on either side of the lead streak. If the veined zone had sufficient sulfide, it was mined and shipped along with the high-grade. In most cases ore was hand-sorted before shipping to a smelter, in which case recorded grades of ore produced usually reflects this selected material. In later days, ore mills were erected in Silver Plume and in Georgetown and the necessity of hand sorting diminished.

Following the railroad excursion, we will proceed to the town of Silver Plume via Interstate 70. At the Silver Plume exit, continue straight ahead after the stop sign along the main west-heading paved road, the old Highway 6. At 0.7 miles past the stop sign, we will park at the large open space by the Silver Plume granite quarry. We will discuss the quarry operation and, depending on time, we will hike first to the portal of the Mendota Mine and then back to the west about ¼ mile past the granite quarry to the Terrible Mine shaft. Subsequently, we will return to Silver Plume and have the option of walking through this dilapidated but original mining town and/or cross under I-70 at Silver Plume and enjoy a vista of the Silver Plume district from the far side of Clear Creek, where the remnants of a devastating snow avalanche can be viewed.

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Field Trip D: Leadville Area
July 24, 2017

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The Leadville Mining District

Introduction

The Leadville district was discovered by panning for gold in the Spring of 1860. By July there were 10,000 miners working the California Gulch placer, and by 1868 the placer was mined out. The first major silver lode ores were discovered in 1874, and in 1875-1876 a second rush of about 40,000 miners took place. Many of the orebodies were mined out within a few decades. Many others closed in the metal price collapses of 1893 and 1918. By 1927 the district was in serious decline. In 1938, ASARCO and Newmont became interested in the district, and initiated the exploration program that culminated in development of the Black Cloud mine (Smith, 1988). The Black Cloud was a major, modern production facility that began operation in 1971 and closed in early 1999.

History. In addition to the ore produced, the Leadville district is significant for the pioneering geological work that was completed there. The first two mining districts in the United States studied in detail by the U.S. Geological Survey were Leadville and Comstock (Nevada), and those two studies stand as landmark contributions to the science of economic geology. The Leadville work was carried out by S.F. Emmons, who published a famous 770 page USGS Monograph 12 in 1886. Many of Emmons' concepts of ore genesis have withstood the test of time.

Mining and Processing. The Black Cloud mine, the last modern facility in the Leadville district used a room and pillar, cut and fill method. Rubber-tired equipment was used in the stopes, and rail haulage transport carried ore to the Black Cloud shaft, 505m deep. The ore was concentrated in a flotation mill adjacent to the shaft station and produced a lead concentrate (65% Pb, mill recovery = 87%) and a zinc concentrate (50% Zn), both of which were Ag- and Au-bearing. Copper was not recovered. The coarse-grained tailings were used to backfill the stopes, and the fine-grained tailings were sent to a pond in Iowa Gulch. The concentrates were shipped by rail to smelters at East Helena, Montana and El Paso, Texas. The production rate of the mine was 720 tonnes per day with approximately 160 employees onsite.

Production/Reserves. Cumulative production of the Leadville district through 1987 was estimated at 10,700 kg of placer gold, and about 23.8 million metric tonnes of lode ore with an average grade (using metal recovery data) of 0.2% Cu, 3.0% Zn, 4.2% Pb, 3.65gpt Au, and 320 gpt Ag. Reserves at the Black Cloud mine as of 31 December 1987 were 805,000 metric tonnes averaging 2.4 gpt Au, 0.20% Cu, 3.95% Pb, 8.09% Zn, and 68.1 gpt Ag (ASARCO 1987 Annual Report).

Geology

Sedimentary Rocks. The Leadville district is located on the eastern flank of the Laramide Sawatch uplift. The ores are hosted by a thin (<200m) Cambrian to Mississippian sequence of sedimentary rocks which dip 10 to 25˚ eastward and are exposed repeatedly (Figure 1) by a series of north-striking, west-dipping normal faults. Most of the ore at Leadville has come from orebodies in the Mississippian Leadville Dolomite.

Igneous Rocks. Upper Cretaceous to middle Tertiary igneous rocks intruded the Paleozoic rocks in the district. At least five separate pre-ore igneous rock units are distinguished. These units, the Pando, Lincoln, Evans Gulch, Sacramento, and Johnson Gulch Porphyries, are monzonite to quartz monzonite in composition, and occur as sills, dikes, and stocks that either expand or eliminate the Paleozoic section. The oldest, the Pando Porphyry, was emplaced primarily along the Upper Mississippian unconformity on top of the Leadville Dolomite or synchronously along low-angle Laramide thrust faults. The youngest of the pre-ore Tertiary igneous bodies, the Johnson Gulch Porphyry, forms a stock beneath Breece Hill (Figure 1) and cuts the Evans Gulch Porphyry. Fission-track dates on apatite and zircon from unaltered Sacramento and Johnson Gulch Porphyries yield 43.9 and 43.1 Ma, respectively (T.B. Thompson unpublished data). The Johnson Gulch Porphyry has a late phase that resembles the Lincoln Porphyry. Consequently, the Johnson Gulch Porphyry was thought to be older than the Lincoln Porphyry, which is 65.6 Ma at a locality about 10 km away from the Leadville district (Pearson et al., 1962). Post-mineral rhyolitic breccia pipes, locally with massive sulfide replacement ore fragments, appear to have been emplaced immediately after formation of the principal Leadville district ore deposits, as they are locally cut by veins with similar mineralogy and fluid inclusion data (Hazlitt, 1985).

Faults. Laramide low-angle to steep reverse faults and later normal faults cut the Paleozoic sedimentary rocks (Figure 1). Tweto (1960) was able to discern a sequence of faulting based on localization of various igneous rocks along the faults or by destruction of the fault by subsequent igneous intrusions. Middle- to late-Tertiary extensional tectonics associated with the Rio Grande rift exposed the up-dip portions of the replacement orebodies, facilitating their early discovery and beneficiation. One graben, referred to as the “down-dropped block” occurs immediately east of Breece Hill and is the site of the Black Cloud mine ores.

Ore Deposits. Orebodies within the main part of the Leadville district developed in two separate events: (1) skarns formed during emplacement of the Breece Hill stock; and (2) sulfide vein and mantos formed later. The skarns are magnetite-rich, and occur around the perimeter of the Breece Hill stock as well as in large blocks within the stock. Calcsilicate minerals have been converted to serpentine by subsequent hydrothermal activity, and massive magnetite has been replaced by sulfides in many localities.

The second event, also focused around the Breece Hill stock, generated veins and dolomite-hosted massive sulfide replacement deposits (mantos). These ore types have been responsible for most of the production in the district. Surface exposure of the veins and mantos and subsequent physical transport of weathered material led to the development of placers. Only the placer deposits in California Gulch (Figure. 1) survived, because all the other canyons extending westward over the district and off the Mosquito Range were scoured by Pleistocene glaciers.

Veins. Veins in the district consist of quartz-pyrite-gold-wolframite within and adjacent to the Breece Hill stock and quartz-pyrite-base metal sulfides peripheral to the gold-bearing veins. Both types are

Metal Zoning. Metal zoning in the Leadville district was described in general terms by Loughlin and Behre (1934). The highest Au:Ag ratios occur in the veins and mantos within or adjacent to the Breech Hill intrusive center. With increasing distance from the Breece Hill stock silver increases relative to gold (Figure 2). Many of the mantos in the fringes of the northern and western part of the district were oxidized, and it has not been possible to extend the Ag:Au ratio lines there. The asymmetry of the district west and northeast of Breece Hill is due principally to east-dipping sedimentary rocks and faults,

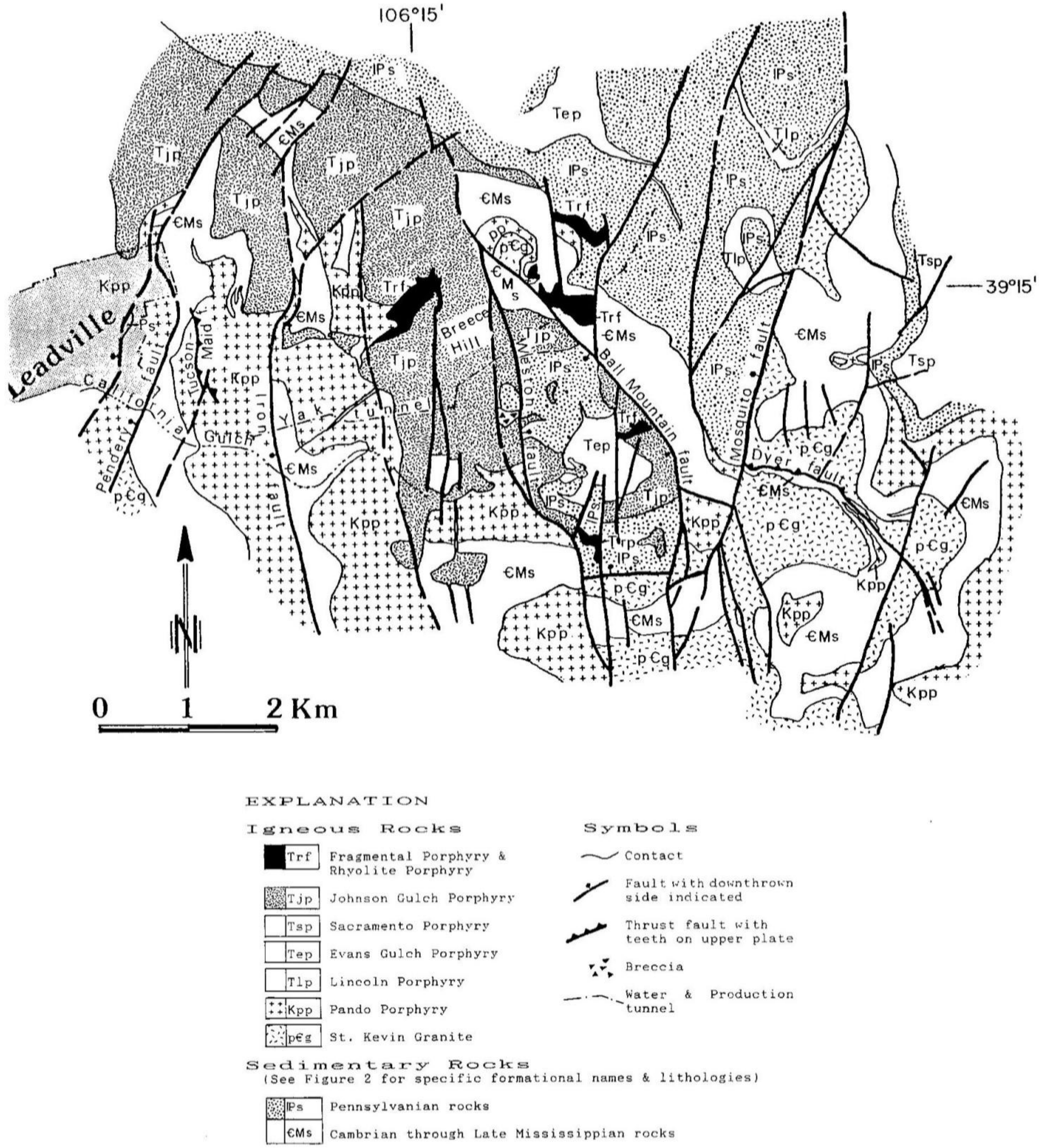

Figure 1. Generalized geologic map of the Leadville district, Colorado. Area to the west of the Iron fault modified from Emmons *et al.*(1927); remainder of area mapped by T.B. Thompson (1974-1987).

particularly the low-angle faults (e.g., Tucson-Maid fault; Figure 2). Manganese content of the ore-related carbonates increases away from the Breece Hill center.

Hydrothermal Alteration. The mantos have sharp boundaries against their wallrocks. Dolostone wallrocks may exhibit a zone of recrystallized white dolomite less than 2 cm thick; locally, small dissolution tubes extend away from ore as much as 5m. These tubes, referred to as "birdseye" texture (Thompson, 1976; Thompson et al., 1982) appear as small (<1 cm) white spots in darker dolostone and have quartz and sulfides in their centers, forming a reflective central pupil of the "birdeyes." The only other effect on dolostones adjacent to ore is weak to strong dissolution around dolomite grain boundaries, resulting in material that ranges from porous, weakly consolidated rock to freely-running dolomite sand.

Igneous wallrocks exhibit zonal alteration that extends as much as 100m from ore (Thompson, 1976). The alteration ranges from a distal propylitic assemblage (chlorite-epidote-calcite) through weak argillic to intermediate argillic (kaolinite-smectite-sericite-sulfides-dolomite) to proximal phyllic (quartz-sericite-sulfides-siderite). The sulfides occur in veinlets as well as in pseudomorphs replacing feldspar and ferromagnesian mineral phenocrysts. Trace element dispersion halos and the zonal igneous rock alteration are excellent guides to manto exploration (Thompson, 1976).

Fluid Inclusion Data. Thermometric analyses of fluid inclusion have been conducted on Leadville ores (Thompson et al., 1982). The fluid inclusions are simple water-vapor, and all exhibit consistent liquid-vapor ratios (about 5:1). Pressure correction of filling temperatures has been accomplished utilizing Scott's (1973) sphalerite geobarometer, yielding a total pressure of 1.2 kb. District-wide thermal zoning is apparent with central quartz-pyrite-gold veins (T_f: 469-422˚C) extending outward to the mantos (T_f: 410-310˚C). Fluid salinities are less than 5.2 equiv. wt. percent NaCl (Thompson et al., 1982). The thermal zoning parallels metal zoning described above.

Isotopic Data. Oxygen, hydrogen, carbon, sulfur, and lead isotope studies have been used to help interpret ore genesis. Whole-rock $\delta^{18}O$ in altered igneous rocks is highest on Breece Hill (+10.4 to +12.2‰). Beneath Breece Hill on the Yak tunnel level (Figure 1) and within the Black Cloud mine workings, altered igneous rocks have lower $\delta^{18}O$ (+8.7 to +10.9‰). Hydrothermal quartz from many different settings, including large quartz-sulfide veins, is relatively high-$\delta^{18}O$ (+8 to +13‰). Dolostone wallrock exhibits slight decreases in $\delta^{18}O$ from >24.0‰ regionally to +19.5 to +23.9‰ adjacent to mantos. Whole-rock δD of altered igneous rocks is relatively heavy (-116 to -83‰).

Calculated $\delta^{18}O_{H2O}$ for the Leadville vein manto system ranges between +5 to +10‰, while δD_{H2O} ranges between -45 to -70‰. These values lie within the compositional range interpreted as magmatic water. Late golden barite found throughout the Leadville district clearly indicates the influence of collapsing meteoric water on the ore system with $\delta^{18}O_{H2O}$ of -18‰.

Sulfide isotopic analyses ($\delta^{34}S$) of pyrite (+1.3 to +3.2‰), sphalerite (-0.5 to +2.2‰), galena (-2.4 to +0.7‰), and golden barite (+7.8 to +15.6‰) yield a calculated $\delta^{34}S_{\Sigma S}$ of +1.8. Sulfide mineral pairs (pyrite-marmatite and marmatite-galena) yield temperatures within the ranges obtained from pressure-corrected fluid inclusion filling temperatures.

Lead isotope analyses of pre-ore Tertiary igneous orthoclase and galena from Leadville contrast sharply with the Leadville Dolomite lead (206Pb/204Pb = 21.2 to 22.7) and the Precambrian basement rocks (208Pb/204Pb = >36). The galena leads (206/204: 17.46-18.26; 207/204: 15.51-15.59; 208/204: 38.18-38.59) are more thorogeneic compared to the orthoclase lead (208/204: 37.9-38.3), but otherwise they are compositionally identical. The data from Leadville define an isochron that intersects the model curve at 1.70 Ga, the age of basement rocks in central Colorado.

Geochronology. The extensive ore-related alteration of porphyritic igneous rocks at Leadville is ideal for fission-track dating methods. Apatite (where not destroyed by the hydrothermal alteration) and zircon

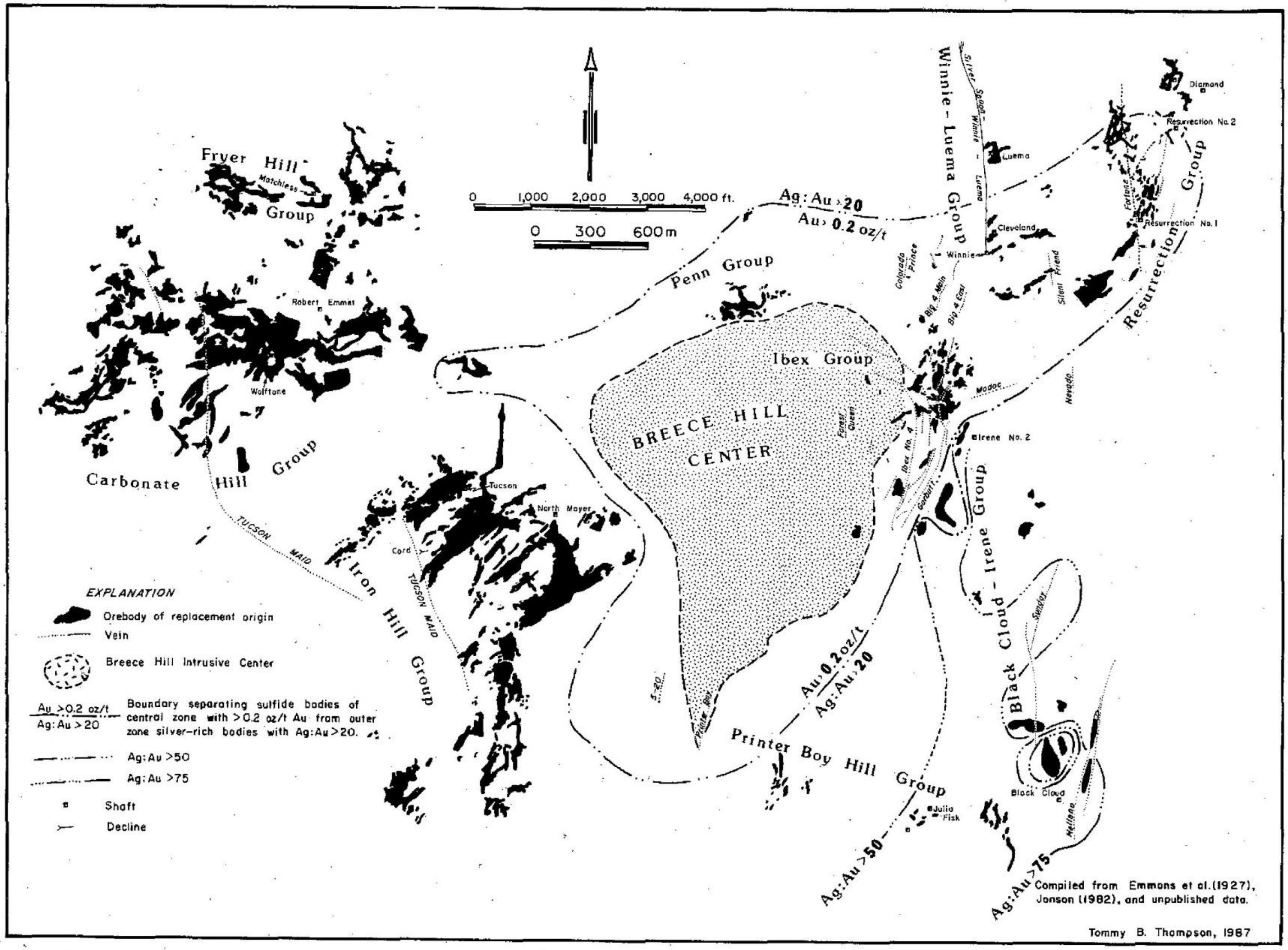

Figure 2. Map of the Leadville district with projections to the surface of mantos and veins (modified from Emmons *et al.*, 1927, with addition of orebody outlines from portions of the Black Cloud-Irene area. Significant veins within and adjacent to Breece Hill are indicated. Silver:gold ratio contours are for sulfide ores.

from the Johnson Gulch Porphyry yielded an average age of 33.4±5.1 Ma from 15 samples collected within the thermal and alteration halos of the mantos.

Genetic Model. The mineralogical-metal and thermal zoning about the Breece Hill center suggests that a thermal source lies beneath the exposed pre-ore intrusive center. The heating event associated with ore emplacement has been dated by the fission-track method at about 34 Ma. The ore-related magma was derived from a deep crustal source based on the lead isotopic data. Similarly, the sulfur is of magmatic origin. Ore fluids of magmatic origin spread upward along low- and high-angle faults and, to a lesser extent, along bedding planes in the lower Paleozoic rocks. Pore fluids were hot (469˚ to 310˚C), weakly acidic, and reacted rapidly with carbonate rocks to form the mantos. Lower reaction rates between the ore fluid and igneous rocks led to wider alteration halos in igneous rocks than in dolostones. The vertical and lateral movement of ore fluids and their interaction with rocks at depths of 3,600m led to ore fluid cooling, isotopic exchange, and, on the high levels, and margins of the system, mixing with meteoric fluids. Late in the main stage of the mineralizing event, fluidized breccias were emplaced, cutting ore. The breccias were locally veined by late-stage minerals with similar fluid inclusion thermometric data and isotopic compositions. The breccia distribution around the Breece Hill stock (Figure 1) suggests that the entire area beneath the stock and graben were underlain by the magmatic source system. Expulsion of the large volume of ore fluid and fluidized rock column in the breccias resulted in roof collapse with graben formation.

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An Abbreviated History of the Leadville Mining District

(Modified from ©2013 Society of Economic Geologists
SEG Guidebook Series, Volume 43)

Introduction

Much has been written on the geology and the characters involved with the discovery and development of the Leadville mining district. One of the first studies conducted by the newly-formed U.S. Geological Survey and initiated in 1879 was by S.F. Emmons (1886) who interviewed one of the discoverers of placer gold in California Gulch and who conducted geologic surveys of surface exposures and mine workings. Many famous and not-so-famous individuals worked or visited the district. Certainly one of the more famous was the Guggenheim family, headed by the father, Meyer (and his 7 sons), who developed a fortune and vast mining-smelting empire (Unger and Unger, 2006) from their entry into mining at Leadville. American Smelting and Refining Company (now ASARCO) was taken over by the Guggenheims in 1901 and continued as a major mining company until purchased by Grupo Mexico. A joint venture between ASARCO and Newmont Mining Company, the Resurrection Mining Company, developed the last mine, the Black Cloud, in the district. It closed in early 1999, ending 130 years of nearly continuous mining activity in the Leadville district.

At least four Ph.D. studies (Linn, 1963; Banks, 1967; Nadeau, 1971; Horton, 1985) and seven M.S. theses (Jonson, 1955; Arehart, 1978; Johansing, 1982; Osborne, 1982; Hazlitt, 1985; Gray, 1988; Campbell, 1989) have been completed on aspects of the Leadville district. The U.S. Geological Survey continued studies after Monograph 12 (1886) by Emmons and Irving (1907), Loughlin (1918), Emmons et al. (1927) with regional and district-wide studies by Behre (1953), Thompson (in Shawe and Ashley, eds.,1990), and Tweto (1960, 1961, 1968a, b, 1972,1979). Guidebooks by the Denver Region Exploration Geologists Society (DREGS; 1982) and the Society of Economic Geologists (SEG) Guidebook (Thompson and Beaty, eds., 1988) provided additional information largely gained from the studies conducted by this author and his students at Colorado State University beginning in 1974 and continuing up to 1989. Many publications, too numerous to cite here, have given insight to the details of Leadville geology. One essential publication, SEG Monograph 7 (Beaty et al., eds., 1990) summarized much of the research and identified some remaining issues related to district geology. SEG Guidebook Series Volume 43 (2013) (Stegen and Thompson, eds., 113p.) included the latest Leadville district publication.

History of the Development of the Leadville Mining District

The late Ogden Tweto's 20-year association with the Leadville mining district provided much of the timeframe of district development (e.g., 1968b), and his summary will not be repeated here. Instead, focus on individuals and their involvement with district development will be summarized. The district geology is covered by papers taken from Economic Geology Monograph 7 (Thompson and Arehart, 1990; Thompson and Beaty, 1990).

Emmons (1886) interviewed one of the six prospectors who discovered placer gold in California Gulch in early 1860. Two pits exposed rich placer gold, and later the placer miners noted the presence of another heavy gray mineral, identified as cerrusite. Placer mining continued for nearly 20 years; lode gold veins at the Printer Boy and 5-20 (same vein), near the head of California Gulch, contributed to the placer deposits. Farther up-slope, veins and disseminations with gold were discovered and led to underground development. In the late 1870s, the cerrusite sources were discovered in oxidized replacement deposits in dolostone hosts.

Another placer miner, H.A.W. Tabor, arrived shortly after the placer discovery and, along with his wife Augusta, established a mercantile in Oro City in California Gulch, ultimately moving the business into the present site of Leadville (Blair, 1980). After opening mercantiles there and in South Park, Tabor moved both to Leadville. He was eager to be involved in mining and grubstaked several well-known prospectors. On 15 April 1878 he grubstaked two German prospectors who headed out to Fryer Hill, an area that had yielded high-grade silver ore in a single mine. Several stories exist, but the most commonly cited is that the grubstake included a bottle of whiskey. The two prospectors stopped to consume its contents and decided at the conclusion to sink a pit, ultimately a shaft, at that site. Two additional grubstakes, costing Tabor a total of $17.00 (Blair, 1980), led to the intersection at a depth of 27 feet of high-grade silver ore, assaying 200 ounces per ton. This discovery made Tabor very rich, and before it was mined out Tabor sold this Fryer Hill interest for $1,000,000.

The district was not without questionable activities. One prospector, William H. Lovell, (aka Chicken Bill) had a claim, the Chrysolite, to the south of Fryer Hill. He sank a shaft and salted it with high-grade ore from Fryer Hill. He grudgingly agreed to sell his quarter interest in two properties to H.A.W. Tabor for $10,000. It became apparent that the shaft had been salted; however, after sinking the shaft another 10 feet, high-grade silver ore was intersected. Tabor fared well with his purchase but wanted to own a mine without others involved. Another property, the Matchless, was purchased by Tabor in September 1879 from three owners for $117,000. It took 8 months and additional investments to develop ore at the Matchless mine; in 1880 Tabor was realizing $2,000 per day, and one ore shipment gave returns of 10,000 ounces of silver per ton.

Other mines in the Fryer Hill area contained high-grade ore as well. One, the Robert E. Lee mine, yielded a total production of $118,500 in 17 hours (Blair, 1980) although silver sold for less than $1.00/ounce. Fryer Hill mantos extended over approximately one square mile, and this one area funded many notable opera houses, hotels, etc. in and around the Leadville area.

In 1880, Mayer Guggenheim, a Philadelphia merchant, invested $5,000 in a property in California Gulch where earlier placer mining had occurred. Additional expenditures to pump water as shaft sinking occurred in the A.Y. made Guggenheim question his venture into mining. Two months after departing Leadville he received a telegram stating “RICH STRIKE FIFTEEN OUNCES SILVER SIXTY PERCENT LEAD.” He then purchased the Minnie-Moyer mine in November 1980; the same orebody in the A.Y. extended to the Minnie-Moyer. By Summer 1980, the two properties were yielding profits of $2,000/day (Blair, 1980), and they continued to yield profits for more than a decade. The Guggenheim venture into the smelting world was initiated in Leadville but extended into Mexico when the McKinley tariff was enacted. In March 1899, most of the major smelters and big money men in the mining industry combined to form American Smelting and Refining Company; the Guggenheims were asked to join but declined. Even with the competition from the new combine the Guggenheims produced a profit of $3,600,000 from three smelters compared to $3,500,000 from 20 smelters by their competition. The combine realized they needed Guggenheim expertise, and they were invited to join with a gift of stock worth $36,000,000 (Blair, 1980); as the major shareholder, the Guggenheim family became owners of American Smelting and Refining Company in 1901. The fortune garnered by the Guggenheims resulted in long histories for two of their companies, ASARCO and Kennecott Copper Corporation.

While Leadville is best known for its silver-base metal production, gold from placer, lode, and manto sources was significant. One such gold deposit, the Little Jonny, became famous, although the background of its discovery is not clearly known. The Little Jonny is located within a ”gold belt” extending from Evans Gulch southward across Breece Hill into Iowa Gulch. More than 100 veins with gold-tungsten-quartz veins were discovered. More than 60 shafts and drill programs were underway in 1895. Early production from the Little Jonny had been more silver-base metal-dominated; in 1893, J.J. Brown became the superintendent of the complex known as the Ibex Group properties. He deepened the

Little Jonny shaft, looking for a second ore interval. Although sanding in dolostone created a problem in the shaft sinking, Brown was able to overcome this, and high-grade gold-copper was discovered, so rich that more than $1,000,000 in dividends was paid by the company in 1894. J.J. Brown shared in the dividends. Today, he is best known as the husband of the "Unsinkable Molly Brown", whose heroic efforts during the Titanic sinking in 1912 made her an international celebrity.

Manto deposits adjacent to the Breece Hill intrusive center invariably yielded higher gold grades with reduced silver grades compared to more peripheral mantos like those of Iron, Carbonate, and Fryer Hills. The #3 manto in the Black Cloud mine averaged 0.5 ounces gold per ton (Thompson, 1976), and it was adjacent to the ore fluid source in the Breece Hill stock complex.

The wealth gained by Horace A.W. Tabor was incredible, and he shared it by construction of the Tabor Grand Hotel and Tabor Opera House in Leadville as well as the Opera House in Denver. He built mansions in both places and travelled extensively. He was the Leadville Mayor as well as Lieutenant Governor of Colorado. Behind the scenes he and his wife, Augusta, were not getting along as a couple. He had met a young lady, and in July, 1880, Tabor moved out of the home he shared with Augusta. The Tabor Opera House was built only a few steps from the Clarendon Hotel and Tabor moved the young lady, now known as "Baby Doe" into a suite on the top floor of the Clarendon. In addition, he built a walkway from his office complex on the top floor of the adjacent opera house to the Clarendon. He married Baby Doe in St. Louis on 30 September 1882, thinking that he was divorced from Augusta, but he wasn't!! The scandal reverberated from Washington, D.C. to Colorado. In spite of the scandal, the Tabors continued their high-living style until the silver crash of 1892-1893, when they lost their fortune. The Tabors struggled to live but the much older Horace died of appendicitis on 10 April 1899 (Blair, 1980); his last words to Baby Doe were to "never let the Matchless mine go as it would make her wealthy again" (Blair, 1980). She lived her last 30+ years at the mine site, a pauper with dependence on friends in Leadville. She ultimately froze to death at the mine site, and her body was found on 7 March 1935 by a friend who didn't see any smoke from her heat source (Blair, 1980). Thus ended an era of incredible mine development, wealth creation, scandal, and Baby Doe's survival as a pauper. Recent drilling 50 feet from the Matchless mine shaft has intercepted ore-grade intervals of silver; H.A.W. Tabor may have been correct that more silver ore could be found on the Matchless mine site.

So many other events have occurred at Leadville ranging from mine strikes, an ice palace celebration, railroad conflicts, actions of many unique individuals, and company growths/declines, that it is not possible to document or describe them all here. This type of story has been repeated at numerous other mining districts world-wide, but none have had the long lasting and world-impacting story that is Leadville.

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Road Log - Leadville District

The Leadville district enjoyed metal production from 1860 (placers) up to 1999 (complex Zn-Pb-Cu-Ag-Au mantos in dolostone). The last operating mine, the Black Cloud, is shown near the southeast corner of the fieldtrip stop index map (Figure 1 of this Road Log section). All of the fieldtrip stops are located on the index map in the order of visitation. The main business thoroughfare in Leadville is Harrison Avenue (U.S. 24); all site visit road logs depart from that avenue leading to the east and indicated by white dashed lines to the planned stops.

Mileage	Description
0.0	Depart from Harrison Avenue on east 5th street
0.1	H.A.W. Tabor home and museum (on left)
0.6	End of pavement – Start of Lake County 1 Road
0.8	Resurfaced mine dump and concrete mill footings in Stray Horse Gulch
1.0	Wooden headframe of the Robert Emet on the immediate north side of road.
1.2	Road south along paved bike trail with re-contoured mine dumps along south side.
1.5	Catchment Pond dam for surface run-off that has reacted with upstream mine dumps.
2.1	Adelaide Park and intersection with Lake County Road 2A. Continue on Road 1.
3.2	Road to left down into Evans Gulch
3.7	Road to right up to Hopemore mine (2 headframes)

3.75 Lake County Road 38 down into Evans Gulch

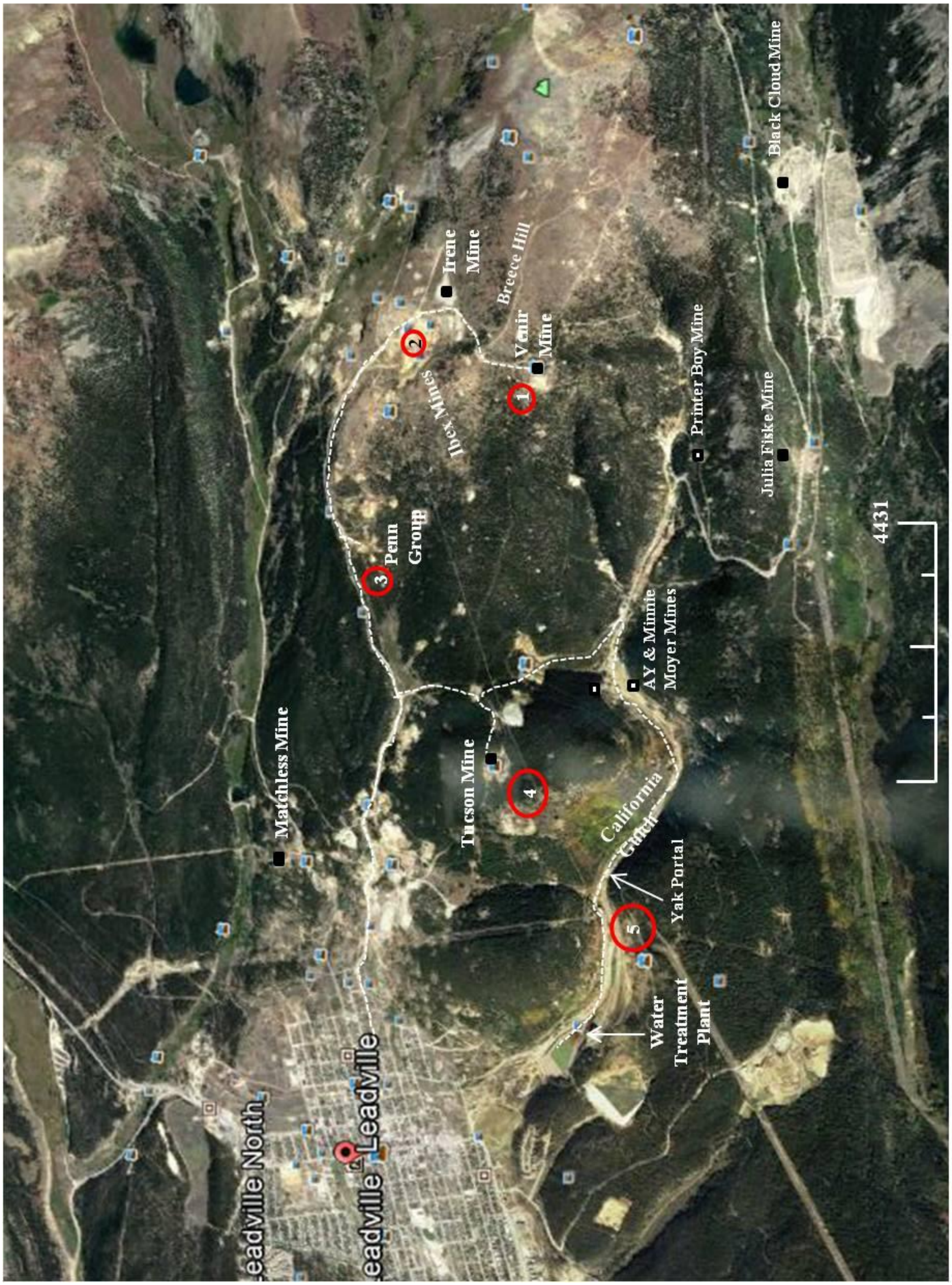

Figure 1. Field trip stop index map, Leadville District, Colorado

4.0 Turn south on Lake County Road 1 going uphill past Irene No. 2 steel headframe and metal buildings; these workings connected with those of the Black Cloud mine to the south.

4.3 **STOP 1** – Venir mine (dumps and collapsing wooden buildings). The Venir mine was focused on vein quartz-pyrite-gold in sericitized Breece Hill stock (quartz monzonite porphyry). This vein system was one of numerous vein and disseminated deposits that contributed gold to the California Gulch placers. The Venir mine was developed on 4 levels with intervening stopes along northeast-striking veins in Johnson Gulch Porphyry and operated between 1920 and 1935.

We have a spectacular view of the Sawatch Range uplift to the west, Turquoise Lake with its terminal moraine dam, and jarositic mine dumps north and south of the lake along veins of the St. Kevin and Sugarloaf districts in Precambrian host rocks.. The lake and shorelines are underlain by the Turquoise Lake stock, a molybdenum target drilled by Bear Creek Mining Company in the 1970's.

From the end of the Venir mine dumps we can see the mine dumps in California Gulch that were the Minnie Moyer and A.Y. mines funded by Meyer Guggenheim and that ultimately yielded

$15million and the start of the Guggenheim fortune. To the north of California Gulch is Iron Hill and a dolostone-covered mine dump that we will pass by en route to the Tucson mine (Stop 4).

Behind us to the east is the grassy "hill" of Ball Mountain, near the eastern margin of the Down-dropped Block. The boulders at start of the pathway onto the dump are glacial erratics of the Proterozoic St. Kevin Granite.

Retrace our route back to the north off Breece Hill.

5.0 **STOP 2 -** Ibex mines dumps and large wooden ore bins. Intensely sericitized Breece Hill stock with pyritic veinlets were mined for high-grade gold-silver veins. Breccia zones with minor wolframite and scheelite are present; however, no tungsten was ever recovered. More than 100 quartz-pyrite-precious metal veins occur within or adjacent to the Breece Hill stock, most with a northerly strike and steep (>70°) dips.

6.3 **STOP 3** – Penn Group mines (Figure 2). Turn south on narrow gravel road for 0.2 miles to stop 3. The visit is on one of several inclined adits along the northwestern contact of the quartz monzonite porphyry (Breece Hill stock) with Paleozoic carbonate rocks which have been contact-metamorphosed to a magnetite-hematite-serpentine skarn that extends 600 feet to the south. The skarn is locally siliceous and was used as a flux in smelting. In underground workings the magnetite is replaced by sulfides with high (17 to 170 g/ton) gold grades. A fissile post-mineral rhyolite dike (Trp) cuts all rock units (Figure 2). An exposure of Pennsylvanian Belden Shale in the eastern part of the map area indicates that the magnetite skarn replaced the Leadville Dolomite.

Return to Park County Road 1.

7.2 Intersection of Lake County Road 1 and Lake County Road 2A with turn to south on the latter.

7.5 Turn west off County Road 2A past mine dumps with white crushed dolostone placed by EPA contractors on top of the North Moyer mine dump.

7.8 **STOP 4** – Tucson Mine. The shaft site is covered; only the concrete foundation for the hoisting equipment is present. On the north side of the dump (past the black clinkers from the boiler that powered the hoisting equipment) is dump material with the light-gray pyritic Gilman Sandstone

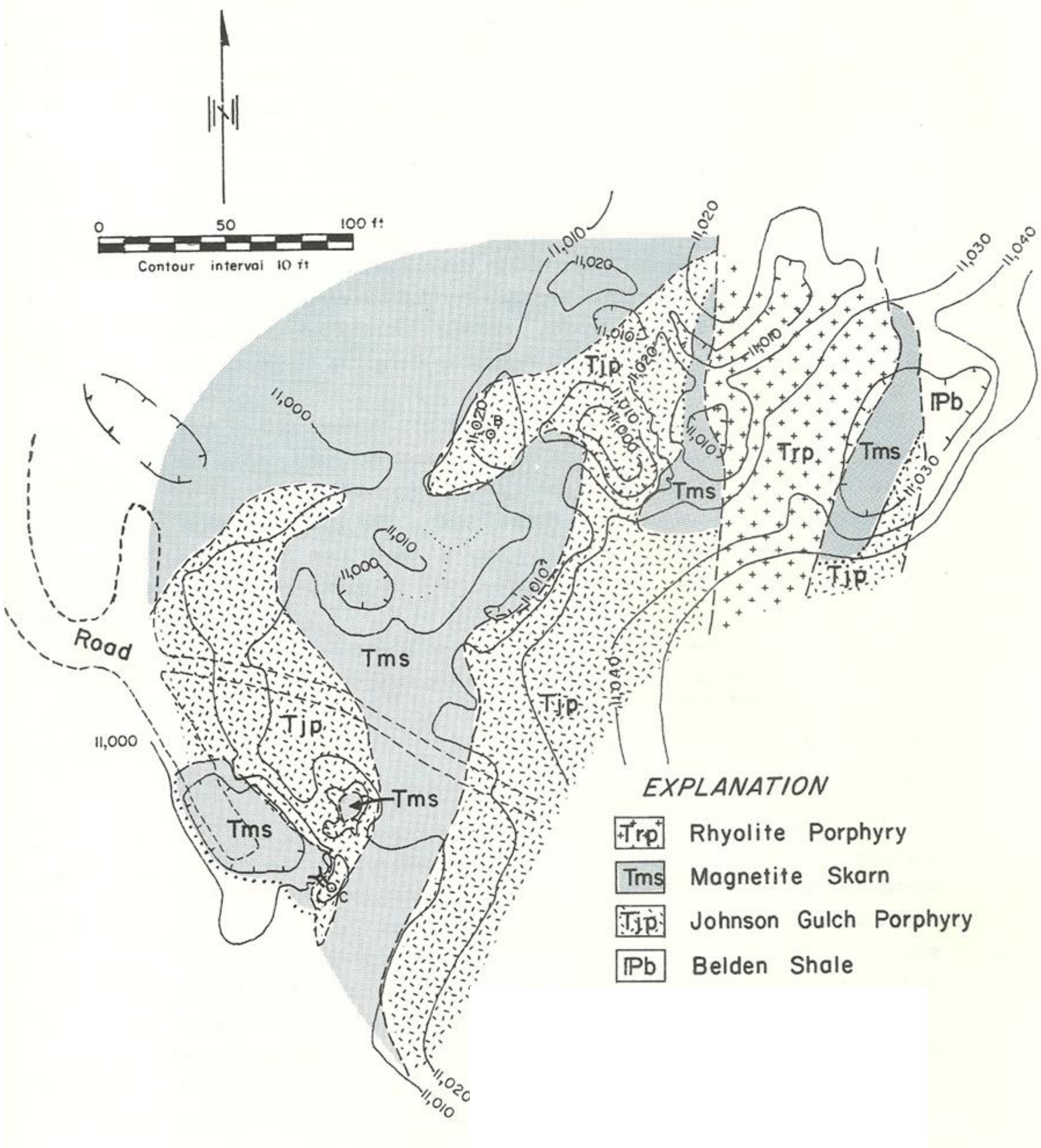

Figure 2. Stop 3 Area; Geologic Map of the Penn Group, Leadville District, Colorado. Geology by Tommy Thompson

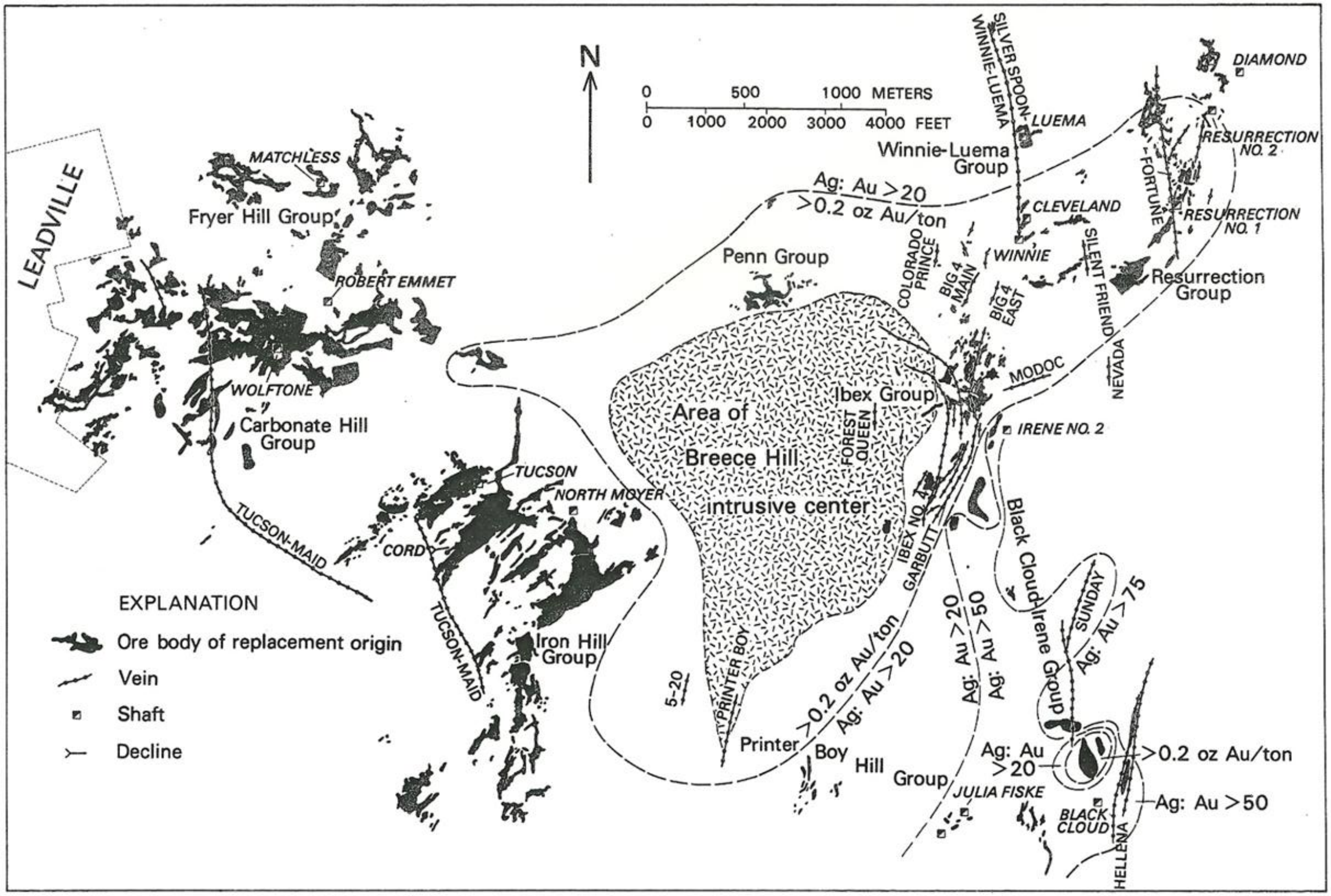

Figure 3. Leadville district map with the Breece Hill Intrusive center, distribution of orebodies (projected to map view), and district-wide gold and silver zoning. Long-dashed lines separate areas of the indicated gold content and Ag:Au ratios of ores (from Thompson, 1990).

(present stratigraphically at the base of the Leadville Dolomite). To the west along the north side of the wood loading bin you can collect massive sulfide (pyrite-sphalerite-galena) ore samples. The Tucson mine yielded complex sulfide ores that were oriented to the northeast (Figure 3) along faults and veins of the same strike. A low-angle thrust fault, the Tucson-Maid appears to have been a major feeder structure for the hydrothermal fluids that were released from the deeper productive intrusive phase of the Breece Hill intrusive center.

Return to Leadville by continuing south on Lake County Road 2A down to California Gulch. This route allows us to see the extensive dumps of the Minnie Moyer and A.Y. mines that provided the Guggenheims's fortune.

STOP 5. Mill building at the Yak mine portal, now a core and pulp-reject sample storage facility for the closed Black Cloud mine samples.

Return to Leadville down California Gulch where placer mining occurred. The water treatment plant just west of the Yak building is operated by Newmont. It processes water from the Yak tunnel.

STOP 6. National Mining Museum

Review of core from a drill hole 50 feet from the Matchless mine shaft (see Figures 4 & 5 for geology of the Matchless mine area). The core log with spot silver assays is shown in Figure 6.

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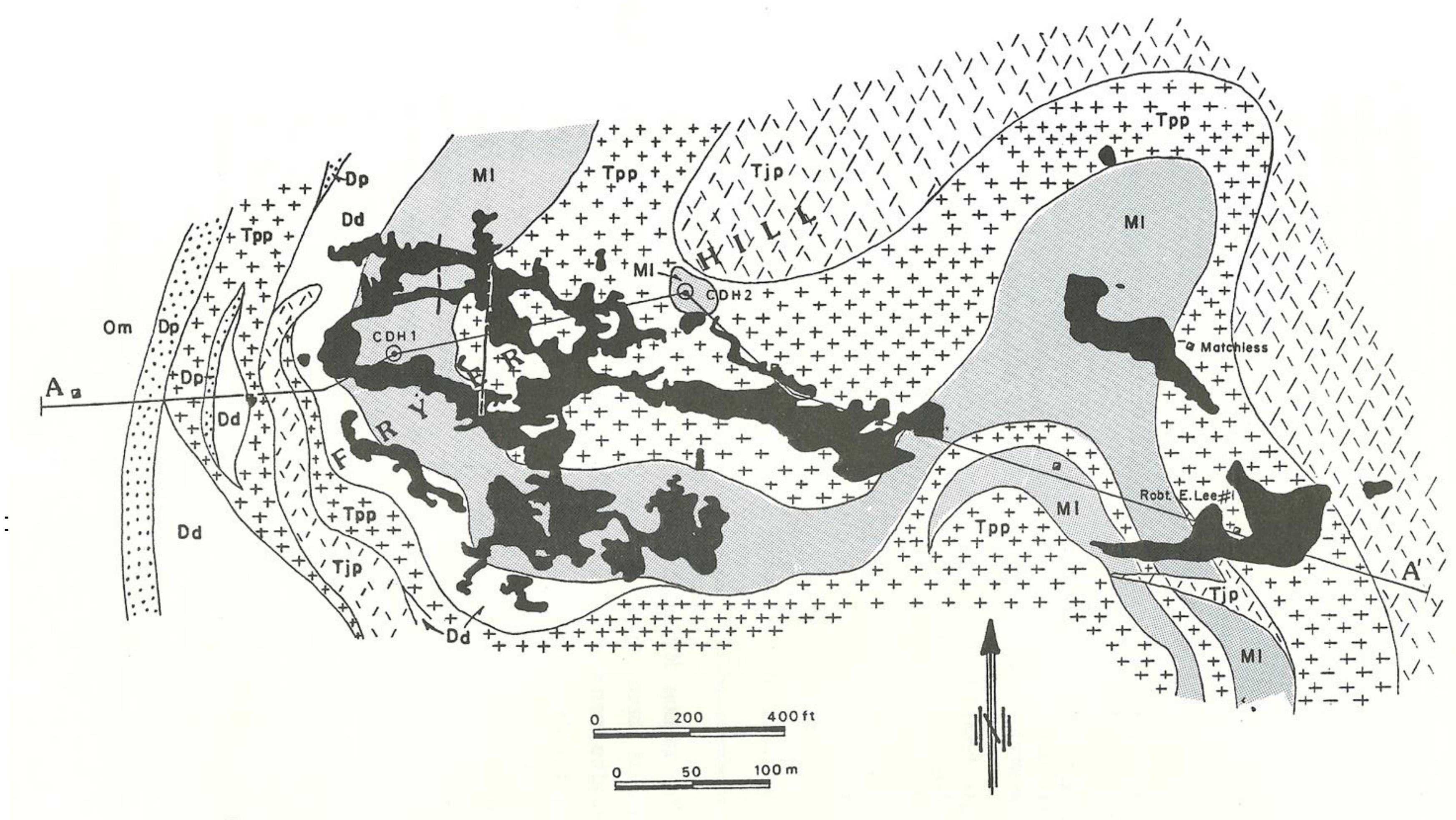

Figure 4. Geologic map of the Fryer Hill area (modified from Emmons *et al.*, 1927) with orebodies projected to the surface. Line of cross section A-A' shown (Figure 5). The Matchless mine is in the eastern part of the map area.

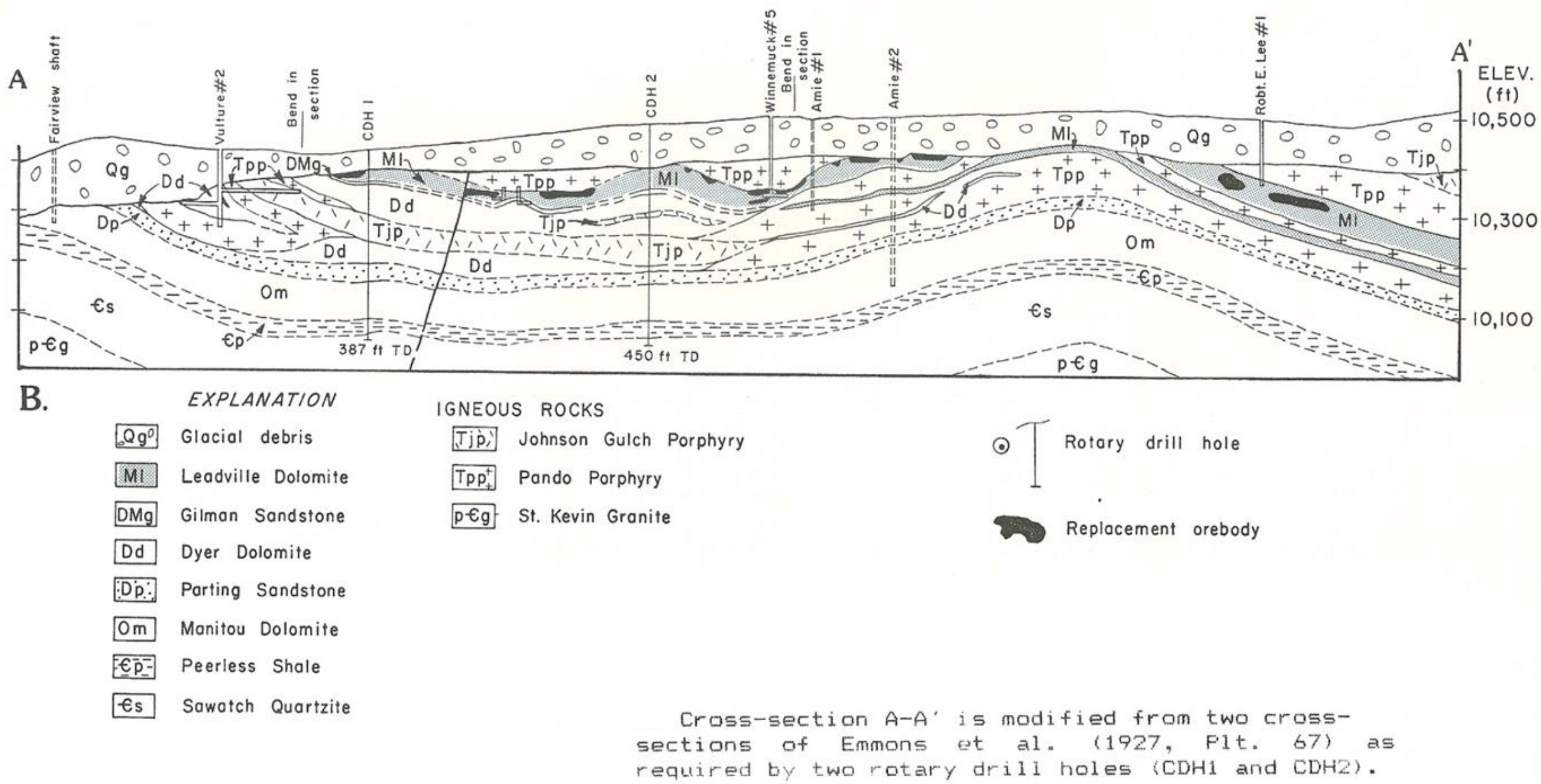

Figure 5. Geologic Cross section A-A' through the Matchless mine area showing orebodies localized within the Leadville Dolomite.

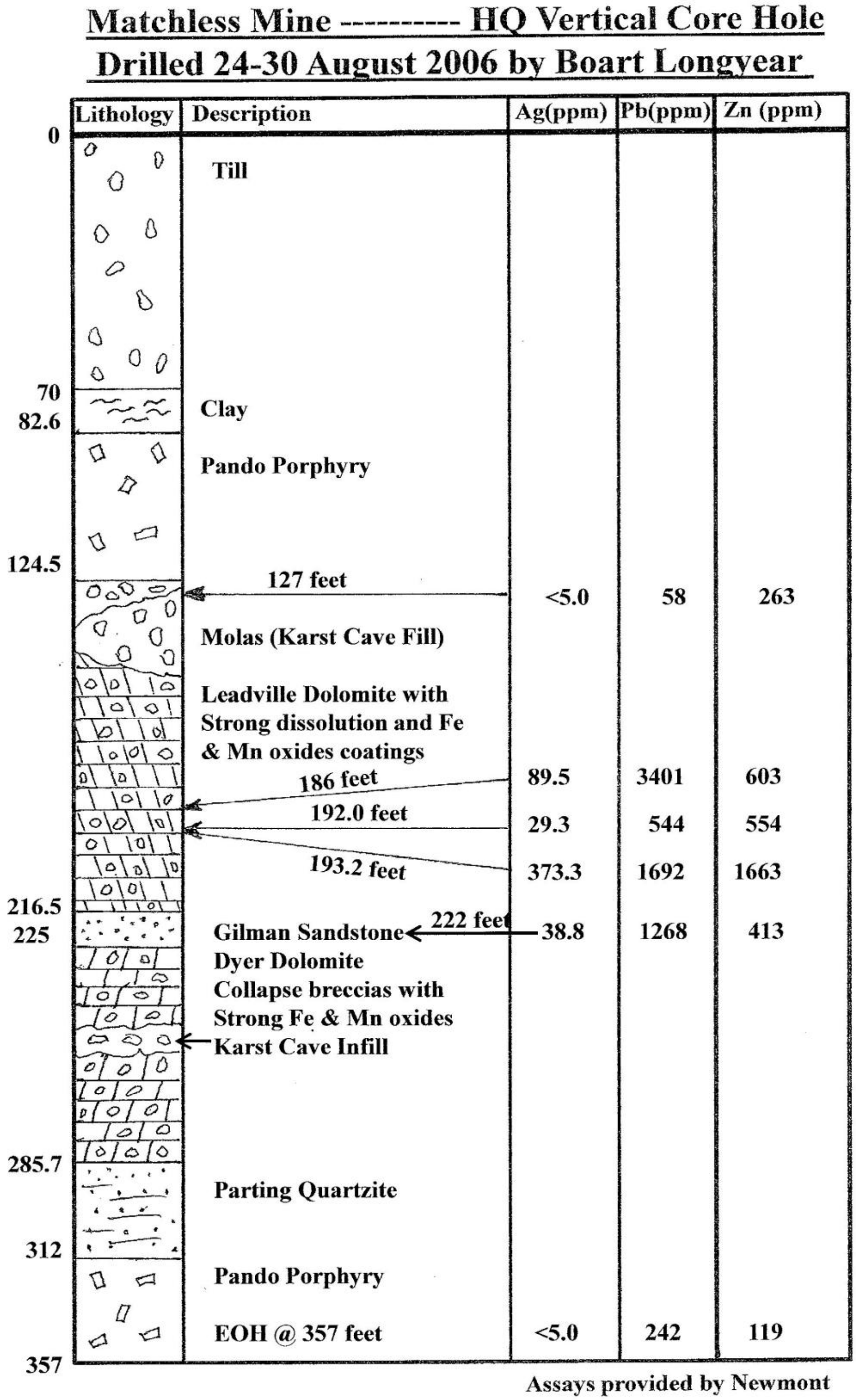

Figure 6. Core log with spot silver assays from drill hole located 50 feet from the Matchless mine shaft (see Figures 4 & 5 for geology of the Matchless mine area).

Field Trip E: Alma / Fairplay Area
July 21, 2017

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Abstract

The field trip provides a general geologic overview of the gold and silver deposits of the northwest corner of South Park. The mountainous Alma District has a long and colorful mining history that is seen in the many mines and historic structures both in the field and in the mining towns of Alma and Fairplay. In keeping with the symposium's theme of Au and Ag deposits, the emphasis of the field trip is on gold and silver mines in the northwest corner of South Park, but we will also discuss the history of this fascinating district.

There are seven stops and a few short walking excursions. There will be a short geologic presentation at each stop with time for a bit of rock breaking at the Sweet Home and London mines along with the Combination and Pfister/Sanborn placer mines.

Many important papers have been written about mineral deposits in the Alma District, as well as mapping and data collected by the USGS, Colorado Geological Survey, University theses and private company reports. It is very difficult to acknowledge all of the contributors, but many of the most important can be found in the References. Among the most seminal are Butler, et al. 1912, Singewald and Butler, 1941 and Singewald, 1950.

Hoosier Pass Overview Stop

This stop provides an elevated panoramic view looking south into the northwest end of South Park. Elevations in the area range from about 10,000 to over 14,000 feet. The park-bounding north trending Mosquito Range is on the right (west) and the Mount Silverheels laccolithic intrusive complex on the left. Placer gold mines begin near Alma, just out sight in the valley below, and continue to Fairplay.

The Mosquito Range is the eastern limb of the north-northwest trending Precambrian-cored Sawatch anticline, the axis of which is about 25 miles to the southwest. Basement is comprised of crystalline Precambrian rocks roughly 1.4 to 1.7 b.y. (Figures 1 and 2). The basement is typically composed of schist or migmatite intruded by granitic rocks. The basement is overlain by Cambrian to Pennsylvanian sedimentary rocks which dip gently to the east (Figures 3 and 4). The Cambrian to lower Pennsylvanian section is dominated by carbonates with lesser shales and quartzites that were generally deposited in marine environments. The middle Pennsylvanian to Permian red beds of the Minturn and Maroon formations were shed from the Ancestral Rockies in middle Pennsylvanian time.

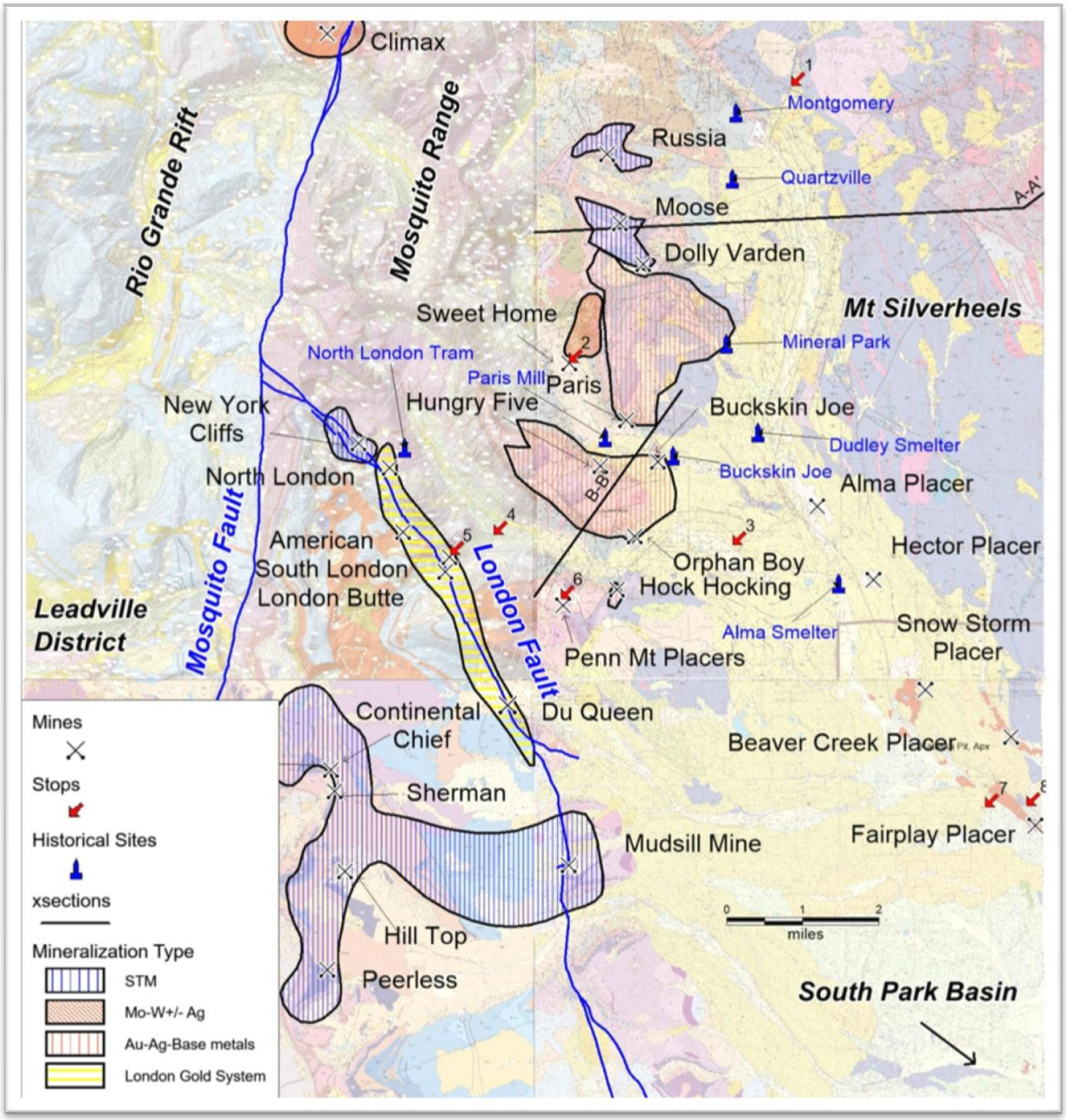

Figure 1. Geologic map of the Alma District compiled after Widman, et al.(2004), Widman et al. (2007), McCalpin et al. (2012), Bohannon, R.G. et al. (2013), Green, G. N. (1992).

Figure 2. Stratigraphy of the Alma District after Widman, et al., 2004.

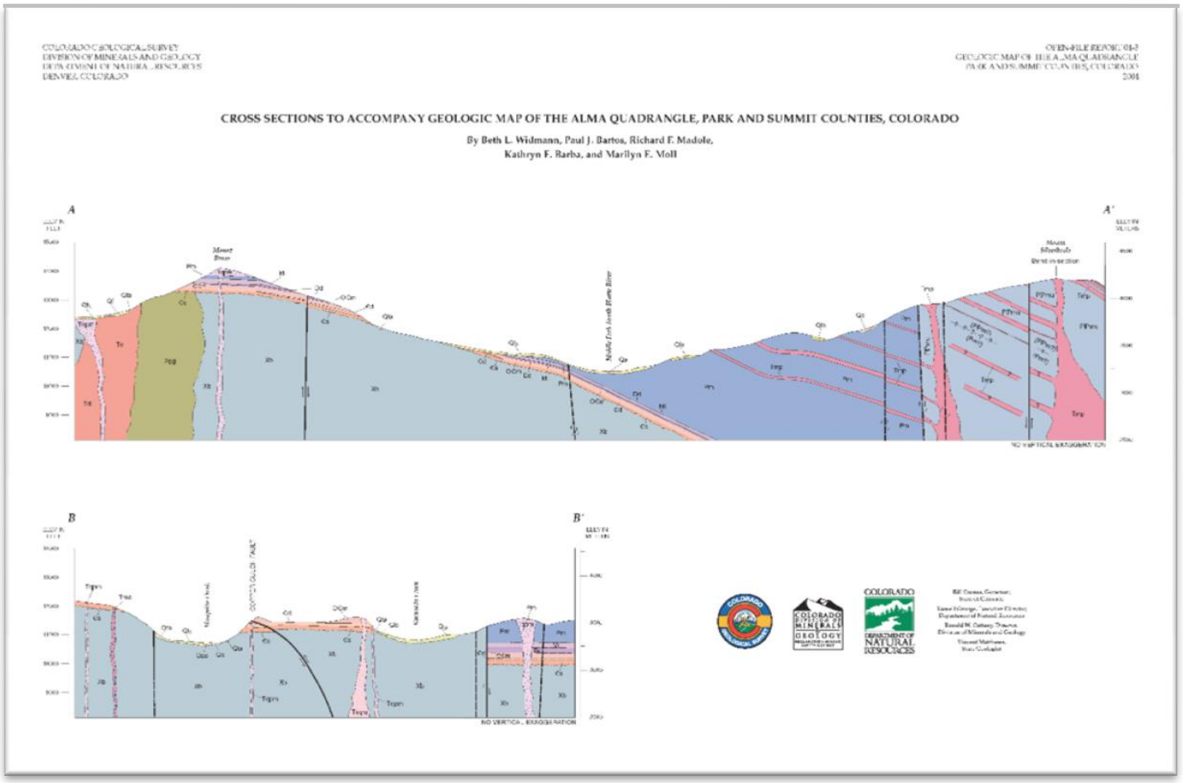

Figure 3. Alma Sections A-A’ and B-B’ after Widman, et al. 2004.

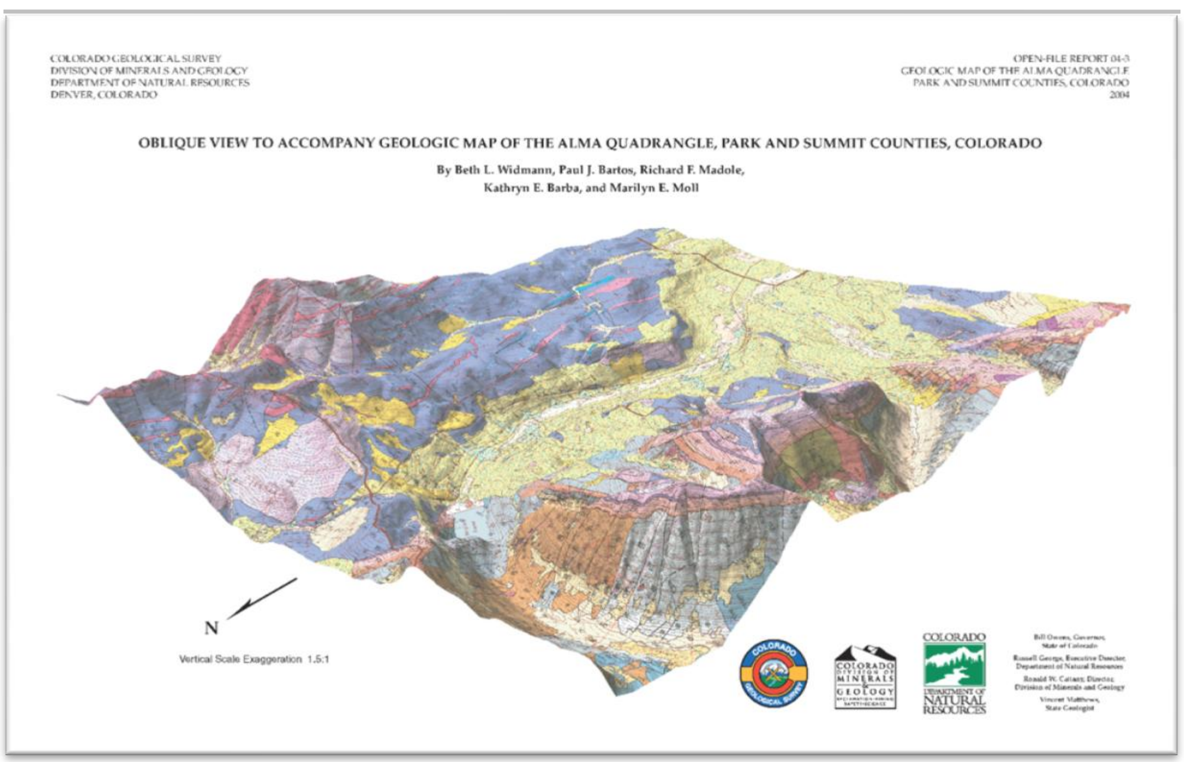

Figure 4. Oblique view of the Alma Quadrangle, after Widmann, et al., 2004.

The area is traversed by the Colorado Mineral Belt (COMB) which lies within the larger northeast trending Colorado Lineament. This transcontinental scale feature extends to Lake Superior and has a middle-Precambrian ancestry (Warner, 1978). Within the COMB, Laramide and Tertiary stocks, dikes and sills are common. These are typically calc-alkaline with volumetrically minor high silica intrusive. Within the Alma District, large laterally extensive Laramide sills are usually monzonite to quartz monzonite in composition with some latite. Tertiary stocks typically are monzonitic to granitic. Intermediate and mafic intrusive rocks are rare, except within the Silverheels laccolithic intrusive complex and a few intermediate intrusives in Buckskin Gulch.

Low angle faults are common in the Paleozoic section on Mounts Bross and Lincoln and have been recognized as an important ore control as well. These are have been interpreted as a northern continuation of the Cooper's Gulch thrust by Karr and Johansing (Karr, L. J., and Johansing, R. field and mine mapping).

A variety of ore deposit types are present within the Alma District, including Au and Ag veins hosted in crystalline basement and Paleozoic sediments, Laramide aged replacement Au – Ag deposits in Paleozoic carbonates, Mississippian/Permian/Laramide aged Ag-Pb-Zn-Cu-Ba 'Sherman Type' (STM) deposits, middle Tertiary intrusives with elevated Mo-W-F, gold mineralization in skarn, and finally, alluvial and colluvial placer gold deposits.

Mineralization on Mounts Lincoln and Bross

Sherman Type Mineralization (STM) occurs near the summits of mounts Lincoln and Bross, where the Moose, Russia and Dolly Varden mines exploited replacement Ag-Zn-Pb-Cu-Ba ore in the Leadville Dolomite. Back in the day, burro trains were used to transport high grade silver ore from these mines to the smelters near Alma.

STM deposits are formed near the top of the Leadville Formation and are typically hosted in paleokarst. High and low angular faults are also important ore controls. Deposits are associated with widespread fine grained silica replacement of the Leadville formation (jasperoid) and the sphalerite tends to be low iron. The Leadville Formation is dolomitized district wide. The genesis of STM has been hotly debated, with one school of thought arguing for a Mississippian to Permian-aged Mississippi Valley Type (MVT) style of mineralization, while another advocates for a hydrothermal origin related to Laramide intrusive activity. Permian ages are indicated by paleomagnetic data, while proponents of younger ages point to veining and hydrothermal alteration in the hanging wall porphyry sills. Those interested in the controversy will find papers arguing both positions in the references section (Berry, D., 1990, Beaty, et al. 1990, Butler and Singewald, 1940, DeVoto, 1983, Landis, G.P., and Tschauder, R.J., 1990, Leach, et al. 2010, Leach, et al. 2002, Johansing, R.J., 1990, Johansing, R.J., and Thompson, T.B., 1990, Singewald, Q.D. and Butler, B.S., 1931, Symons, D. T. A, et al. 2000,).

The STM ores are typified by having heavy sulfur isotopes, suggestive of an evaporative source rock in the adjacent South Park Basin, and J-type (radiogenic) lead isotopes. In this sense they are distinct from ores at Leadville, which contain sulfur isotopes characteristic of a magmatic source and non-radiogenic lead isotopes. Curiously, the London gold system is characterized by J-type lead and is proximal to the STM mineralization in the New York Cliffs area (Berry, D., 1990).

STM mineralization is widespread in the Mosquito Range (Figure 1). Unfortunately all the sites are at high altitude in difficult to access areas, and time does permit visiting them.

Further south, on the southeast slopes of Mount Bross and eastern slope of Loveland Mountain, are found numerous prospects and small mines developed on small replacement bodies in the lower Paleozoic section. Here, northeast trending feeder veins in Precambrian basement, seen in the walls of Buckskin and

Mosquito gulches, feed Au rich vein and replacement bodies in the carbonate rich beds within the Sawatch Quartzite and Dotsero Formation (formerly the Peerless Shale). These veins also fed the carbonate replacement bodies in the Manitou through Dyer formations. In places ore is developed beneath a porphyry sill which acted as an aquitard to ascending hydrothermal fluids. This is the case at the 'Orphan Boy Contact' and it is a common ore control throughout this region. The northeast trend of the feeder veins are typical of nearly all veins within the COMB. These veins and replacement deposits tend to be richer in gold and copper than the Leadville hosted STM deposits.

The upper oxidized parts of these veins and replacement deposits were mined during the early days of the district because they were free milling, meaning that the gold could be easily extracted by simple crushing and washing. In the early 1870's the Alma and Dudley smelters were constructed to treat unoxidized sulfide ore (Figure 1).

Mount Silverheels

At Mount Silverheels, a laccolitic intrusive complex comprised of diorite to quartz monzonite stocks and sills intrudes the Maroon/Minturn formations. Hornfels alteration is widespread. It is likely that the poddy auriferous magnetite skarns found here are the source of the Tarryall and Beaver creek placers (Singewald, 1943).

Sweet Home Mine

The Sweet Home Mine is a historic Ag-Zn-Pb-W mine located at the base of Red Amphitheater, so named for the hematite formed by oxidation of abundant disseminated pyrite mineralization. The intermediate sulfidation quartz–sphalerite–galena-tetrahedrite-hubnerite–rhodochrosite–fluorite veins were originally mined for silver starting in 1873. The veins are hosted dominantly in Precambrian granite gneiss and formed in two stages at approximately 30 Ma (Figures 5 and 6). The first stage veins contain primarily quartz, sericite, and pyrite, with green fluorite and hubnerite. The second stage veins contain base metal minerals, purple to blue fluorite, and rhodochrosite. Vugs hosting fine rhodochrosite specimens occur at fault intersections and near foliation-influenced vein orientation changes. Right-lateral, oblique slip along pre-mineral faults provided wider openings for later ore shoots to develop. When mineralization ceased before an opening could be filled completely, vugs were formed (Barba, K. E., et al. 2004).

For 13 years prior to 2004 the mine has produced world-class rhodochrosite specimens. Some of these specimens are considered to be among the finest mineral specimens ever produced and the finest of their species, with values well over $1 million. Sweet Home Mine applied innovated mining, preparation, and marketing techniques to the mineral specimen business.

The Sweet Home is widely regarded as the upper level manifestation of a Climax-type porphyry molybdenum system (Bartos, et al. 2007). Vein related sericite and potassium feldspar dated by K-Ar age, and U-Pb on hubnerite and apatite yield ages of 25 to 26.3 m.y. (Romer, R.L., et al., 2006, Luders, V., et al., 2006). These are very similar to ages obtained for the Climax molybdenum system which is only 5 miles to the northwest.

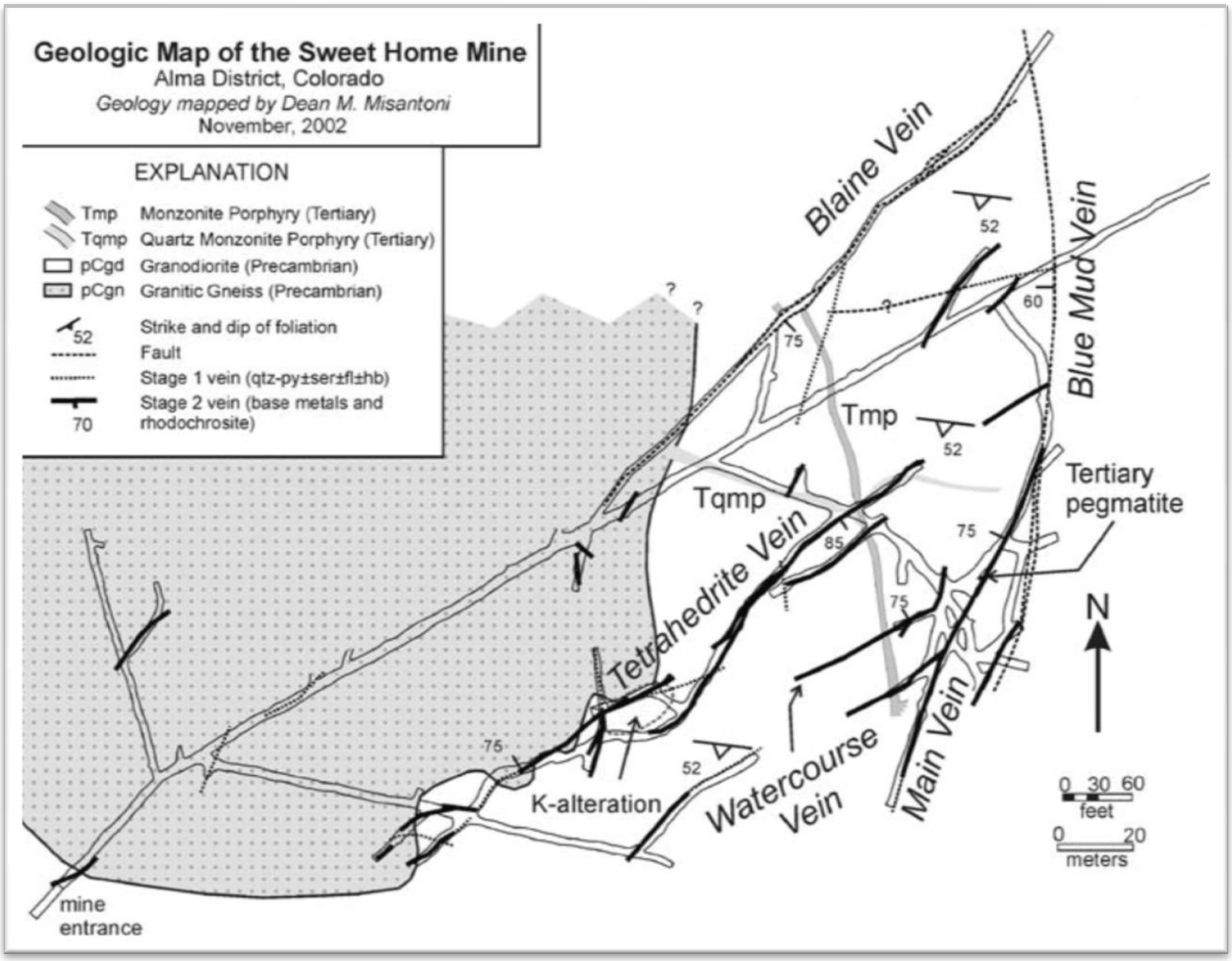

Figure 5. Map of the Sweet Home Mine from Misantoni, in Bartos, et al. 2007.

London Mine

The London mine is one of the largest gold mines in Colorado, having produced between 750,000 to 1,000,000 ounces of gold from its discovery in 1873 until 1989 (Johansing, et al. 1992). Prior to 1942, ore was usually hand sorted and grades were often greater than 1 opt at a production rate of 75 to 200 tpd. Production briefly surged in the 1930's and by the late 1930's four mills were producing as much as 500 tpd (Johansing, et al. 1992). The sub-district was in continuous production from 1873 until 1942.

Mineralization is hosted by several styles of vein, stockwork, replacement and breccia deposits in the footwall of the Laramide aged London Fault. Alteration is typically dominated by silicification and sericite +/- carbonate. Fission-track dates from apatite and zircon in one altered pre-ore porphyry sample indicate an age of mineralization of approximately 42.5 Ma (Thompson and Johansing, 1988).

The London Fault, which lies within the area of yellow cross hatching in Figure 1, is a north-northwest trending, reverse fault that dips steeply to the northeast and has approximately 3300 feet of reverse throw on Pennsylvania Mountain (Berry, 1990). The entire Paleozoic and the lower part of the Mesozoic section are preserved in the footwall (west side). The sedimentary section was intruded by Laramide aged monzonite and quartz monzonite sills and subsequently folded into a syncline that plunges to the

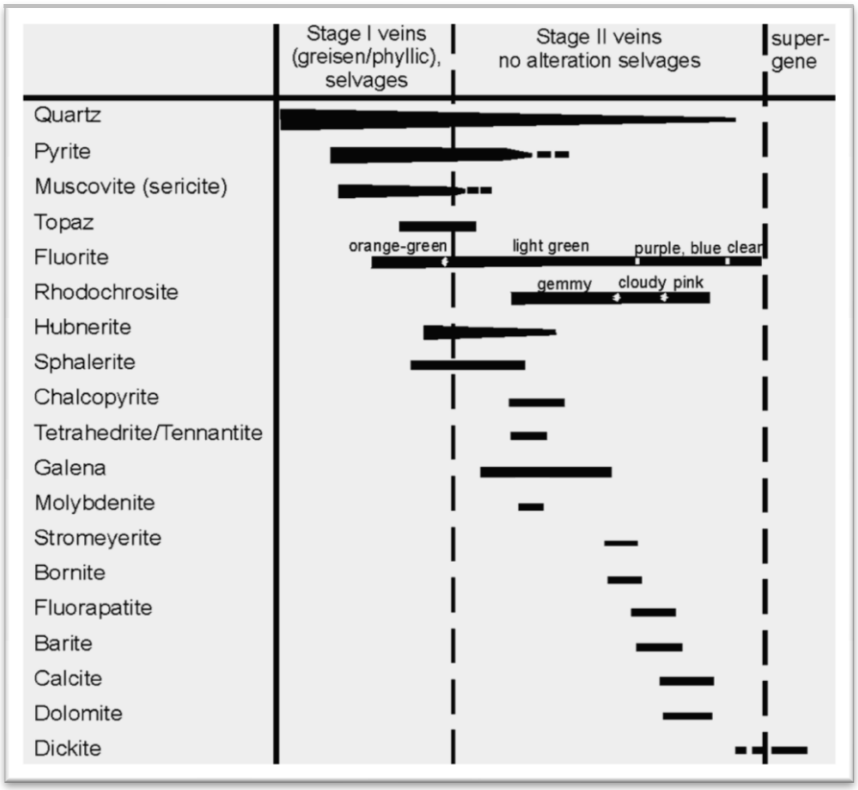

Figure 6. Paragenetic diagram of Sweet Home Mine mineralization, from Bartos, et al., 2007.

southeast (Figure 7). The London Fault is truncated by the Mosquito Fault about 2 miles northwest of the North London Mine. The north trending Mosquito Fault is the east bounding fault of the 29 m.y. Rio Grande Rift. Its throw is estimated at 9,000 with 1,500 feet of left lateral displacement (Wallace, et al. 1968). To the southeast, the London Fault continues into South Park.

Gold ore was first mined from the north end of the system, where gold quartz veins cropped out (Figures 8 and 9). These so called “McDonald” veins often occurred at sill-shale contacts at the base of the Minturn Formation/Belden Shale, formerly called the Weber Formation, or ‘Weber Grits’ (Figure 10). Most of the production came from these gold quartz veins in the syncline’s steeply dipping east limb. Ore

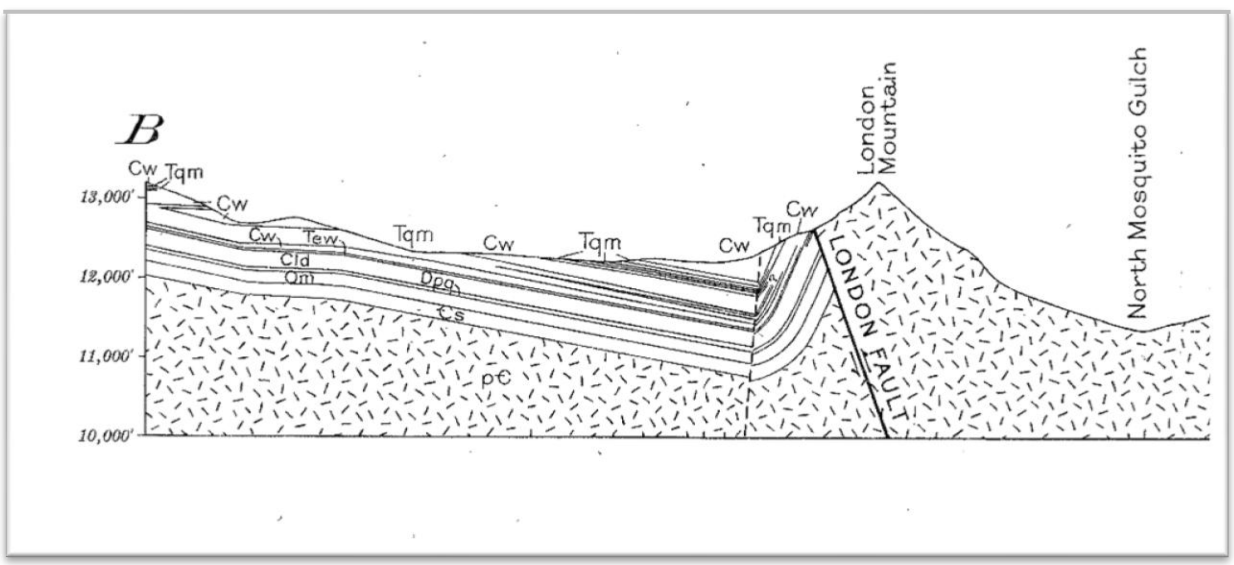

Figure 7. Portion of Section B-B' though the London Fault from plate 2 of Singewald and Butler (1911).

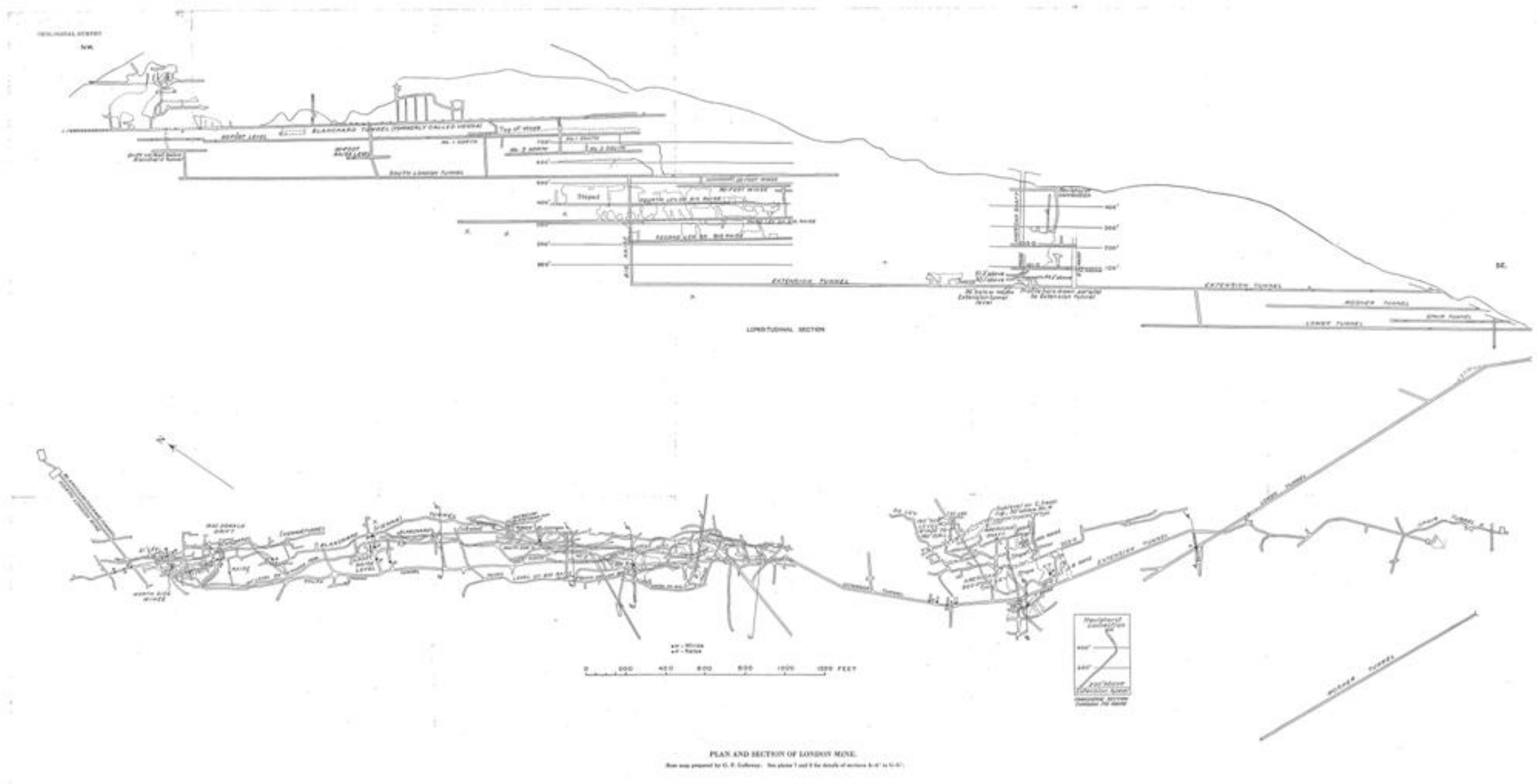

Figure 8. Plan and Longitudinal section through the London Mine, plate 6 after Singewald, 1941.

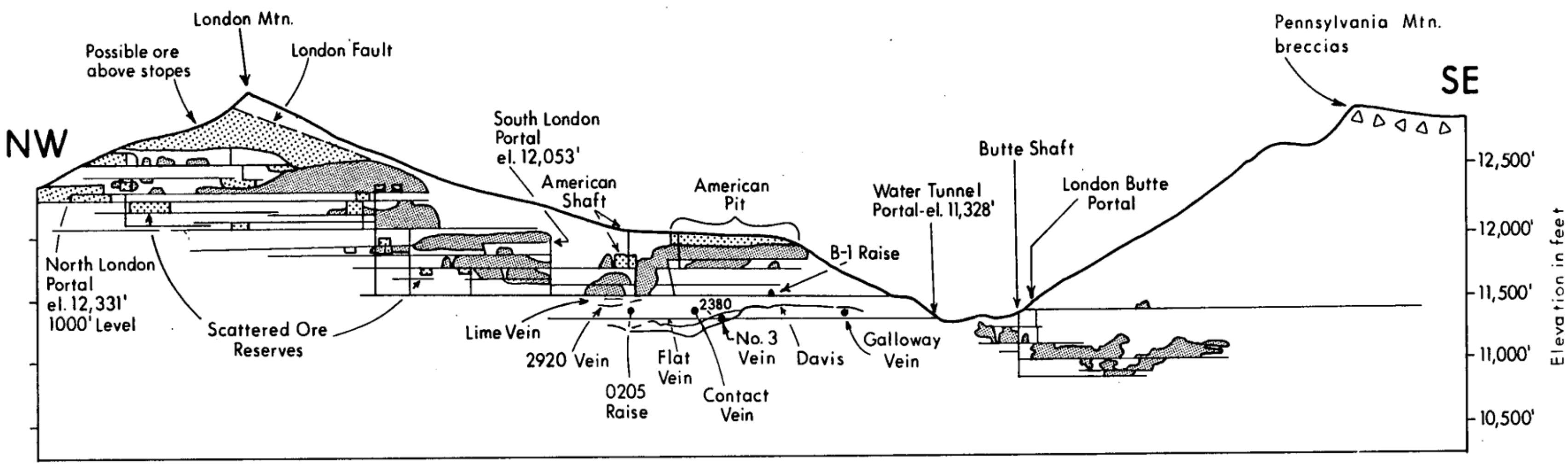

Figure 9. Longitudinal Section of the London mine showing extent of stoping and various deposits. After Johansing and Misantoni, 1992. The majority of stopes shown were developed on McDonald veins. Notable exceptions are 'Lime Veins' in the American area and named deposits beneath it. The 'Water Tunnel' is referred to as the 'Lower Tunnel' in Figure 7.

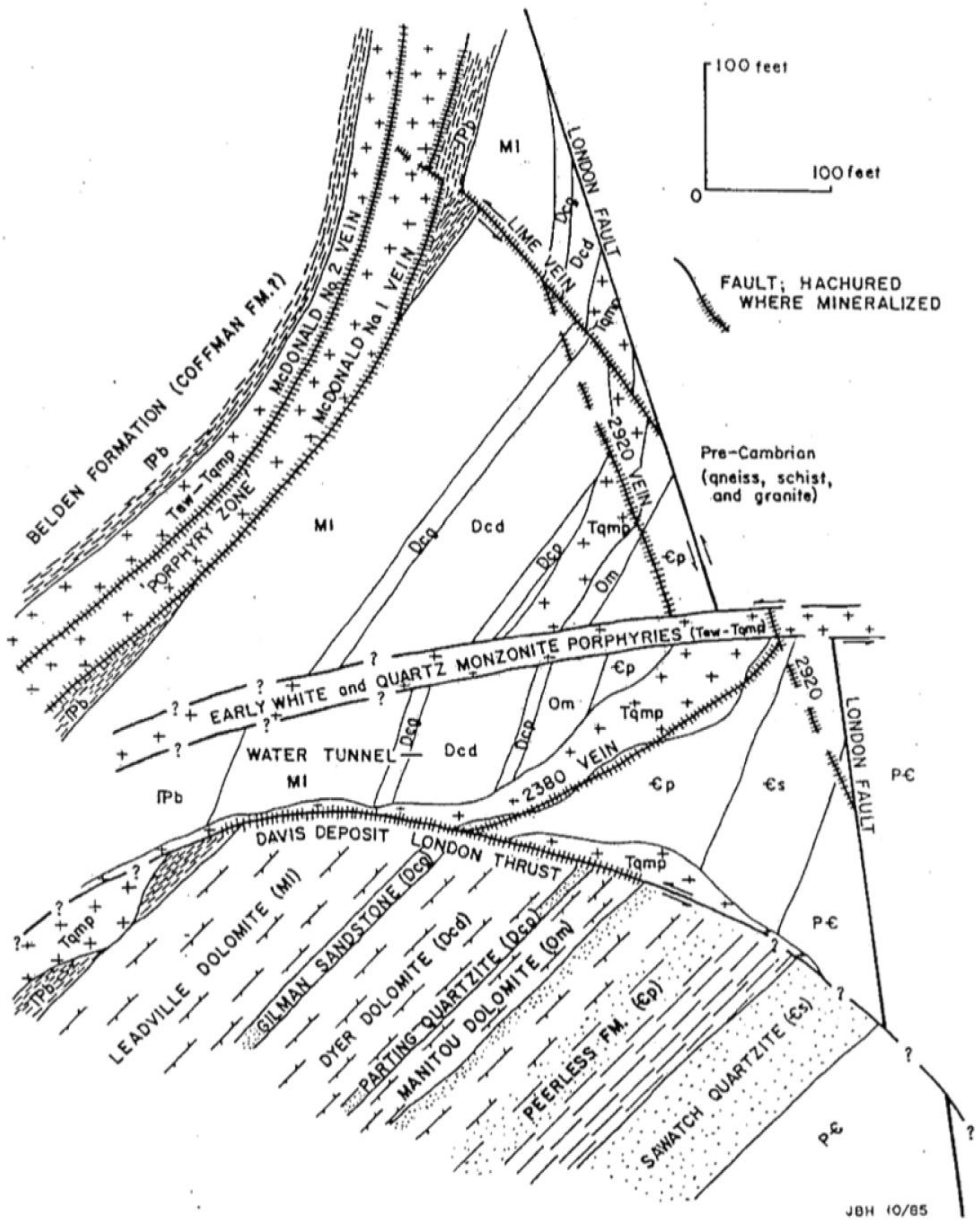

Figure 10. Cross Section showing the relation of gold deposits to lithology and structure, after Johansing, et al. 1992.

shoots rake down and to the southeast, roughly parallel to the plunge of the syncline. This style of mineralization extends from the North London Mine, where it was first exploited, to beneath Pennsylvanian Mountain, where it remains open at depth. Large tonnages of low-grade gold-quartz stockwork mineralization are present in porphyry sills in the hanging wall of these veins (Tedrow's 'broad lode'), but in the past they were not of economic importance.

The ore has a low silver content and locally contains minor galena, sphalerite, tetrahedrite and chalcopyrite that rarely exceed 5% combined base metals. The Au:Ag ratio varies from 1 to 0.4 and appears to decrease from the south to north in the direction of the Sherman Type silver mineralization in the New York Cliffs area. Berry noted a zone of 'transition veins' between the London MacDonald style veins and the Sherman Type Mineralization at New York Cliffs. These veins contained both silver sulfosalts and elevated gold values with Ag:Au ratios ranging from 10 to 1,000. Interestingly, the lead in these transition veins are J-Type, as are the lead isotopes from the Alma District's Sherman Type deposits (Berry, D. W., 1990).

A small but high grade gold vein and replacement orebody, known as a 'Lime Vein' in the Leadville Formation was mined stratigraphically and structurally beneath the MacDonald veins in the American Mine. This orebody was blind in that it terminated upwards against the London fault and did not crop out. It was developed from a shaft that was collared in the Precambrian hanging wall of the London Fault. The relatively small American claim was quickly embroiled in apex litigation with the London Mining Company, and in the end, the owners of the American Mine prevailed.

Deeper yet in the section veins are developed within the Leadville, Dyer, Manitou, and Peerless (aka Dotsero) formations (Figure 9). Some of these are high angle, but others, such as the Davis Deposit developed from the London Extension level, are low angle antiformal surfaces that are structurally discordant with the surrounding high angle stratigraphy. These orebodies were discovered and mined by Cobb Resources in the 1980's. Mineralization is sometime associated with cross cutting northeast structures that are interpreted to be feeders (Misantoni, 2017, personal communication).

Low grade disseminated/stockwork gold mineralization also occurs in the Sawatch Quartzite in the immediate footwall of the London Fault. Gold bearing breccias are also present at the top of Pennsylvania Mountain. These targets remain poorly explored, as do extensions of mineralization at depth.

A post/syn-ore hydrothermal breccia pipe containing ore fragments is located a short distance northwest of the South London portal. Breccia from this pipe is found cross cutting ore in the Davis deposit. This breccia is similar in character to post mineral hydrothermal breccias in the Leadville District only three miles to the west. The breccia's carbonaceous matrix contains traces of disseminated pyrite, low iron sphalerite and, locally ribbon-textured chalcedonic quartz. Large volumes of recrystallized carbon ("graphite") derived from shales in the Paleozoic section, are remobilized into these breccias matrices (as well as other faults/vein types), sometimes showing fluidal, flow banded textures.

Gold Placers

The discovery of placer gold on the Middle Fork of the South Platte occurred as early as 1804, by trapper James Pursley, but no production occurred in what was then Spanish territory (Parker, 1974). Placer mining began in earnest in 1859 with the discovery of placers along Tarryall creek near Como and subsequent discovery of placers along the South Platte River between Fairplay and Alma (Figure 11).

The richer placer deposits were quickly depleted and by about 1861 most of the miners had decamped, although several placers, including the Alma, Fairplay, and Beaver Creek, were worked continuously for many years. In 1922 the first dredge was installed at Fairplay. Dredges worked the Alma and Beaver Creek placers in later years. Placer mining enjoyed a vigorous uptick in the 1930's as the depression and increasing gold price lured (drove?) men to work in the mines. The renaissance was short lived, however, when on October 8, 1942 the War Production Board declared gold mining a nonessential industry and ordered most gold mines to close indefinitely. In recent decades several placer mines have reopened, and presently there are eight mines in operation.

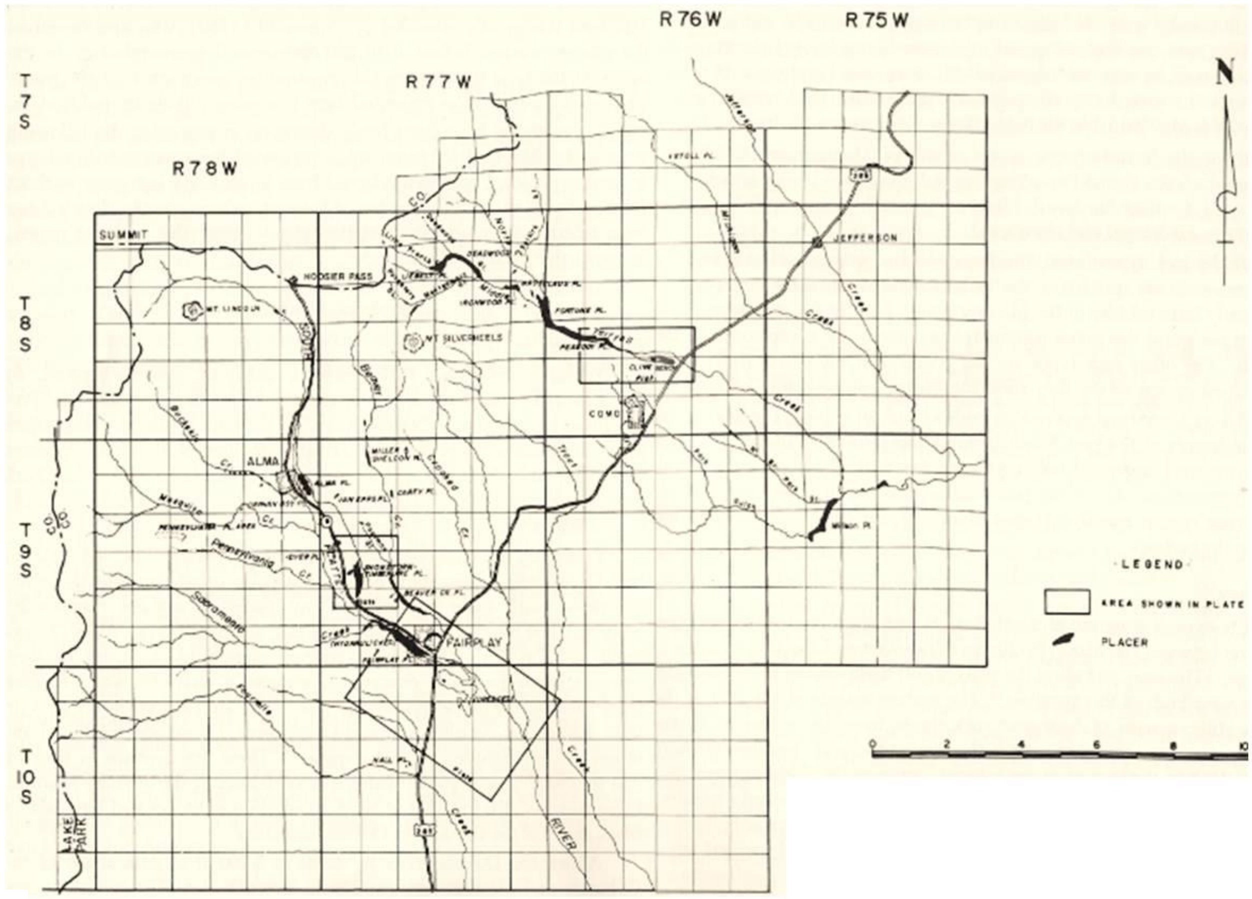

Figure 11: Gold Placers of northwestern Park County, after Parker (1974)

The placers in the South Platte valley were formed mainly by the concentration of glacial deposits by streams (Parker, 1974, Singewald, 1950). Glaciation greatly accelerated erosion of lode gold sources and increased the volume of material available for concentration. There were two significant periods of glaciation, the Bull Lake and the Pinedale, occurring about 50,000 to 125,000, and 10,000 to 29,000 years ago respectively. Repeated advances of glaciers bulldozed massive amounts of material downslope and scoured-out the classic “U-Shape” valleys in the Buckskin, Mosquito and Sacramento drainages and the South Platte River above Montgomery. Gold was liberated as the glaciers ground rock to gravel and silt. Repeated melting events flushed away much of this material and concentrated the gold in ancient river beds and outwash fans. The richest deposited were created when glacial debris were eroded into a river channel directly on bedrock. Subsequent glacial and alluvial deposition often buried these deposits, leaving them hidden beneath tens of feet or more of barren or low grade glacial till. In some cases, gold was concentrated in glacial sediment, particularly if the advancing glacier entrains a preexisting alluvial deposit, but glacial moraines are usually low grade and uneconomic. It is not uncommon for an advancing glacier may override an alluvial deposit and bury it under barren or low grade moraine.

The rich pay streaks in paleochannels are every placer miner’s dream, especially when concentrated in bedrock ‘gutters’. In reality these are really quite rare. The grade of most of the 65 gold placers examined by Orris ranged from 0.056 to 0.31 grams/cubic yard, or $2.25 to $12.84 per cubic yard at today's price (Orris, et al. 1985).

Glacial moraine was plowed against the east side of the South Platte valley between Alma and Fairplay by glaciers moving down the Buckskin, Mosquito and Sacramento drainages. This accounts for the nearly continuous belt of placer deposits in that area. Most of the placer gold likely came from the London gold system, it being by far the largest source of bedrock gold in the entire district, although some contribution from the gold rich Orphan Boy-Phillips system is likely.

Above Alma, only small placers are present (one being beneath the dam on Montgomery Reservoir). This is probably due to either the absence of significant lode gold deposits on the adjacent mountains and/or their removal by glaciation.

Pennsylvania Mountain Placers

The Pennsylvania Mountain placers are unusual because they are colluvial placers (aka 'residual' placers). Colluvial indicates that the host is soil and decomposed bedrock what was formed more or less in place (ignoring the possibility of displacement by downslope creep, slumping and landslides). This deposit is famous for its coarse, crystalline nuggets, which have been attributed to in situ growth within the soil profile (Kenah, 1991). The nuggets have also been suggested to be derived from a proximal bed rock source as some are attached to quartz vein and even galena has been noted (Singewald, 1950, Art Braun, pers. commun.). Another possible source is upslope from the London Fault. The largest nugget recorded weighed 11.95 troy ounces (Parker, 1974).

Pfister/Sanborn Placer

The Pfister/Sanborn Placer Mine is a short distance west of Fairplay. This mine is developed in terminal glacial moraine immediately west of Fairplay (Figure 12). Some of the earliest workings in the county were located where the South Platte river breached this terminal moraine and enriched the gravels by removing waste. The South Platte also reconcentrated gold into an outwash fan south of Fairplay. A floating dredge worked this deposit leaving stacks of gravel in its wake. The dredge has long since decamped to South America.

Road Log

6:00 AM meet at the Rally Area at the **Wooly Mammoth Park and Ride** on the NW corner of I-70 and Highway 26 and departure at 6:15 AM sharp. Please see the attached Map (Figure 13). I will be driving a silver Toyota Tundra crew cab. We will collect field trip waivers before departing.

Proceed to I-70 West and travel to about 1 hour to the Frisco exit (exit 203). Turn south on US Hwy 9 and continue south to Breckenridge. Transit through Breckenridge (Breckenridge District) and continue south to Hoosier Pass, about 30 minutes.

8:00 AM **Stop 1 -** Hoosier Pass. There is ample parking on the west side of the pass. This stop provides an elevated panoramic view looking south into the northwest corner of South Park. The park-bounding Mosquito Range is on the right and the Mount Silverheels laccolithic intrusive complex is on the left. The South Platte River valley is centered below. There will be a brief discussion on the history of metal mining in the region including the regional geologic setting (South Park Basin and Laramide tectonics, the Colorado Mineral Belt (COMB) and the Rio Grande Rift) and an overview of district metallogeny

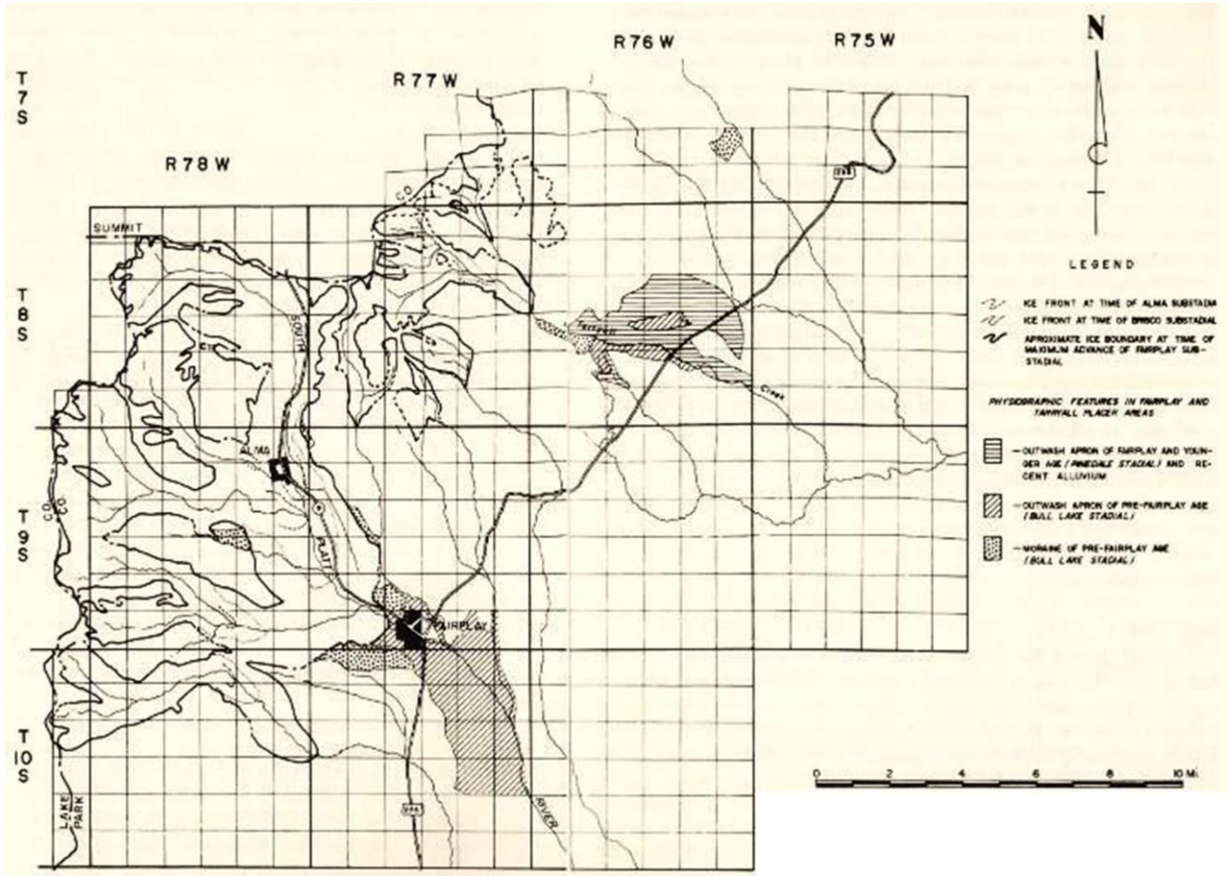

Figure 12. Map of Pinedale ice fronts and glacial deposits of Northwestern Park County, after Parker, 1974.

which spans the Permian, Laramide, mid-Tertiary, and Quaternary and includes a variety of deposit types (STM-LTM, porphyry Mo and associated veins, gold deposits and placers)..

From this vantage point we can also see:

- Portions of the Consolidated Montgomery District (visible lower right), and the location of the Historic settlement of Montgomery, now largely beneath Montgomery Reservoir.
- Alma District (mid-distance right)
- The Russia, Moose, and Dolly Varden mines on Mounts Lincoln and Bross. These are Sherman Type (STM) deposits
- The old townsite of Quartzville

The Penn Mountain colluvial gold placers, and the Sweet Home, London, Hock Hocking, and Hilltop/Sherman, mines are hidden behind topography in the distance.

The Pollock Placer, in the Upper Blue River District, is immediately north of Hoosier Pass and an old placer water ditch is on northeast side of Hoosier Pass.

Figure 13. Field trip meeting point at the Rally Area near corner of I-70 and Highway 26.

8:20 AM proceed southwards on Hwy 9 to Alma, turn west on County Road 785 (Buckskin Road) for 3.9 miles to Stop 2.

8:40 AM **Stop 2 - Sweet Home Mine**. Restricted surface tour only. This famous rhodochrosite mine was formerly a Ag-Pb-Zn-W producer. Mineralization at the Sweet Home Mine is related to a Climax style Mo system. Nearby there are out crops of a pebble dike, greisen, and garnet skarn. Northeast trending feeder veins in Precambrian and Paleozoic rocks are visible in the Canyon walls. In this area, there are several styles of mineralization in the Paleozoic section (vein, replacement). The Paleozoic stratigraphy is well exposed in the canyon walls and the remains of several historic aerial trams are visible.

9:30 AM proceed toward Alma, turn south on highway 9 and proceed to 1.2 miles south to County Road 12 (Mosquito Pass Road). Proceed 1.4 miles west to Stop 3.

9:50 AM **Stop 3 –View of Mosquito Gulch and the Pennsylvania Mountain placers**. This stop will afford an overview of the Penn Mountain placers and the Paleozoic stratigraphy exposed in the side of the Mosquito Gulch glacial valley.

10:10 AM Proceed up Mosquito Gulch 2.6 miles to Stop 4.

10:20 AM **Stop 4 - London Mine**. Surface tour only. Discuss London District, London Fault, London gold mineralization, South London, Penn Mt Breccia, post mineralization breccia pipes, New York Cliffs STM, relation to Leadville District, and more.

11:20 AM travel east towards Alma to the Hock Hocking road (Park County Road 698), approximately 2.7 miles. Travel up Penn Mountain roughly 2.7 miles to the Combination Placer mine.

11:45 PM **Stop 5 Combination Placer**. Here we will view recent and historic placer workings in this unique colluvial gold placer.

2:00 PM Proceed to the Pfister/Sanborn Placer via Zebulon Street and Park County Road 1, approximately 6.7 miles

2:15 PM **Stop 6 – Pfister/Sanborn Placer**. This active placer mine is located at the upper end of the Fairplay Placer. Currently the reality TV series "Gold Rush" is operating this placer.

3:15 PM proceed to Fairplay and South Park City.

3:30 PM **Stop 7 - South Park City**, Fairplay. Discuss Fairplay placer: discovery, odd name, history, operation/mining methods(ground sluicing, hydraulic mining, dredge, current.

5:00 PM Return to Denver, via US 285. This will provide an excellent overview of the Mosquito Range and Mount Silverheels from South Park. We will drive by the Como placers along Tarryall Creek. In the 1800's, some late-arriving placer miners, finding that all the good ground along Tarryall Creek had been claimed by the use of unusually large mining claims, decamped to the present site of Fairplay. They christened their new town "Fairplay' because only smaller claims were permitted, thus allowing "fair play"! A panoramic view of South Park is offered near the top of Kenosha Pass (**Optional Stop**). ETA Golden is at 6:30 PM.

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Field Trip F: Cripple Creek/Victor Gold Mining District

July 24, 2017

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Meeting Time, Location, and Preface

Trip participants will meet at 9:30AM at the Victor Lowell Thomas Museum, 3rd St. and Victor Ave., Victor, CO (museum@victorcolorado.com). There, we will board a bus for a tour of the Cresson mine, operated by Cripple Creek & Victor Gold Mining Co., a subsidiary of Newmont North America. The following outline includes topics that **may be covered** and is modified from CC&V documents, complements of Brad Poulson, External Relations Representative, Newmont North America.

Welcome Everyone!

Pre-Lunch Field Trip Outline

Company and Safety Introduction

- Newmont North America/CC&V Operations. North American Headquarters in Nevada, Global Headquarters in Greenwood Village (Denver Metro Area). Mines around the world including Ghana, Australia, and Peru.
- Description of Tour – Large, high-tech, modern mining operations. Operations take priority and may affect the tour.
- Safety Issues – SOS (See it. Own it. Solve it.)
  - High Altitude
  - Hard Hats/Safety Glasses/High Visibility Vests all will be provided
  - Listening to instructions when outside the vehicle
  - Rough ground warning

Historical Introduction

- In 1874, The Hayden Survey documented the presence of gold on the west side of Pikes Peak but little notice was taken until later.

- Bob Womack – Discovered gold in 1887; located source of gold in 1890. El Paso Lode mine. Sold for $500 and case of whiskey to become Gold King Mine producing over $3,000,000 in gold.
- Uniqueness of gold ore in this area - Sylvanite and Calaverite – tellurides--and pyrite – Sulfide.
- During 1890's the Cripple Creek & Victor Mining District boomed
- Cripple Creek formed in 1892 from two towns, Fremont and Hayden Placer
- Victor a "planned mining town". Woods' brothers developed the area.
- 1896 fires destroyed the commercial district and a lot of the town of Cripple Creek.
- 1899 fire destroyed the town of Victor.
- Buildings seen in Victor from 1899 rebuild.

Victor Historical Sites

Note: The order in which we view these will be dependent on our route through town.

Lowell Thomas Museum
- Originally a hardware store with the Gold Miners Stock Exchange in the back, then a grocery store and finally the museum
- Named after Lowell Thomas, Victor native who was a radio broadcaster, adventurer and writer
- Lawrence of Arabia was subject of one of his books, which became the foundation of the movie

Monarch
- High Class Saloon for the millionaires and mine owners. Had a whiskey tasting room and billiards room

Fortune Club
- working man's saloon. Adult beverages on the main floor – adult entertainment on the top floor.

CC&V Administrative Offices
- Old Bank and Post Office building

Cresson Head Frame
- Relocated and preserved when CC&V began mining the old Cresson mine area
- Single Hoist
- Man Car or elevator used to bring men and supplies down into the main shaft of the mine and gold ore up out of the mine. Man Car was also commonly called a skip.

Battle Mountain Mines
- Battle Mountain was considered the richest mountain on earth until the 1930's
    - **Ajax Mine**
        - Deepest mine shaft in the district at 3350 feet
        - Longest running large mine – 1890's through 1962. Reopened several additional times between 1960's and 1980's.
        - Produced over $20 million in gold
    - **Strong Mine**
        - Best equipped mine in the district
        - Produced $13 million in gold
        - Like many others in the "boom" days, Sam Strong was a colorful and controversial character who was shot to death in Cripple Creek Saloon over an escalating disagreement.
    - **Independence Mine (1891)**

        - Winfield Stratton – First millionaire in district
        - Mine produced $28 million in gold
        - Stratton's mining and philanthropic legacy includes the establishment of the Myron Stratton Foundation in Colorado Springs
    - **Portland Mine**
        - Highest producing mine in district – produced ½ of all gold out of Battle Mountain
        - Started out with less than 1/10th of an acre
        - Gold out of Portland was such high-grade gold surrounding mine owners took the Portland to court to take over the claim. After three years Portland Mine won the lawsuit and afterward bought up surrounding mines

Railroads

- **Florence/Cripple Creek Narrow Gauge**
    - first railway
    - where Phantom Canyon Road is now
- **Midland Terminal from Divide area**
    - second railway
    - with The Colorado Railroad Railway out of Colorado Springs
    - where Hwy 24 and Hwy 67 are located
- **Short line**
    - third railway
    - where Gold Camp Road is now

<u>Vindicator Valley Trail</u>

- Part of a trail system built on CC&V property with the support of the Southern Teller County Focus Group as part of CC&V's on-going historical preservation of mining structures from the original gold strike

<u>Goldfield</u>

- A town specifically developed for families with no saloons or brothels.

<u>American Eagles Mine</u>

- Highest mine in the district at 10,750 ft.
- Main shaft goes underground around 2100 ft
- Structures are being evaluated for re-location
- New overlooks provide views, access to historical structures and support heritage tourism and mining education

Modern Mining Operations

Note: To be discussed on the way to the Iron Clad

- Permitting
    - Current mine plan has been publicly permitted (by over 17 regulating agencies) with the established mining boundary, to operate at the current pace of mining until 2024. Further extensions are being considered.
    - Within permits, gold processing (leaching) and reclamation will continue beyond mining timelines.
    - CC&V works with government and environmental agencies required for permits to mine.

- Amendment 11 has been approved by the State of Colorado, and is currently being reviewed by county officials.
    - Modify Permit Boundary in Poverty Gulch to include Chicago Tunnel and Storm water Management Ponds;
    - Clarify existing permits for possible underground mining associated with exploration from Chicago Tunnel;
    - Modify mining and backfill plan for WHEX and Main Cresson;
    - Modify mine plan for North Cresson;
    - Modify East Cresson Overburden Storage Area;
    - Modify reclamation plans;
    - Modify stacking plans for Arequa Gulch VLF1.

ECOSA Overburden storage area

- will eventually be 10,900 feet in elevation

Reclamation

- By the end of its current permitted mining plan, it is estimated that the value of CC&V s posted reclamation bond will be over $194 million with the State of Colorado to cover costs of reclamation in case something happens to the company.
- Explanation of Reclamation Process: Goal is to put area back as close to original as possible.
- Back fill of mined area in accordance with approved reclamation plan.
- Contour slope to surrounding area.
- Spread top soil that has been stock piled.
- Hydro seed area with approximately 12 different types of native grasses, shrubs, flowering plants and quick growing sterile grain to minimize erosion.
- Plant trees to match original eco system.
- Place rock and deadfall for habitat

WHEX (Wild Horse Extension)

- Grassy Valley – lots of prospect holes (historic claim sites), only a couple of historic mining operations on the north side of the district.
- Higher grades of Ore found at 400 feet.
- Example: Ore body called "Gold Bug" - higher grade ore.
- Very few historic underground mine workings.

Preserving Our Mining History

- Examples of Restoration of Mining Structures – CC&V Policy.

Entering the Mine at Ironclad

- Ironclad Maintenance Area
    - Ironclad Building (holds HR, Safety, Engineering, and Security);
    - Warehouse/Machine Shop;
    - Small Maintenance Building (for light vehicles);
    - Large Maintenance Building (for big equipment);
    - Bone Yard;
        - Equipment built on site – takes 14-15 semis to bring in all parts for haul truck.
        - Old equipment parted out and/or scrapped.

- <u>Tire Changing Station</u>
    - Tires cost between $32,000 – $36,000 each.
    - Old Tires are recycled – shredded for playgrounds or used as stock tanks.
- <u>Fueling Station</u>
    - 5 tankers of diesel fuel each day.
    - Haul Trucks hold 1000-1200 gallons of diesel fuel.
    - After labor, one of the largest expenses on mine is diesel fuel.
- <u>Safety and Environmental Measures:</u>
    - Left Hand Drive;
    - Dust, Noise and Light Controls;
    - Berms;
    - Water monitoring.

  <u>Monument Truck</u>
    - Euclid Hitachi;
    - 300-ton haul capacity;
    - Diesel Electric Drive, 900 gallon fuel tank, burns 30 gal/hour.

Monument Truck Outlook Discussion

- **Geology:**
    - 32-million-year-old volcano.
    - Concentrated in 10-square-mile area because of Precambrian formations surrounding area.
    - Imploded and erupted approximately 12 times.
    - Volcanic structure called a diatreme.
    - High walls
    - Minerals/elements visible on high walls.
- **Basic Modern Surface Mining Operations**
    - Removal of vegetation
        - CC&V harvests trees and gives to community for firewood or re-planting.
    - Top soil stockpiled to be used at a later date for reclamation.
    - Fracture Rock by Blasting
        - Blast pattern engineered based on geologists' findings, and communicated via computer mapping/GPS.
        - Permitted to blast 1100 holes per day (but typically only blast around 250 at a time to minimize seismic disturbance on communities).
        - Usually Monday –Thursdays between 10:00 and 3:00 as a common courtesy to area towns.
        - Each blast hole is approximately 40 feet deep and 6 ½ inches in diameter.
        - Filled with 450 – 650 lbs of emulsion.
        - Top 10 feet of drill hole backfilled with crushed rock (called stemming).
    - Shovel the muck or fractured rock.
    - Haul the rock containing gold (ore = rock with economic value) to crusher, and overburden to a storage site. (Rock that doesn't contain gold must be mined through until you reach the ore structure. At CC&V we move about 1/3 ore and 2/3 overburden.)
    - Crush the ore.
    - Haul and place on leach field.

Tour of Pits

Note: Tour of Pits Vary Depending on Safety Issues – Optimally leave the Monument Truck

and go into the WHEX to view equipment, circle around the Main Cresson and head to the Crusher Complex

General Pit Information

- **Cresson Pit**
  - Historic mines and production
    - Original underground mines exploited veins that averaged 1-2 oz of gold per ton.
    - Note drifts on high walls.
    - Original Cresson Mine went down 2300 hundred feet below the surface.
    - Cresson Vug – 1200 feet; vug produced 4,000 oz per ton
- **WHEX** – discussed on drive in
- **Globe Hill**
  - Tree and topsoil removal third quarter of 2016.
  - Mining beginning in 2017.
- **South Cresson (behind Ajax Mine above Victor)**
  - Having been mined periodically over the years, this area is now in production again.

CC&V Annual Production

- Current annual production numbers – gold, silver, tons ore and tons overburden.
- CC&V produced its 5 millionth ounce of gold in September of 2015, since starting the Cresson Project in 1994.
- 2 tons of overburden (also known as waste) per 1 ton ore on average (1 truck of ore to every 2 trucks of overburden).
- Approximate value of gold mined by CC&V 0.022 to 0.05 oz gold/ton (CC&V is mining the ore structures (disseminated mineralization) that were left by the historic underground miners).

Safety Measures

- Monitoring the high walls – green triangles holding prisms (Laser Radar) & Slope Radar.
- Drilling, down hole cameras, new and historic maps to monitor old underground mine workings.
- CC&V estimates approximately 500 miles of underground mine workings between Cripple Creek and Goldfield.

Equipment – drills, haul trucks, shovels

Survey Markings

- Lath/stakes with various color codes identify different types of rock and grades of ore and indicate how it will be mined and processed efficiently

Crusher Complex

- Crusher and leaching operation
- Primary Crusher – 65,000 tons/day.
- Conveyor to Screening Plant, Magnet to remove historic steel at top.
- Conveyor to Secondary Crushers, Second magnet.
- Secondary – 3 cone crushers crush ore to ¾ inch in diameter.
- Lime addition to crushed ore keeps pH in process solution high, which reduces the consumption of NaCN.
- Conveyor to Load Out Bin.
- LOB – 400 ton capacity, loads 250 tons in less than 60 seconds.

Valley Leach Facility (VLF)

- Gold and Silver are removed (leached) from the ore with a dilute (approximately 200 parts per million) mixture of sodium cyanide in water – known as process solution.
- The process solution is contained in a Zero Discharge Valley, and is recycled through pumps at approximately 25,000 gal/min
  - Other than evaporation, no loss or release.
- Double and Triple Lined Valley creates zero discharge facility (can be thought of as a bowl)
  - Compacted Clay
  - Plastic Liner
  - Leak detection
- Ore placed in 100' lifts.
- Process Solution applied with Drip Emitters (agricultural irrigation lines).
- Process solution dissolves the gold and silver from the crushed ore into the solution, which becomes pregnant solution containing gold & silver.
- Solution collects on the low portions of the triple lined valley in areas called pregnant-solution storage areas (bottom of bowl full of crushed ore). The pregnant solution is maintained in the pore spaces of rock (not open to the environment) until it is pumped to the Adsorption, Desorption, and Recovery Facility where complicated chemistry and metallurgy are applied to capture the gold and silver (See ADR below).
- Reclamation of Leach Field (different from regular reclamation projects).
  - Rinsed and flushed until water-quality standards are met.
  - Liner punctured to restore historic flows.
  - Slopes re-contoured and reseeded.

NOTE: VLF1 no longer being added to – at approximately 800 feet, this pad may be one of the tallest in the world.

ADR Plant

- Carbon Adsorption – coconut shells that have been processed to make activated carbon (Adsorption)
  - Series of tanks containing carbon.
  - Pregnant solution flows through tanks (gravity fed).
  - Carbon pumped up from bottom tanks.
  - Gold "adsorbs" onto surface of carbon.
- Gold and Silver removed from Carbon in Strip Vessel (Desorption)
  - Heat and Pressure in Alkaline Solution.
  - Gold and silver back into more concentrated solution.
- Electro-winning Cell (Recovery)
  - Gold and silver "plated" onto stainless steel cathodes.
  - Cathodes sprayed off to collect "Mud" containing metals.
- Refinery
  - Mud into furnace with Silica and other chemicals.
  - Heated to 2400 degrees F.
  - Poured into "brick" mold.
- Dore
  - Impurities and Silica are lighter and rise to top.
  - Around 70% Gold, 25% Silver but this varies.
  - 65 – 70 pounds per dore "button".
  - Sent to refinery via armored car, sold on open market.

Mill and VLF2 Overlook

Mill and Flotation Plant (used for higher grade ore = approximately 10% of ore)

- Crushed High Grade Ore is dropped from LOB into Haul Truck and taken to the Mill and Flotation Plant.
- Grinding Circuit: Grinding circuit consists of a single rod mill operating in conjunction with a single ball mill at a rate of approximately 250 tons per hour. High Grade ore is ground from approximately ¾-inch diameter into a fine powder with the consistency of fine grain sugar.
- Cyclone Separation Process: The concentrate is pumped into a conically shaped vessel known as a cyclone cluster. The swirling motion inside the vessel generates a centrifugal force that separates the coarse particle from the fine particles. Faster settling, coarser particles move to the wall of the cyclone and flow back to the ball mill for further size reduction. Fine particles flow to the conditioner tank for further processing.
- Flotation Cells: The slurry advances to a conditioning tank where reagents are added to enhance the flotation process. In the flotation tanks, air bubbles are pumped through the ore mixture; the minerals containing gold and silver particles attach to the bubbles and are recovered and advance to the leach circuit, where NaCN is added to dissolve the gold and silver.
- Leached slurry flows to the carbon in pulp (CIP) circuit where the gold and silver are recovered from the solution. The carbon from the CIP is sent to the ADR for processing like that coming from the leach process above.
- Once the gold and silver are extracted, the leached slurry is processed through a pressure filtration circuit where water is removed to produce a filter cake. The filter cake is transported by conveyor to the stockpile where it will be loaded into trucks and placed on the VLF. Water is re-circulated for reuse in the mill.

Phonolite Dikes and Lamprohyre Breccias

The information presented in this section is slightly modified from Jensen (2008). It discusses an aphanitic phonolite dike and lamprohyre breccias accessed in June, 2017, which are presently exposed in the deep levels of the main Cresson Pit (Figures 1 and 2).

The Bluebird Dike

The Bluebird Dike (487839E 4286692N) is a NNW dike that follows a dominant structural trend seen in the district. Two major phases of phonolitic intrusive activity took place in the district, and the Bluebird dike was emplaced during the second episode. As seen in these exposures, the Bluebird dike cuts through both older generations of phonolitic intrusive rocks and volcanic breccias. Intense K-feldspar + pyrite alteration and gold mineralization are developed along the margins of the dike, along with fluorite-bearing sulfide veins. These features suggest that the Bluebird dike served to focus the migration of ore-bearing fluids along its margins. Veins and alteration are also developed in phonolitic rocks and breccias adjacent to the dike.

The Cresson Pipe Lamprophyric Breccias

The Cresson Pipe Lamprophyric Breccias (487446E 4286321N) represents one of the more notable

 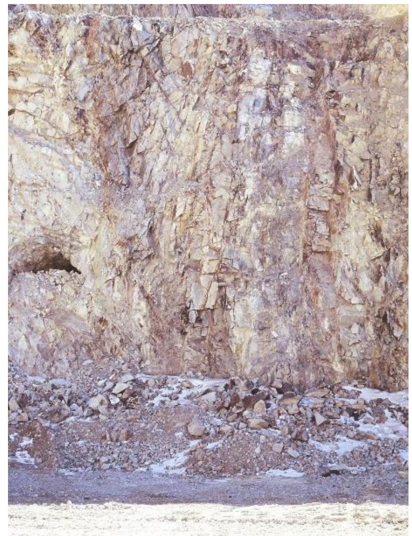

Figure 1 (left): Cresson open pit from American Eagles overlook. **Figure 2** (right): Bluebird dike from bottom of Cresson open pit. (Carnein photos)

geologic features in the district. Lamprophyric rocks are the youngest known igneous rocks exposed in the district. Although they constitute only 1-2% of the volume of igneous rocks in the district, mineralized lamprophyres were mined in roughly 1/3 of the mines in the Cripple Creek district. Lamprophyric rocks derive their name from the Greek root “lampros” and “porphyros” which combine to mean “glistening porphyry”; the name was first applied to mafic to ultra-mafic rocks rich in biotite phenocrysts that appear to glisten within the drab, fine-grained mafic groundmass. As commonly applied, the term lamprophyre is used as a field classification to describe mafic to ultramafic rocks with hydrous mafic phenocrysts, and if feldspars are present they are restricted to the groundmass of the rocks. The Cresson pipe is an elliptical, pipe-shaped body of breccia elongated ENE, with an average diameter of approximately 100 meters. The pipe plunges steeply to the south, tapering and becoming increasingly tabular at depth, and eventually bifurcating into two roots ~600m below the surface. The pipe is composed of heterolithic rock fragments, including a predominance of mafic and ultra-mafic clasts that are supported by a matrix that varies from a fine-grained, crystalline lamprophyric matrix rich in clinopyroxene and analcime (commonly altered to montmorillonite clays and carbonate), to a leucocratic matrix of carbonate-analcime-alkali feldspar±quartz. In portions of the pipe, the leucocratic matrixes contain rounded blebs of dark lamprophyric material. In thin section, the “blebs” are concentrically zoned, and exhibit fine-grained outer rims. These textures suggest that the “blebs” are not mechanically comminuted rock fragments, but were liquid at the time of incorporation into the leucocratic matrixes. These may reflect processes of liquid-liquid immiscibility, with the leucocratic matrixes representing low density, hydrous phases that were exsolved from lamprophyric melts during crystallization. The Cresson pipe both cuts and is cut by lamprophyric dikes. Gold mineralization was strongly developed along the margins of the pipe, and appears to form an annulus around the pipe. Roughly 2.5 million ounces of gold were produced from the Cresson Mine, much of which was mined from the stopes along the pipe margins. It is interesting to note that fluorite was common in wall rocks within the annulus of mineralization that surrounds the pipe, but was notably absent from veins that cut into the lamprophyric rocks inside the pipe.

Perhaps the most notorious discovery in the district was made inside the Cresson Mine and is referred to as the "Cresson Vug". This "vug" was a cavity 8 m x 4 m wide and 13 m high that was opened in the Cresson mine in November, 1914. The cavity walls were lined with gold tellurides, quartz, celestine and a white, soft mineral that was probably kaolinite or dickite. By the end of 1914, nearly 20,000 ounces of gold had been removed from the cavity. Good descriptions can be found in Patton and Wolf, 1915;

Preliminary report on the Cresson gold strike at Cripple Creek, Colorado: Colorado School of Mines Quarterly, v. 9, p. 1-15 and Smith et al.,1985; The Cresson Vug, Cripple Creek: The Mineralogical Record, v. 16, p. 231- 238.

Lunch

After the tour of the Cresson mine, we will eat lunch in Wallace Park, nearly across Victor Ave. from the Lowell Thomas Museum.

Post-Lunch Field Trip Road Log

After lunch, **take 3rd St. north to Diamond Ave.** (less than 0.1 mi.).
Turn right onto Diamond Ave. (CO67).
Follow Diamond Ave/CO67/CO81 (paved road) about 1.9 mi. to CR831 (top of hill).
Turn left onto CR831 (Independence Rd.)
Follow CR831 0.5 mi. to parking area for Vindicator mine and Bebee house.

Stop 1. Vindicator Mine and Ore Sorting House. It is here, where the Vindicator Valley Trail winds through the Vindicator Mine (Figure 3), that whispers of the past fill the area. Operations at the Vindicator mine began in 1895. Over the years, many improvements were made, including the installation of large pumps to remove water and the replacement of the steam-powered hoist with one powered by an electric motor. The timber head frame was replaced by one made of steel in 1908 and was enclosed by a corrugated steel structure. Behind the headframe are the double drums of the hoist operation that used a flat cable hoist that brought the ore to the surface faster. The Vindicator closed in 1953 followed by a brief period of exploration.

During a period of labor strife in Cripple Creek, Harry Orchard, whose real name was Albert Horsely, was paid $500 to place a bomb in the Vindicator Mine. His bomb exploded on November 21, 1903. Orchard meant to kill nonunion scabs working in the mine during a strike, but he put the bomb on the wrong level. The explosion killed the mine superintendent Charles H. McCormick and his shift foreman Malvern Beck while they were inspecting the 7th level of the mine. Governor Peabody declared martial law and sent the state militia to the district to maintain order.

Across from the Vindicator headframe is the Vindicator ore sorting house (Figure 4), one of the best examples of this type of structure in the district. Mine cars brought gold ore on a trestle directly to this structure. A group of sorters stood in front of a moving "picking belt" of crushed ore and hand sorted the material by quality into bins—a crucial step to select higher grade ore for shipment. The hand-selected ore was dropped down into waiting railroad cars on the Golden Circle Railroad and hauled to a mill (Lewis, 2002). Ore that did not make the cut was dumped on the south side of the building (Cafky, 1955). Thirty years later, after the Vindicator closed, this so-called waste rock contained enough gold to make heap leaching cost effective.

The Bebee House (Figure 5) is nearby. This structure was once a log boarding house that served area mines and then later became the home of Alfred Bebee. The home had additions built over the decades as the family grew. Alfred Bebee hosted a party to commemorate the opening of the Carlton Tunnel here in 1941. The tunnel drained water from the district, allowing mines to reach greater depths. The Bebee family lived here until the 1950s when the Vindicator Mine closed. Alfred Bebee had a storied career in the Cripple Creek Mining District. Just down the path is an impressive storage building (Figure 6),

Figure 3. View of the Vindicator headframe. A local hiking trail winds through the area. Photo © bv S. W. Veatch.

Figure 4. The Vindicator ore sorting house is one of the best-preserved buildings of its kind in the mining district. Photo © by S. W. Veatch.

built out of local rocks that held explosives. It provides a good look at local lithology. The roof is an arch on purpose. Should an explosion occur, the explosive force is channeled upward and through the weakest part of the building—the roof, rather than allowing the explosive power to spread out laterally from the building.

After Stop 1, **retrace route to CO81.**
<u>Reset odometer</u>**.**
Turn right onto CO81, returning to Victor.

0.6 mi.: Theresa mine on right (west).

Figure 5. Alfred Bebee added additional rooms to his home as his family grew. The Bebee house is located next to the Vindicator Mine. Photo © by S. W. Veatch.

The trail that goes up the hill to the Theresa headframe is part of the Vindicator Valley trail system, which winds among old mining structures north of Victor, eventually ending at the current boundary of the Cresson mine. (Another trail, beginning near the Cripple Creek District Museum, takes hikers to Robert Womack's El Paso/Gold King mine, the district's original discovery, located below the Mollie Kathleen. This and other trails were developed with the help of grants from CC&V Mining Co.) To the east is the historic town of Goldfield, one of about 15 communities that date to the 1890s and that accounted for the district's population of 55,000 at that time. A union town with about 3000 citizens at its peak, Goldfield's population in 2010 was 49.

Figure 6. Dynamite storage building made of local rocks. The roof is made of bricks and is arched to allow an unwanted explosion's force to go through the roof, causing, less damage, rather than the force going through the sides of the building, which would cause extensive damage. Photo © by S. W. Veatch.

1.1 mi.: Independence headframe on horizon, with remains of the mill on the slope below. We will visit the Independence at Stop 3.

1.5 mi.: Pull into parking area on left; carefully cross the road to examine rocks at Stop 2.

Stop 2. Phonolite Dike. This is a quick stop that gives you an opportunity to see a phonolite dike in place. Here, phonolite cuts the "Ajax granodiorite" (informal name), one of the oldest units in the district. We will see fresh exposures of this rock at Stop 5.

Return to cars, and continue on CO81.

1.8 mi.: **Turn sharply right** onto CR84. Pass the Strong mine on the left. We are on Battle Mountain, site of some of the biggest gold producers in the district, including the Portland 1 & 2, Independence, Strong, and Ajax mines. The Ajax reached a depth of over 3300 ft—the deepest in the district. It was also one of the last underground mines to close (there are still a few small operations, including the Molly Kathleen, which mostly mines tourist dollars). The underground terminus of the Carlton drainage tunnel, more than 6 miles long, is near the bottom of the Ajax. Underground mining here ended as a result of economic factors, drainage problems, and the presence of carbon dioxide gas.

2.1 mi.: **Turn left** into parking lot for Independence headframe and trail.

Stop 3. Independence Mine. A short trail leads to one of the district's large producers, Winfield Scott Stratton's Independence Mine (Figure 7). The foundations of the mine's mill are seen below the towering headframe. Stratton was 42 years old when he arrived in Cripple Creek in May 1891. He staked the Independence Mine and the Washington Mine on July 4, 1891. Stratton received an assay report that indicated good gold values. Operations at the Independence Mine were soon underway and quickly became a solid producer of gold. Stratton took no more than $120,000 per month from the Independence, treating his mine like a bank (Levine, 1981). Stratton soon became one of the district's millionaires and one of the great mining kings.

With two major shafts and extensive underground workings, the Independence became the third largest producing mine in the district. Stratton paid higher wages to his miners and insisted that they keep the mine's operations secret (Levine, 1981).

High grading was a real problem. The largest veins were the Bobtail and the Emerson, and methods to carry out some of the gold by the miners was constantly evolving. One stope at the Independence had such rich ore that the miners called it the "Jewelry Shop" (Taylor, 1966). One night several high graders were surprised by guards at the mine. The miners quickly put out their lights as the guards fired their weapons. Bullets whizzed through the drifts in total darkness. One miner was struck by gunfire, and the other miner fell down a winze shaft. Even these extreme measures did not stop high graders. A miner

Figure 7. The Independence Mine had an extensive surface plant. The mine became the third largest producing mine in the mining district. The underground workings of the Independence were extensive with miles of tunnels and drifts. Photo © by S. W. Veatch.

could make up to $100 a day selling his spoils to shady assay offices, while his 8-hour workday only brought him $3.

Stratton, after taking $4,000,000 out of his gold mine, sold it to a London company for $11,000,000 MacKell, 2003). Stratton maintained ownership interests in several mines, including the Portland

Mine, the largest producer in the district. Stratton always lived a relatively simple life. He could be spotted at the mine always wearing a gray Stetson hat, creaseless pants, and his polished, custom made boots—his only luxury. He died September 14, 1902.

After Stop 3, **retrace route** to Diamond Ave.
2.4 mi.: **Turn right** onto Diamond Ave.
2.5 mi.: **Turn left** onto 3rd St.
2.6 mi.: **Turn right** onto Victor Ave.
2.8 mi.: **Turn left** onto 7th St. (CR87).
3.0 mi.: Outcrops of "Ajax granodiorite".
3.6 mi.: **Turn around** at gate near cemetery entrance and head back toward Victor Ave.
3.9 mi.: Park along side of road; please leave space for cars to pass.

Stop 4. Road to Sunnyside Cemetery. A short county road goes to a cemetery that includes miners, veterans from five wars, and those who pioneered and lived in Victor, the "City of Mines." The earliest grave date is 1891. The road passes embankments filled with rocks from local gold mines. This is a good stop to collect some rocks that are representative of the district.

After Stop 4, **Return to intersection of 7th St. and Victor Ave. (CO67).**
4.3 mi.: **Turn left** onto Victor Ave. (CO 67N). Regular outcrops of "Ajax granodiorite" on both sides of road.
4.6 mi.: **Turn right** into small road/parking area by gate. Please turn cars around to face CO 67.

Stop 5. "Ajax Granodiorite" (informal name).
This is a rare, fresh exposure of the so-called Ajax granodiorite, aka Ajax granite and Boulder Creek granodiorite (Xgd on Figure 14). At 1.7 to 1.65Ga, this is the second oldest and locally most widespread of the district's host rocks. As seen at Stop 3, this rock sometimes exhibits a pronounced foliation (augen gneiss), not readily apparent at this location except where exposures are favorably oriented. Augen gneiss is usually interpreted as a metamorphic rock formed in a deeply buried shear zone where the rocks are close to their melting point.

At this exposure, the lithology is a coarsely porphyritic biotite quartz monzonite or granite (Figure 8). K-feldspar is volumetrically more abundant than plagioclase and occurs as anhedral composite crystals averaging several cm across. Some of these have cores of a different composition, the rock resembling

Rapakivi granite. However, the tectonic setting and composition for Rapakivi granites differ from this rock.

Biotite content varies widely over short distances, and foliation is apparent at several places. Note also the presence of several aplitic dikes with relatively "fuzzy" boundaries.

Three sets of fractures are obvious. Those in "set 1" strike about N5E and dip very steeply (average about 85SE). They are anastomosing and are coated by iron oxide (Figure 9). The most obvious one includes a zone of alteration about 30 to 50 cm wide. Another anastomosing fracture in this set includes some narrow (less than 1 cm) secondary quartz veining. These fractures are similar in character and trend to those containing ore mineralization nearby

Fractures in "set 2" are vertical and strike about N80E. They are also stained by iron oxides; about 20 m southeast of the gate, a member of this set consists of a vein of brown iron oxide, 1 to 2 cm thick, containing granite fragments.

"Set 3", which dips about 65 S20E, is unusual in that at least one example is partly coated by fresh muscovite flakes.

After Stop 5, **turn right** onto CO 67 and continue toward Cripple Creek.
5.4 mi.: Parking area/overlook on left.
5.7 mi.: Crossing bridge; heap leach on right.
5.9 mi.: Start of large outcrops of altered volcanic rocks on left. Breakdown of pyrite, which is nearly ubiquitous, produces rusty stains.
6.4 mi.: Outcrops of granitic biotite gneiss on both sides of road. The rocks show regular fractures, some with slickenlines, on the left and are altered (bleached) on the right.
6.6 mi.: Reconstructed timbering from former Mary McKinney mine on right, followed by CC&V's new leach pad and high grade mill (started in 2014).

7.3 mi.: Phonolite intrusion on right (don't blink!).
7.5 mi.: On hillside above the road are tracks for the Cripple Creek & Victor Narrow Gauge Railroad, which does a 45-minute, 4-mile trip starting near the Cripple Creek District Museum.
8.5 mi.: Park in small cut on the right side of the road, nearly opposite intersection of CO 67 and CR 88 (the "Shelf Road")

Stop 6. Small "Borrow Pit" on the east side of CR 67.
The pit exposes the "Idaho Springs formation" (Xgn on Figure 16), predominantly fine to coarse grained mica schist. Some of the rocks here are dark gray biotite schist to gneiss, in places interlayered with light gray, contorted layers of fine grained biotite gneiss (Figure 10). These pinch and swell irregularly and may represent original sedimentary layers. Locally, the schist is very coarse, dark green to black in color, with centimeter-scale muscovite porphyroblasts. Cleavage in the porphyroblasts is parallel to the foliation in some places but cuts it at a high angle in others. The latter gives the rock a "chunky" appearance (Figure 11). Elongate aggregates of sillimanite with muscovite give the rock a lineation in places, and randomly oriented schorl crystals complicate the texture.

Some of the coarsest layers have lensoid or spherical segregations of reddish pegmatitic biotite-muscovite granite with schorl. The foliation wraps around these and locally exhibits small scale crenulation. Medium grained tan granitic layers also occur within the schist; toward the north end of the cut, one such layer is contorted into a recumbent fold (Figure 12). This layer also exhibits regularly spaced fractures that are perpendicular to the "bedding" (Figure 13). Some quartz-rich layers exhibit boudinage.

Figure 8. Coarsely porphyritic biotite quartz monzonite or granite. (Carnein photo)

Figure 9. Iron oxidized anastamosing fractures. (Carnein photo)

Although compositional layering generally parallels foliation, some exceptions occur near the north end of the cut. Foliation strikes, on average, about N65-80W and dips moderately to the northeast.

After Stop 6, continue on CO 67.
9.0 mi.: Intersection with Myers Ave. **Turn right** onto Myers Ave.
9.2 mi.: **Turn right** onto unnamed street and go about 500 ft. to Stop 7.

Figure 10. Fine-grained biotite gneiss (Carnein photo)

Figure 11. Coarse-grained "chunky" schist with muscovite prophyroblasts. (Carnein photo)

Figure 12. Recumbant fold in fine-grained granite. (Carnein photo)

Figure 13. Granitic layer with regularly spaced fractures perpendicular to the "bedding"

Stop 7. Rock Cuts South of Myers Avenue, Cripple Creek.

Rocks in this exposure consist mostly of fine grained, tan to pinkish or greenish gray quartz-feldspar-biotite gneiss of the Idaho Springs "formation". Note that we are near the contact between the Idaho Springs and the Cripple Creek quartz monzonite (Ycc on Figure 16). Interlayered with the gneiss are bands of pink to pinkish gray, medium grained biotite granite. Granitic bands are locally contorted, pinch and swell irregularly and, in places, form boudins (Figure 14) and ptygmatic folds. In most places, they parallel foliation in the enveloping gneiss, but some granitic layers cut across the foliation at a high angle. Granitic layers commonly exhibit dark colored biotite rich borders (Figure 15), and, where thin layers of gneiss have been fully incorporated into the granite, it appears to have been converted into a very dark mica schist.

One possible interpretation of these rocks is that the gneiss is a metagraywacke—a metamorphosed impure sandstone—or a felsic metavolcanic rock that underwent high grade metamorphism and partial melting. Although the author did not see sillimanite or other metamorphic index minerals at this location, its presence at Stop 6, combined with the general characteristics of the rocks here, is suggestive. The granitic layers may represent segregations of partial melts derived from the gneiss.

Toward the south end of the exposure, coarser grained quartz monzonite or granite dominates. The rock contains schorl and altered biotite, with hematitic margins around K-feldspar grains producing the reddish color. Near the light pole, foliation (and fractures parallel to the foliation) disappears as the granitic rock replaces the gneiss.

Foliation in the gneiss strikes more or less uniformly N85E and dips 40 to 45SW. A prominent fracture set parallels the foliation south of the light pole. Three other fracture sets occur in the gneiss: those of set (1), spaced at decimeter to meter intervals, strike N10-15E, dip 80-85SE; those of set (2) strike N40W and dip 70NE; and those of set (3) strike N80E, dipping 40SE. Fractures in the granitic rocks north of the light pole are more irregular.

This is the last stop of the field trip. Thanks for your attendance, and have a safe trip home!

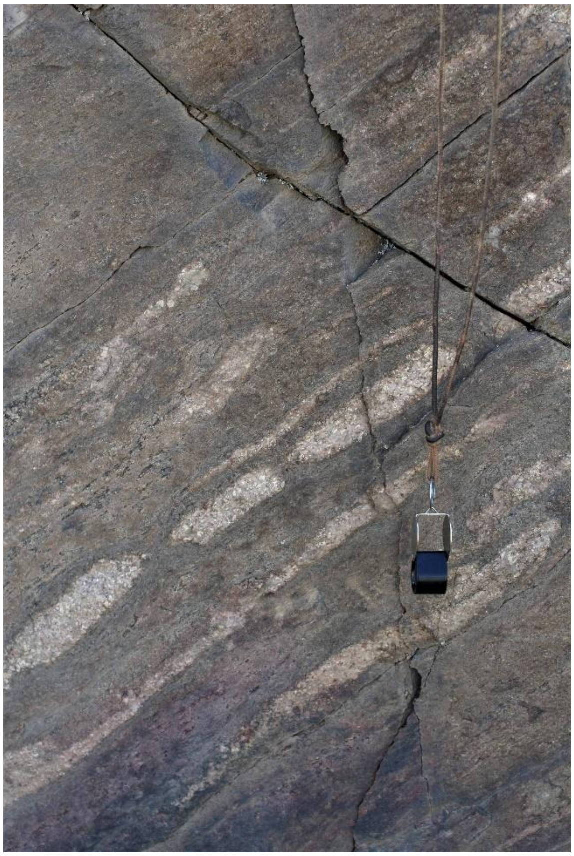

Figure 14. Granitic boudins in gneiss. (Carnein photo)

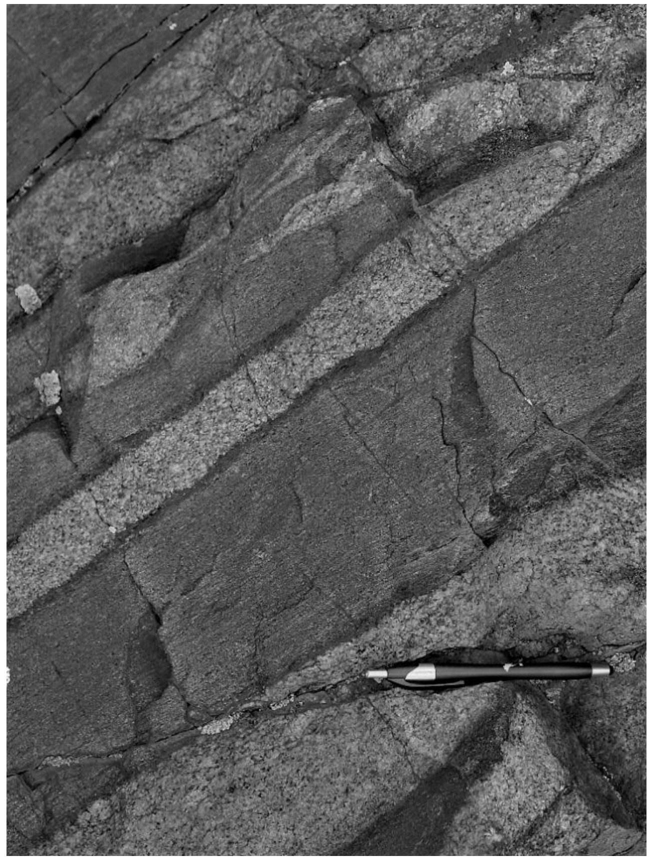

Figure 15. Granitic layering with biotite-rich rims. (Carnein photo)

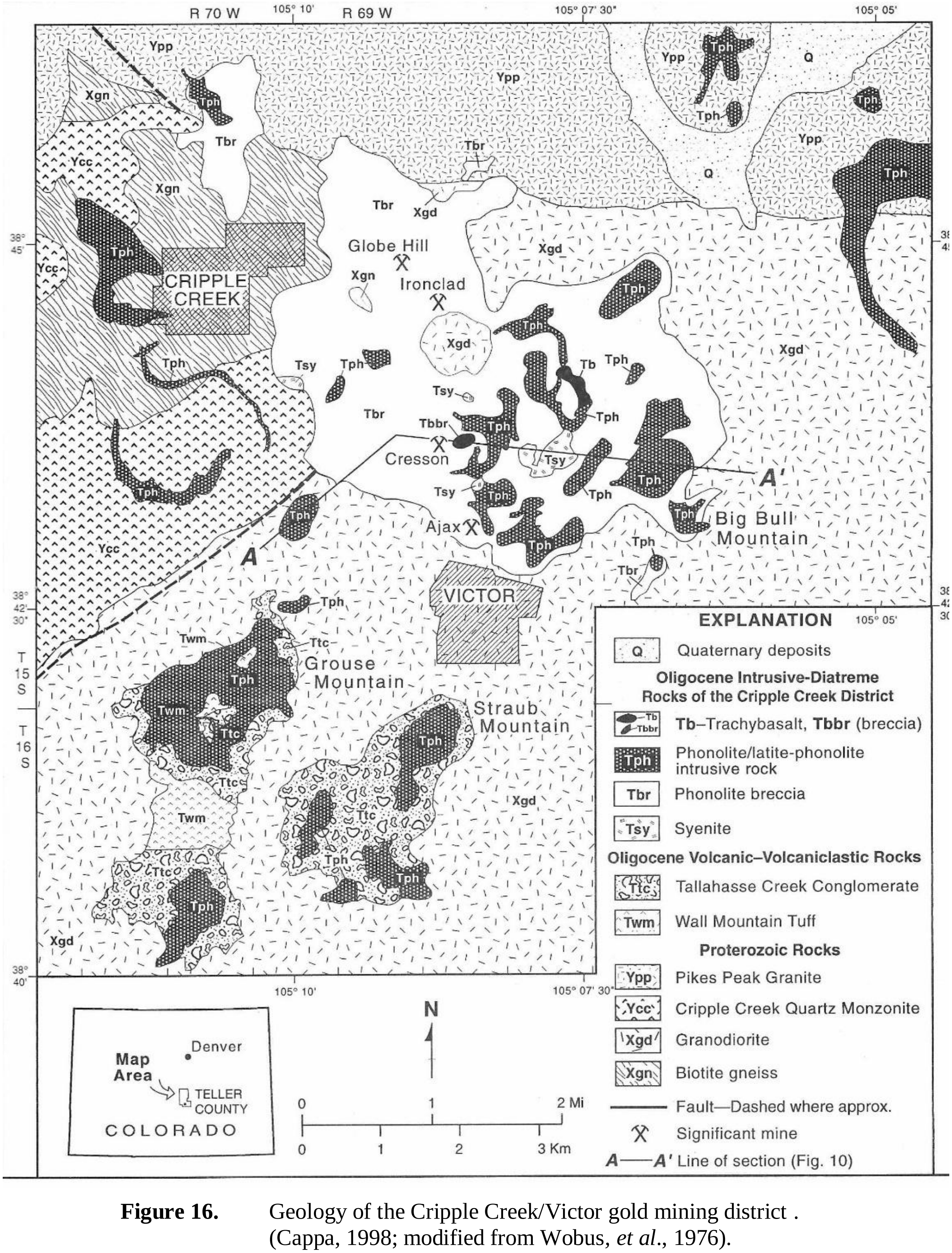

Figure 16. Geology of the Cripple Creek/Victor gold mining district . (Cappa, 1998; modified from Wobus, *et al*., 1976).

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Field Trip G: Central City, Black Hawk, Idaho Springs Area

July 21, 2017

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Introduction

Welcome to the 2017 Central City field trip. We have arranged a trip which will introduce you to an area which was known worldwide as “The Richest Square-Mile On Earth”!! The discoveries made here in 1859 started what was known as the Pikes Peak Gold Rush. Over 5 million dollars of gold were produced here before 1910.

The focus of this trip is the gold and silver deposits of the Central City- Blackhawk- Idaho Springs area, past and present. Activities planned include: underground and above-ground mine visits; a mine waste-water treatment plant and mine mill site tours; drill core examination; a gold panning demonstration; and sample collecting. Our field trip will take participants to seven stops which will expose them to the Geology, Mining History, and Culture of Historic Central City.

Our trip departs from Golden at 7:00AM. Planned field stops (Figure 1) include:

1. Junction Ranch Fault Zone
2. Chaffee underground mine development
3. Bates Hill overlook
4. Couer d’Alene historic mine

5. Glory Hole ("The Patch) overview and Burroughs former vein mine.
6. Argo Historic Mill (museum, gift shop)
7. Water treatment Plant (adjacent to Argo Tunnel portal and mill)

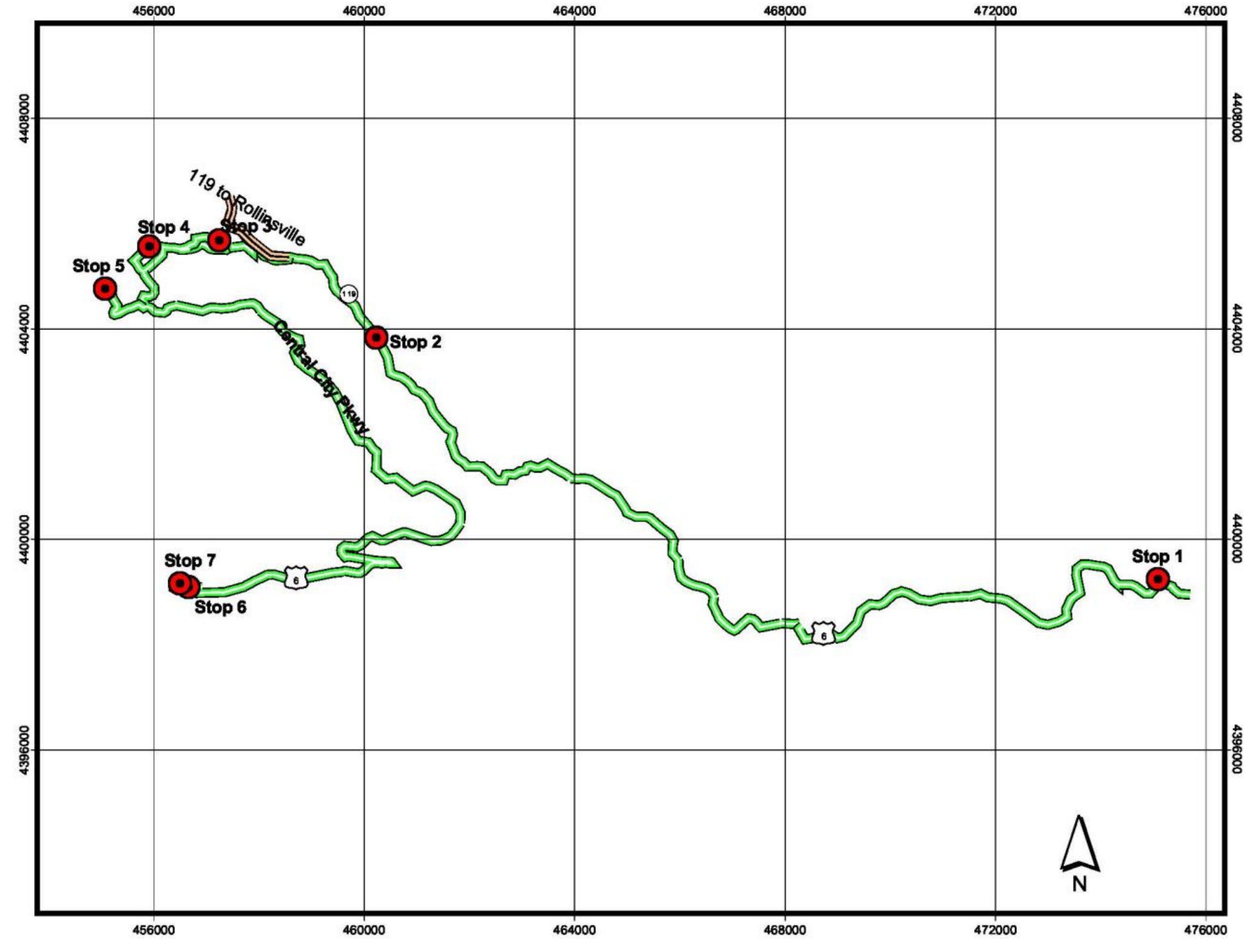

Figure 1. Field trip stops.

The trip route will be counter-clockwise, beginning in Golden, proceeding up Clear Creek Canyon to North Clear Creek and Blackhawk,. It will pass along a back road west of Central City, down the new Parkway to Idaho Springs, and finally return to Golden. Transportation will be in personal 4-or all-wheel vehicles, and carpooling is encouraged. Bring good hiking boots, weather-appropriate clothing, sunscreen, headlamp or flashlight and hard hat if you have one. Plan on bringing your own lunch.

Road Log and Field Stop Descriptions

Introductory Geology

Laramide intrusions in the central Front Range belong to either a calc-alkaline granodiorite suite or alkali-rich monzonite suite (Braddock, 1969). The ages of the intrusions fall into two groups, an older calc-alkaline granodiorite suite that is dated from 72 to 58 Ma and includes the Apex, Empire, Georgetown, Eldora, Caribou and Audubon-Albion stocks. After a lull in plutonism and volcanism during the Oligocene (55-38 Ma), tectonism was dominated by alkali-rich monzonite intrusive suites ranging in age from 51-44 Ma that includes the Porphyry Mtn. (Jamestown), Bald Mtn. (Gold Hill), Sugarloaf and Mad Creek (Empire) stocks. The Mo bearing Urad Porphyry is the youngest intrusive at 25-30 Ma (Gable, 1985). The location of these Tertiary intrusives defines the northern portion of the northeast-trending Colorado Mineral Belt. Large-scale regional uplift brought the area to its current elevation. Repeated cycles of alpine glaciation occurred during the Pleistocene. Extensive erosion has exposed the mineralization and caused supergene enrichment of gold, silver, and copper near the surface.

Tertiary through Oligocene-aged igneous rocks of the Central City district consists of leucocratic granodiorite porphyry, quartz monzonite porphyry, bostonite porphyry and quartz-bostonite porphyry (Sims, Drake and Tooker, 1963). The older intrusions tend to form small irregular stocks and the younger ones form long thin dikes that trend northwest, northeast, and due east. Field relations clearly indicate that the quartz bostonite porphyry and bostonite porphyry are the oldest Tertiary intrusive rock, and these early bostonites show a close spatial association with uranium mineralization that dates at 58±1 Ma (Phair, 1979). The Laramide intrusive rocks of the region are among the most radioactive igneous rocks in the world (Larsen and Phair, 1954); the quartz bostonite porphyry, for example, is about 15 times as radioactive as the average granitic rock (Sims, 1982).

The gold, silver and base-metal veins of the Central City mining district are not "typical" epithermal veins they were buried below something like 1 km of cover, from 2-6 km above a cupola of quartz monzonite hosted porphyry Cu–Mo (Au) mineralization. Any evidence of a large scale blanket of advanced argillic alteration has long been eroded. Exhumation of the Central City mining district was broadly contemporaneous with evolution of the hydrothermal system.

Two distinct pulses of magmatic fluids best explains the vein textures, minerology and trace element geochemistry of the Central City epithermal vein system. The bulk of mineralization at Central City is the result of post-seismic fluid flow that occurred during and after a seismic event. In general, the veins characteristically lack banding and show little repetition, implying the mineralization was a continuing passive process of focused fluid flow along networks of active faults sustained in pipe-like pathways along fault jogs, bends, branches, terminal splays, and intersections with Pre-Cambrian folds, host rock competency and permeability contrasts. The first pulse of hydrothermal solutions altered the wallrocks with quartz-pyrite-sericite and formed coarse-grained pyrite veins. The quartz-sericite-pyrite alteration intensity is directly related to the amount of fluid flow through the fracture and distance from the source. These veins, with a few exceptions, became mostly clogged with coarse pyrite and mineralization generally ceased. After renewed district wide refracturing, coarse chalcopyrite of the main stage was deposited closest to the source, and galena, sphalerite, and argentite were deposited farther from the source of the fluids. Progressive temperature and pressure decrease resulted in tennantite/enargite surrounding coarse broken chalcopyrite grains.

The principal ore controls in the Central City mining district vary from mine to mine but they all represent different variations of focused hydrothermal fluid flow and permeability. The high-grade ore shoots involve structures that focus significantly large amounts of hydrothermal fluids into dilatational fracture sets adjacent to intersections with pre-existing metamorphic folds, rock type changes and permeable host rocks. In the Central City mining district it is not uncommon for veins to be deflected along the axial planar cleavage of Pre-Cambrian folds and lithologic contacts. In Central City, the microcline gneiss and especially the pegmatite units preferentially shatter adjacent to major veins providing the permeability to effectively capture the vein fluids as they migrate upwards and are channelized along the lower margin of the contact with the biotite schist.

It is no coincidence that Central City is centered on a Precambrian NE-trending doubly plunging antiformal structure. Fluid flow and permeability of the enclosing rock not only applies to ore localization, it applies to magma ascension too. The structure of the overlying Precambrian rocks is of paramount importance in localizing the ascent of porphyry cupolas from the top of a large magma chamber. There are no regional-scale fault structures centered on the district, only relatively small oblique-normal displacement veins and faults that are localized in the center of the district and diminish away from it. The dominance of NE striking compared to radial vein orientations was influenced by the metamorphic host rock fabric, regional stress field, and depth of emplacement.

Principle stress directions in the Central City area during Laramide time were oriented northeast-southwest at 068° (Caine et al., 2006) resulting in conjugate vein sets oriented northeast-southwest, and roughly east-northeast and west-southwest.

In Bobtail and Packard Gulch, the northeast-southwest trending veins are the most productive veins. The best ore shoots are sub-vertical chimneys formed where the northeast trending master vein is crossed by a roughly east-west trending vein set. The master northeast trending veins typically contain coarse sulfides (chalcopyrite, pyrite), are silicified and often display evidence that they were open for all four stages of mineralization. Two to five feet of right-lateral displacement along the master northeast trending veins has opened the more easterly-trending portions of the vein, and closed the more northeasterly-trending vein portions. The east-west veins are only productive where they cut the northeast oriented veins. The east-west trending veins are sheeted veins of fine–grained sulfides, black quartz, hessite (?) and white clays with 1-3 feet of left-lateral displacement. Gold-silver tellurides (petzite) are found in the hanging-wall of the northeast-trending master veins such as the Gregory, Fisk and Bates veins where they cross the east-west trending vein such as the Mammoth, Groundhog, and Hartford veins.

Road Log

St*__op 1.__* Time 7:30 am. The Junction Ranch Fault Zone: U.S. Highway 6,(near Guy Gulch) (475081 E, 4399287 N).

- Introduction to the Idaho Springs-Ralston Shear zone (IRSZ).
- Brittle fault rocks and breccia/gouge/cataclastites in damage zone along margins bounding core.
- Syn-post tectonic fluid flows are responsible for alteration and in damage zones .
- Ductile shear zones with mylonite series rocks, with gradational contacts, may have peudotachtylite overprints (Caine and Ridley, 2010). Plastic deformation occurs in ductile zones and rock's cohesion is not compromised.
- Mineral samples from this locale are shown.

__Stop 2.__ Time 9:00 am. Chaffee Mine / placer. Jesse Peterson property. (460234E, 4403827N) .

- Underground tour in old-time adit (mine car and rail)
  NOTE: This tour presents many hazards. If you have doubts about accompanying a group through narrow dark wet passages, or have poor mobility, consider staying outside!.
- Placer demonstration.

Stop 3. Bates Hill Overlook / Gregory Vein. Short hike along vein outcrop. (457236 E, 4405886 N).
Historical discussion by Brian Alers and Larry James. Presentation and discussion of core. (see Appendix 2).

The stop at the top of Bates Hill in Central City will focus on the gold and silver deposits of the historic Central City mining district, which started the Pikes Peak Gold Rush in 1859.

Central City is among the largest and most famous mining districts in Colorado. It is well known for production from extremely high-grade gold ore shoots; it has been estimated that more than 4,134,000 ounces of gold and 118,900,000 ounces of silver were produced in the Central City Mining District between 1859 and 1947 (Fossett, 1876; Calbreath, 1899; Simms, Drake, and Tooker, 1963). The majority of this production occurred before 1880 when record-keeping was not a priority, so this number could be significantly higher.

We will first hear the story of the historic discovery of the Gregory Vein, the first lode discovery in what was to become Colorado, on May 6, 1859 and the early history of the mining district. Then, from the vantage point of Bates Hill we will point out the Gregory discovery site, trace the Gregory, Fisk, Puzzle, Bobtail, Bates, Gaston, Buell, Mammoth, Groundhog, and Hartford veins across Bobtail and Packard Gulches and identify many historic mines including the 1250 foot deep Cook shaft located on the Gregory and Fisk Veins. This major early 20th Century production entry was operated by The Fifty Gold Mines Co., that had recorded production of over $5,138,837 (256,941 ounces) of gold before 1887 (Bastin and Hill, 1917).

We will then give a general geologic overview of Central City that includes: the regional tectonic environment, evolution of the epithermal gold and silver veins, the district wide regional metal zonation, and structural controls of high-grade ore shoots.

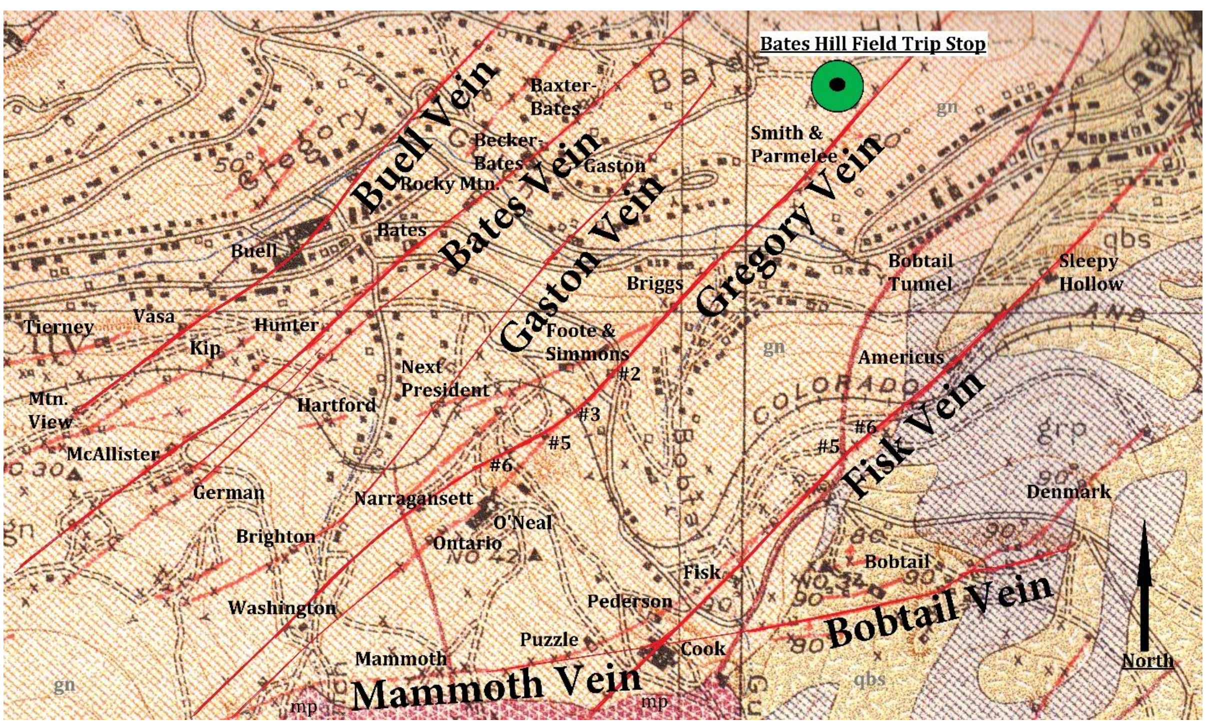

Figure 2: Taken from Bastin and Hill (1917).

Figure 3. Gregory Vein and Mines (1878-79), Photo courtesy Denver Public Library.

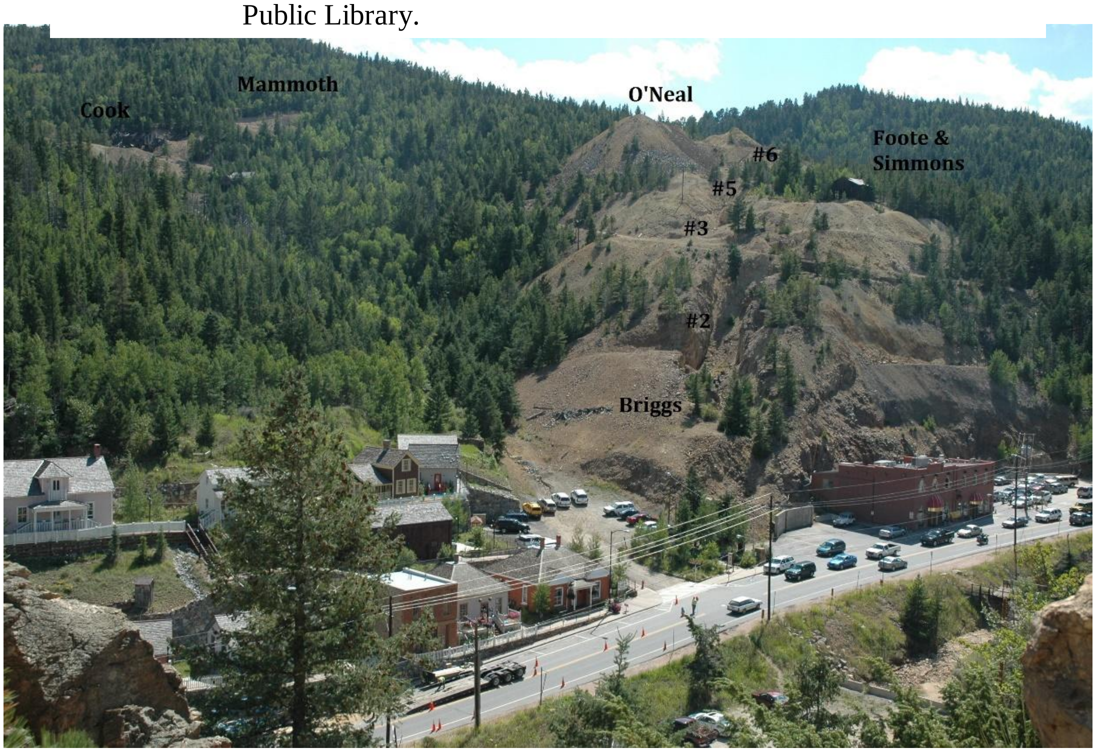

Figure 4: Gregory Vein and Mines (2009).

Diamond drill core and underground vein samples with assay data from the Bates Hunter Mine will be displayed that illustrate the distinctive vein textures, minerology, and trace element geochemistry of the evolving epithermal gold and silver vein system.

The Bates vein was located by John H. Gregory, 13 days after his discovery of the Gregory vein. The Bates Vein is parallel to, and 750 feet to the northwest of the Gregory vein. The diamond drill core will show; early barren coarse pyrite from the south end of the Gregory vein, high-grade sulfide rich gold vein in hanging wall of old stope, shattered pegmatite breccia with visible gold, high-grade gold silver vein from a depth of 1300 feet below the surface, and silver-telluride mineralization from the Groundhogg vein.

<u>Bates Hunter Mine, Diamond Drill Core, Vein Classification Examples</u>

Figure 5. Buell (UPR) Vein at -1300 ft. (-396 m) depth, Main Stage Composite Sulfide Vein, fractured coarse chalcopyrite grains surrounded by tennantite stockwork, 9.21 oz/t Au, 6.3 oz/t Ag and 3.43 oz/t Au, 5.37 oz/t Ag,4.48% Cu, BH07-08, 2147 ft.

Figure 6:. Foot & Simmons Vein, Main Stage Composite Sulfide Vein, fractured coarse chalcopyrite grains surrounded by tennantite, 0.183 oz/t Au, 1.78 oz/t Ag, 1.58% Cu, BH0602, 388.2-389.2 ft.

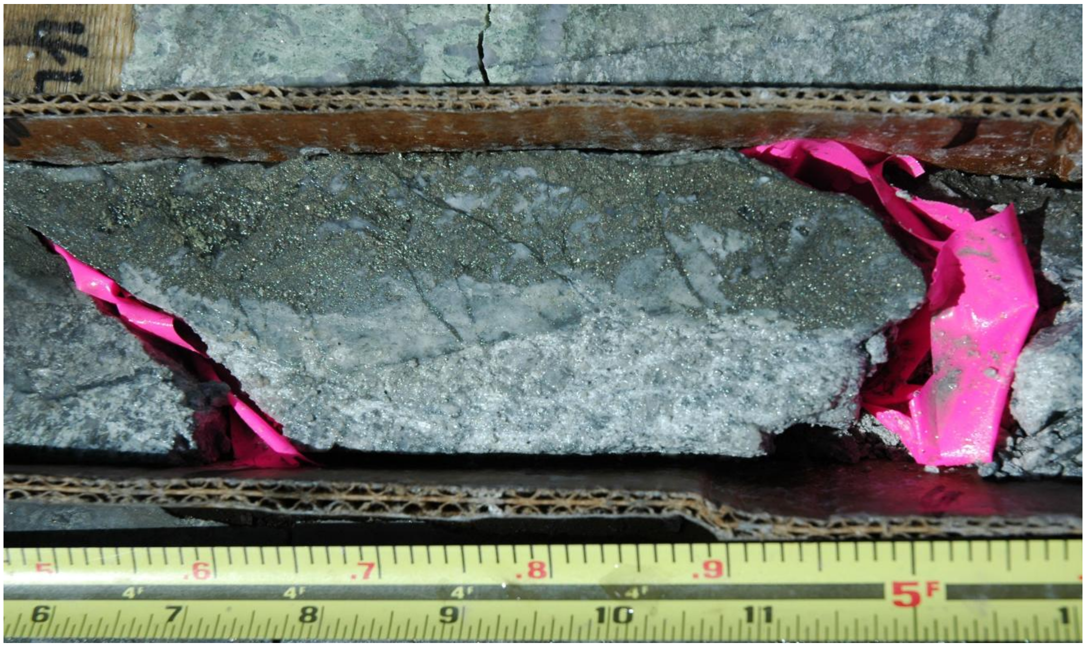

Figure 7. Hartford Vein, fine-grain pyrite and chalcopyrite with white clay alteration, 1.77 oz/t Au, 1.08 oz/t Ag, 1.09% Cu, BH0602, 146.5-147.5 ft.

Figure 8. Shattered Pegmatite Breccia, Cousin Jack Vein, 0.75 oz/t Au, 0.28 oz/t Ag, 0.02% Cu, 5 ppm Te BH08-09, 501.5-503.5 ft.

Figure 9. Hartford Vein, hessite (?) silver telluride vein adjacent to fragmental tan chalcedony vein, 0.028 oz/t Au, 2.27 oz/t Ag, 0.4% Cu, 24 ppm Te) BH0707, 1655.5-1656. Ft.

Table 1

Bates Hunter Project																
June 19, 2017																
	Hole/Vein	**Depth (ft)**	**thick ft**	**Au opt**	**Ag opt**	**Au/Ag**	**Cu %**	**Te ppm**	**Pb ppm**	**Zn ppm**	**Mo ppm**	**As ppm**	**Bi ppm**	**Sb ppm**	**U ppm**	**V ppm**
Figure 5	**BH-07-08**															
	Buell (UPR) Vein	2146.4-2147	0.6	3.434	5.37	0.64	4.480	8	1100	2710	34	1890	765	946	16	3
Figure 6	**BH-06-02**															
	Foot and Simmons Vei	388.2-389.2	1.0	0.183	1.78	0.10	1.580	<5	2810	3990	8.3	342	118	117	-3	6
Figure 7	**BH-06-04**															
	Hartford Vein	146-146.5	0.5	1.776	1.08	1.64	1.090	<5	169	287	1.8	678	45	10	-3	6
Figure 8	**BH-08-09**															
	Cousin Jack Vein	501.5-503.5	2.0	0.749	0.28	2.65	0.020	5	180	376	14	93	26	28	-3	-1
Figure 9	**BH-07-07**															
	Hsrtford Vein	1655.5-1656	0.5	0.028	2.27	0.01	0.400	24	1910	6950	3	460	207	200	4	10

<u>Stop 4.</u> Time 12:30 Our lunch stop will be at Coeur d'Alene Mine. (455914 E, 4405569 N).

- Discussion of unusual "disseminated" precious metals deposit, 19^{th} Century mine shaft with steam hoist, stamp and flotation mill devices, Chilean mill, gravity concentration by Larry James.
- During lunch, Potty stop.

<u>Stop 5.</u> Time 2:45 pm. Glory Hole or Patch. (454995 E, 4404995 N). (see Appendix 4)

- Pit overview from distance. Please do not enter into pit or pit ramp. This is posted private property with many significant hazards. Owners are adamant: "Keep Out".
- Geological description of stockwork zone ("The Patch") and mining history.
- Sample collection at Burroughs claim, near eastern end of a vein extending to westerly side of Quartz Hill. An early discovery of, high grade mined to ca 1800' depth in some shafts (Figure 15).

Figure 10. Glory Hole, with breccia in foreground.

Figure 11. Light grey matrix supported breccia, with clasts of Precambrian biotite gneiss, pegmatitic quartz and feldspar up to 20 mm in diameter, supported in a crushed matrix of quartz and

feldspar (altered to clay), with 10% pyrite and 2% chalcopyrite blebs finely disseminated throughout the matrix. Weathered surfaces are stained with iron oxides.

Figure 12. Vuggy bostonite from shaft (dump) that produced from Hidden Treasure vein, northwesterly slope of Quartz Hill. This is probably the California dike (Sims et al.,1963 plate 1). Lilac with beige oxidation fronts, very fine grained, equal granular, vesicular, with secondary rusty brown Fe oxide stained quartz lining vugs up to 3-6 mm, with oxidized sulfides, and occasional clots of fine grained pyrite. 1 % 1mm anhedral - euhedral quartz phenocrysts occur sporadically throughout sample in groups. <1 % 3-4 mm Clay altered K feldspar subhedral phenocrysts are found with trachoidal alignment. Minor anhedral epidote green phenocrysts , plagioclase altered to sericite. Trace pyrite blebs <0.5 mm disseminated in ground mass. Hairline Quartz veins with minor fine galena salvages.

Figure 13. Mixed breccia with angular clasts.

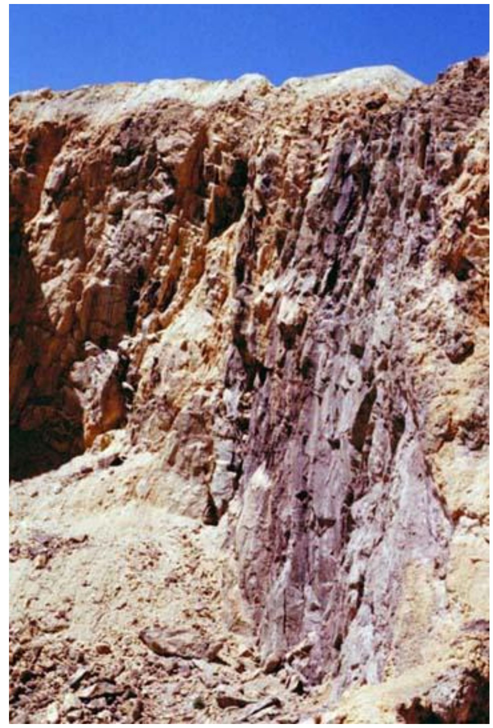

Figure 14. Bostonite dike in Glory Hole.

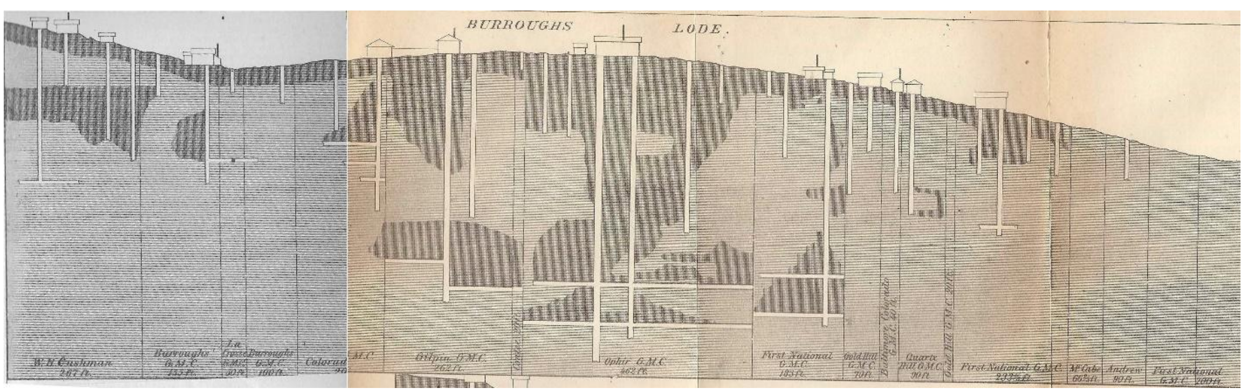

Figure 15: Section of Burroughs Lode, showing stopes and workings, looking South . (R. W. Raymond, 1872). Our stop is by old shafts near the East end of this section . This vertical vein complex extends eastward for about 2700 feet from the northwesterly slope of Quartz Hill. In early years owners of the claims along strike leased or sold “feet” along the lode to stock companies. The holder of each vertical “block” of ground (recorded along the bottom of this section) sank shafts within their allotted “feet”. As shown, one company’s shaft might closely abut adjacent competitors’ operations. Plate 3 of Sims et al. (1963) includes a plan map of the Burroughs workings.

Burroughs "Lode" (N. side of Quartz Hill), discovered May, 1859. Partial description and available data on ore produced from the four shafts on the property. No information for numerous years (Sims 1963, p.72). Hague (1870) describes vein width and mineralogy.

Year	Crude ore shipped (tons)	Concentrates shipped (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Remarks
1887	(?)		3, 571. 00	3, 134	15, 129			
1888	(?)		1, 260. 00	175	4, 806			
1889	(?)		600. 00	1, 503				
1891	(?)		793. 00	75				
1892	(?)		1, 190. 00					
1902	2, 615		1, 582. 97	3, 316		2, 814		From Mackey-Burroughs.
1904	1, 250		1, 201. 00	2, 456	75, 742			Do.
1905	3, 047	787	1, 774. 02	2, 931				Do.
1906	1, 881		945. 73	1, 567	57, 940			Do.
1907	588	28	233. 51	423	1, 495			Do.
1909	5	5	15. 60	53	186			From Ophir-Burroughs.
1915	180		46. 78	205				Do.
1916	262	70	336. 48	2, 936	7, 947	495		Do.
1917	633		467. 59	4, 226	35, 954			Do.
1918	12		12. 90	213	426	5, 055		Do.
1920		4	7. 72	63	252	204		Do.
1921	4	56	112. 74	746	2, 024	1, 553		Do.
1922	815	91	281. 62	1, 355	6, 895			Do.
1923	12	9	48. 70	307	736	191	349	Do.
Total	11, 304+	1, 050	14, 481. 36	25, 684	209, 532	10, 312	349	

[1] Compiled by U.S. Bureau of Mines. Published by permission.

Note: Mine opened 1859-1860. Last ore mined ~1940?. Production records unavailable for most years.

Figure 16: Table showing available data on production from some of the Burroughs workings – compiled from Sims et al. (pp 359).

Stop 6. Time 3:30 pm. Argo Mill tour – Idaho Springs (456653 E, 4399087 N). See Appendix 5.

Stop 7. Time 4.30 pm. Water Treatment – plant (456483 E, 4399158 N). This plant was built to treat Acid Rock Drainage and metals from the Argo tunnel plus several other drainage adits and gulches known for heavy seasonal discharge.

Appendix 1: The Geological Society of America Field Guide 18, 2010

Nature and Varied Behavior of Structural Inheritance in the Proterozoic Basement of the Eastern Colorado Mineral Belt over 1.7 Billion Years of Earth History

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The eastern central Front Range of the Rocky Mountains in Colorado has long been a region of geologic interest because of Laramide-age hydrothermal polymetallic vein-related ores. The region is characterized by a well-exposed array of geologic structures associated with ductile and brittle deformation, which record crustal strain over 1.7 billion years of continental growth and evolution. The mineralized areas lie along a broad linear zone termed the Colorado Mineral Belt. This lineament has com monly been interpreted as following a fundamental boundary, such as a suture zone, in the North American Proterozoic crust that acted as a persistent zone of weakness localizing the emplacement of magmas and associated hydrothermal fluid flow. However, the details on the controls of the location, orientation, kinematics, density, permeability, and relative strength of various geological structures and their specific relationships to mineral deposit formation are not related to Proterozoic ancestry in a simple manner. The objectives of this field trip are to show key localities typical of the various types of structures present, show recently compiled and new data, offer alternative conceptual models, and foster dialogue. Topics to be discussed include: (1) structural history of the eastern Front Range; (2) characteristics, kinematics, orientations, and age of ductile and brittle structures and how they may or may not relate to one another and mineral deposit permeability; and (3) characteristics, localization, and evolution of the metal and non–metal-bearing hydrothermal systems in the eastern Colorado Mineral Belt.

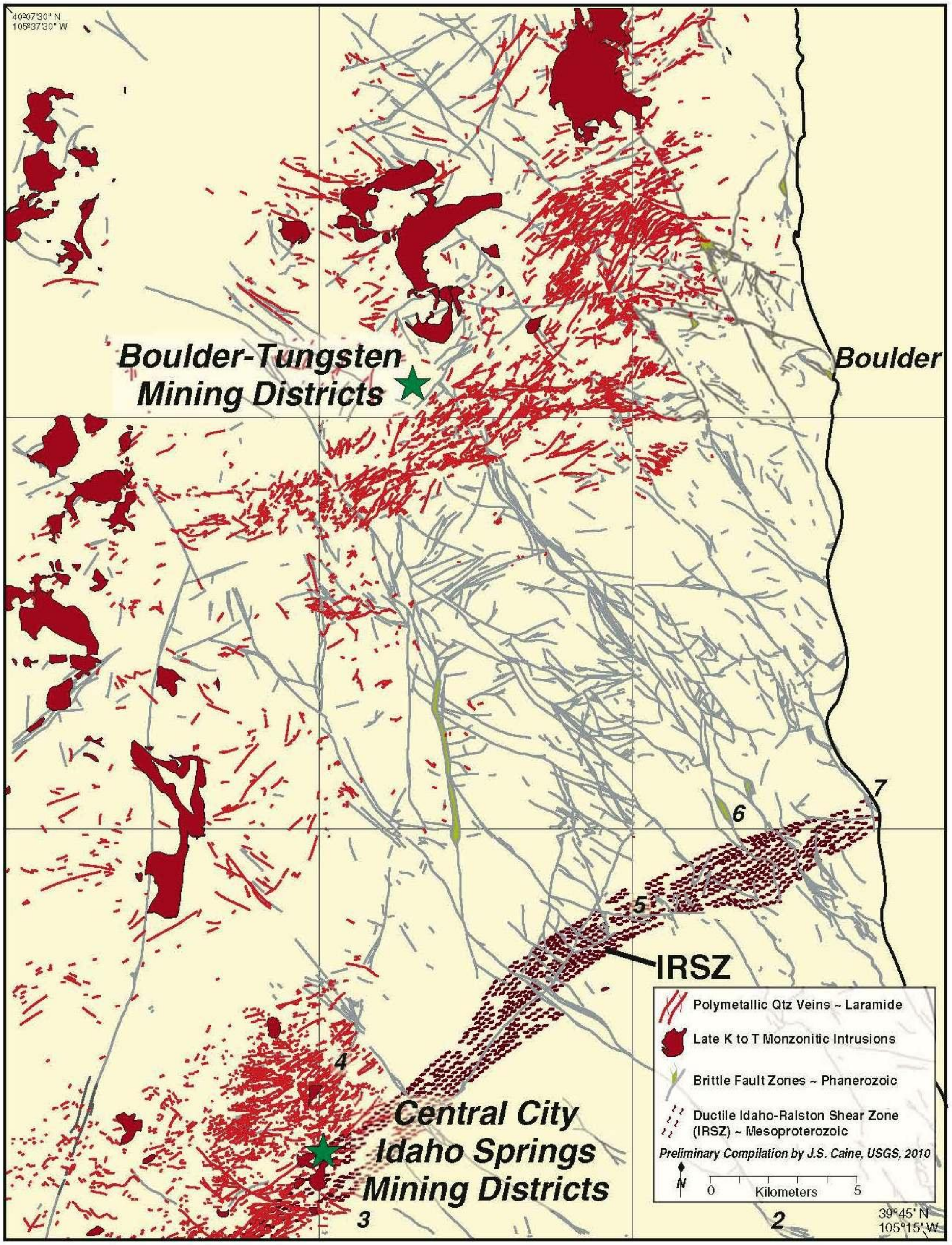

Fig. 17. Preliminary compilation map showing the mapped extent of the Idaho Springs–Ralston Ductile Shear Zone (IRSZ, brown squiggled lines), all major brittle faults (light gray lines), and Late Cretaceous–Early Tertiary plutons (red polygons). Data digitized from Sheridan et al. (1958, Ralston Buttes); Wells (1963, Eldorado Springs); Sims (1962, Central City); Wrucke and Wilson (1967, Boulder); Gable (1969, Nederland); Gable (1972, Tungsten); Gable and Madole (1976, Ward); Taylor (1976, Black Hawk); Gable (1980, Gold Hill). The Overview (1), Junction Ranch fault zone (2), and Central City parkway (3) stops are just off the map. The Gregory fault vein (4), Golden Gate Canyon mylonite (5), Coal Creek fault zone (6), and Mouth of Coal Creek Canyon (7) stop locations are also shown.

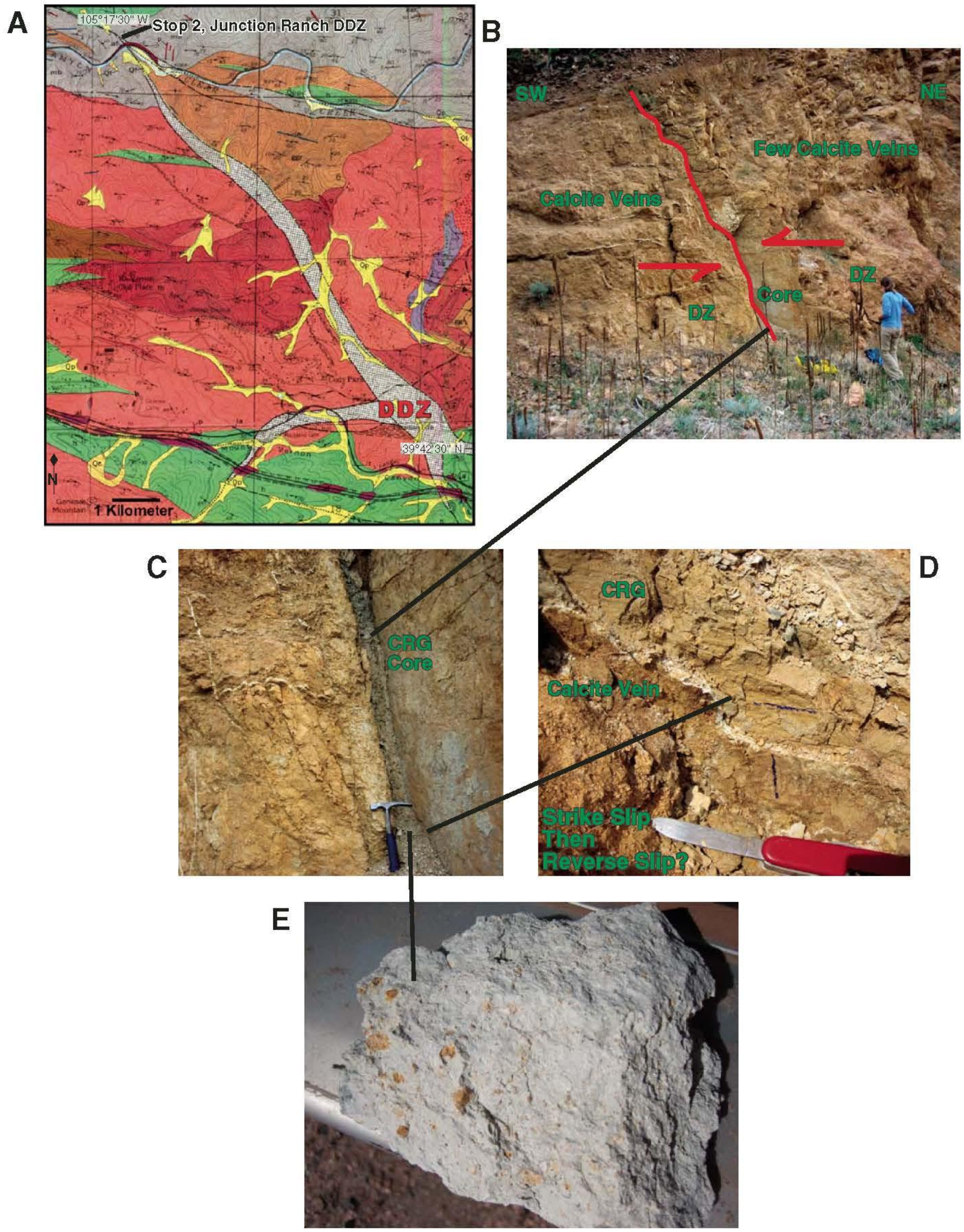

Figure 18. Taken from Caine, et al. (2010).

Appendix 2: History

Brian Alers

Even though lode mining had begun in Mountain District #1 (Gold Hill) west of Boulder during the winter of 1859, John H. Gregory is credited with the first lode discovery in what was to become Colorado. He located the Gregory vein on May 6, 1859, between present day Central City and Black Hawk. John H. Gregory left his home in Georgia in 1857 for the Frazier River gold fields in California. While at Fort Laramie he heard of the gold discoveries of 1858, near present day Denver, and in the spring of 1859 he started prospecting along the base of the mountains. He found little until he reached the Vasquez Fork (Clear Creek) of the South Platte River. Alone, he followed the gold showings up the branches of the river into the mountains until he was convinced that he had found the place in the creek from where the gold had come. Before he could further examine the area, snow forced him to return to town for supplies. Gregory was penniless, so after considerable effort he convinced a stranger, Wilkes Defrees of South Bend, Indiana, to accompany him back to the mountains. Three days later they scraped away grass and leaves to find dirt that yielded $4.00 in gold (0.2 ounces) from a single pan. The next day Gregory and Defrees washed out 40 pans of dirt that contained 2 ounces of gold (worth $40), and returned to town. A heavy storm prevented anything from being done for 10 days, but by the 1st of July,1859, hundreds of sluice boxes were in operation near the discovery. It was said that on the 8th of September, Gregory left Denver with $30,000 worth of gold dust in his pocket.

The Bates vein was the second lode discovered in Colorado. The Bates vein was one of the richest and most productive in the early history of the area, but it was never consolidated or mined to any great depth. Large-scale mine development was greatly inhibited by the fragmented land ownership created by so many small lode mining claims in the early days of the district. Successful consolidation of the Gregory vein, directly south of the Bates vein, led to production of over 341,000 ounces of gold to a depth of 1,250 feet. Many of the larger veins have been mined successfully to depths of over 1,500 feet. The deepest production in the district has come from the California mine (2,250 feet) and the Old Town mine (1,950 feet). The veins generally are higher grade but become much thinner (<1 foot) with depth. Forbes Rickard in 1899 stated that, "In the deepest mining, that of the California mine just instanced, the lode shows no essential change of character in its deepest developments," and he reported that the ore shoot in the California mine continued below the 2,250 foot (675 m) level.

Appendix 3: Vein Types, Mineralogy and Hydrothermal Gold Transport

.Alexander Gysi and Lee Alford

Vein types and mineralogy

Two significant stages of veining and mineralization have been recognized in the Central City district by Sims et al. (1963) including: I) a higher temperature stage containing Au within dominantly quartz-pyrite veins, and ii) a lower temperature stage containing galena-sphalerite veins with base metal mineralization (i.e. Pb and Zn), Ag and rare gold. These two significant stages have been spatially separated into a central and peripheral zone, respectively, with a transitional intermediate and an uneconomic barren zone. The central zone contains quartz-pyrite veins that can be subdivided into Type A veins devoid of base metals and sulfosalts, and Type B veins containing abundant copper minerals, which are chalcopyrite and enargite mostly (Sims et al., 1963). Type A veins are constrained to the inner Central Zone, and are uneconomic while Type B veins occur along the boundary of the Central Zone, and are historically economic sources of gold and copper. The transitional intermediate zone contains Type C pyrite veins with significant quantities of sphalerite, galena, and copper minerals such as chalcopyrite, enargite, and tennantite. The peripheral zone, with sparse quantities of pyrite, contains the sphalerite-galena veins with a high silver to gold ratio, and accompanied by carbonates, chalcedony, quartz and barite. The outermost barren zone is recognized as containing uneconomic quartz veins with galena, carbonates, and barite. Based on solubility of metals and fluid inclusion analysis, these concentric zonal patterns are presumed to indicate a decrease in hydrothermal fluid temperatures from the central to the barren zone (Sims et al., 1963; Rice et al., 1985).

Hydrothermal gold transport

The transport paths of hydrothermal fluids in the Central City district, are represented by the quartz-pyrite veins that represent snapshots of dynamic fluid-rock interaction processes. Gold will be transported in a hydrothermal fluid as either Au chloride complex at low pH or as Au bisulfide complex near neutral pH (see Figure 1), which permits to increase the solubility of gold in a fluid. The stability of Au chloride and bisulfide complexes will depend on pH, and concentrations of chlorine and sulfur in the fluids, and temperature. Fluid inclusions, are trapped fluids that can be found in quartz crystals, and were used to determine fluid temperatures of ~290 to 380 °C in the Central City district (Rice et al., 1985). The pH can be evaluated by looking at the alteration mineralogy found close to the quartz-pyrite veins, which includes sericitization (phyllic alteration) of feldspar, and indicating pH values <5 during fluid-rock interaction and gold mineralization.

The mineralization of gold from a hydrothermal fluid can be achieved by different mechanisms, with the controlling factors being pH, redox and temperature (points A and B in Figure 12). A typical chemical equation explaining this process is:

$$Au(HS)_2^-{}_{(Au\ transprort)} + 1/2H_2(g) = Au^0{}_{(Au\ mineralization)} + 2HS^- + H^+$$

The highest gold concentrations may be found in near neutral pH fluids (point A), and precipitated by acidification for example by adding magmatic volatiles, by oxidation during fluid-rock reactions, and possibly decrease in sulfur concentrations for example by the precipitation of pyrite. The exact driving mechanisms for hydrothermal gold transport and mineralization in the Central City district remain to be determined. Constraining the conditions of ore formation and fluid-rock reactions in this district is part of our ongoing research at CSM.

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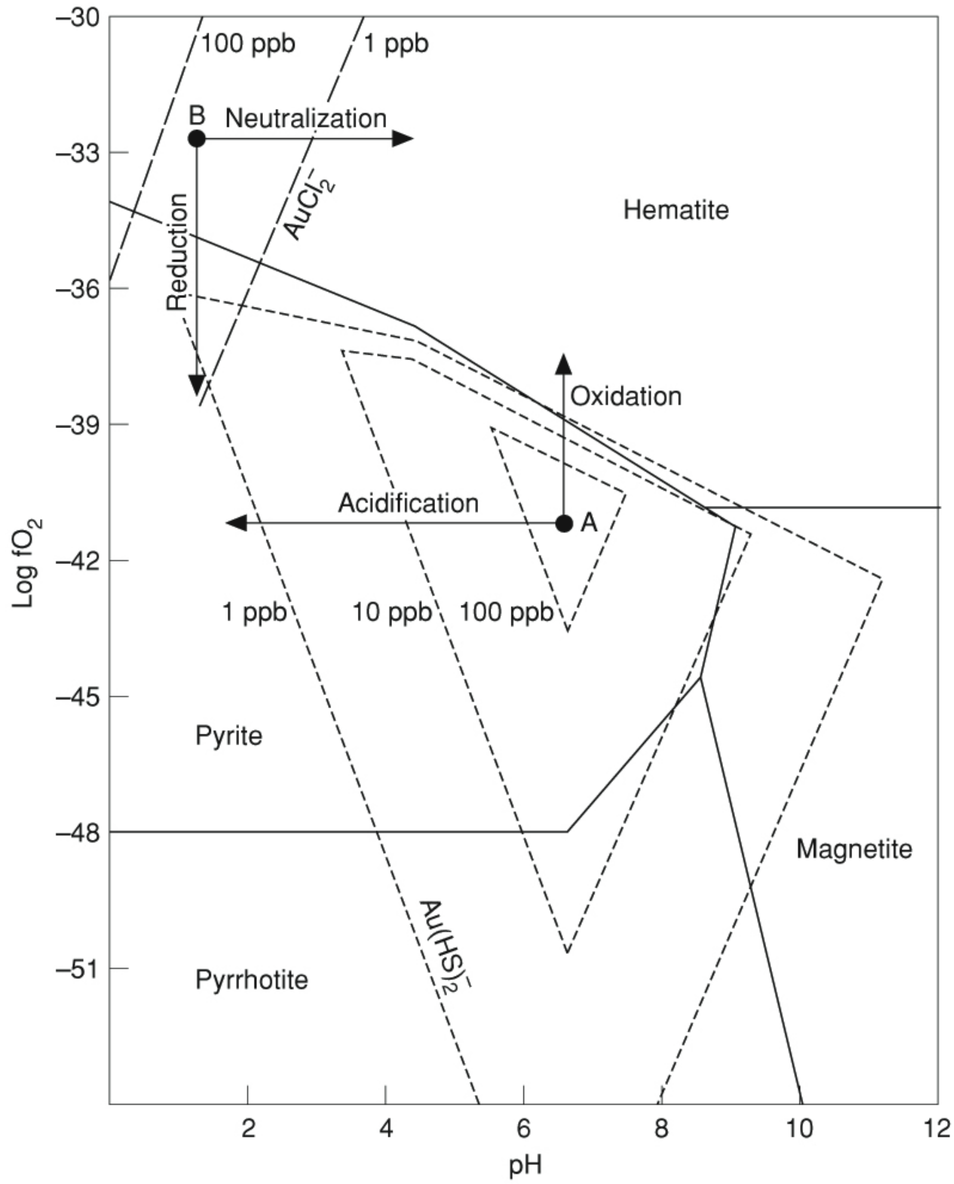
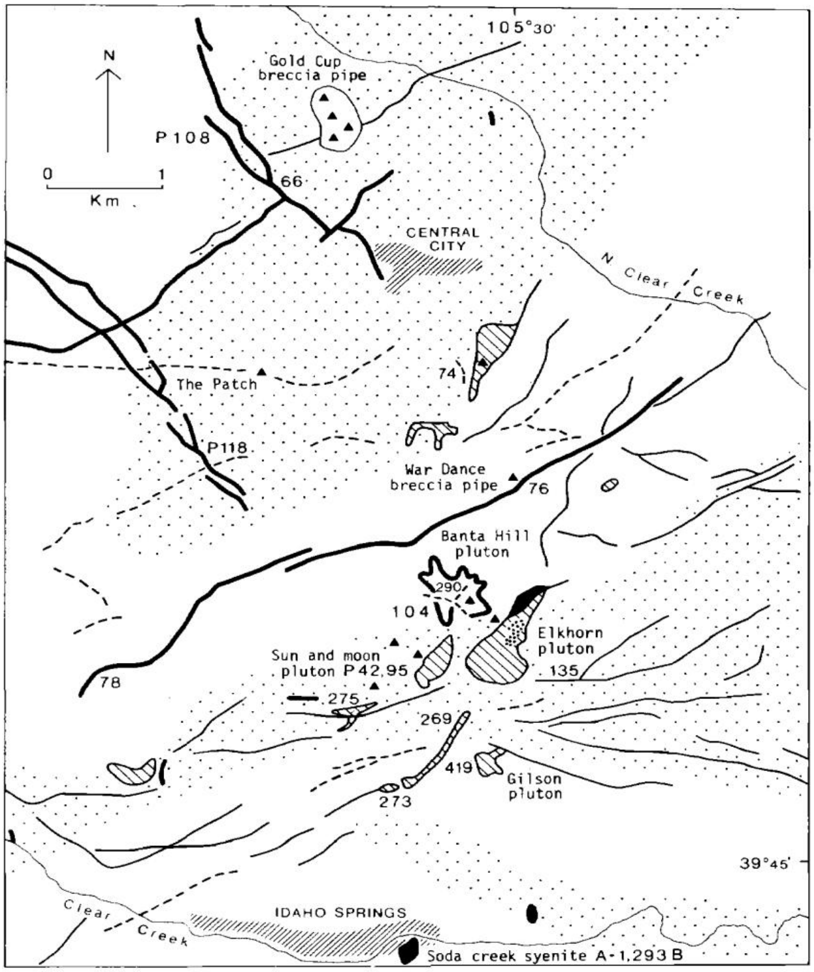


Figure 19. $\log fO_2$-pH diagram showing the contours for Au solubilities and mineral stability fields for sulfides and oxides. *From Robb (2004).*

Appendix 4: Bostonite and Quartz Bostonite Dikes & Time-space Sequence of Mineralization at the Patch, Central City, Colorado

James Piper

Bostonite and quartz bostonite dikes are found in the Central City District and are spatially related to gold and telluride mineralization. The term bostonite, associated with gold ore, is found in older literature, was a term used by miners. A more modern name for bostonite, from the Streckheisen classification, is ***alkali feldspar syenite***. Bostonites are leucocratic, aplitic rocks, with radiating clusters of tabular - interlocking laths of anorthoclase and orthoclase feldspars in sheave-like blades, or ovoid shapes, which may be the product of devitrification (Williams et al., 1954). Quartz may occur interstitially, with biotite, augite, and



General geology of the Central City and north Idaho Springs districts compiled from Sims et al. (1963a), Moench and Drake (1966a), and this study. Legend: Laramide intrusions: = quartz bostonite, – – – = bostonite, = leucocratic monzonite, = syenite, ▲ = intrusive breccia; = zone of quartz veining and silicification; Precambrian: = biotite gneiss, = feldspathic gneiss; numbers = sample locations.

Figure 20. Taken from Rice, et al., 1985.

Figure 21. California Dike (?) on NE Quartz Hill. Altered bostonite, dump of Hidden Treasure mine. Note vesicles. Pinkish-beige, with lilac color in dense aphanitic, fine-grained groundmass, equigranular texture, w/10% light grey 5mm siliceous clots, with sulfide blebs less than. 1mm. Clay alteration, abundant goethite. 1 mm quartz veinlets. Ovoid vugs with secondary quartz lining, 2-5 mm, lenticular cavities. Vugs exhibit flow alignment. Euhedral plag. laths 4 mm; equant K-feldspar phenocrysts less than 1-2%. Green mineral, less than 1mm with tabular habit, sericitically altered. Clay altered collapsed vesicles? Clay appears to replace grains of feldspars.

hornblende or riebeckite. Accessory minerals include apatite, zircon, and iron ore. Quartz bostonite is described as lilac to reddish brown in color, porphyritic, with quartz poikilitically enclosing feldspar crystals, and free lath exhibiting a trachytic texture, with a parallel to subparallel alignment in the flow direction, with altered +/5mm prismatic pyroxene crystals (Bastin and Hill, 1917). Sericitic alteration produces a greenish white color, argillic bleaching may be present, and oxidation of mafic components may stain the rock yellow-reddish brown.

Dikes, cupolas, and breccia pipes of bostonite and quartz bostonite in the Central City District are shown in Figure 14. The dikes are typically 5 to 10 feet wide, with exceptions of up to 100 feet. Anomalously high tellurium, silver, gold, lead, zirconium, thorium, uranium, and arsenic in the quartz bostonite dikes and stocks together with the spatial association of molybdenum, and uranium mineralization suggest a genetic link between these rocks and ore-bearing fluids, (Budge, 1982; Rice et al., 1982). Radiating bostonite dikes mapped by Bastin and Hill (1917)suggest a high level intrusive source for these dikes.

Age dates for pitchblende veins which cut the dikes gave age dates of 58±1 Ma (Phair, 1979) , but galena used for the Pb correction was from the base metal stage which postdates pitchblende vein mineralization (Wallace, 1989). The age of bostonite dikes (Wallace, 1989), ranges from 62.6±1.3 to 63.3±2.2 Ma using K-Ar methods by Rice, et al. (1985) (Figure 3) . Rice et al. (1985) suggested that differentiation of alkali syenite-monzonite may be responsible for quartz bostonite cupolas forming above quartz monzonite porphyry plutons.

Within the Colorado Mineral Belt (CMB) Au-Te deposits associated with alkaline intrusives were emplaced during northeastern regional compression, shortening and uplift during Laramide (Kelley, Ludington, 2002). These alkaline Au-Te deposits are found in the northeastern and southwestern ends of the CMB. The Central City plutons fall within the Laramide – Oligocene period of compression, which ended the rate of subduction increased. Regional shearing allowed the upward movement of these intrusions from the upper mantle/lower crust to rise to shallow crustal levels. A later episode of intrusive activity was associated with early crustal extension during which other alkaline related gold deposits were formed (Kelley, Ludington, 2002). Thompson (1982) described an alkali types of molybdenum-bearing stocks with low fluorine in the Nogal-Bonito District New Mexico, which evolved from little or limited fractionation. Ag-Pb-Zn (±Au, Mo) and Au-Ag fissure veins, and gold-bearing breccia pipe deposits with associated tellurium are also found in the Nogal-Bonito District (McLemore et al., 2014).

The intrusive activity can be summarized as the emplacement early calc-alkaline intrusives, followed by multiple intrusions of alkaline rocks.

Sulfide Vein Types

Three vein types at Central City are shown below (Sims, et al., 1963).

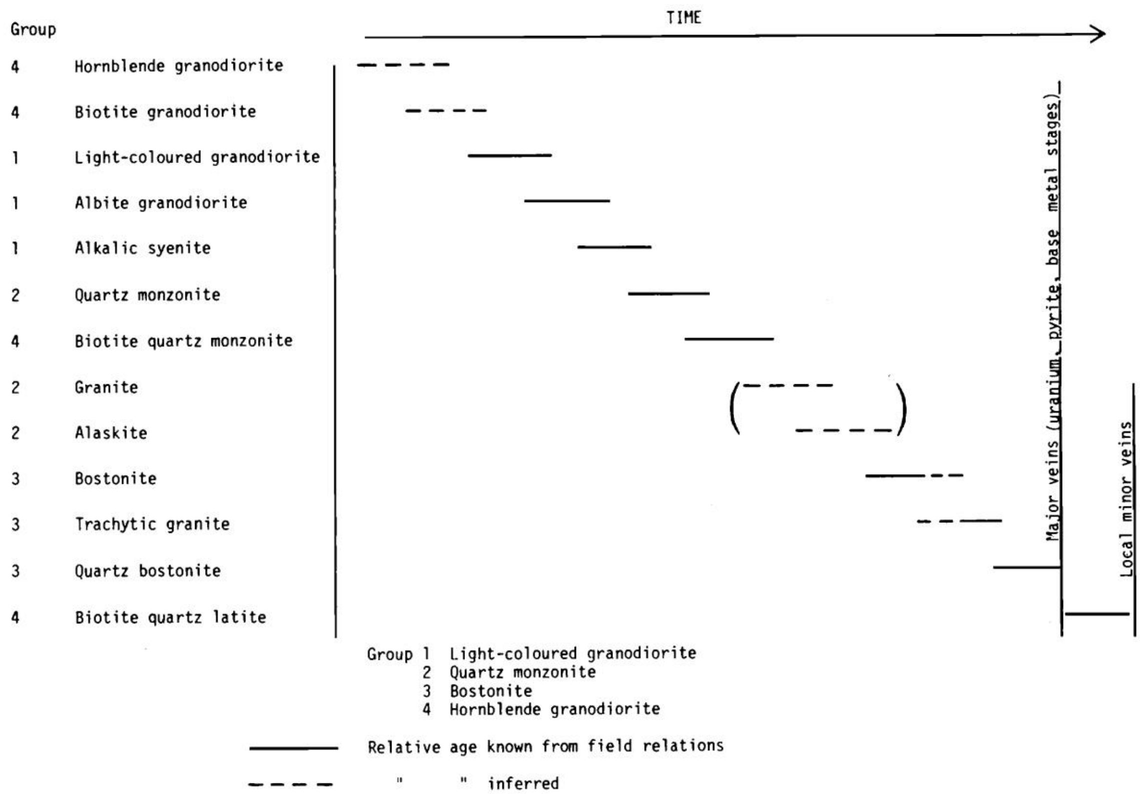
- Pyrite vein, without gold or base metals, or sulfosalts (lower gold and silver, than in B and C).
- Pyrite + abundant copper minerals + sulfosalts + gold and silver.
- Pyrite + copper minerals, sphalerite, galena + sulfosalts + gold and silver.

Mineral paragenesis is shown in Figure 15, and a mineral zonation map is shown in Figure 16. The four hypogene zones, based upon silver to gold ratios, are depicted on the map as a central core bounded by successive zones, labeled as - Central Zone, Intermediate Zone, Peripheral Zone, and a Barren Zone.

- Central Zone. Characterized by type A veins, with type B veins along the outer margins, as the copper mineral abundance increases.
- Intermediate Zone. The silver to gold ratio increases in this zone, with type C veins, which include base metal sulfides and sulfosalts.
- Peripheral Zone. Silver increases locally outward, gold values decrease, and carbonates increase, with chalcedonic quartz and barite first appears in this zone.
- Barren Zone. In this zone deposits are small and sporadic. Galena becomes dominant, iron manganese carbonates, cryptocrystalline quartz, and barite are dominant gangue minerals.

Later work, outlined below, divides mineralization into four stages (Alers, 2008).

- Stage 1 mineralization - pitchblende and local secondary uranium minerals, found sporadically in small pods or lenses along pyrite and composite veins associated with early uraniferous quartz bostonite porphyry dikes.
- Stage 2 mineralization - quartz pyrite braided network of veins with 0 - 0.8 opt Au, hosted in sericite altered envelopes up to 80 feet thick.
- Stage 3 mineralization - composite base-metal sulfides, set in gray to dark gray, and black quartz veins 0.1 to 6 feet wide, coarse grained chalcopyrite and pyrite dominant, with minor base metal and secondary sulfides, and variable gold.
- Stage 4 mineralization – Tellurides in networks in 0.5-foot-thick hairline veinlets, with blue-gray cherty silica/chalcedony, ferruginous calcite, white clays, purple fluorite, Au and Ag-bearing telluride minerals. Gold is high grade and variable.



Laramide intrusive sequence in the central Front Range after Wells (1960).

Figure 22. Laramide Intrusives. (Taken from Rice et al., 1982.)

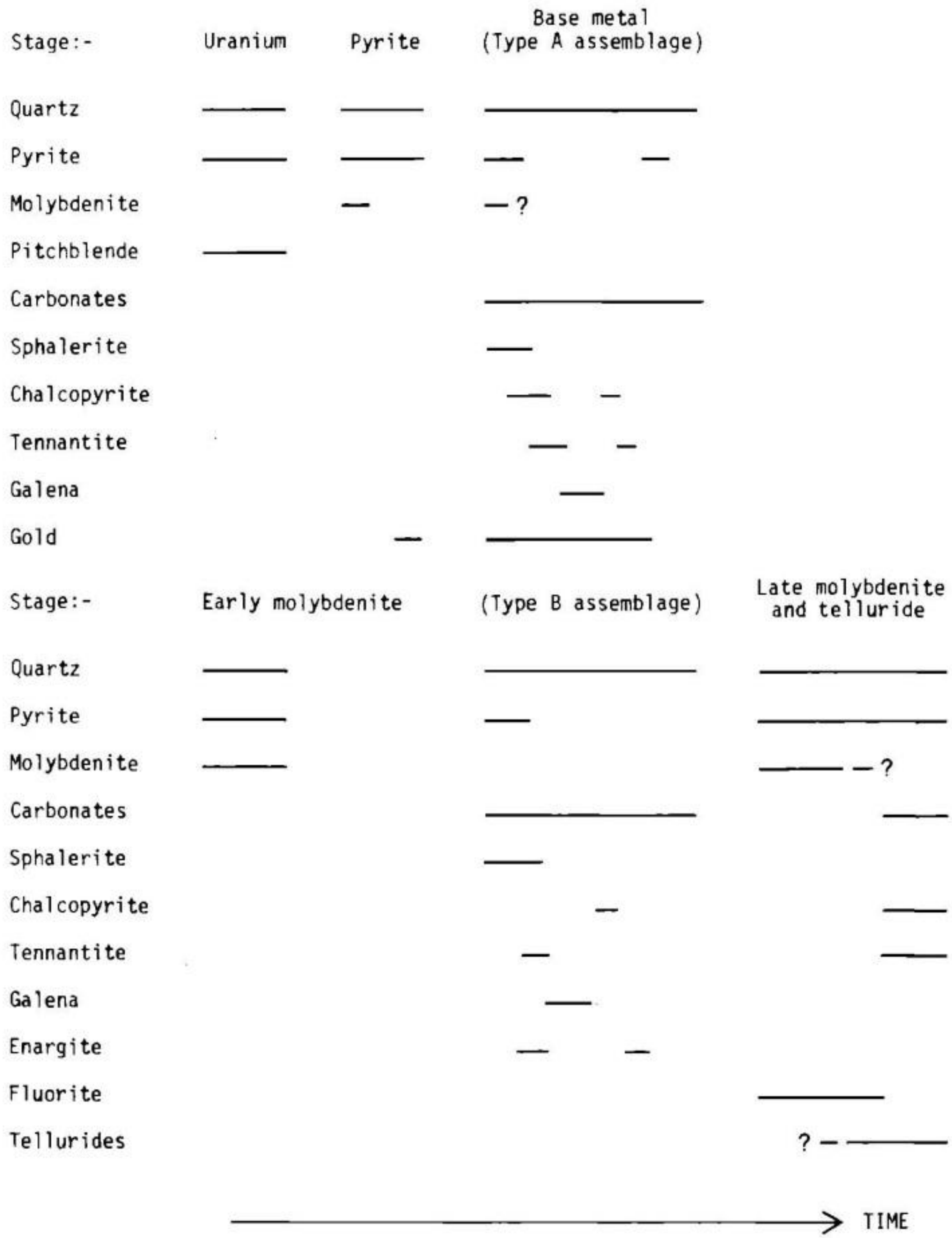


Figure 23. Inferred paragenesis of the main vein-forming minerals in the Central City and north Idaho Springs districts compiled from Sims et al. (1963a), Sims and Barton (1961). Taken from Rice, et al., 1985.

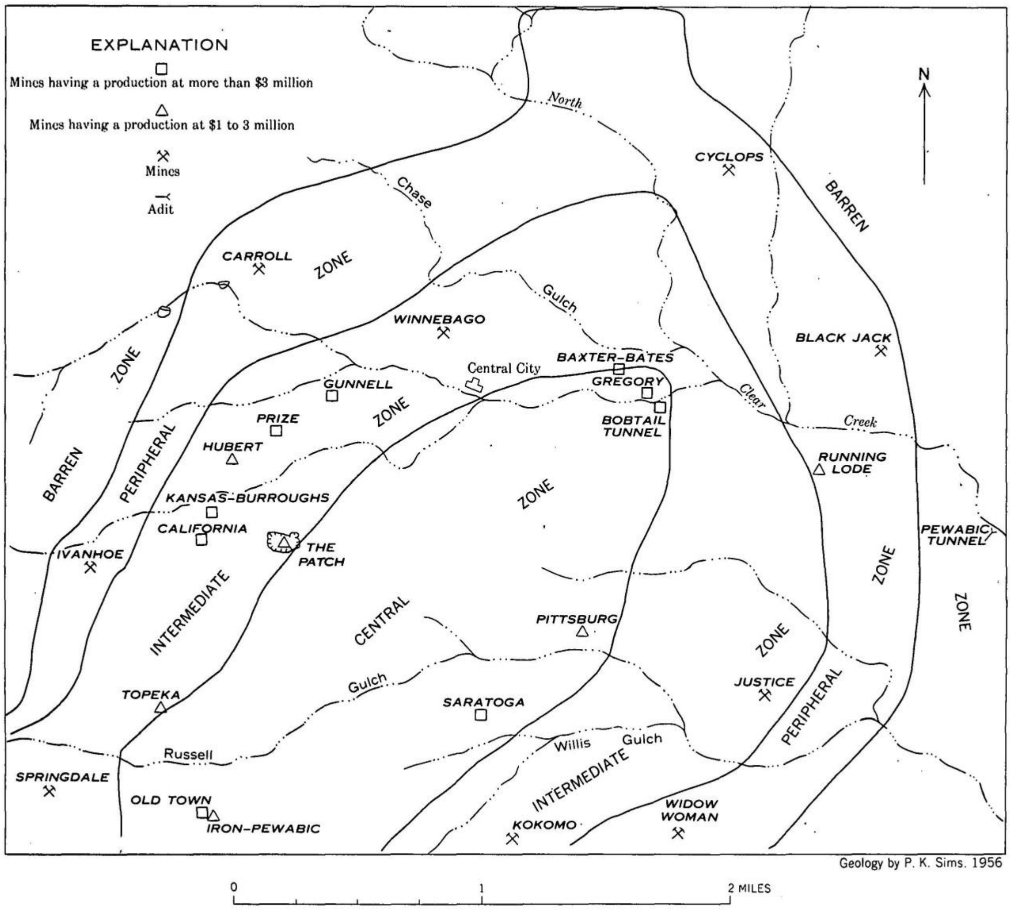


Figure 24. Zonation Map, from Sims, et al. (1963).

Quartz Bostonite at the Patch

Figure 25. Photo of breccia at the Patch. Clasts as large as 6 cm diameter are visible**.**

A mineralized phreatic breccia occurrence in the Central City District, is the Patch, or Glory Hole (or Chain O'Mines), dated at 59 Ma, is a steep pipe, plunging north, 750 ft east-west X 450ft north-south, with angular to rounded breccia clasts of bioitite-gneiss set in a matrix of rock flour (Sillitoe, 1985) . The breccia was produced by fracturing of brittle microcline gneiss along veins intersections (Cappa, J.A., 1998). This pipe consists of stockwork breccia, which predates mineralization, with sulfides in tabular vein deposits cut by a quartz bostonite dike (the California dike), and in places, is cut by younger veins (Sims, et al., 1963).

Several explanations, listed below have been proposed for the origin of this breccia:

- Collins (1907) proposed that the breccia was related to the quartz bostonite intrusion emanating upward from an intrusion at depth.
- Bastin and Hill (1917) argued that shearing along fissure veins along vein intersections were responsible for the development of the breccia.
- Spurr (1923) thought that an Avant-Coureur, or forceful rupturing by gases preceding an intrusion caused the brecciation.
- Lovering and Goddard (1950) presented the concept that an igneous pipe followed a pre-existing shear.
- Sims et al. (1963) concluded that an igneous mass forcefully pushed upward along a zone of weakness to produce a pipe. Alteration followed the brecciation, and was intruded by the quartz bostonite dike later, followed by faulting and vein development.
- Another explanation in Spry (1987), proposes that breccia pipes and vein stages mineralization at the Patch are not genetically related and argues that the character of the vein minerals to be the same as Sims type A veins, pyrite with base metals. Spry concludes that these veins intersected the pipes which provided ground preparation which would be a favorable host for mineralizing fluids. Fluid inclusion studies suggest that fluids were derived from the molybdenite and late base metal mineralizing events. CO_2 in fluids at the Patch are notably higher in contrast to other mineralized breccia pipes Spry (1987). Sulfur studies suggest magmatic-sedimentary mixing of sulfur from both a hydrothermal sources and Cretaceous sea water. Fluid inclusion data with minimum pressure for type 2 inclusions of 480 bars suggests inclusion entrapment between 1.4 – 1.9 km.

Ore minerals vary through the pipe, with along the southern side of the Patch, with pyrite, chalcopyrite, quartz, and a little tennantite and sphalerite, while sphalerite is the most abundant mineral, and is associated with a little pyrite, galena, chalcopyrite, and gangue of quartz, and ankerite (in the matrix) along the northern side.

Rich grades from the San Juan Mine averaged 2.09 oz/ton. Au, 6.81oz/ton Ag, and 1.5-9% Cu from 1988-1909, although average grades were much lower. The weighted average of samples taken from the south wall of the pit in the Argo tunnel ran 0.071oz/ton Au and 0.489 oz/ton Ag(Sims, et al., 1963). The Chain'OMines, Inc mined the Patch, accessed from the Argo tunnel, from 1927-1937. Lower grades were also mined in the Glory Hole and prior to tunnel/pit development.

The Patch or Glory Hole, was developed from three tunnels (Figure 26) –

- the La Crosse Tunnel at the 300 foot level,
- the Quartz Hill Tunnel, at the 700 foot level,
- and the Argo (or Newhouse) Tunnel, at the 1,650 foot level (Kile and Modreski, 1988).

Gravity and selective flotation was employed by the Chain 'O Mines at a 1,500 TPD mill (Sims, et al., 1963), and a 5,000 TPD capacity mill processed ore from the Patch in the 1950's (Kile and Modreski, 1988). The Chain 'O Mines mill is located at the turnoff from Russell Gulch along the field trip route. A description of the Chain 'O Mines sagais provided by Don McCoy and included in Appendix 6.

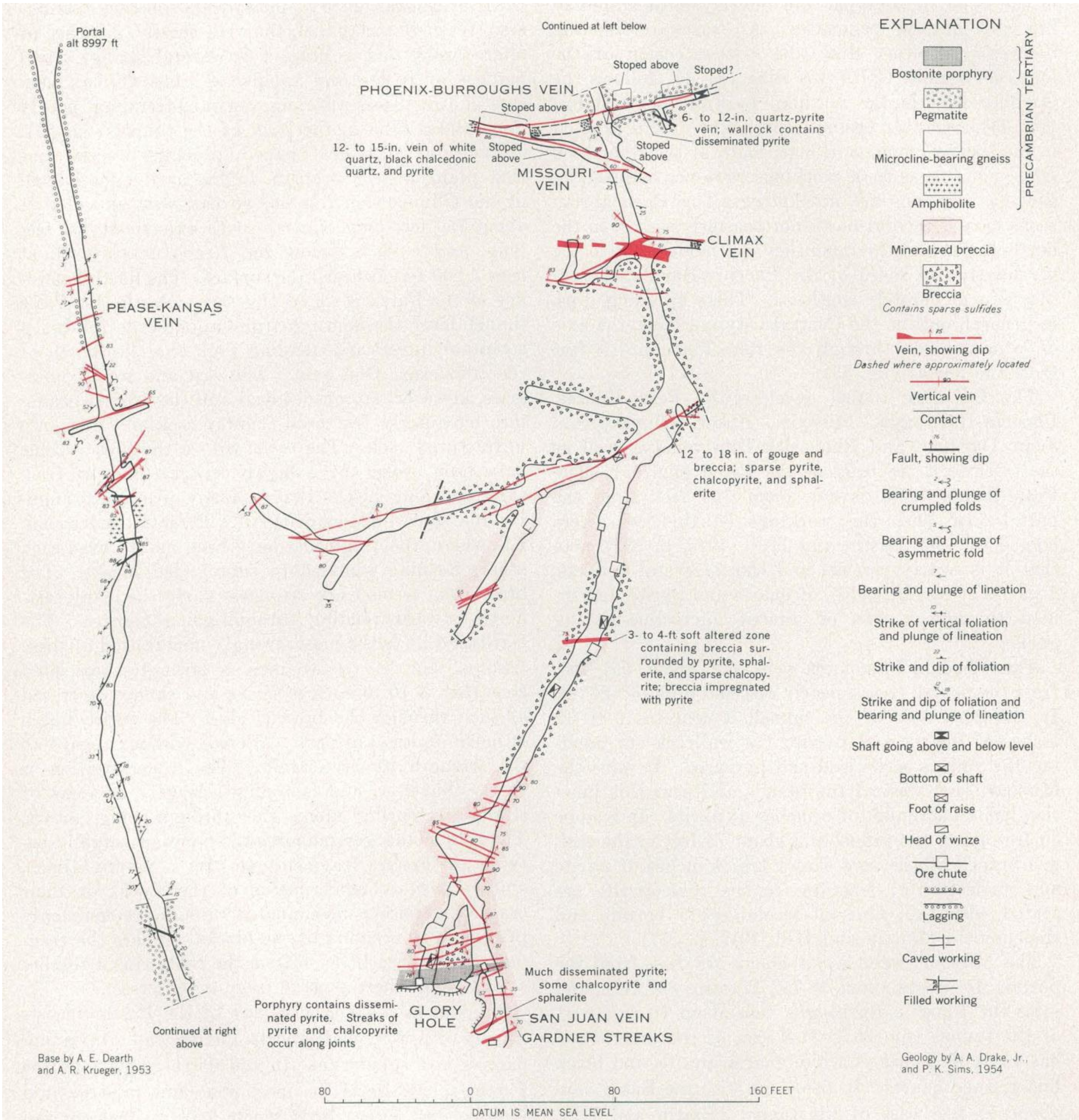


Figure 26. Geological Map of the Patch from Sims, et al., 1963.

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Appendix 5: Some More Colorado History –The Argo Tunnel (a mining story)

Laurence P. James

The Argo tunnel, described by government geologists Bastin and Hill (1917) as "the largest and most important mining work in the Central City - Idaho Springs district" was begun in 1893. By 1910 it was completed, extending 4.16 miles northward to the workings of the Gunnell and Prize mines, due west of Central City.

Samuel Newhouse. a noted international promoter financed the driving of the tunnel. He and Lafayette Hanchett, his capable engineer, then went to Utah, investing first in a small porphyry copper mine in Beaver County and then in half of the Bingham deposit (James, 1978). A large custom mill, with bins for ore from a dozen mines, was erected at the Argo portal. A tour through this Plant (now a museum) is recommended for anyone interested in the state of the art of metallurgy circa 1920.

Laterals were driven toward the shafts of the Saratoga, Old Town, Calhoun, Mammoth and other mines. some of which eventually reached the Argo level. Some veins proved to be sub economic, or just mineralized structures. Others, such as the Dyke vein at 20,370 feet from the portal, proved to contain 0.3 to 2 ounces of gold in strong to massive pyrite as much as 2.5 feet wide. Base metals were lacking in this locality.

Between 18,867 and 19,412 feet from the portal the tunnel cut The Patch (c.f. Stop 3) intrusion breccia. According to Bastin and Hill (1917) The Patch was bounded to the south on the adit level by a fault zone. Rock fragments in the breccia are generally less than 4 feet in diameter, and are heterogeneous in size, lithology, and degree of rounding. They are set in an arkose-like matrix. Sulfides are present only in a few areas.

The Kansas shaft, on Quartz Hill above Central City reached depths at which pumping proved uneconomic, with a wide vein of good ore in the bottom. A drift from the California crosscut, extended west from the Argo tunnel, followed the probable downward continuation. Raises were driven on ore shoots, and a fan of core holes was put out to seek the water-filled shaft. The danger of 1200 feet of flooded workings overhead, partially filled by old stope gob, was recognized. There was uncertainty as to which structure the workings actually followed. The holes made substantial water, but failed to intersect the Kansas workings. During the depression George E. Collins, a noted Colorado mining engineer, organized the California-Hidden Treasure Mines Co. (Figure 27) to explore areas far back in the Argo tunnel. Merle Sowell went to work as a miner for Collins in December 1940. In 1974 he vividly recalled (in the Front Range Journal, v.47 #35) the tragic last day at the Argo:

ALIFORNIA-HIDDEN TREASURE MINES CO—Boston Bldg, Denver, Colo.
OFFICERS: George E Collins, pres & mgr; Ed P Eppich, sec.
CAPITALIZATION: $350,000; $1 par; 190,225 shs outstanding.
MINES: at Argo, Colo; gold-silver producer; John Grenfell, supt.
MILLS: at Idaho Springs, Colo; 200-ton amalgamation-flotation plant. At Central Cit
50-ton amalgamation-flotation plant, partly dismantled.
PRODUCTION: 1940, 1,396 ozs gold, 6,760 ozs silver, 18 tons copper, 5½ tons lead, 13 to
EMPLOYEES: 1940, average number, 6 men. **From:** *Mines Register*, 1940 (and 1942) editions

Figure 27. California-Hidden Treasures Mines CO

"Collins' worst problem was to keep skilled miners on the job. Even with rubber suits, hip boots and waterproof hats it was like working in a shower bath with full pressure turned on. The best he could do even in the depression was to keep about 5 or 6 men inside on the crew. During the 1930s all other mines quit operating through the Argo except the Kansas ...

"At first I set to work driving prospect raises on another vein about 40 feet south of the Kansas, and it was fair ore. It looked like this vein would intersect the Kansas at the upper level. We drifted on this vein from a raise ... The vein widened to about 20 inches and the grade was very good. We used a wheelbarrow to convey ore to the main raise, where it was dropped to the Argo level and trammed to the mill ... I drove the drift 160 feet more. The vein widened out to 30 inches. It assayed from 5 to 7 ounces gold, 50 ounces silver and 8 percent copper ...

"We broke a four foot round each day, six days a week. The worst problem was high pressure water... Every morning there would be new squirts, coming from the walls, the back or the breast. The vibration from drilling caused water to squirt 20 or 25 feet down the drift. We had to dodge these jets. My helper, Bill Bennett, and I talked about what we would do if the water broke in from the Kansas shaft. We would run like heck and escape. Soon I found a drier job and flew the coop.

"For the next two years they worked this vein in earnest. They laid track for a car, and drifted further east. By the end of 1942 they had mined this stope up about 80 feet, still with good values. The water pressure increased as they went up, and the last few weeks they started using 30 minute fuses to fire the shots in the stope. [This allowed the miners to get much further from the scene, perhaps even out the portal].

"On Saturday afternoon, January 19, 1943, about 45 minutes before firing time, Bill Bennett walked out to the main Argo tunnel to run a loaded ore train to the mill. He used the big trolley locomotive. The miners firing the shot, his brother Charles Bennett, Claude Alberts, Sam Mettras and Ray Hamilton, planned to follow on the small battery-powered motor. They had had gone back to using ten minute fuses ...

"Mr. Collins had made his weekly check of mine operations that day and left about an hour before firing time, on his small motor. He walked over to the bus station for his return to Denver. The bus was to leave about 4:30.

“Bill had almost made it to the portal of the Argo tunnel, lacking two or three hundred yards, when the power went off. When the rumble of the train stopped he heard a terrific roar. Guessing what had happened, he raced to the portal. When he made the portal he was waist deep in water.

“The outside compressor man sounded the alarm to the fire department, which blew the whistle. By the time people arrived the tunnel was flowing water up to the top. It gushed across the portal yard, down across the creek and onto Colorado Boulevard.

“From the bus window, George Collins saw how the creek just below town had risen and was full of reddish yellow water. He guessed what had happened, got off the bus, and hitched a ride back. At the tunnel he was treated very coldly and received many bitter words as being responsible. George was an old man, and he nearly collapsed. He never fully recovered from the shock and sorrow...

“About 11 pm the flood began to recede. The state mine inspector sent in men to check for hazards when the water dropped below hip deep. There were some obstructions along the way from timber debris and rock falls. Next came the stretcher carriers. It was a four mile walk. Each man had the faint secret hope that the miners might still be alive…

"Several of the bodies were found only after extensive search, as each was partly covered by mud and gravel. One had been washed further back into the main tunnel, toward Central City. No one has yet been back to the stope, and it is not known where the breakthrough came from the old Kansas workings. All the ladders and timbers had been washed out, so there was no access. The mine inspector closed the operation. Only a few desultory attempts have since been made to open it.....

Appendix 6: What was The Chain O' Mines?

Donald McCoy

The Chain O' Mines was incorporated in 1926 under the direction and ownership of Dr. William Muchow (pronounced *Muck'-O*). "The Doc" as he was called by those who knew him well, first visited the Central City District a couple years before he started his company and of course, was intrigued and inspired by what he soon learned of "The Richest Square Mile on Earth" as Ulysses S. Grant had called it on his visit in 1872. By late 1926 Dr. Muchow had consolidated more than 200 well-known mines on Quartz Hill constituting most of "The Patch". One only need look at any claim map of the time to understand the appropriateness of the name and the magnitude of that accomplishment. Originally, claims in 1859 were as small as 50'X50' and were overlain upon each other and mined according to the laws of equilateral rights, of which all mining people are well aware of.

As the mining district matured, the miners agreed to a standard lode claim of 150'X1500' along the vein. The Mining Law of 1872 extended that standard to 600'x1500', but the original claim sizes remained the same as they were before they were patented. When new lodes after the Mining Law were staked, claimed and patented they could be any size up to the new standards. Imagine the conflicts along the veins and their intersections with the nearly 14 million sq. ft. surface expression of the breccia pipe that became Central City's most famous mining feature, The Gloryhole (Figure 28). Where Dr. Muchow could not purchase claims outright, he made typical and atypical deals with owners who refused to sell at his offerings. Some of these deals lasted into this current century.

Dr. Muchow raised hundreds of thousands of dollars for his venture over the years, mostly from investors from Chicago, Illinois' society elites. There were many anecdotes regarding his money raising schemes. His most famous (or infamous, depending on how you look at it) was in 1928 when at the Chicago Metropolitan Opera, during the start of an intermission, he dropped a 6" round gold ball. Weighing about 35 pounds, it quickly gained speed as it bounced between and off seat legs, shoes and ankles, eventually making its way to the front row. He loudly exclaimed "My Gold!, My Gold! Please help me get my gold back!. I have to exchange it so I can pay my miners!!" A very distinguished man in the front row retrieved the ball and called out to Dr. Muchow that he had secured the treasure. Doc quickly maneuvered though the throngs of those exiting but now watching intently and with both hands, lifted the proffered ball over his head and proclaimed "Praise God for honest men! Sir, for your honorable deed, I am willing to let you in on an investment opportunity of a lifetime!" Of course he said this loud enough for all to hear and that night raised a little more than a million dollars for his new mill to be located at the foot of Quartz hill, near downtown Central City.

Any investor who contributed $10,000 or more was treated to a train ticket to the Central City and lodged for three days at the Chain O' Mines hotel on the southeast corner of Lawrence and Main St. Doc would meet then at the train station, escort them to the hotel. The following day he would take them by bus to the top of Quartz Hill and show them the mines, where he would ply his next famous technique. He would give everyone a gold pan, tell them to get a pan full of dirt from anywhere on the hill and bring it back to his panning trough. Occasionally, an investor would find flakes of gold on the first try, but mostly, Doc would show them how to correctly swirl the pan as he eagerly gnashed on his large cigar. Sure enough, every pan he swished would show flour gold. How could that be true? The cigar of course! He would carefully roll flour gold that would come from local miners into his cigars and when the ashes fell into the pan-Presto, gold in every pan full!

By December 1928 Doc had reconditioned the Quartz Hill tunnel, driven the Lacrosse tunnel through the hill to connect with workings in the pit area. He also installed what may have been the largest shaker table operation in the United States. The mill consisted of a 5,000 ton-a-day crushing and concentrating mill just above the train station. The crushing circuit consisted of a 2'x 5' toggle jaw primary crusher and an 8’ secondary gyratory crusher. The comminuting circuit had two-6’ Allis-Chalmers conical ball mills, two-6’x 14’ Denver-Miner cylindrical ball mills and an 8’ x 22’ Denver cylindrical rod mill. Each mill had a large rake classifier. The pulp from each mill was run through a triple-deck Denver diaphragm jig and the overflow dropped into a splitter that fed twenty-two 8’X24’ Wilfley rougher shaker tables which in turn fed fifteen 8’x24’ middling tables which then fed six 8’x20’ finishing tables. Low grade middling concentrates would be sent to a regrind circuit consisting of a 4’ Marcy conical ball mill and two 8’x20’ finishing tables. Telluride bearing concentrates would be sent to a Merrill-Crowe mill consisting of a 6”x4’ throw stamp mill with cyanide solution used to flush crushed product into a 2500 gal. California red wood barrel vat. After the barrel vat was charged to capacity, it would be agitated for 24 hours and the pregnant solution precipitated by dissolving zinc shavings and the sludge smelted in a 30 cu. ft. crucible and poured into miners’ bars. The bars were then sent to El Paso, TX for refining. Finishing table concentrates would be sent to a 4’x6’ amalgamator and the mercury charge sent to a large volume retort with the final retort product also sent to El Paso.

All told from 1928 to 1969, Doc’s mines and mills produced 300,000 ounces of gold from just over 800,000 tons of ore. There were several iterations of the Chain O’ Mines during those years. There were some very good times, but mostly very tough times. Doc kept the Central City mill running until Roosevelt’s war order L208 at the start of WWII. Fortunately for the Chain O’ Mines, there was a very important deposit of rare earth ore which was needed for the war effort.

Unfortunately for the district, all the gold mines were shut down then the miners were brought into town, then assembled on the big tailings dump where they were separated into the three branches of service by the order in which they showed up. The order was Army, Navy, Marines and repeated until every able-bodied miner was drafted and sent to boot camp. Part of the provisions of L208 included the dismantling of unessential infrastructure for scrap metal. This included mining equipment, hoists and cables, and most of all, non-vital rail line equipment, especially rail and engines. Entire rail lines were scrapped, including Central City to Golden.

A skeleton crew was scabbed together from those who did not meet the minimum requirements for military duty and Dr. Muchow was allowed to mine strategic metals for the war effort. These included rare earths, radioactive ores and what Doc had convinced the war department was iron ore from the Old Town-Pewabic group via the Argo tunnel. Of course, there was little oversight from the government on his actions so he kept mining, milling and smelting precious metals to keep the locals employed and to set up investors for plans after the war. Doc was appointed to the board of directors to American Strategic Metals, Inc. which was a government backed corporation to supply the war machine with needed metal and nonmetal resources. One of these small groups of local miners consisted of 5 men who were following a high grade ore shoot on the Kansas vein. The Kansas had been dormant since near the start of the War and was full of water to elevation 8889’, just below the Lacrosse tunnel level. The Kansas Vein accessed the Argo tunnel via the Burroughs workings at an elevation of 8315’. Legend has it that this was to be the last round pulled as the miners had piloted a hole hitting excessive water flow at 33’. Unfortunately, when the round was pulled, it broke into the lower levels of the Burroughs with about 550 feet of head, which translates to about 250 pounds per square inch! One miner was pushing a cart near portal of the tunnel and was able to swim free before the full power of the breach reached the adit. The other four were not so lucky. The only trace of them was a bandana that was known to belong to one of the miners, found in the roaring gush into Clear Creek. There are also stories of body parts and lunch boxes being found. George Trader, one of the assayers at the Argo portal, had taken the night shift off, and recalled awakening the roar of a crashing freight train rocking the town. He lived nearly a half mile from the portal.

Figure 28. Photo of the Gloryhole mines showing draw chutes taken in 1962.

After the War, Doc quickly went to work raising money for a new mill. Another couple trips to Chicago and he soon had over $1million. The mill construction in Leavenworth Gulch began January 14, 1946 and was completed in the fall. Muchow claimed the production of more than 1 million ounces of gold between 1946 and 1969. District production records, however, do not support this claim. Still, It was a good money raising claim.

The Chain was a primary and contract employer of Gilpin County for more than 50 years, but it was not always beloved by the locals. When Doc died in 1969, he left control to Harold Caldwell, an ex-government man from Washington who had previously been assigned to the gold detail after the War. This did not set well with the men who had been loyal to the "Chain" since its inception. Many of Doc's loyal employees jumped ship and moved on. Some vowed to fight for control. This led to many years of bitter law suits, one of which was finally successful in wresting power from Caldwell in 1994.

During the Caldwell reign, there were many deals made to keep the mines and mills operating. The most infamous was that of Central Gold Corp. run by Australian businessman Arvey Drown. Drown used the operations to raise and launder more than $400 million of which perhaps less than a percent was actually spent on the mining endeavor. Exaggerated gold assays, an incredible "ponzi" scheme of using new investors to pay off old ones in exchange for raving reviews in turn caused a flood of gold rush money to Drown's company.

The greed soon led to a plot to murder the principles in the Chain. Drown and his henchmen decided that Harold Caldwell, Don McDaniels (Chain Superintendent), Frank Toma (Director) and Mattie McDougall (Secretary) had to go. Drown called for a board and officer meeting at the National mine. Frank Toma and Mattie McDougall were in California and weren't available so only Harold and Don were going to attend. Drown decided to take out these two now and get the others later. Harold was attending a meeting with the Gilpin County Commissioners, wooing their approval for an upcoming permit expansion. McDaniels was to go alone, but Caldwell asked his father-in-law, Luke Claiborne, to go along with his proxy until he showed up, in case voting issues came up. Drown's head of security, George Crowder, waited in the National Shaft house with two of his employees. Crowder was an ex-student and instructor of Ed Parker, the world renowned founder of the Ed Parker School of Kenpo Karate. When the two Chain men walked in, they were immediately beaten to death and their bodies disposed of.

McDaniels and Claiborne were the subject of missing persons searches for the next two decades. Caldwell's meeting with the commissioners ran four hours late, so he missed Drown's meeting. In 1995, one of Crowder's henchmen was arrested for armed bank robbery in Tennessee and turned state's evidence on Drown and Crowder. Crowder was arrested and received 18 months in a plea bargain for evidence against Drown and the whereabouts of McDaniels and Claiborne. Drown escaped to the Philippines but was captured and held for ransom by Pilipino communist rebels. The U.S. held negotiations for his release but could not come to an agreement with the rebels, or so the U.S. negotiators say. Drown was never heard from again.

Several more attempts were made following the Drown episode but nothing came together. Caldwell had previously been awarded a development project for South Padre Island in exchange for his work on the National Seashore project under President Kennedy. He raised several million dollars from investors and built the first causeway and roads on the island. One of these investors was a Judge Robert Barnes from Brownsville, Texas. Barnes loaned Caldwell $50,000 on a promissory note for a one percent share of the project which was to develop 20 miles of ocean front real estate for condos and resorts. The project was bought out by several interests, of which Barnes was a principle owner. When gaming came to Central City, Barnes hired an attorney, filed a lawsuit in Hildago County, TX. A process server was hired by Barnes to sign off on service to Caldwell, and when Caldwell didn't show, a summary judgment in the amount of $50,000 and an annual interest rate of 8% was awarded to Barnes in 1992. The total amount was $226,800. Barnes lawyer then entered this foreign judgment in Jefferson County, Colorado, but somehow the amount became $150 million. Collusion between Barnes' Lawyer, Judge Kenneth Barnhill and Barnes was suspected but never proved. Judge Barnhill soon retired after the ruling and Barnes took control of the Chain, thus ending its long and troubled reign.

Epilogue

I was Chain O'Mines Executive Vice President from 1982 until the Chain's demise in October of last year. Hired as Chain Superintendent in 1981, I replaced Don McDaniels. One of the most memorable events occurred after the Drown caper. A mine ops man from Central Gold formed a Canadian mining company called Intermountain Mining, Inc. (IMI:TSV) and ran from 1980 until 1983. When lettered stock became free trading, and after the stock ran from $0.01 to $2.00 the officers dumped their stock, stripped the mill and held me and my four man underground crew in the mill bunk house until they were done stripping the mill. I was able to sneak out a secret escape way Doc Muchow built in 1946 and collected two Sheriff's deputies. The Sheriff was out on vacation but deputies Hartman and Martinez met me at the Glory Hole bar on Main Street. I had checked my guns with the bartender, but collected them before I got the deputies. I immediately asked what weapons they brought and after they told me they had only their 9mm service pistols, I told them to go back and get automatic rifles if they were going to confront the same at the mill. They had to call Sheriff Weezy to get permission from her to open the SWAT cabinet. They returned, fully armed in about 10 minutes and we went up to the mill. When we got out of the police SUV with weapons drawn, the guards lay down their weapons and stepped back. The mining company was instructed to leave what was left and wait until morning to sort everything out. There were forty JARTRAN trucks loaded with mill equipment all impounded and in the morning everything except about 20 truckloads was returned to the mill. The ten greyhound buses full of immigrant workers left quickly without resistance and eventually Chain secured a $2million judgment against the mining company. We never collected a dime!

Field Trip H: Guide to the Aspen Mining District
July 24, 2017

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Tour Overview

A field trip to the Aspen area will examine aspects of the silver-rich manto deposits from underground and surface exposures within the productive part of the mining district. The visit will commence at the Smuggler mine where an overview of the geology, discovery and mining history, mineralogy, and production of the Aspen district will be presented. We will then examine via underground drifts and stopes of the Smuggler mine the diverse styles of brecciated host rocks developed within and atop the Leadville Limestone and their role in hosting the manto mineralization. The underground visit will also provide an opportunity to observe the character of the mantos, plus the alteration features developed within limestone, breccia bodies, and a Laramide-aged sill situated proximal to the mineralization.

The trip will then drive part-way up Aspen Mountain to the Vallejo Gulch area where the geology and mineralization features important to the discovery and early high-grade mining of the district will be visited - including a discovery adit and mine dumps of the Spar, Aspen, Emma, and Durant mines. A traverse along a road cut at Spar Ridge will examine the barite-rich manto mineralization within the Contact breccia at the Spar adit discovery location, then into Vallejo Gulch for a discussion of the historic apex law suit between rival claim owners. At the portal of the Compromise tunnel, a presentation will be made of the mineralization features of this area including the important control of the Aspen fault and its intersection with breccia bodies and limestone that localized the large manto deposits along the east limb of a syncline. We will continue by walking across the Aspen and Emma mine dumps to a ridge west and observe the alteration features of a Laramide-aged sill altered to a sericitic-pyrite assemblage. Following is an examination of jasperoid masses within the Leadville Limestone in Pioneer Gulch and their relationship to mineralization.

Stop Descriptions

Stop 1: Smuggler Mine

From the Smuggler mine parking area, we will walk via a dirt road to the number 2 tunnel mine dump. Here geologic overviews of the Aspen area (Figure 1) and Smuggler mine (Figure 2) will be provided. Following will be short presentations of the history of the mine and district production. Before going underground there will be a safety presentation and the issuance of hard hats, lamps, and brass tags.

We will walk into the mine via the number 2 tunnel. A series of underground stops will be made that will focus on the brecciated host rocks developed within and atop the Leadville Limestone and their role in

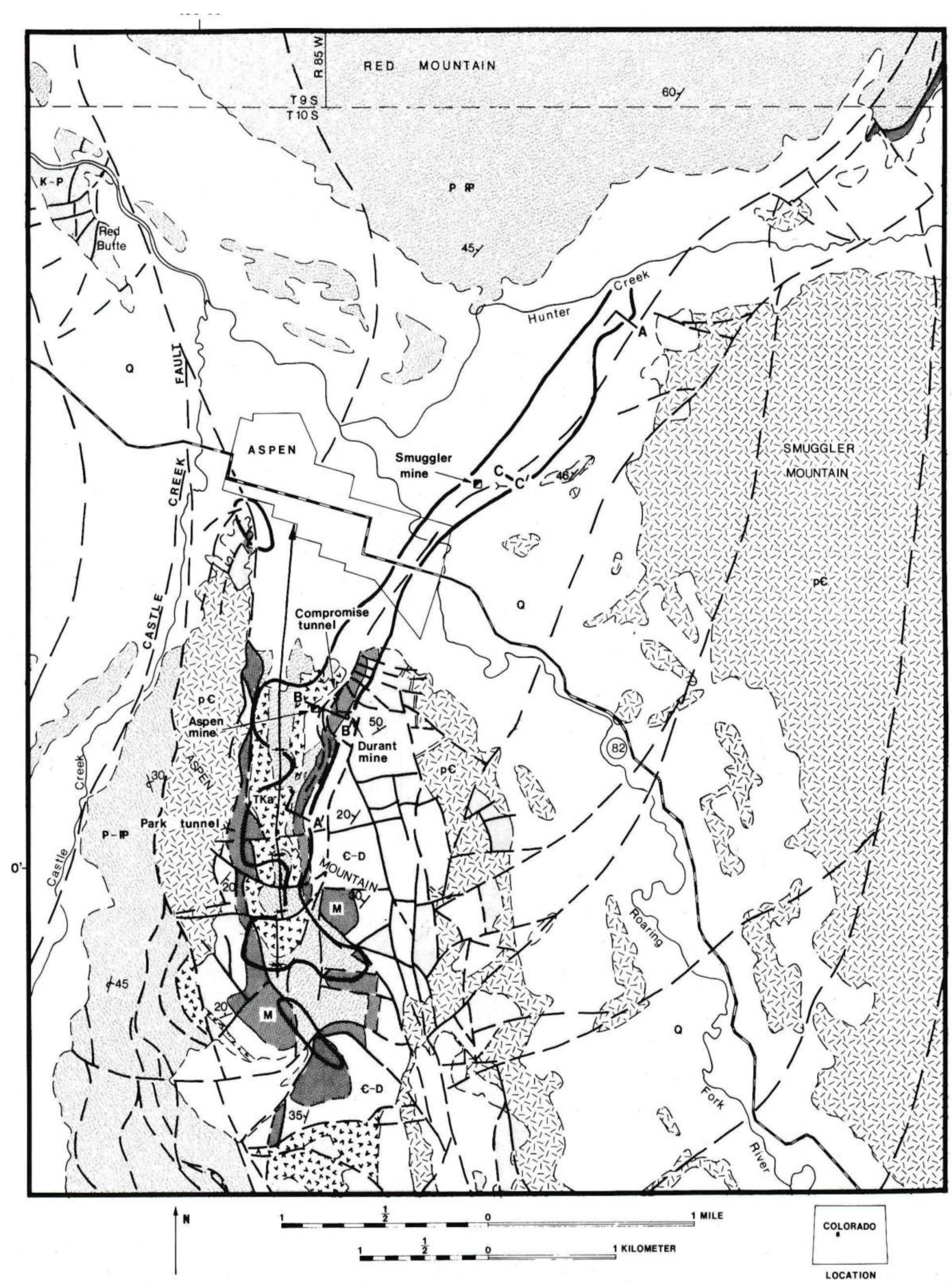

Figure 1. Simplified geologic map of the Aspen area (modified from Bryant, 1971). Symbols used with map: Q – Quaternary deposits, TKa – Aspen Mountain sill, P-IP – Permian & Pennsylvanian rocks, M – Leadville Limestone, C–D – Devonian, Ordovician and Cambrian rocks, pC – Proterozoic rocks. Area of significant Ag-Pb-Zn production within bold, solid line.

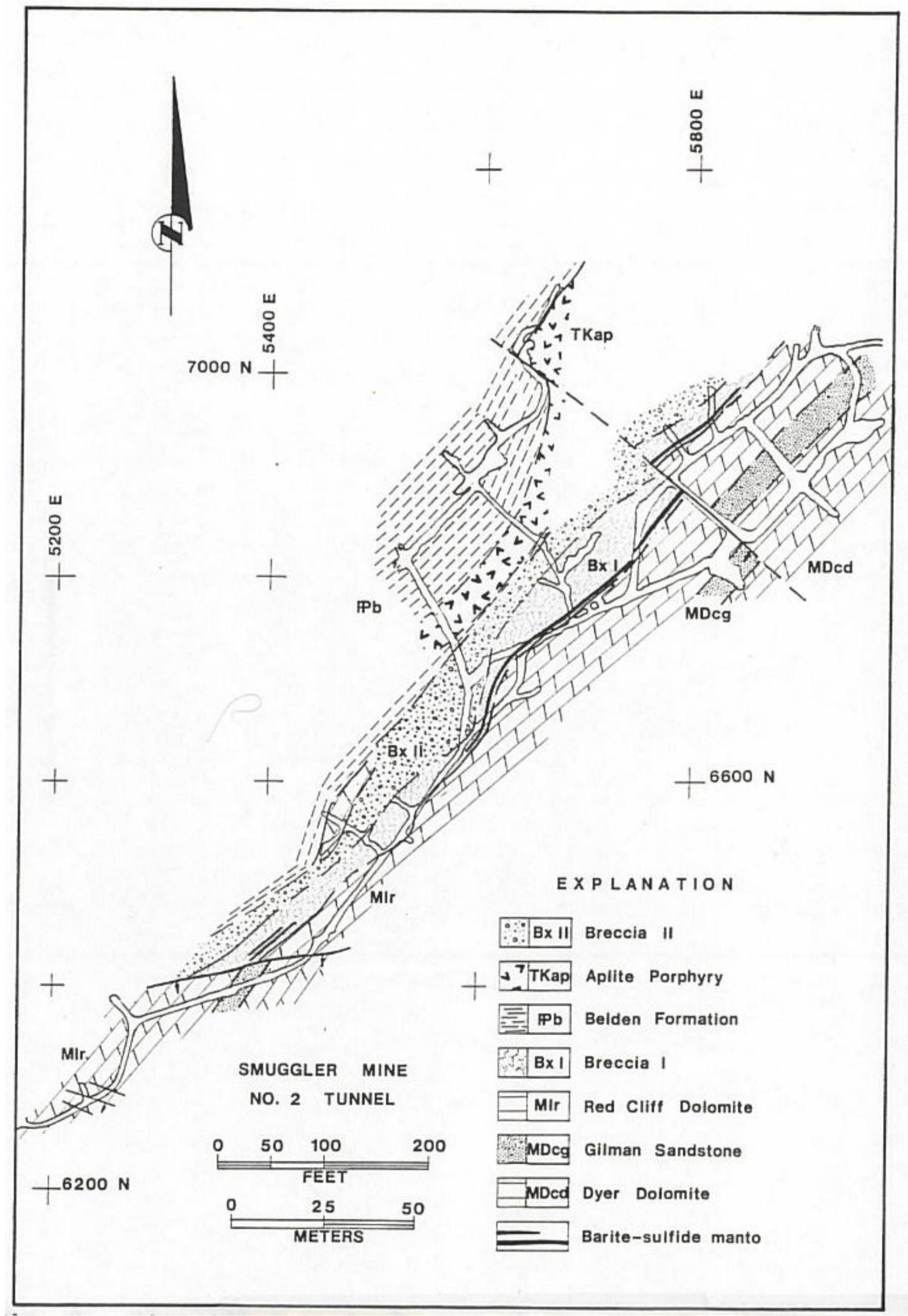

Figure. 2. Geologic map of the Smuggler number 2 tunnel showing the locations of the two breccia masses, manto, and aplite porphyry relative to Leadville Limestone and Belden Formation. Map from Stegen (1988).

hosting the manto mineralization. The stops will also observe the character of the mantos and alteration features developed within limestone, breccia bodies, and a Laramide-aged sill situated proximal to the mineralization.

Stops 2 through 6: Aspen Mountain

For the remainder of the field stops, we will drive through the town of Aspen and up the Summer Road to the Spar Gulch area of lower Aspen Mountain. Please carpool with others to reduce vehicles on Aspen Mountain because parking is limited. From the Smuggler mine proceed on South Original Street to the Aspen Mountain Summer Road and drive the dirt road to the compressor building and turn left. Continue on this secondary dirt road to a small open valley (Vallejo Gulch) then past the prominent ridge (Spar Ridge). Park along the dirt road that leads into Spar Gulch and from here visit stops 2 through 5 (Figure 3).

Stop 2: Spar Ridge Road Cut

At this stop the Red Cliff and Castle Butte members of the Leadville Limestone are exposed within the road cut (Figure 4). The Contact Breccia, an important host to the manto mineralization is poorly exposed between the two Leadville Limestone units. Barite, some with disseminated malachite occurs as float in the lower part of the road cut. We are immediately north of a discovery location for the district (Spar adit). Please do not attempt to climb into the upper part of the exposure as we will see the breccia and barite mineralization at our next stop.

Stop 3: Spar Mine and Durant Decline

In this vicinity are several mines important to the discovery, early mining, and apex-sideline litigation of the district. The first stop is a caved adit of the Spar mine. The adit was driven within the Contact Breccia and here contains barite with trace malachite. According to Henrich (1889), about six meters inside the portal a winze was sunk on the Contact Breccia containing a silver-rich orebody. From the winze, large quantities of high-grade silver ore were mined including that from the "extremely rich" Bridal Chamber (no grade provided). We will traverse south along the trace of the Contact Breccia to the Durant decline. The Castle Butte Limestone forms the prominent cliff above us. The decline was driven down along the Contact Breccia into the Hooper orebody, a previously discovered high-grade manto in the Emma and Aspen mines located east of here (Figure. 5). South of the Durant are five other declines (including the Visino) that were driven from the apex or surface outcrop of the breccia downward to confirm the continuity of mineralization in support of their position with the claims litigation.
Breccia and here contains barite with trace malachite. According to Henrich (1889), about six meters In this vicinity are several mines important to the discovery, early mining, and apex-sideline litigation of the district. The first stop is a caved adit of the Spar mine. The adit was driven within the Contact

Stop 4: Compromise Tunnel

This tunnel or Court drift was driven as a court-mandated compromise between the apex and sideline claim owners lawsuit. A short distance from the portal the drift intersects the Durant decline along the Contact Breccia. The drift then followed the lower contact of breccia within the Aspen Mountain syncline and eventually joined the Traynor tunnel on West Aspen Mountain. The Emma and Aspen mines each sank shafts in Vallejo Gulch (Figure 5) that collared in Aspen Mountain sill and below

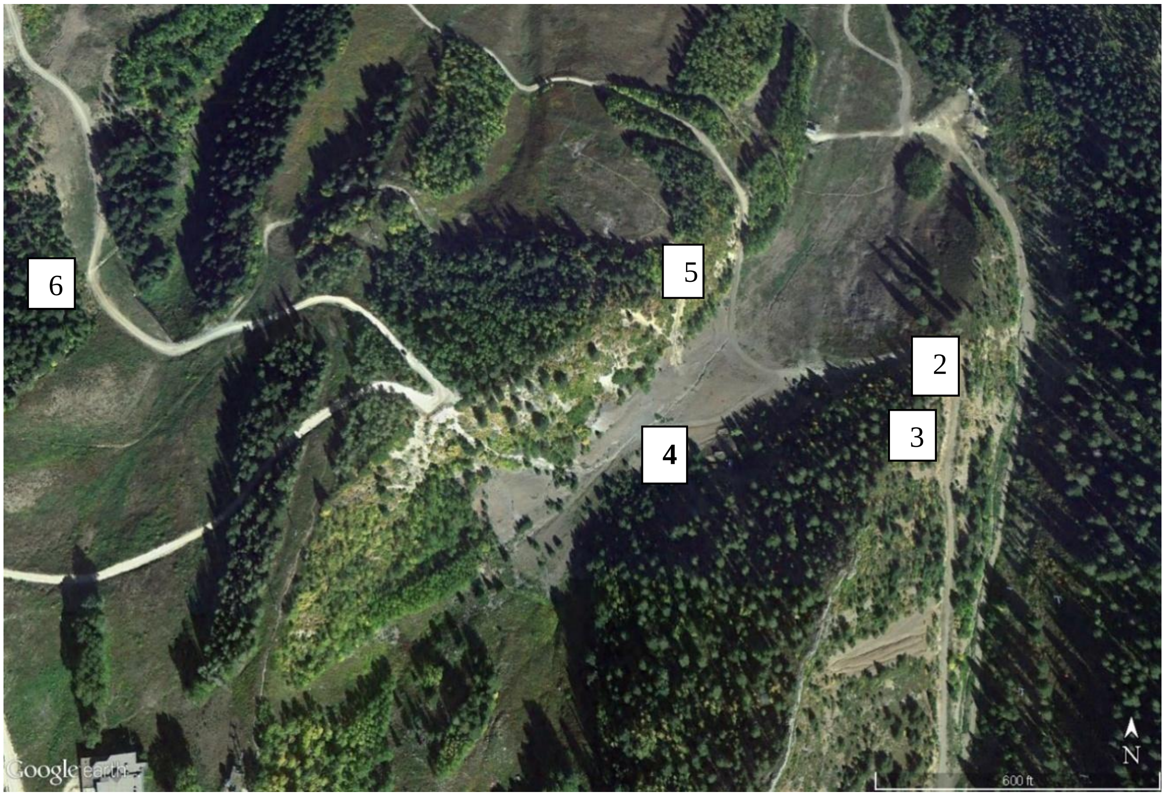

Figure 3. Field trip stop locations at the Spar Ridge, Vallejo Gulch, and Pioneer Gulch areas of lower Aspen Mountain

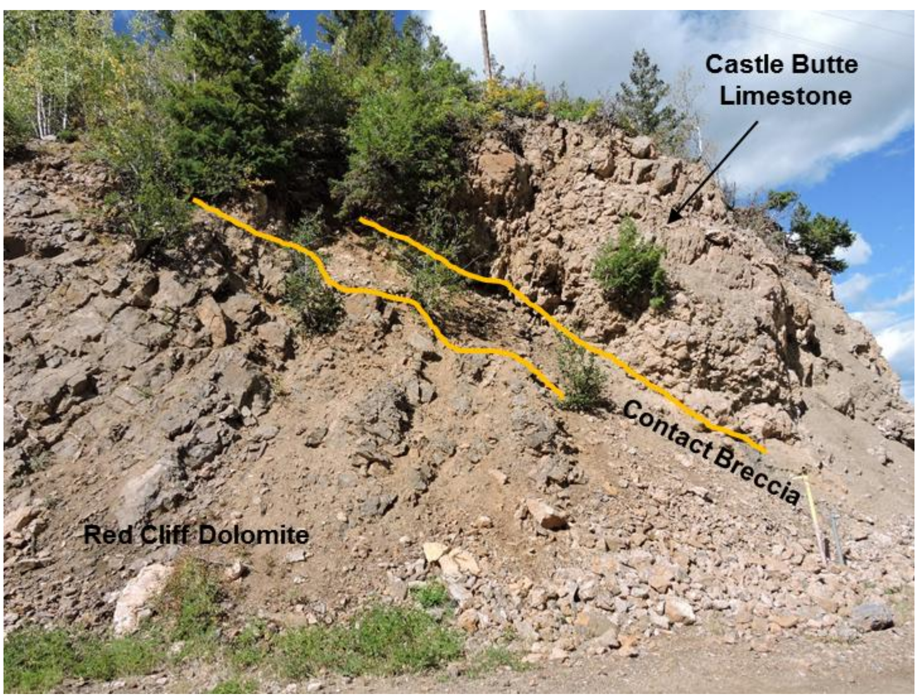

Figure 4. Road cut exposure of Leadville Limestone and Contact Breccia from north area of Spar Ridge.

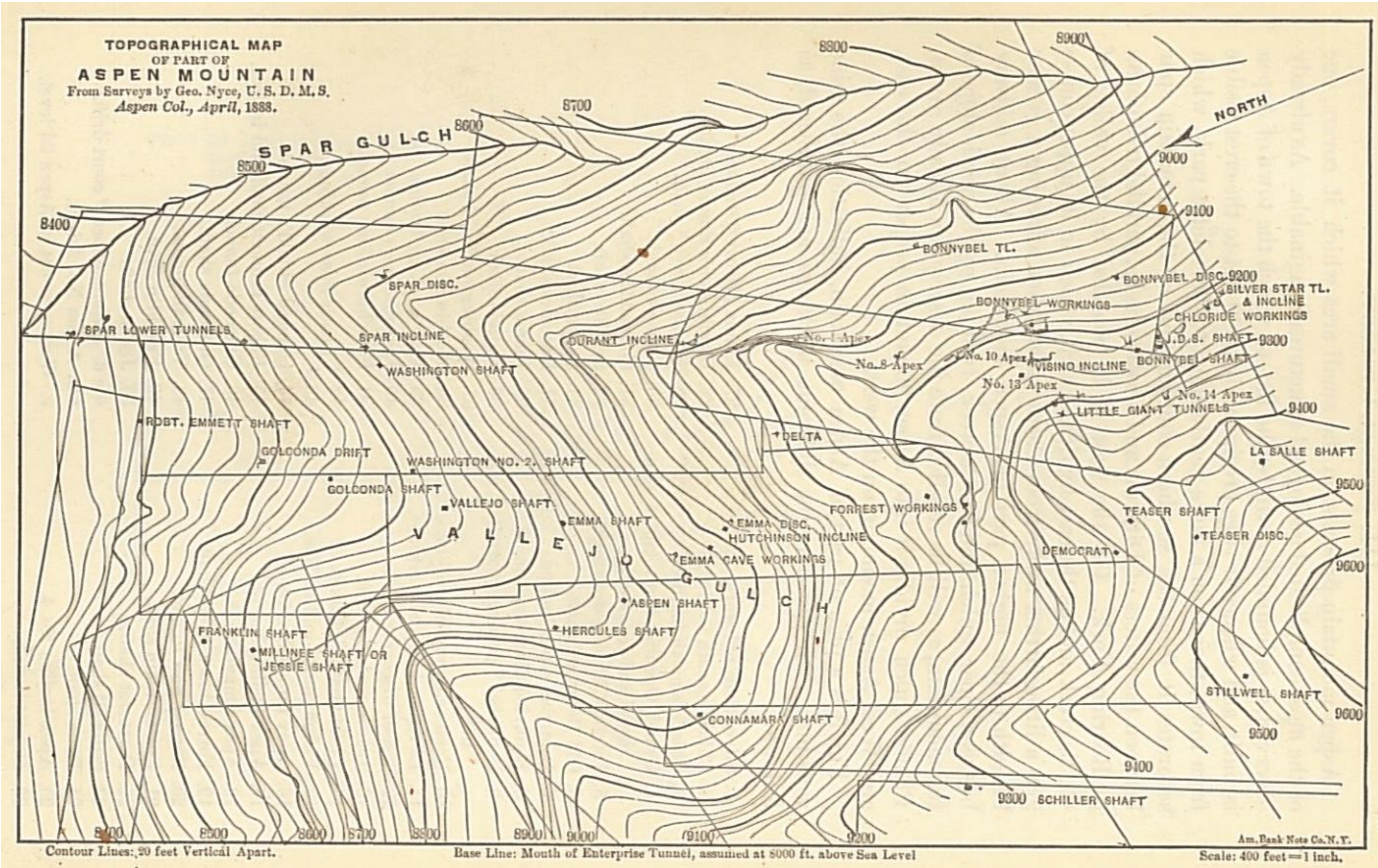

Figure 5. Map of the Vallejo Gulch and Spar Gulch area of Aspen Mountain from Henrich (1889).

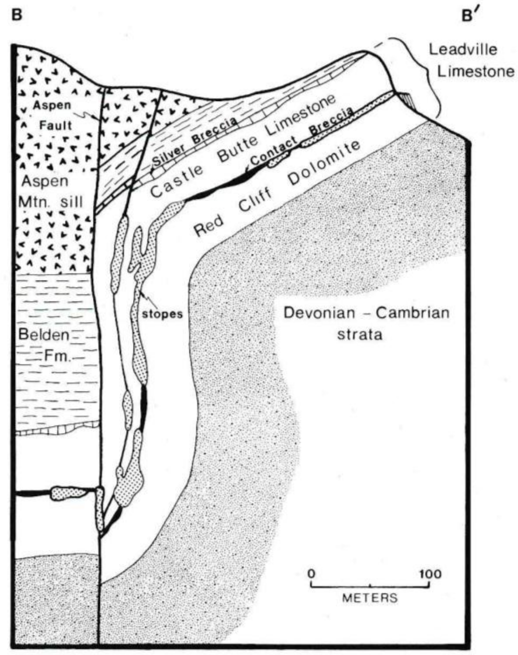

Figure 6. West – East cross section view to the north through Emma and Aspen mines, Vallejo Gulch (section from Spurr, 1898).

intersected silver-rich mantos within the Contact Breccia at depths of 30 and 45 meters respectively (Henrich, 1889). The orebodies, particularly in the Aspen mine were "enormously" rich and were believed to be the incentive for the protracted litigation between claim owners (Henrich, 1889). The orebodies were mined from the Contact Breccia and also along the Aspen fault (Figure. 6).

Stop 5: Aspen Mountain Sill

Our next stop involves a short traverse westward across the Aspen and Emma mine dumps to the ridge west of Vallejo Gulch. A road cut exposes Aspen Mountain sill, an aplite porphyry that occurs as a sill in the lower part of the Belden Formation (Bryant, 1979). The aplite porphyry contains phenocrysts of sericitized feldspar and mafites set within a fine-grained sericitically-altered groundmass (Stegen, 1988). Pyrite is disseminated and also found within thin veinlets with quartz. The sill extends from Smuggler Mountain at the north to Tourtelotte Park on the south, or within the area of the productive mines in the district. Aplite porphyry fission track dates in the district average about 30 Ma (Bryant et al., 1990) and furnish no definite evidence for the age of the ore deposits.

We will return to the vehicles and drive down to the Summer Road and turn left at the compressor building and proceed into Pioneer Gulch and turn left at a side road and park.

Stop 6: Jasperoids in Pioneer Gulch (Optional)

At this optional stop the purpose is to examine jasperoid within Leadville Limestone near West Aspen Mountain. The term "jasperoid" was first introduced by Spurr (1898) for exposures in the Aspen district.

According to Spurr (1898), jasperoid accompanied the ore deposition but is more widespread and is in areas with no known mineralization. In a study of jasperoid at Aspen, Lovering (1972) noted some contain pyrite, sphalerite, galena, and barite and anomalously rich in lead, zinc, copper, and barium. A subset of these samples contain anomalous values for Fe, Mn, Ag, Be, Co and Mo.

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GOLD AND SILVER DEPOSITS IN COLORADO SYMPOSIUM

EXPLORATION

DISCOVERY

PRODUCTION

DEVELOPMENT

BERTHOUD HALL, COLORADO SCHOOL OF MINES
GOLDEN, COLORADO
JULY 20-24, 2017