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MINERALIZATION IN THE SAN JUAN MOUNTAINS, COLORADO

by

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THESIS

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Silverton-Type mineralization in the western San Juan Mountains, Colorado

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REGIONAL SETTING

Tertiary epithermal and mesothermal base and precious metal deposits occur in Precambrian crystalline rocks, Paleozoic and Tertiary sedimentary rocks, and Tertiary volcanic rocks within the San Juan Volcanic Field of southwestern Colorado (figure 1). Mineralization occurred between 5 and 15 myr following igneous activity associated with resurgent doming of the San Juan and Uncompahgre calderas 28 Ma and the formation of the Silverton caldera 27.5 Ma (Casadevall and Ohmoto, 1977). In the western portion of the field around Ouray and Silverton, mineralization occurs as fissure veins or lodes, mineralized breccia pipes, replacement bodies, and porphyry-type disseminations and stockworks. This spectra of mineralization shall be hereafter referred to as "Silverton-Type".

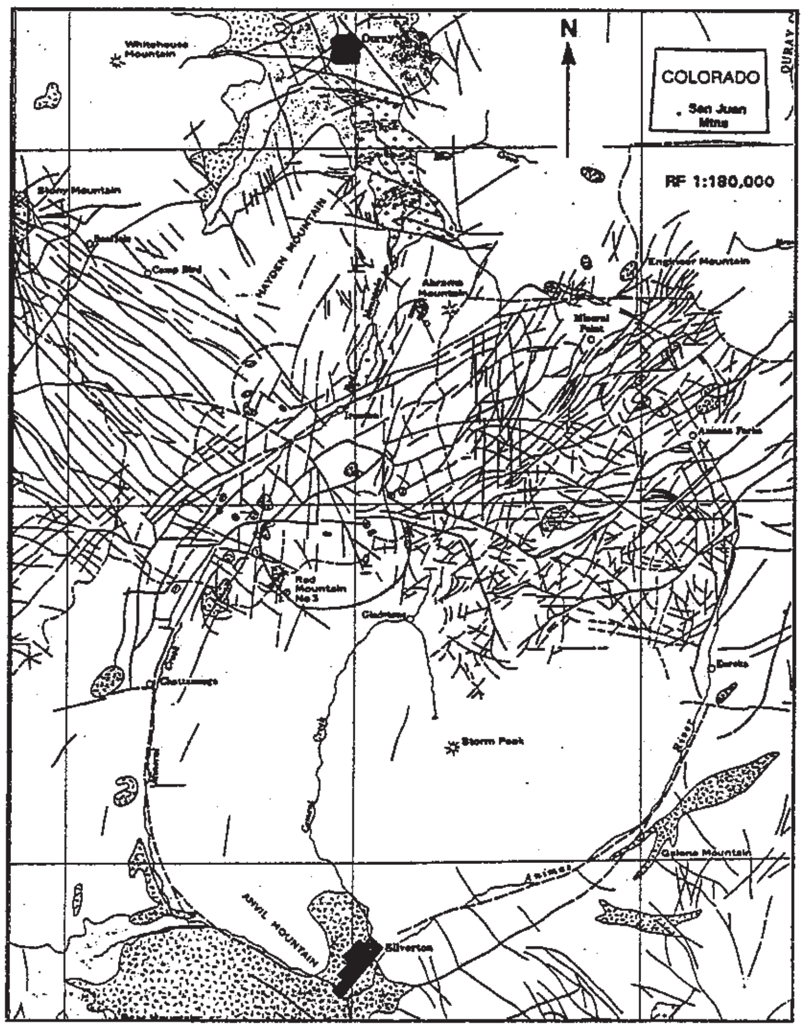

Figure 1. Location map showing structure related to Tertiary volcanism (Burbank and Luedke, 1969).

ORE DEPOSIT TYPES

Fissure Veins

Within the study area the most common as well as the most economically important ore deposits are fissure veins. These veins are generally vertical or near vertical and range from a few centimeters to tens of meters in width. More commonly widths are on the order of 5 feet although many variations are noted due to pinching and swelling of the veins. Ransome (1901) reported that the Sunnyside vein was up to 50 feet wide at the surface whereas the Little Mary vein, also of the Sunnyside, is nothing more than a limonite-stained fracture at the surface (Westervelt, 1994). Faults hosting these veins show little or no offset. This can limit ore deposition, for structures with great offset generally provide more open space as seen at Creede, Colorado (Cross and Larsen, 1935). These veins were deposited as open space filling along faults and fractures developed in response to resurgent doming of the San Juan and Uncompahgre calderas approximately 28 Ma ago and the eruption and subsequent collapse of the Silverton caldera some 27.5 Ma (Lipman and others, 1973).

Mineralization followed some 5-20 Ma after deformation and volcanic activity. Altered wall rock adjacent to vein material from the Sunnyside mine has been Rb/Sr dated at 13.0 - 16.6 Ma (Casadevall and Ohmoto, 1977). These ages are representative of the most recent hydrothermal leaching of Sr^{87} from the wall rocks and most likely the contemporaneous mineralization. These dates are in reasonable agreement with other mineralization in the general area. At the Camp Bird mine, K-feldspars from two distinct zones; a high level ($\simeq$ 3450m elev.) vein and a deep ($\simeq$2790m elev.) replacement orebody yielded dates of 10.5 ± .5 Ma and 10.2 ± .3 Ma respectfully (Lipman and others, 1976). Fission track dating of apatite from the Camp Bird shows a date of 7.0 ± 4.8 Ma (Billings, 1980). The Idarado mine mineralization has a K-Ar date from K-feldspar of 17.0 ± .6 Ma. This disparity of dates is borne out by field observations of cross cutting relationships of dikes and veins seen within the Camp Bird and Idarado mines (Lipman and others, 1973). This clearly indicates at least two stages of mineralization or, more likely, one long period of mineralization, 7-15 myr in duration, during which there were episodic pulses in different areas.

Most of the veins are hosted by altered quartz latite, tuffaceous sediments and flow breccias. Pre-ore propylitization or pervasive wall rock alteration (PWRA) is district wide. Vertical zonation of the PWRA has been documented at the Sunnyside mine by Casadevall and Ohmoto (1977). At the surface (≈3900-4000 m elev) the alteration assemblage is primarily chlorite, calcite and pyrite with locally minor epidote increasing with depth. This grades downward into a zone where gypsum is commonly present. At depths below the American Tunnel (≈3260m elev.) the assemblage is tremolite-actinolite, epidote, chlorite, anhydrite, pyrite and minor sericite. This gives way to quartz, sericite, andradite, anhydrite, and pyrite at greater depths (≈2500-2600 m elev.). A vein related alteration envelope commonly found next to the mineralized structures varies in width from a few millimeters to as much as a few meters. Intense silicification identifies the zone closest to the vein. This grades laterally into a zone of quartz, sericite, pyrite, and locally zunyite [$Al_{13}Si_5O_{20}(OH,F)_{18}Cl$]. This zones yields to a transitional area in which primary textures are preserved and apatite appears. Farther from the vein, sericite dominates until the effects of the vein alteration are no longer apparent overprinting the PWRA.

Vein mineralogy typically consists of quartz (25-50%), sphalerite, galena, pyroxmangite ($MnSiO_3$), pyrite, and considerably lesser quantities of other ore and gangue minerals. Detailed mineralogy of the study area is addressed later in this study. Although well over 50 mineral species have been documented from these veins, most individual veins are restricted to only a few ore minerals accompanied by similarly few gangue minerals.

These veins commonly show episodic mineralization. At the Sunnyside mine six distinct stages of mineralization have been identified (Casadevall and Ohmoto, 1977). At the Osceola mine 3 stages have been identified (Cooper and others, 1980). At least 4 stages are known at the Idarado mine (Hillebrand, 1957). Five hypogene stages are present at the Dunmore mine although the first is possibly related to Ouray-type mineralization (Kelley and Silver, 1946). A generalized composite paragenetic sequence is presented in Figure 2. Vertical and lateral zonation vary considerably among the lodes of the study area although the more auriferous deposits tend to be above and more centrally located than those with high silver values. Very little supergene enrichment has been encountered with the notable exception of mineralized breccia pipes. This is due to the great relief and consequential high erosion rates for the area and relatively recent glaciation (Ransome, 1901).

Fluid-inclusion studies from the Sunnyside mine indicate that most mineralization occurred between 250 and 320°C with a late and volumetrically insignificant stage of mineralization occurring between 170 and 245°C. The depositional pressure was between 110 and 220 bars for the main mineralization and approximately 35 bars for the later stage. Freezing studies concluded that the ore fluids were largely K-Na-Ca solutions ranging from 0.03 to 0.27 wt.% K; 0.23 to 0.65 wt.% Na; and 0.03 to 0.26 wt.% Ca (Casadevall and Ohmoto, 1977). These figures are in general agreement with data from the Osceola mine where temperatures were found to be 249, 255.6, and 230.5°C from sphalerite, calcite, and quartz respectfully. Although no freezing data is available from the Osceola, the complete lack of daughter minerals in inclusions suggests a very dilute ore fluid (Cooper and others, 1980). Similar data from the Pride of the West and Little Fanny mines indicate a temperature range of 201 to 312°C from solutions containing 1 to 5 wt.% NaCl equivalent salinity (Hardwick, 1984). Inclusion studies from the Camp Bird mine show a slightly different range with a number of fluorite samples indicating temperatures of 175-180°C with 0.9 wt.% NaCl equivalent salinity (Hutchinson, 1988). Camp Bird sphalerite was formed at about 250°C. Evidence of

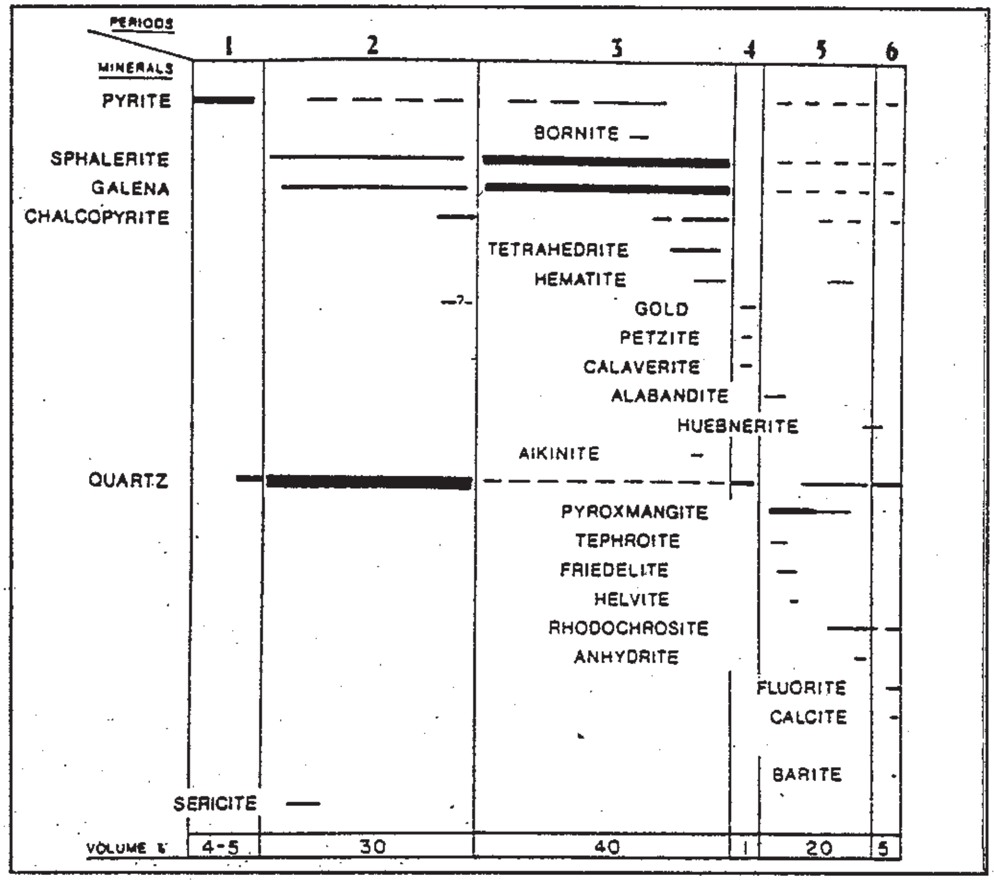

Figure 2. Generalized Paragenetic Sequence of Silverton-Type Mineralization as seen at the Sunnyside Mine (Casadevall and Ohmoto, 1977).

boiling is presented within comb quartz which does not have constant liquid to vapor ratios, indicating temperatures of less than 200°C. Limited data collected to date suggests that boiling was a larger factor at the Camp Bird than elsewhere in the district although one sample from the Sunnyside showed evidence of boiling.

Sunnyside δD and $\delta^{18}O$ studies indicate that the ore fluids were meteoric in nature (Doe and others, 1979). These fluids experienced isotopic exchange with the country rocks during the main mineralization stage. Little if any exchange occurred during the late stage. Values of $\delta^{13}C$ for the late stage mineralization from calcite and rhodochrosite are indicative of a limestone source for the carbon in calcite, whereas a meteoric or magmatic source of carbon is suggested for the earlier rhodochrosite. Lead and rubidium/strontium studies indicate that the metal in the ores of the Sunnyside were leached from the Precambrian basement as well as the Tertiary volcanic pile. All lead isotope data from the study area is indicative of a basement source for the lead found in these ore deposits. This is strong evidence to support a convecting cell of circulating meteoric waters leaching metal from both the Tertiary volcanics and the Precambrian basement with upward ascent from the basement to various widespread depositional sites. Ore deposition was largely the result of decreasing temperatures (Doe and others, 1979). An alternative deposition scenario indicates that Fe^{2+} in wallrock silicates reduced S^{6+} in the sulfate anion of the ore fluids to S^{2-} which triggered sulfide precipitation (Casadevall and Ohmoto, 1977).

Breccia Pipes

Several very rich deposits of copper, lead, and silver were mined from ore chimneys within breccia pipes near Red Mountain Pass, Colorado. These pipes are largely confined to a belt of fractured volcanic rock within a zone of ring faults along the northwest margin of the Silverton caldera (Hillebrand and Kelley, 1957). This belt, striking N 30° E, is approximately 7 miles in length and over a mile wide. The breccia pipes were formed when hot solutions and gases, derived from magma at depth, rose along vertical to near vertical fractures in the volcanic rock. These fluids and gasses brecciated and fluxed the rock along their paths (Burbank and Luedke, 1969). Subsequently, these rocks were metasomatized. This reconstituted material was then at least partially fused into competent rock, albeit leaving great amounts of open space near the surface. Field evidence suggests episodic brecciation in many of the

pipes. Advanced argillic alteration extends over 5000 feet vertically. Individual pipes are up to 2000 feet in length and up to 1200 feet in width. Most pipes are elliptical in plan view due to elongation along primary structures (Fig. 3). Some of the smaller pipes have sharp contacts with the volcanic country rock whereas the larger, better developed pipes are commonly surrounded by vertically sheeted silicified country rock. Within many of the breccia pipes there exist mineralized chimneys.

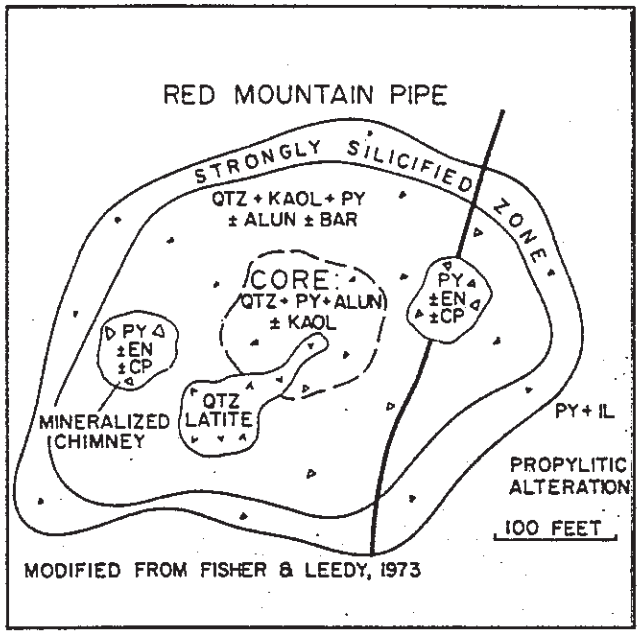

Figure 3: Plan view of Typical Breccia Pipe.

These chimneys show distinctive vertical zonation (Fig. 4). This zonation has been telescoped over a 1000 foot vertical range (Park and McDiarmid, 1975). The deepest workings in the district indicate that the chimneys consist of massive pyrite at the bottom. Overlying the pyritic zone is a zone of pyrite and chalcopyrite which grades upward into a zone of copper and silver minerals dominated by bornite, secondary copper minerals, and sulfosalts. Nice crystals of Enargite (Cu_3AsS_3) can be found on most of the dumps. Nearer to the surface the ore becomes markedly plumbiferous with lesser amounts of silver. In this zone metallic carbonates and silver salts are not uncommon (Ransome, 1901). In all chimneys, the gold shows an increase with depth. In some of the pipes, mineralization at depth is restricted to vein filling along strong north-south fissures (Burbank and Luedke, 1969).

The entire chimney is usually enveloped laterally by a blue-grey fine grained quartz and is capped by a vuggy leached siliceous sinter. Pervasive throughout the chimneys and cutting all zones of mineralization are narrow veinlets of galena and sphalerite indicating several stages of mineralization (Bejnar, 1957). Gangue minerals are characterized by a number of different clays as well as quartz, sericite, zunyite, barite, fluorite, illite and pyrophyllite (Burbank and others, 1988). The clay minerals have been reported by previous investigators to be largely kaolinite with lesser amounts of dickite, beidellite $[(Na,Ca/_2)_{0.33}Al_2(Si,Al)_4O_{10}(OH)_2 \cdot nH_2O]$, and nacrite $[Al_2Si_2O_5(OH)_4]$ although unpublished work by the USGS indicates that a good deal of the clay is

actually rectorite which is interstratified pyrophyllite-vermiculite (Luedke, 1994). Lead isotope data is inconclusive as to the source of the metal contained in these deposits, although a well-mixed solution is indicated (Doe and others, 1979).

The pipes are intimately associated with small quartz latite intrusions or plugs which have been radiometrically dated at 22.7 to 22.6 Ma (Lipman and others, 1976). These dates would tie the pipes temporally into the Lake City caldera events, some 20 miles to the east. The date of the mineralization of the chimneys is thought to be around 22 Ma, however the fission track dating of apatite from the National Belle mine yields an age of 12.9 ± 2.6 Ma which more closely coincides with the dates of vein mineralization in the region (Lipman and others, 1976). Since apatite is readily annealed at relatively low temperatures, it is likely that this younger date is simply overprinting.

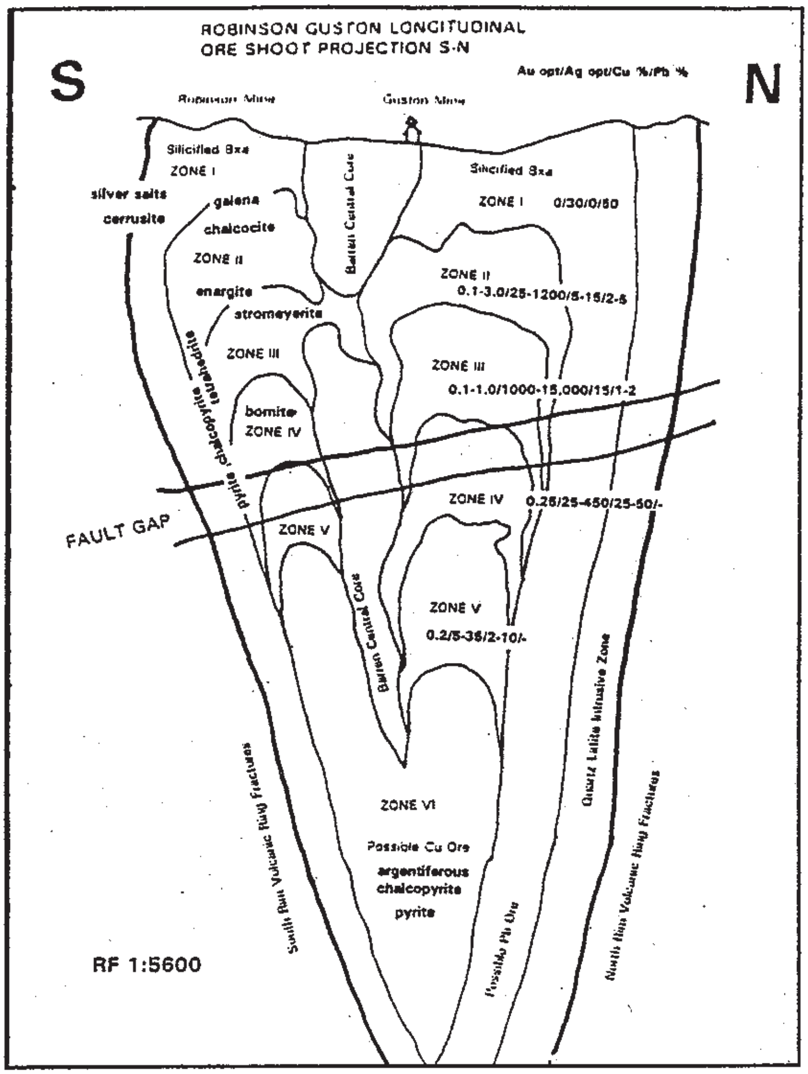

Figure 4: Generalized Cross Section of a Typical Mineralized Breccia Pipe (compiled from private company reports).

Replacement Orebodies

Lead and zinc with lesser amounts of silver and gold are found in ore minerals replacing sedimentary rocks within the study area. These sedimentary layers are

commonly discontinuous blocks of Leadville Limestone engulfed in Tertiary volcanic rocks within or adjacent to known caldera structures. Outward from the caldera margins, replacements are known to occur in and along several favorable horizons, namely:

Tertiary............Telluride Conglomerate

Triassic............Dolores Formation

Permian.............Cutler Formation

Pennsylvanian........Hermosa Formation

Mississippian........Leadville Limestone

Devonian............Ouray Limestone

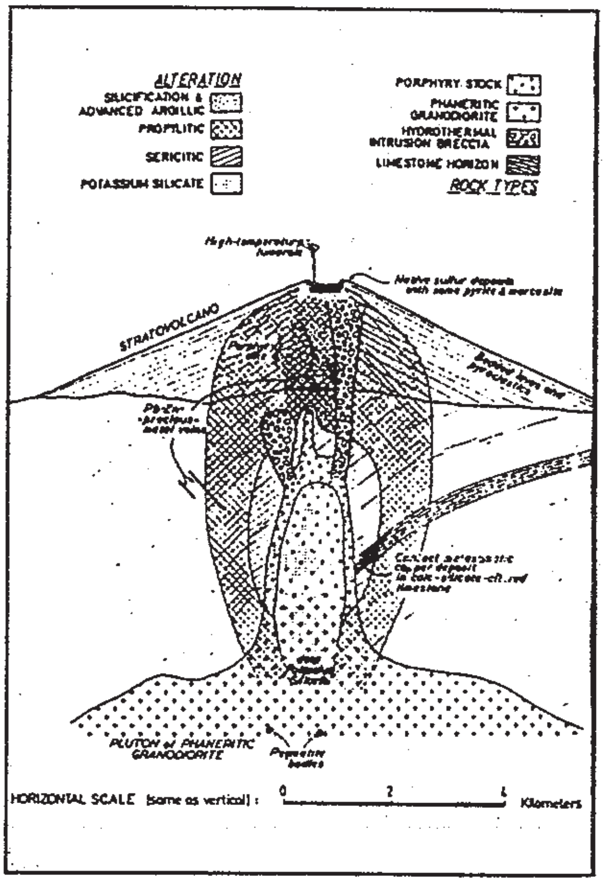

Figure 5. Generalized cross section of a buried porphyry system and its relationship with veins, breccia pipes, and replacements in the San Juan Mountains, Colorado (Sillitoe, 1973).

These replacements range from small sporadic lenticular pods to massive, completely replaced beds of significant tonnage. These replacement bodies are always in close association with mineralized fissure veins. The mineralogy of these replacement bodies is generally much less complex than that of the vein type deposits of the area. Principal ore minerals , in order of abundance, are sphalerite, galena and chalcopyrite. Common gangue minerals include quartz, pyroxmangite, rhodochrosite, calcite, pyrite, epidote, piedmontite $[Ca_2(Al,Mn^{3+},Fe^{3+})_3(SiO_4)_3(OH)]$ and chlorite.

Porphyry-Type Mineralization

Although no economically viable deposits of this type have ever been exploited in the western San Juans, they have been identified in several areas. These deposits

underlie the aforementioned mineralization, sometimes at great depths (Fig. 5). Molybdenite stockworks such as that observed in the Railroad porphyry on the south side of Red Mountain Pass, are found sporadically throughout the area. In general these deposits have a characteristic alteration zonation consisting of an advanced argillic zone proximal to mineralization and a more distal phyllic zone.

MINERALOGY

The mineralogy of the various ore deposits in the area is rather varied in that 77 different species of ore and gangue minerals have been positively identified (Table I). Many more have been cited in the literature but have not been authenticated.

Table I.

ORE MINERALS:

Acanthite	Ag_2S	Polar Star and Palmetto mines near Engineer Pass, mines of Maggie Gulch; as well as an amorphous black soot at NY City lode at Silver Lake.[1]
Aikinite	$PbCuBiS_3$	Present at the Dunmore, Sunnyside, and Alaska(?) mines.[3,4]
Alaskaite	$Pb(Ag,Cu)_2Bi_4S_8$	Abundant at the Alaska mine and Acupulco claim.[1] May actually be a combination of Matildite and aikinite.[4]
Anglesite	$PbSO_4$	Common supergene mineral.[1]
Atacamite	$Cu_2(OH)_3Cl$	Supergene mineral found in the mines of Kendall Mountain.[4]
Azurite	$Cu_3(CO_3)_2(OH)_2$	Supergene mineral common in areas of cupriferous mineralization.[1]
Beegerite	$Pb_8Bi_2S_9$	Barstow mine and mines of Poughkeepsie Gulch.[1]
Bismuthinite	Bi_2S_3	Niegold claim, Cunningham Gulch; and Sunnyside mine.[1,2]
Bismutite	$Bi_2(CO_3)O_2$	Alteration product of primary Bismuth minerals.[4]
Bornite	Cu_5FeS_4	Principal "deep" ore at the Yankee Girl and Guston mines; commonly argentiferous.[1]
Bournonite	$CuPbSbS_3$	With pyrite and zunyite in the Zuni and Yankee Girl mines.[1]
Calaverite	$AuTe_2$	Camp Bird and Silver Ledge mine.[1]
Cerargyrite	$AgCl$	Noted at the Saratoga mine in Ironton Park.[1]
Cerrusite	$PbCO_3$	Widespread in small quantity; noted from the Zuni, Silver Lake, and breccia pipe mines.[1]
Chalcocite	Cu_2S	Supergene mineral in upper levels of breccia pipes.[1]
Chalcopyrite	$CuFeS_2$	Abundant at the Titusville near Silver Lake and at the breccia pipes; common elsewhere; auriferous at the Sound Democrat and at the pipes, and is often argentiferous at the pipes.[1]
Colusite	$Cu_3(As,Sn,V,Fe,Te)S_4$	Noted at the National Belle mine.[4]
Copper	Cu	Sunnyside Extension, Royal Tiger, and Tom Moore mines; at the latter, Cu occurs with heubnerite cutting "Silverton Type" mineralization.[1]
Cosalite	$Pb_2Bi_2S_5$	Yankee Girl and Alaska mines.[1]
Enargite	Cu_3AsS_4	Principal ore mineral of most of the breccia hosted orebodies of Red Mountain.[1]
Friebergite	$(Cu,Fe,Ag)_{12}Sb_4S_{13}$	Philadelphia, Mountaineer, and Pride fo the West mines of Cunningham Gulch; also reported from Red and Sultan Mountains, Silver Lake, and Picayune and California Gulches.[1]
Galena	PbS	Ubiquitous; commonly argentiferous when fine grained with bluish tint.[1]
Galenobismutite	$PbBi_2S_4$	Yankee Girl and Alaska mines.[1]
Gold	Au	Occurs as free gold in "arborescent" sheets in quartz and pyroxmanganate; as crystals on faces of quartz crystals in vugs; embedded in lightly colored sphalerite, galena, or molybdenite(?); occurrences in bunches in Savage Basin and Arrastra Gulch began the San Juan mining boom of the 1870's.[1]
Guitermanite	$Pb_3As_2S_6$	Anvil Mountain; with pyrite, bournonite, enargite, barite, kaolinite, and $PbSO_4$[1].
Hessite	$AgTe$	Magnet mine; and auriferous variety at Barstow mine.[1]

Huebnerite	$MnWO_4$	Associated with quartz and fluorite; abundant at the Adams mine on Bonita Mountain; also Sultan Mountain.[1] First noted in the U.S. at the Royal Albert mine near Ouray.[4]
Kobellite	$Pb_2(Bi,Sb)_2S_5$	Silver Bay mine.[1]
Malachite	$Cu_2CO_3(OH)_2$	Supergene mineral widespread in areas of cupriferous mineralization.[1]
Matildite	$AgBiS_2$	Noted from the Camp Bird mine.[4]
Molybdenite	MoS_2	Sporadicly occurs in deeper workings throughout the area. A dubious report of free gold and molybdenite was reported from the Sunnyside Extension.[1]
Petzite	$AuAg_3Te_2$	Present at the Sunnyside mine.[3]
Proustite	Ag_3AsS_3	Polar Star, Yankee Girl, and Genesee-Vanderbilt mines along with other minor occurrences.[1]
Pyrite	FeS_2	Pervasive throughout the area; in all types of deposits; auriferous at the Silver Lake mine.[1]
Scheelite	$CaWO_4$	Sunnyside mine and most likely same locales as heubnerite/wolframite.[2]
Silver	Ag	Pride of the West , Antiperiodic, Sunnyside Extension and Aspen mines.[1]
Sphalerite	ZnS	Always with galena, commonly associated with Au when lightly colored.[1]
Stibnite	Sb_2S_3	Sultan Mountain Mines.[1]
Tennantite	$(Cu,Fe)_{12}As_4S_{13}$	
Tetrahedrite	$(Cu,Fe)_{12}Sb_4S_{13}$	Most important ore mineral common throughout the area.[1]
Wolframite	$(Fe,Mn)WO_4$	Empire Victoria mine.[1]
Zinkerite	$PbSb_2S_4$	Noted from the Brobdignag claim near Red Mountain.[1]
Tl and Se minerals:		Although none of the species listed has been positively identified, their existence is highly probable as up until the 1960's the only domestic recovery of Thallium was from the lead and zinc ores of the San Juan and La Plata Mountains. Furthermore up to 1.5% of the mattes from zinc box percipitates at the Camp Bird mine were Selenium.[4]
Crookesite	$(Cu,Tl,Ag)_2Se$	
Hutchinsonite	$PbS{\cdot}(Tl,Ag_2)S{\cdot}2As_2S_3$	
Lorandite	$Tl_2S{\cdot}As_2S_3$	
Vrbaite	$Tl_2S{\cdot}3(As,Sb)_2S_3$	

GANGUE MINERALS:

Alabandite	MnS	From the Sunnyside mine.[4]
Alleghanyite	$Mn_5(SiO_4)_2(OH)_2$	From the Sunnyside mine.[4]
Aluminite	$Al_2(SO_4)(OH)_4{\cdot}7H_2O$	Rarely at the National Belle mine.[1]
Alunite	$KAl_3(SO_4)_2(OH)_6$	Pervasive throughout the Red Mountain area.[1]
Anhydrite	$CaSO_4$	As an alteration product in the Sunnyside mine.[3]
Ankerite	$Ca(Fe^{2+},Mg,Mn)(CO_3)_2$	Conspicuous at the Mineral Farm area.[4]
Barite	Ba_2SO_4	Common throughout the area; often present with Ag-Pb ores.[1]
Calcite	$CaCO_3$	Ubiquitous; often very late stage mineralization.[1]
Chlorite	$(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2$-$(Mg,Fe)_3(OH)_6$	Ubiquitous.[1]
Diaspore	$AlO(OH)$	Alteration product from the National Belle mine.[4]
Dickite	$Al_2Si_2O_5(OH)_4$	One of the dominant alteration species present at the National Belle.[4]
Dolomite	$CaMg(CO_3)_2$	
Epidote	$Ca_2(Al,Fe)Al_2O(SiO_4)$-$(Si_2O_7)(OH)$	Ubiquitous.[1]
Fluorite	CaF_2	Massive veins in Picayune and California gulches and E. of Lake Como; associated with Au when fine grained and in minor amounts. Common with heubnerite.[1]
Friedelite	$Mn_8Si_6O_{15}(OH,Cl)_{10}$	From the Sunnyside mine.[4]
Gibbsite	$Al(OH)_3$	Rarely at the National Belle mine.[1]
Gypsum	$CaSO_4$	Vug filling in Red Mountain mines; especially the National Belle.[1]
Helvite	$Mn_4(Be_3Si_3O_{12})S$	Found at the Sunnyside mine.[3]
Hematite	Fe_2O_3	Occurs in quartz veins; widespread.[1]
Illite	$(K,H_3O)(Al,Mg,Fe)_2$-$(Si,Al)_4O_{10}{\cdot}(OH)_2,H_2O$	Members of this clay group are widespread as alteration products throughout the district[3]
Pyroxmangite	$MnSiO_3$	Common in the Sunnyside and northeast of Silverton[3]
Quartz	SiO_2	Ubiquitous.[1]
Rhodochrosite	$MnCO_3$	Specimens occur in the Grizzly Bear mine; occurs throughout the district.[2]
Rhodonite	$MnSiO_3$	Commonly cryptocrystalline N. and E. of Silverton; replacing limestone in the Saratoga mine of Ironton Park.[1]
Scorodite	$Fe^{3+}AsO_4{\cdot}2H_2O$	Charter Oak mine in the Red Mountain district.[4]
Sericite	$KAl_2(AlSi_3O_{10})(OH)_2$	Ubiquitous.[1]
Sulfur	S	Noted at the Red Mountain breccia pipes.[4]
Tephroite	Mn_2SiO_4	From the Sunnyside mine.[4]

Zircon	$ZrSiO_4$	Locally as an alteration product within the Tertiary volcanics.[1]
Zunyite	$Al_{13}Si_5O_{20}(OH,F)_{18}Cl$	Anvil and Sunnyside mines; with guitermanite at the Zuni.[1]

References:
1-Ransome, 1901
2-Westervelt personal communication, 1994
3-Casadevall and Ohmoto, 1977
4-Eckel, 1961

SILVERTON-TYPE MINERALIZATION PERIPHERAL TO THE OURAY MINING DISTRICT

The Sunnyside Mine

The Sunnyside mine, located 9 air miles S8°E from Ouray, can be considered to be the "type" locality for Silverton-type mineralization. Gold, silver, lead, zinc, and cadmium have been produced from veins filling vertical to near vertical faults and fractures in a northeast trending graben developed as a result of resurgent doming of the San Juan-Uncompahgre calderas about 28 Ma (Casadevall and Ohmoto, 1977). The principal Sunnyside vein can be traced for 6000 feet along its strike of N 50° E and followed down its dip of 65° SE (Ransome, 1901). Mineralization is present over a 2000 foot vertical range (Panze and Cruson, 1983).

The veins consist of various mineral assemblages with quartz, sphalerite, galena, and pyroxmangite accounting for 60 - 80% of all minerals. Other vein minerals in order of diminishing abundance, are pyrite, rhodochrosite, chalcopyrite, tetrahedrite, fluorite, calcite, hematite, gold, petzite ($AuAg_3Te_2$), calaverite ($AuTe_2$), alabandite (MnS), heubnerite ($MnWO_4$), tephroite (Mn_2SiO_4), friedelite [$Mn_8Si_6O_{18}(OH,Cl)_4 \cdot 3H_2O$], helvite [$Mn_4(Be_3Si_3O_{12})S$], anhydrite, sericite, aikinite ($PbCuBiS_3$), bornite, barite, and gypsum.

The Idarado Mine

Workings of the Idarado mine span the entire 4.24 mile distance from Red Mountain Pass to Telluride. Mineralization is hosted within both high-angle vein deposits and sizable replacement deposits developed largely within the Eocene Telluride Conglomerate. Smaller replacement ore bodies have been found in the underlying Cutler and Dolores formations of Permo-Triassic age. All replacement bodies are related to mineralized veins and a genetic relationship is inferred. The veins fill fractures of orientation N35°W ± 30° that appear to be radials emanating from

the San Juan/Silverton caldera complex.

Although significant production has come from the veins, the replacement ores have been the primary target of exploitation. Typical replacement bodies occupy the total 0 to 100 foot thickness of the conglomeratic unit as 70 to 80% massive sulfides. Partial replacement characterizes a second type of ore wherein massive sulfides make up only 10-20% of the rock generally in small discontinuous pods around which conglomeratic texture is still present. Of little economic importance is the siltstone hosted ore in which sulfides are truly disseminated in sandy and or silty units without any appreciable concentrations.

Veins of the Idarado average 5 to 8 feet in width although considerable variability is noted. The principal veins are continuous along strike for as much as 8000 feet and down dip for at least 3600 feet. Lead to copper to zinc ratios for the veins are 2:1:3, whereas the same ratio is 3.5:1:10 for the replacement bodies and the feeder veins (Mayor, 1972).

The Camp Bird Mine

The Camp Bird mine is located 4.5 miles S42°W from Ouray, Colorado. Like the Idarado, mineralization occurs in both fissure veins and replacement ore bodies. The Camp Bird vein trending nearly east-west, is the most prominent vein representing radial stress induced shearing along fractures which spiraled away from the subsiding Silverton caldera. This epicycloidal shear has been reactivated episodically (Hutchinson, 1988).

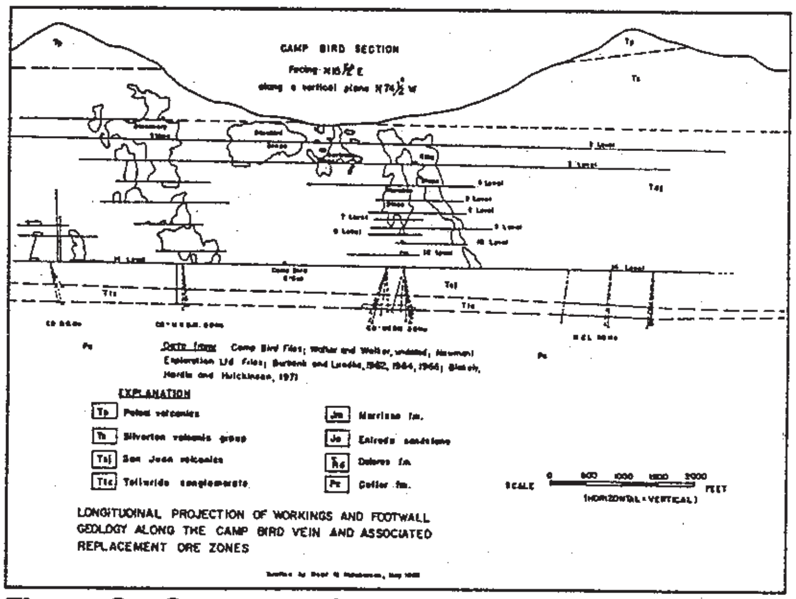

Figure 6. Cross section of the Camp Bird Mine (Hutchinson, 1988).

Gold mineralization was preferentially developed along cymoidal loops where cross cutting veins intersected the primary structure. Gold occurs in a gold-quartz breccia which is spatially distinct from

the sulfide mineralization (Ransome, 1901). Below the main workings, were found vein-related replacement bodies in the Telluride Conglomerate that were first mined in the 1970's by Federal Resources Corporation (Fig. 6). Mineral assemblages of the Camp Bird deposits are typical for the district in both the vein and replacement orebodies with the notable addition of an abundant specularite in the eastern portion of the main vein.

Camp Bird has produced and milled 2,491,158 dry short tons of ore yielding 1.4 million ounces of gold, 4.58 million ounces of silver, 72.3 million pounds of lead, 12.04 million pounds of copper, and 67.62 million pounds of zinc from 1896 through 1981 (Points, 1982). Of this total, 32.2 million pounds of lead, 4.4 million pounds of copper, 48.4 million pounds of zinc, and 587,000 ounces of silver were produced from the replacement deposits.

The Red Mountain Breccia Pipes

The famous mines of the Red Mountain breccia pipes are shown in Figure 7. The Yankee Girl mine produced ore from 4 mineralized chimneys, the largest of which was approximately 30 feet in diameter (Ransome, 1901). Two of the chimneys coalesced at ≈400 feet below the surface. Although the deposit was mined to depths of 1050 feet, the character of mineralization was that of a fissure vein at depths greater than 700 feet. The principal vein at depth was 10 - 12 feet wide and oriented north-south. Supergene enrichment is present to a depth of 500 feet where a flat lying structure of minimal displacement cuts the orebody. As with many of the pipe deposits, acidic water was a major problem within the mine. The water was so acidic and charged with metal ions that steel tools would be copper plated within minutes of exposure to the water.

The Guston mine is very similar to the Yankee Girl mine. Underground workings show stopes of up to 200 feet in length and well over 100 feet high (Ransome, 1901). Below a depth of 500 feet the ore tended to be more vein-like ranging in width from 3 to 30 feet. This ore was continuous along strike for 200 feet. This mine was the deepest in the district with a shaft in excess of 1300 feet. At the lower level of the mine, the ore was mostly pyrite averaging 3 to 5% copper with less than 20 ounces of silver and 1 ounce per ton gold. The mine made in excess of 100

gallons per minute of highly acidic water at the lowest level.

The Genesee-Vanderbilt mine consists of two small chimneys within the same breccia pipe (Ransome, 1901). The two chimneys were originally worked as two separate mines as the name might imply. Although these deposits possessed the same mineralogy and corrosive mine water as the two aforementioned properties, they did not have a flat-lying structure to act as a conduit for circulating water so important to supergene enrichment. Instead, the Genesee-Vanderbilt is said to have a spiral corkscrew ore-breaking fracture which is confined to the interior of the host breccia pipe. The ore is only found on the hanging wall of this structure. The structure rotates through 140° before disappearing at a depth of 700 feet.

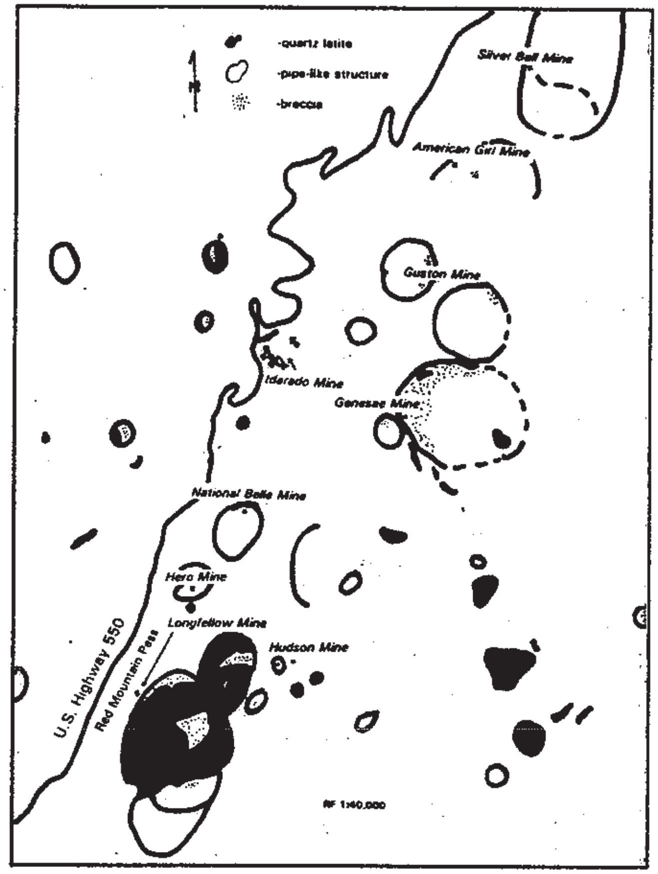

Figure 7: Map of the Red Mountain Breccia Pipes and their Associated Mines.

The National Belle Mine differs from the other chimney deposits in that ore occurs much more sporadically as lenses or in pockets (Ransome, 1901). Commonly these pods were on the order of only a few feet in any direction although one stope is 75 feet by 60 feet in plan view. The ore seldom had even a tenth of an ounce of gold per ton with many shipments not containing any payable gold. The shaft was sunk to a depth of only 490 feet and hence did not encounter the water problem so typical of the other deposits in the district. This lack of water may have been responsible for the relatively insignificant amount of supergene ore encountered. Cosalite [$Pb_2Bi_2S_5$], a mineralogical curiosity, has been found in relative abundance along with enargite crystals within the workings as well as on the dump.

SILVERTON-TYPE MINERALIZATION IN THE OURAY MINING DISTRICT

The Grizzly Bear Mine

The Grizzly Bear vein of orientation N40-50°W, 70-90°SW, consists of base-metal sulfides cut by quartz-rhodochrosite veinlets across a 10 foot width (Westervelt, personal communication, 1994). This vein contains many volcanic inclusions as screens and breccia clasts. Elsewhere in the mine, the mineralization consists of massive quartz with pervasively disseminated huebnerite and local fluorite. At least 4 stages of mineralization are represented correlating to the second, third, fifth and sixth stages seen in Figure 2. The ore here is argentiferous as a result of its distal location within the district.

The Mineral Farm Mine

Base- and precious-metal ores are found along small flexures and in sinuous paleokarst channelways at the top of the Mississippian Leadville Limestone immediately beneath the unconformable contact with the red chert-bearing shales of the Pennsylvanian Molas Formation (Burbank, 1940). Along the crests of these flexures, the shale capping was intensely silicified. Subsequent fracturing of these crests allowed circulating hydrothermal solutions to enrich some of the deposits. The entire Mineral Farm area is cut by narrow weakly mineralized high angle veins of no economic importance. The date of the replacement mineralization is in question although it is likely of Laramide age for it can be distinguished from the Tertiary ores of Hayden Mountain by the paragenesis of pearceite, tetrahedrite, and ankerite (Luedke, 1994). If this is the case, the high-angle veins are probably a Tertiary overprinting phenomenon.

The Portland Mine

Base-metal and precious-metal fissure veins cut Mississippian Leadville Limestones and overlying Tertiary volcanics (Burbank, 1940). Replacement bodies are localized along the basal members of the San Juan Tuff and in the underlying brecciated limestone. The tuff is locally calcareous which allowed access to the mineralizing

solutions. This mineralization is regarded as Silverton-type hence Tertiary in age (Luedke, 1994).

The Dunmore Mine

The Dunmore is the only significant deposit in the Precambrian Uncompahgre Formation. It is a complex deposit with ore occurring in fissure veins and two mineralized chimneys within breccia pipes along a N 70 ± 5° W trending, steeply S dipping fault (Kelley and Silver, 1946). The principal vein is several feet wide and occurs in a fissure zone nearly 100 feet in width and over 2 miles in length. Unlike most if not all of the faults in the area, the structure at the Dunmore, may have over 4500 feet of vertical separation of the Precambrian units prior to the deposition of the San Juan Tuff. Late Tertiary reactivation of the structure added another 80 feet of throw (Hillebrand and Kelley, 1957). The dip of the structure in the volcanics is much flatter. Movement along this fault during the Tertiary resulted in the creation of open space within Precambrian quartzites below and subsequent base-metal mineralization. Although Kelley and Silver believe that over 4500 feet of separation has occurred in the Precambrian, Harris (1987) indicates little if any offset of the quartzites along the structure which approximates the hinge surface of a large upright F_2 anticline.

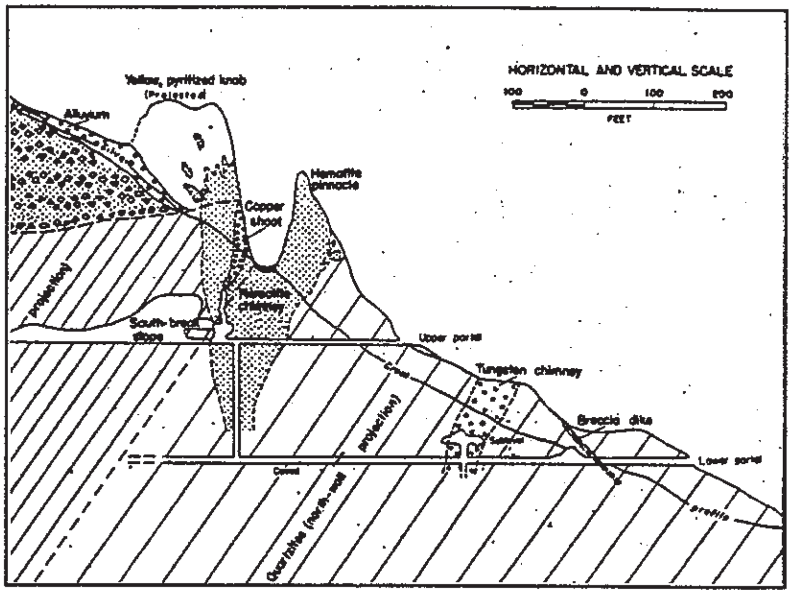

Figure 8: Cross Section of the Dunmore Mine (Kelley and Silver, 1946).

Although some of the production has come from the vein, most of it has been derived from the chimneys. The relationships of the deposit are shown in Figure 8. One ore chimney is composed primarily of hematite and copper minerals. This chimney is approximately 25 feet in diameter and is hosted in a tapering breccia pipe 180 feet in diameter. Chalcopyrite, argentiferous aikinite [Pb(Cu,Ag)BiS$_3$], barite,

rhodochrosite, chlorite and pyrite occur with lesser amounts of quartz, sericite, and kaolinite. The entire chimney is encased in a fine grained pyrite blanket.

The other breccia pipe is only about 35 feet in diameter and is mineralogically quite distinct from any pipes in the area. In this pipe heubnerite ($MnWO_4$) and sphalerite are the dominant ore minerals accompanied with very coarse grained quartz, pyrite, and minor fluorite. The mineralization is pervasive throughout the pipe.

The Highway 550 Pipe Prospect

The breccia pipe occurring at mile 1.7 in the accompanying road log is comprised of angular to rounded fragments of Precambrian quartzite, rarely brecciated, in a matrix of rock flour, clay, and pyrite. The clasts show silicification and locally disseminated pyrite. The pipe is approximately 96 feet long and shows pronounced elongation along a north-south axis. The northern contact with Precambrian quartzite is quite sharp but the southern contact is obscured. Field evidence suggests that this pipe was emplaced at the intersection of a north trending structure and a cross-cutting structure at the southern edge of the pipe. Atomic absorption analyses were made of two samples from the pipe for gold, silver, copper, lead, and zinc; although results were often below detection and sometimes inconclusive, a trend of slightly increased copper, zinc, and silver values within the fine grain component of the matrix of the breccia pipe was noted. There was no detectable gold.

RECENT ACTIVITY

The area is just emerging from a period of mining quiescence with the leasing of the Virginius mine by Sunshine Mining Corporation and the operation of the Grizzly Bear mine by Savage Mining Company. Sunshine's short-term plans for the property include analysis of various underground mining methods and possible additional exploration drifting and drilling (Davis, 1994). Several other smaller operations are planning to open this summer. The omnipresent cycle of boom and bust continues.

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Ouray-Type mineralization in the Uncompahgre Mining District, San Juan Mountains, Colorado

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REGIONAL SETTING

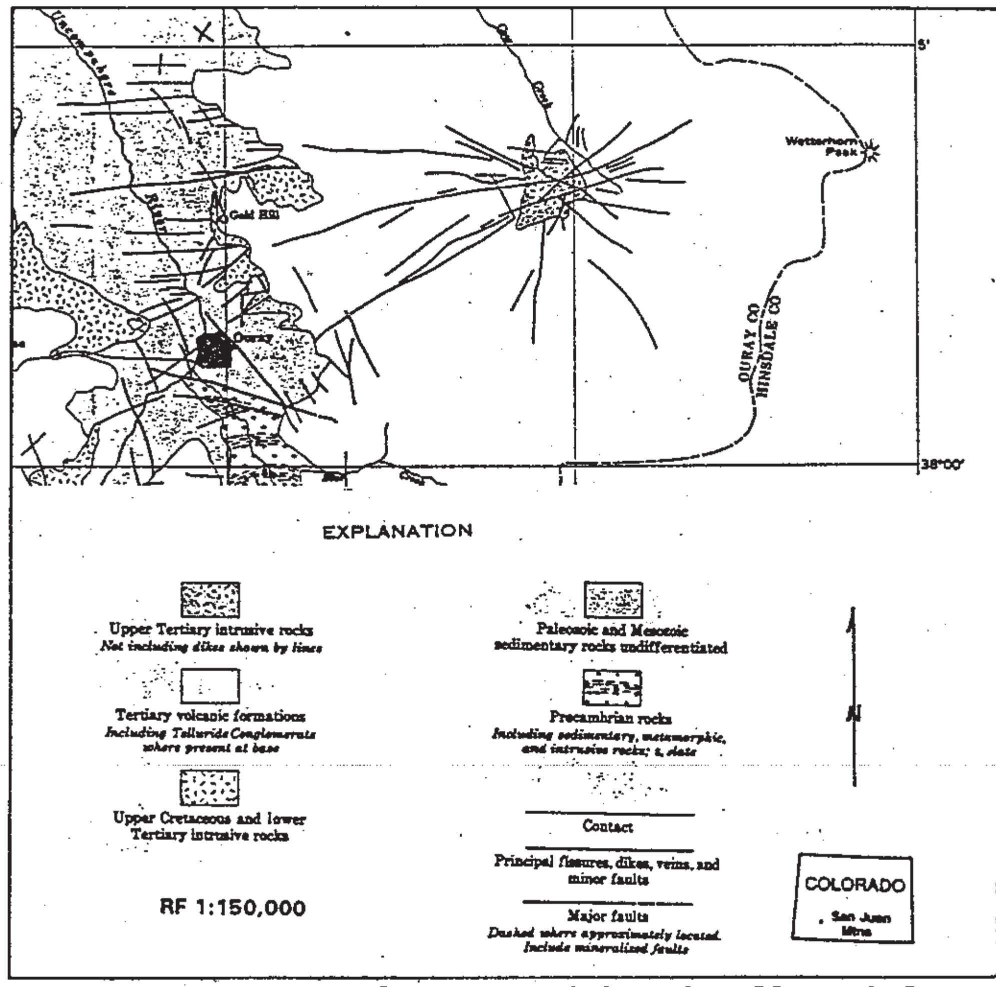

Figure 1. Generalized Geology and Location Map of Ouray, Colorado area (Burbank and Luedke, 1969).

Laramide and late Tertiary base- and precious-metal mineralization occurs in the vicinity of Ouray, Colorado in the Uncompahgre Mining District (Fig. 1). The Laramide mineralization is considered temporally unique and differentiates this district from others located throughout the San Juan Mountains of southwest Colorado (Burbank, 1940). These deposits shall hereinafter be referred to as "Ouray-type" mineralization.

Ouray-type mineralization is associated with the center of a laccolithic intrusive complex of granodiorite to quartz monzonite porphyry, associated cross-cutting dikes

and sills, and local uplift. This mineralization is apparently unrelated to the Tertiary volcanism with which all surrounding districts are associated.

Burbank (1940) sub-divides the district into four quadrants separated from one another by two dominant structural features in the area: the Uncompahgre axis, a zone of brittle deformation restricted to shallow tensional fractures and faults bearing N25°W parallel to the Uncompahgre River valley, and an intrusive belt 12,000 feet in width trending N55-60°E. The prominent Ouray stock occurs at the intersection of these two structural belts. The majority of the reported district production comes from the northern quadrant, the site of several field trip stops.

NORTHERN QUADRANT

Virtually all of the production form this region has been confined to the rims of the Uncompahgre River canyon, Dexter Creek, and other tributaries along which erosional incision has exposed the more favorable stratigraphic horizons as well as prominent structures (Burbank, 1940). Several distinct ore assemblages occur within this quadrant (Fig. 2) and define a typical zonation outward from the aforementioned structural intersection and stock as seen in Figure 3 (Trujillo, personal communication, 1994).

TYPES OF DEPOSITS		
Siliceous-Baritic Silver-Lead-Zinc	**Magnetite-Pyrite-Garnet Skarn**	**Quartz-Pyrite & Pyritic Base Metal**
PRIMARY ORE MINERALS		
Galena	Magnetite	Pyrite
Sphalerite	Pyrite	Chalcopyrite
Pyrite	Chalcopyrite	Sphalerite
Chalcopyrite	Specularite	Galena
Freibergite	(Galena)	Tennantite
Argentiferous Tetrahedrite	(Sphalerite)	Tetradymite
Pearceite	(Gold)	Hessite
Polybasite		Benjaminite
Pyrargyrite		Cosalite
Proustite (?)		Gold
(Gold)		(Molybdenite)
		(Calaverite)
		(Petzite)
		(Specularite)
SECONDARY MINERALS		
Limonite	Limonite	Limonite
Wad	Clays	Goethite
Azurite	Goethite	Jarosite
Malachite	Jarosite	Copiapite (?)
Chrysocolla	Chalcocite	Clays
Native Silver	Covellite	Chalcocite
Acanthite	Malachite	Malachite
Chalcocite	Azurite	Azurite
Covellite		Cerussite
(Proustite ?)		Gold (?)
(Chalcopyrite)		Gypsum
Sulfur		Sulfur
Calcite		Native Copper
Aragonite		Hydrous sulfates of Fe, Cu, and Zn.
GANGUE MINERALS		
Quartz	Andradite	Sericite
Chert	Hornblende	Quartz
Jasper	Actinolite	Chlorite
Barite	Epidote	Calcite
Rhodochrosite	Quartz	Siderite
Ankerite	Calcite	Barite
Calcite	Chlorite	(Dolomite)
	Apatite	(Rutile)
	Rutile	(Anatase)
	Siderite	(Apatite)
	(Zircon)	

Figure 2. Ore Mineral Assemblages of Differing Types of Deposits (Burbank, 1940).

Distal Deposits-Carbonate Hill

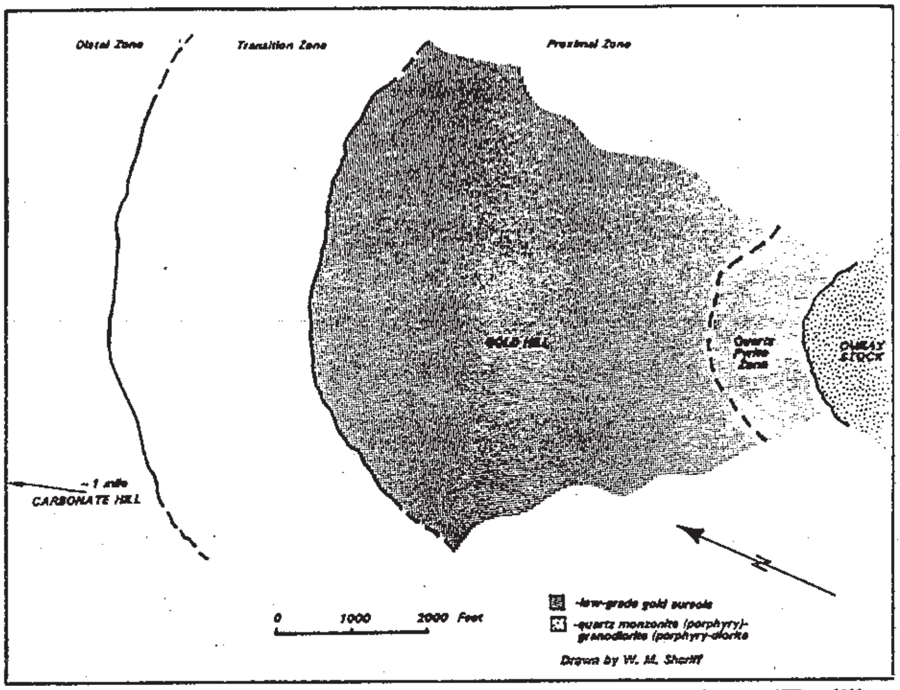

Figure 3. Northern Quadrant District Zonation (Trujillo, 1994).

The ores of the Carbonate Hill area are siliceous silver-rich base metal deposits with abundant barite, pyrite and only minor gold present as auriferous pyrite (Irving and Cross, 1907). The mines of this area are developed along east-west trending veins variably dipping 60 to 90° with average widths of 3 feet. Displacement along these structures is less than 10 feet. Argentiferous galena, freibergite, chalcopyrite, pyrite, and minor sphalerite occur with the gangue minerals rhodochrosite, barite, and quartz as open space filling within veins or as replacement bodies in the adjacent wall rock. This replacement is commonly up to 30 feet away from the feeder vein in favorable horizons such as the Cretaceous Dakota Quartzite. Smaller bodies occur in the Jurassic Morrison Formation. The principal veins of the area are not exposed at the surface as their controlling faults did not penetrate the Cretaceous Mancos Shale. Ore values in the veins abruptly end upon passing into the lowermost shale. Base-metal depletion and the presence of abundant native silver near the surface are evidence of extensive supergene enrichment.

Transitional Deposits

A zone of transition lies between the argentiferous Carbonate Hill deposits and the auriferous deposits of Gold Hill (Trujillo, personal communication, 1994). The deposits occurring in this irregular ½-mile-wide zone share characteristics of both of

the adjacent zones. Mineralized east-west veins are developed below the Mancos shale. Replacement bodies are best developed in the Pony Express Limestone member of the Jurassic Wanakah Formation. Mineralization consists of chalcopyrite, pyrite, and lesser amounts of base-metal sulfides and argentiferous tetrahedrite with an increase in gold values from those found at Carbonate Hill (Irving and Cross, 1907). Gangue mineralogy is similar to the aforementioned although no rhodochrosite or native silver has been reported and calcite is common.

Proximal Deposits-Gold Hill

Although the deposits of this area are developed around east-west trending mineralized veins, the economically important deposits are roughly tabular in shape and are either magnetite-pyrite-garnet skarn with minor chalcopyrite and gold, quartz-pyrite replacements containing significant chalcopyrite and gold, or pyritic base-metal ores containing native gold and gold-silver tellurides (Burbank, 1940). All of these deposit types occur within an area of a broad low-grade gold aureole presumably produced by the nearby Ouray stock (Trujillo, personal communication, 1994). Gold values are enriched in the proximity of the east-west veins or structures. The primary structural control of mineralization in the Gold Hill area is the Memphis Dike which appears to be the main feeder zone for ore fluids. The most favorable horizons within this zone include the Pony Express Limestone of the Jurassic Wanakah Formation, the Bright Diamond member of the Jurassic Morrison Formation, and the Cretaceous Dakota Sandstone.

Area Adjacent to Ouray Stock

A relatively narrow quartz-pyrite zone, 1000 to 1500 feet in width, lies between the Gold Hill area and the Ouray stock (Trujillo, personal communication, 1994). This area is pervasively silicified with abundant pyrite and shows anomalous gold values as it also lies within the low-grade gold aureole associated with the Ouray stock. Stringers of high grade gold ore do occur in this area however no economical concentrations have been located to date.

Ouray Stock

The Ouray stock (field trip stop #20) is a composite pluton of quartz monzonite (porphyry)-granodiorite (porphyry)-diorite phases with a core characterized by pervasive argillic alteration (Trujillo, personal communication, 1994). This stock hosts a low-grade copper-molybdenum porphyry which was the focus of exploration work by Bear Creek Mining, a subsidiary of Kennecott Copper Corporation (presently owned by Rio Tinto Zinc Ltd.) in the early 1960's. Geochemical analysis suggests that this stock was the source of much of the pyrite in the quadrant as well as the gold aureole adjacent to the intrusion.

GENESIS OF ORE DEPOSITS

There is evidence that the Laramide Ouray stock contributed at least some of the iron, gold, and possibly base metals to the mineralization in this quadrant (Burbank, 1940). The enrichment of gold along east-west trending structures emanating from the Tertiary Cow Creek intrusive complex located 4 miles N85°E, as seen in Figure 1, suggests an overprinting enrichment during the late Tertiary (Trujillo, personal communication, 1994). The quartz latite of Cow Creek is thought to be 22 Ma, the same age as the quartz latites of the Lake City and Red Mountain areas (Lipman and others, 1976). If this is the case, the question arises as to what extent the Laramide event actually influenced the observed mineralization. The Ouray-type mineralization may very well be nothing more than a variant of the Silverton-type Tertiary mineralization common to the surrounding districts of the San Juan Mountains.

MINES OF THE NORTHERN QUADRANT

The Bachelor Mine

The Bachelor mine is located on the south side of Dexter Creek about 2 miles north of Ouray in the Carbonate Hill zone (Irving and Cross, 1907). Siliceous, baritic silver-lead ores occur as open space filling in a vein of orientation N83°W cutting the Morrison, Dakota, and Mancos Formations (Fig. 4). Replacement bodies adjacent to the vein are well developed in the Dakota just below the contact with the Mancos

Shale.

The deposit was discovered in 1892 and had become the principal producer of the district by 1895. Some shipments in the early 1900's ran as high as 15,000 ounces of silver per ton however ore grades varied considerably. Total production has been estimated at $3.5 million (1940) dollars (Burbank, 1940).

The Pony Express Mine

The Pony Express mine (field trip stop #16) is the type example of a transition zone deposit. The ore consists of freibergite, galena, and minor chalcopyrite as disseminations or irregularly formed bunches in a barite and calcite gangue with minor silica replacing the Pony Express Limestone adjacent to an east-west trending structure (Fig. 4). Replacements up to 100 feet wide occur throughout the 30 foot thickness of the limestone and extend over 1000 feet laterally along the structure. Run-of-mine ore grades were on the order of 20-30 ounces of silver per ton with 0.1-0.3 ounces of gold per ton and small credits for lead and copper (Irving and Cross, 1907).

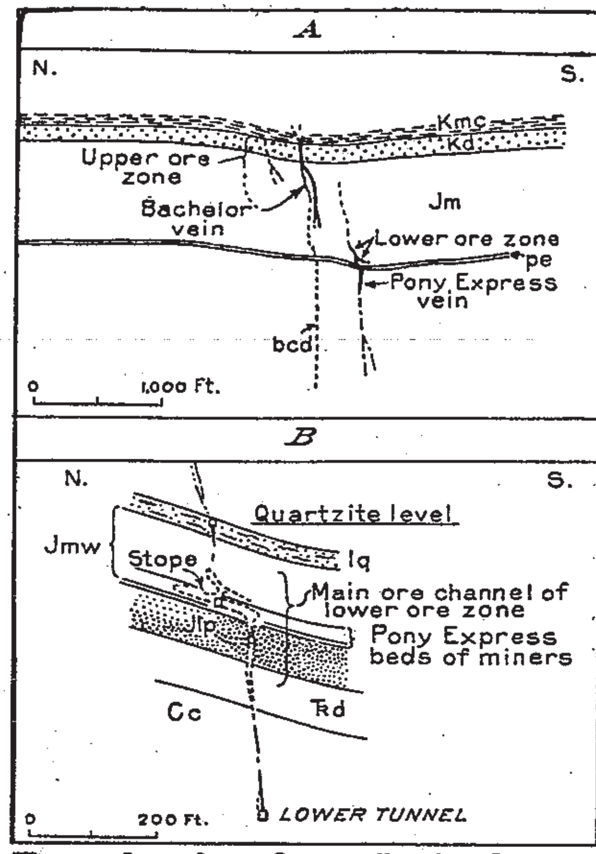

Figure 4. A- Generalized Section Through the Bachelor and Pony Express Veins; B- Section Through the Pony Express Vein and Bedding Channel (Burbank, 1940).

The American Nettie Mine

Irregular replacements and cavity fillings occur along fractures near the top of the Dakota Sandstone in the Gold Hill zone as seen in Figure 5 (Irving and Cross, 1907). Ore deposition was localized by two fault breccias and one latitic dike (Figs. 7,8). This deposit is of the pyritic base-metal type as the primary ore is pyritic with chalcopyrite, galena, gold-silver tellurides, sphalerite, molybdenite, and argentiferous

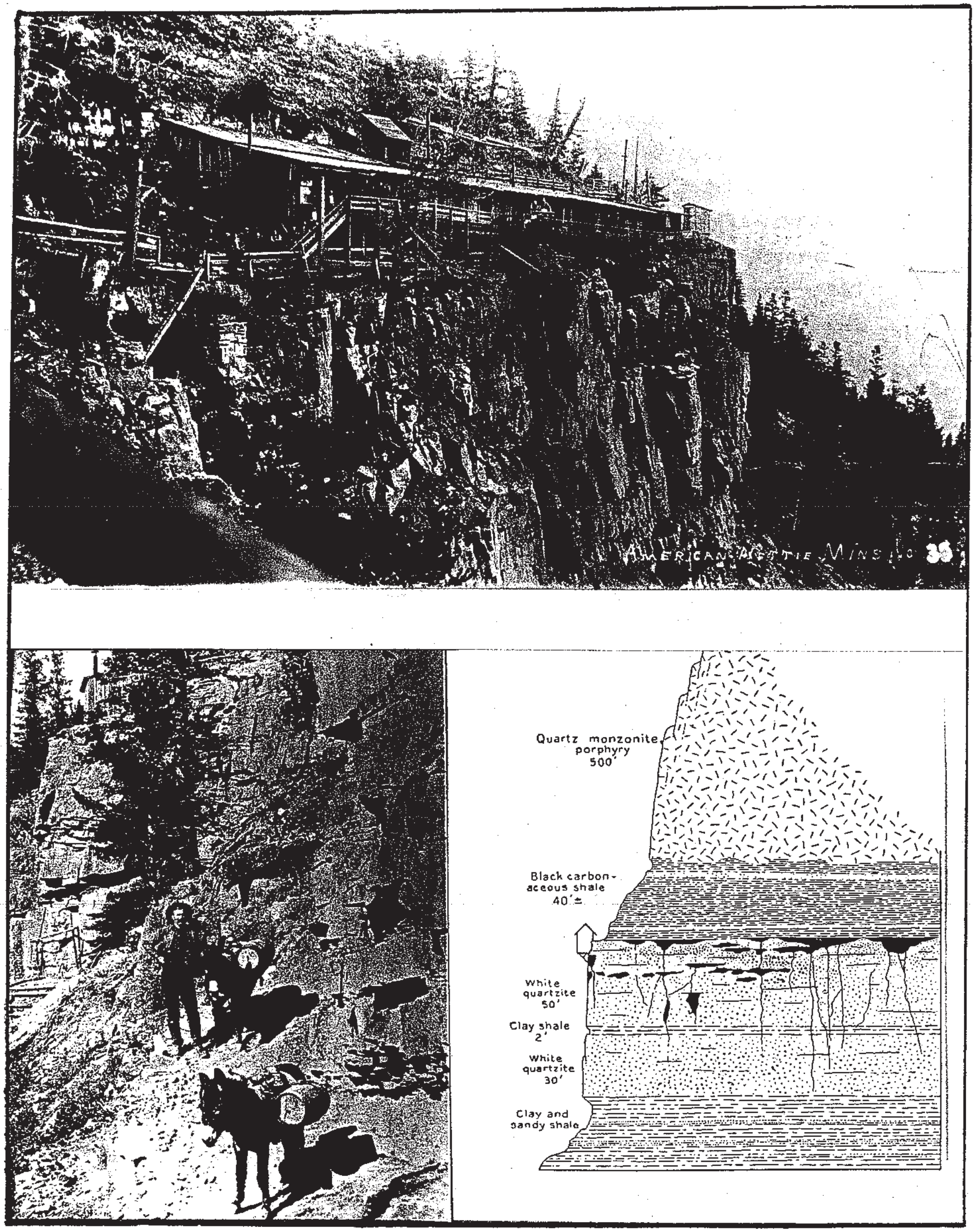

Figure 5. *top of page*-Early Day Photo of the American Nettie Mine, *lower left*-Miner with Burros on the Gold Belt Trail (note American Nettie Mine on cliff), *lower right*-East-West Section of the Rocks and Orebodies in the American Nettie Mine, Ouray, Colorado (Irving and Cross, 1907; photos courtesy of Ouray County Historical Society and John Trujillo).

tetrahedrite occurring in a quartz-barite-gypsum gangue (Irving and Cross, 1907). A paragenetic sequence is shown in Figure 6. Secondary mineralization near the portal consisted of limonitic dirt with native gold which was initially shoveled into ore sacks and directly shipped.

Although gold values of up to 194 ounces per ton and silver values of 120 ounces per ton have been reported, ore values averaged 6 ounces of gold per ton with minor silver credits between 1885 and 1905. Similar mineralization occurs at the nearby Jonathan and Schofield mines.

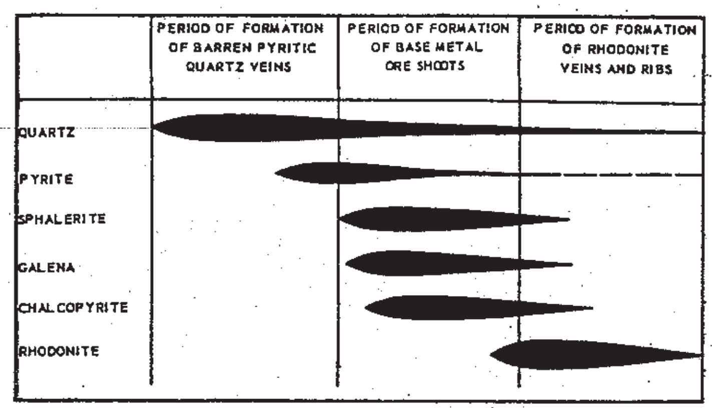

Figure 6. Paragenetic Sequence of the Mineralization at the American Nettie Mine (Bejnar, 1957).

The Wanakah and Bright Diamond Mines

The Wanakah and Bright Diamond mines (field trip stop #18) of the Gold Hill zone consist of workings along the Pony Express member of the Wanakah Formation and the Bright Diamond member of the Morrison Formation, respectively, as seen in Figures 7 and 8 (Burbank, 1940). Magnetite-pyrite-garnet skarn with little gold characterizes the upper levels of the mine whereas the lower levels are developed in quartz-pyrite replacements with significant chalcopyrite and gold (Trujillo, personal communication, 1994). Minor production has come form mineralized veins. Gold has been preferentially concentrated along channels associated with northeast trending fractures, at breaches in the northwest trending Iron dike, and along the east-west Memphis dike . At least 4 stages of mineralization have been identified (Burbank, 1940). The initial mineralizing event was the formation of the lime and

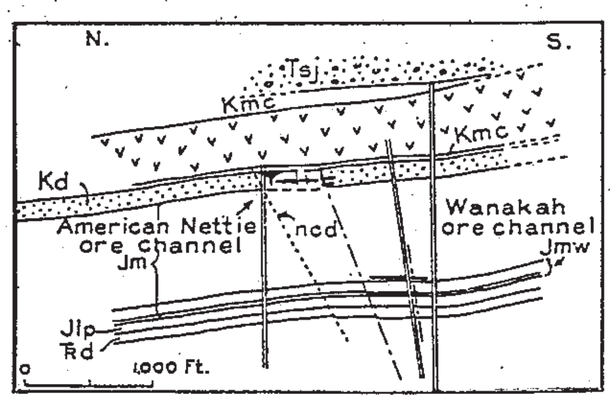

Figure 7. Generalized Section through American Nettie and Wanakah Mines (Burbank, 1940).

iron silicates followed by the introduction of iron oxides. Sulfide mineralization and the introduction of native gold followed.

The Memphis Mine

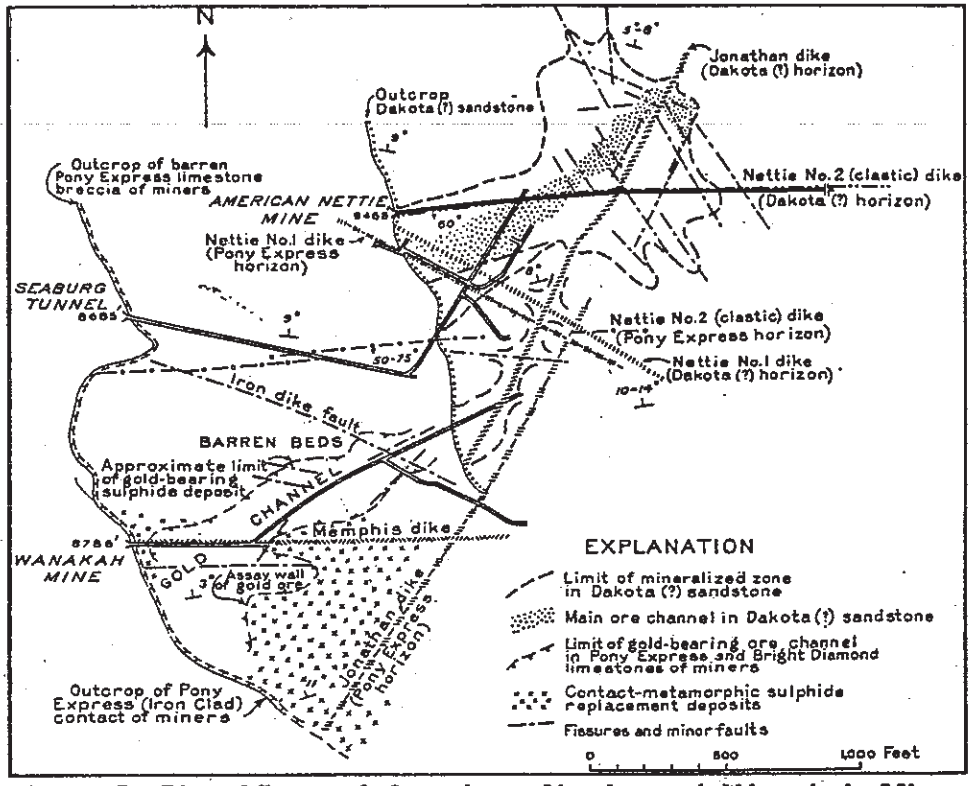

Figure 8. Plan View of American Nettie and Wanakah Mines (Burbank, 1940).

The Memphis mine exploited high grade gold ores along the east-west Memphis Dike in the Gold Hill zone (Burbank, 1940). The ore is principally confined to mineralized fissures with little replacement of wall rock. This pyritic-base-metal deposit consists of pyrite, chalcopyrite, hematite, sphalerite, galena, and native gold in a gangue of quartz, sericite, epidote, and apatite.

CURRENT ACTIVITY

American Gold Resources of Denver, Colorado controls 2100 acres covering and area extending 3 miles north from Twin Peaks (Trujillo, personal communication, 1994). Ongoing exploration is directed toward increasing proven and probable tonnage in and around the Wanakah mine. The company is currently seeking joint-venture partners for this development opportunity.

ACKNOWLEDGMENTS

Particular thanks are extended to T. N. Westervelt and J. R. Trujillo for their input and insightful comments.

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Road log from Ouray, Colorado to the Blowout via Gold Hill

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INTRODUCTION

This trip, necessitating the use of four-wheel drive vehicles (assuming half-tracks are unavailable), will take you from subterranean depths to dizzying heights culminating in unbelievable vistas. In addition, much of the Permian through Cretaceous is well exposed at several of the stops along the way. The highlight of the trip will be an underground tour of the Wanakah mine where you will be able to sample two types of mineralization on Gold Hill. BUCKLE UP!!!

Cumulative Mileage	*Interval Mileage*	*Description*
0.0	**0.0**	**START** at Ouray Variety Store, 7th and Main. Proceed west on 7th.
0.2	0.2	Turn Right on County Road 17 Along Uncompahgre River.
0.5	0.3	**STOP 14.** City Garage. At 12:00 the dump of the Wanakah mine is visible on the hillside. The Blowout (Ouray stock) is evident at 1:00. At 2:00 the negative topographic expression of the weathered Ouray stock is noted. Note the engulfed in-place block of hornsfelsed Jurassic Morrison Formation near the top of the intrusion. The stock is composed of quartz monzonite (porphyry)-granodiorite (porphyry)-diorite with a minimum suggested age of 54.1 $\pm$4.0 Ma based on fission-track analysis of zircon from a similar nearby stock traversed by the Weehawken pack trail, Ironton quadrangle, Colorado (Cunningham, 1994 personal communication). This is a minimum age because apatite from the same sample shows that the rock was reheated. A paleovalley incised into the Ouray stock is filled with Oligocene San

Juan Formation. At 3:00 the Two Kids mine is developed along the Swimming Pool fault in the locally hornsfelsed Pennsylvanian Hermosa Group. The Lone Widow mine exploited a magnetite skarn deposit in the Permian Cutler Formation along an unnamed east-west trending structure at 3:30.

0.85	0.35	Passing old mill foundation and mine dumps (aerial tram) from Speedwell mine with redbeds of Permian Cutler in monoclinal fold at 10:00
1.4	0.55	Trailhead for Twin Peaks Loop trail.
1.5	0.1	Silvershield mill at 9:00; the last operating mill for Gold Hill ore.
1.55	0.05	**STOP 15.** Just North of Silvershield Mill.

The Memphis dike, the feeder for the ore deposits of Gold Hill, is seen at 3:00. The Memphis mine, high on the cliff in Permian Cutler Formation, exploited high grade gold veins along the east-west Memphis dike. The deposit carried significant base-metal mineralization as well. The stratigraphy and favorable horizons for ore deposition are seen in Figure 1. The Ouray County Historical Society has graciously allowed us access to some old photos of the bygone era, two pictures of which are reproduced on the following page as Figure 2.

2.4	0.85	Intersect Highway 550; turn right.
2.6	0.2	Turn left on County Road 14. Roadbed is still in Cutler Formation.
3.0	0.4	Continue past Panoramic Heights built on American Lead and Zinc Mill tailings.
3.2	0.2	Green rock debris from Pony Express granodiorite dike.
3.3	0.1	Looking up Dexter Creek at 12:00, Gold Hill (auriferous mines) is located to the right with Carbonate Hill (argentiferous mines) to your left.
3.65	0.35	Bear right at fork onto CR 14. The left fork leads to Cutler Creek, the type section for the Cutler Formation.
3.9	0.25	Turn right onto private road headed for Bachelor-Syracuse mine tour.

The American Nettie has a new tramway, whose catenary curve sweeps from the high cliffs of Gold hill, and, with undeviating line, bridges the abyss of the valley. It is a picturesque bit of engineering. A descent of 1,820 feet is made in 4,200 feet. The span that crosses the valley is 2,100 feet long, and in that distance the drop is 915 feet. The engineers of the Leschen Company built it and, owing to the abrupt contour of the ground, they had to make especial provision for safety. The descending side has a cable 1⅛-inch diameter, while the cable upon which the empties return is one inch in diameter. The traction rope is ¾ inch. To the latter, button-shaped clips are permanently attached, with intervening spaces, the length of which is regulated by the number of buckets in use. The buckets are automatically detached and attached to the rope, at the loading and terminal stations; at both terminals the buckets receive a retarding and accelerating movement, as they arrive and depart, respectively, in order to diminish the vibration attendant on the removal of the load from the line, and the return of it into service.

-Passage from T. A. Rickard, 1902

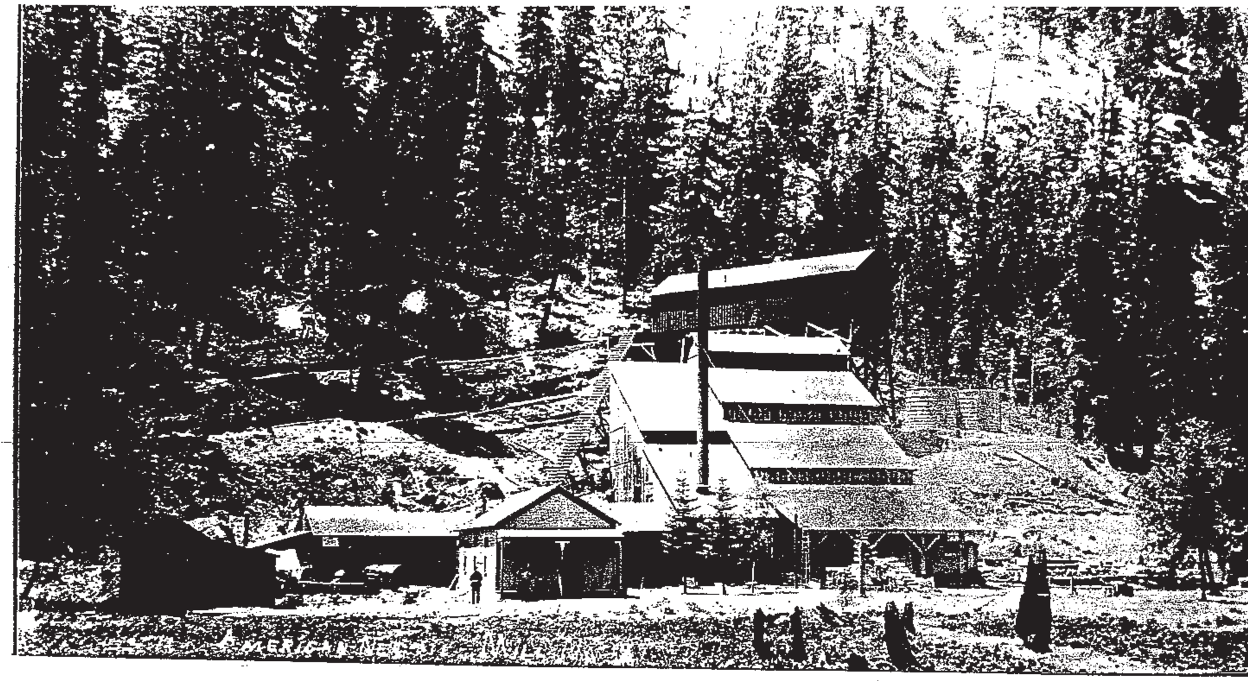

Figure 2. The Silvershield Mill.

TABLE 3

NOMENCLATURE CHART (Stratigraphy of th

ERA	PERIOD	EPOCH	UNCOMPAHGRE MINING DISTRICT FORMATION	MEMBER	MINES WITH Au* & Ag• PRODUCTION
CENOZOIC	TERTIARY	Miocene	San Juan	Upper	Portland•
		Oligocene		Lower	Hayden Mt.•
		Eocene	Telluride Cong'l		
MESOZOIC	CRETACEOUS	Late	Mancos Shale		
			Dakota Sandstone		American*• Nettie*• Jonathan*• Chipeta*• O & N *•
		Early	Burro Canyon S.S.		
	JURASSIC	Late	Morrison	Brushy Basin	
				Salt Wash	
				Bright Diamond	B.D. Mine*
			Junction Creek S.S.		
			Wanakah	"Marl" Member	Newsboy-Black Gi Pony Express Min Bachelor•
				Bilk Creek S.S.	
				Pony Express L.S.	Wanakah Mine*
			Entrada S.S.		
	TRIAS	Late	Dolores		
PALEOZOIC	PERMIAN		Cutler		Memphis Mine*
	PENN	Upper	Hermosa	Rico Formation	
		Middle			
		Lower	Molas		Mineral Farms Mi
	MISS	Late	Leadville L.S.	Upper	Mineral Farms Mi
				Lower	Mineral Farms Mi
	DEV		Ouray L.S.		
Precambrian			Uncompahgre Fm.		

Uncompahgre Mining District

THICKNESS	Descriptions and thicknesses are taken from Bulletin 906-E with modifications and additions by JRT.
1800'- 3000'	Chiefly andesitic and latitic volcanic debris, light grey-green to pale violet in color, near the base is well stratified tuff, in part conglomeratic. Tuff-breccia in upper part.
0'- 50'	Mostly a crs. cgl. containing grit to boulder size fragments of granite, quartzite, porphyritic igneous rocks, and Paleozoic and Mesozoic sedimentary rocks.
0'- 1200'	Dark grey to black marine shale with thin beds of limestone.
135'- 150'	Grey or rusty brown quartzose sandstone with shale partings, and locally carbonaceous shales in middle and upper part. Basal sandstone contains chert pebbles. Beds altered to quartzite in areas of strong mineralization.
0'- 100'	Light-grey to green claystone, present only in sporadic lenses.
500'- 700'	Brushy Basin, mostly variegated shales, with green colors predominating except where altered; also red and brown shales and yellowish to grey sandstones. In Salt Wash member discontinous thin grey limestone lenses, and interbedded white to grey sandstones and red-brown and green shales.
25'- 30'	Grey to light brown ss, locally altd. to qtzt, very continous in thickness and appearence
85'- 125'	Upper unit chiefly green and brown shales, with green ss locally at base; thin beds and lenses of limestone; widespread layers of chert beds near top. Middle unit a soft, friable, grey to lt.brown ss, with clayey layers near the top. Basal unit is a dark bituminous shaly limestone, overlain by limestone breccia.
45'- 80'	Very massive friable white sandstone, distinctly cross bedded in upper part.
40'- 100'	Fine grained bright-red sandstones, sandy marls, and shales. Contains beds of limestone pebbles or pebble conglomerate.
0'- 2100'	Alternating bands of bright-red sandstones, pinkish grits, and conglomerates, and red-brown shales locally with earthy reddish limestones.
1400'- 1600'	Near base greenish sandstones and dark marine shales with thin interbedded fossiliferous limestones. The middle and upper parts contain thick beds of arkosic grits with inter-beds of shale and limestone.
40'- 60'	Red calc. sh. and ss with pebs of qtzt and chert and interbedded conglomeratic layers.
180'- 230'	Upper part mostly coarse-textured clastic limestone with interbeds of reddish shale. Lower part predominatly dark-blue-grey or brownish-grey limestone, with sandy layers near base.
100'- 120'	Mostly grey, buff, white, fine-textured dolomite or dolomitic limestone, locally layers of pinkish clastic limestone. Basal part referred to as Elbert formation. Thin bedded buff, dolomitic limestone.
5000'- 8000'	Massive to thin-bedded quartzite with minor shale partings; in wide bands alternating with slate or shale beds. Quartzite, white, pink and dark brown to black; slates and shales dark brown to black.

4.0 0.1 Bear left.

4.2 0.2 **STOP 16.**
The Pony Express Mine.

Freibergite, galena and chalcopyrite occur as disseminations or as irregular masses in a barite and calcite gangue replacing the Pony Express Limestone Member of the Jurassic Wanakah Formation. Here, the Pony Express can be divided into 3 units. The upper unit ($Jwpe^3$) is a limey sandstone, the middle unit ($Jwpe^2$) is a massive limestone breccia cemented by barite and calcite, and the lower unit ($Jwpe_1$) is a basal calcareous shale to argillaceous limestone. Replacements 0-100 feet wide and up to 30 feet thick extend over several thousand feet laterally along east-west vein-dike systems. Run-of-mine ore grades averaged 20-30 ounces of silver per

ton with minor gold and base-metal values.

Excellent exposures of the Upper Permian Cutler Formation, Triassic Dolores Formation and Jurassic Entrada Formation may be viewed just north of the switchback.

4.75 0.55 **STOP 17.**
Roadcut.

Quick stop to further assess the lower two units of the Pony Express Member of

the Jurassic Wanakah Formation.

5.0 0.25 American Gold Resources Corporation Gate.

5.1 0.1 Outcrop of the Bilk Creek Member of the Jurassic Wanakah Formation which is always highly fractured due to collapse into underlying cavities formed by the dissolution of the Pony Express limestone. Where this intensifies, the Pony express is entirely missing and the jumbled Bilk Creek is referred to as the pinch-out breccia.

5.25 0.15 Bear Right at Fork in Road.
Sieberg (Seaburg?) Tunnel, a haulage level beneath replacement orebodies in the Pony Express limestone that connects to the Wanakah mine, our next stop.

5.35 0.1 Jonathan Gully.
The Bright Diamond Member of the Jurassic Morrison Formation, a good host-rock for replacement deposits, crops out along the south side of the gully. Debris in gully is dump material from the Jonathan mine.

5.55 0.2 Nearing Wanakah mine dumps.
Bright Diamond quartzite exposed in roadcut. Portal of Southwest Adit just north of Memphis dike.

5.60 0.05 **STOP 18.**
South Portal of Wanakah Mine.

Mineralization in the Wanakah mine consists of magnetite-pyrite-garnet skarn in the upper levels and quartz-pyrite replacements with significant chalcopyrite and gold in the lower levels. Both types of mineralization will be seen on our underground tour. These tabular bodies occur adjacent to east-west trending mineralized structures in the Pony Express Member of the Wanakah Formation. The Wanakah is credited with production of 100,000 ounces of gold.

Proceed uphill to the Bright Diamond boarding house and Silvershield Mill tram terminus where you will be treated to a set of dinosaur tracks left by a baby apatosaur walking north on a Jurassic Junction Creek beach (Lockley, personal communication, 1990). Now you've seen it all!

Retun to last intersection.

6.5 0.9 Back at Intersection.
Heading uphill through Wanakah Formation and outcrops of the Salt Wash and Bright Diamond Members of the Morrison Formation.

6.75 0.25 Left at Fork in Road by Overlook.

6.8 0.05 Above Bright Diamond Mine.
Mine is located 400 feet below current location. High grade gold was concentrated at the Memphis Break in the Jurassic Morrison sandstone units.

6.85 0.05 Dike on Corner.

6.9	0.05	Fork in Road. Turn left on bench of Salt Wash Member of Jurassic Morrison Formation following road toward Jonathan mine and boarding house. Further along this road lie the Schofield and American Nettie mines.
7.0	0.10	**STOP 19.** Overlook.

Breathtaking vista of Ouray and the surrounding area from atop the contact between the hornfelsed Brushy Basin and Salt Wash Members of the Jurassic Morrison Formation.

8.0	1.0	**STOP 20.** Top of the World...(The Blowout).

Should your senses be able to absorb still more geology after being overwhelmed by the nineteen previous stops and the incredible vista presently before you, we will set out along a goat trail to examine cliffs of San Juan lahars and volcanoclastic alluvium that were deposited in a paleovalley cut into the argillized core of the Ouray stock. Please use a rope should you wish to make controlled contact with the stock itself. Although the trail is quite exposed in places, covered with loose material, and subject to some rather perilous rockfall (a good place for hard hats with chin straps!), it is not overly dangerous by Eiger standards. Megan Westervelt traversed it at age three (dangling from a rope tied on to her father's belt loops!). Road continues downhill for a short distance to beautiful Bridal Veil Falls, but I'm afraid that we'll have to save that experience for another day, or else forego our dinner at the Bon Ton!

Vita

Before his graduate studies at the University of Texas at El Paso in Mining Geology and Mineral Economics, William Sheriff received his B.Sc. in Geology from Fort Lewis College, Colorado. He has over 30 years experience in the mineral exploration and development business.

Sheriff currently serves as the Chief Executive Officer and Chairman of Gold Predator Royalty and Development, non-Executive Chairman of EMC Metals Corporation, and a Director of Evolving Gold Corporation, Western Lithium Corporation, Artha Resources Corporation, and Platoro West Holdings, Incorporated. He was the co-founder and served as Director and Chairman of Energy Metals Corporation (formerly a public company listed on the NYSE as Arca) and also of TSX, which was acquired by Uranium One for $1.8 billion in 2007. Sheriff also serves as President of Pacific Intermountain Gold Corporation (PIGCO), a private corporation owned by Seabridge Gold Corporation. PIGCO holds over 30 advanced gold exploration projects throughout Nevada. Sheriff also held various positions within the securities industry for A.G. Edwards & Sons Incorporated, Mitchum Jones & Templeton Incorporated, and his own securities investment firm.

As the founder and past-President of Platoro West Incorporated, Sheriff specialized in project identification and acquisition. A leading prospect developer in the Western United States, he has generated numerous exploration projects for major mining companies including NewMont Gold, Anglo, Uranerz, Atlas, Cordex, Homestake and others. To date Sheriff has raised in excess of $125 million for projects under his leadership.