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PROTEROZOIC SYNGENETIC MASSIVE SULFIDE DEPOSITS IN THE GUNNISON GOLD BELT, COLORADO

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INTRODUCTION

Proterozoic rocks exposed in the region south of Gunnison, Colorado contain precious-metal and base-metal massive sulfide deposits, which have been referred to in the past as the Gunnison Gold Belt. Work by several authors (Afifi, this guidebook; Drobeck, 1979; Riesmeyer, 1978; Beaty and Zahoney, 1977; Hartley, 1976; Trost, 1975) provides compelling evidence that these deposits were originally formed by subaqueous fumarolic activity during deposition of the local statigraphic successions. A feature that sets these deposits apart from many other districts of syngenetic, subaqueous, fumarolic-volcanogenic deposits is the variety of subaqueous environments in which the Gunnison deposits occur. Associations include: 1) within a series of basalt and basaltic-andesite flows (Ironcap Mine), 2) in a chert horizon near the contact of komatiitic flowrock and arkosic sediments (Gunnison Mine), 3) within a sequence of rhyolite pyroturbidites (Denver City Mine), 4) along a disconformity within argillites and siltites (Yukon-Alaska Mine), and 5) within a sequence of felsic water laid tuffs and flows (Vulcan Mine) (fig. 1). The lack of a preferred stratigraphic occurrence hampers exploration evaluations within the region.

The deposits commonly contain a simple ore assemblage with pyrite and sphalerite comprising 15 to 90 percent of the ore (usually 80-95 percent of the sulfides). Quartz ± chlorite ± calcite ± dolomite gangue usually comprises 20 to 80 percent of the ore. Chalcopyrite and pyrrhotite are usually present as accessories (rarely as much as 10 percent together) and galena is commonly absent, or less than 2 percent. Silver and gold occur in anomalous concentrations in the ores, but only a few samples showed precious metals values of interest as ores (as high as 2 oz/T Ag and .15 oz/T Au at the Ironcap deposit).

Lithogeochemical samples from mineralized areas in the belt were analyzed for Cu, Pb, Zn, Ag, Au, Se, and Te using a leach-

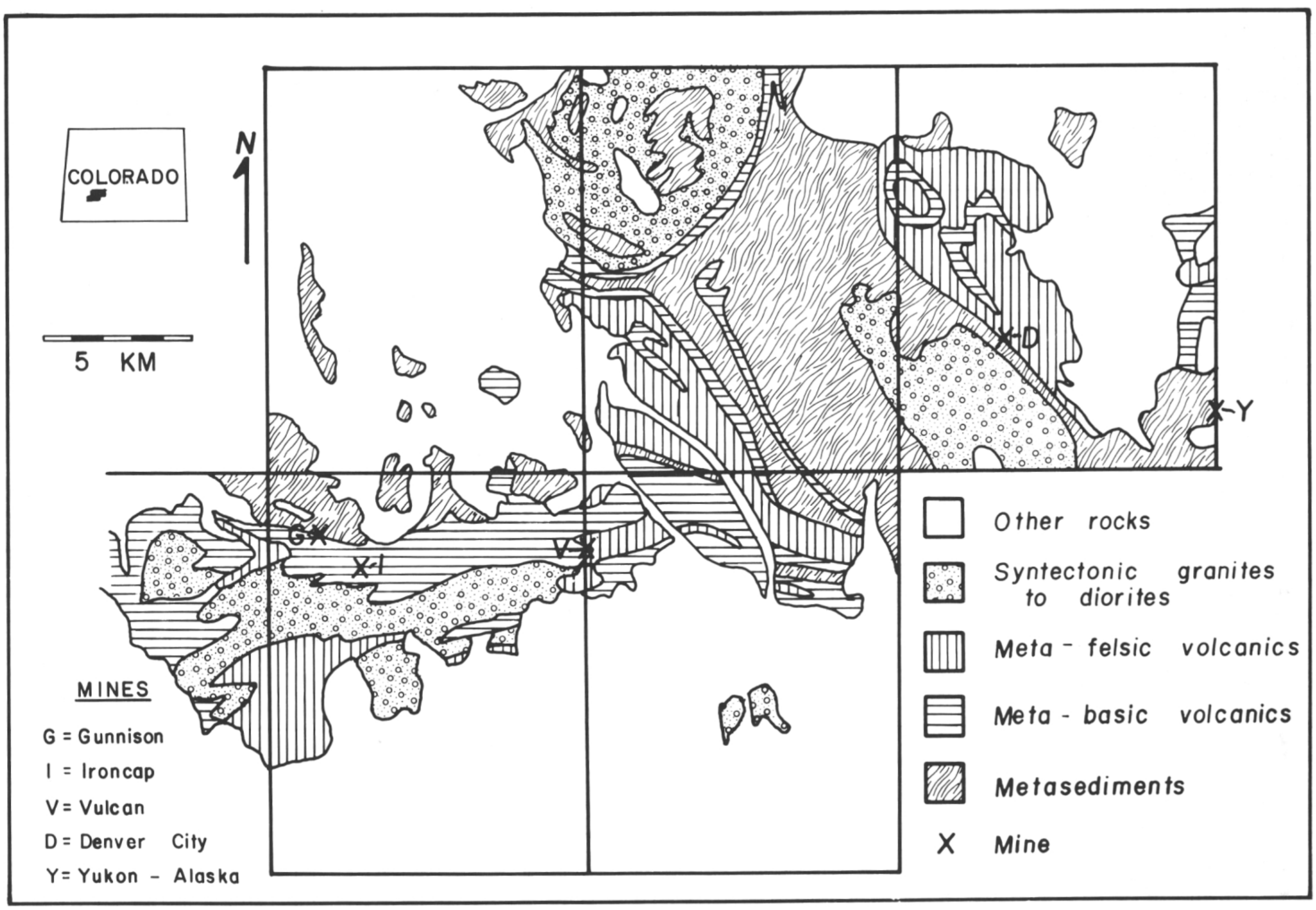

Figure 1. Generalized Precambrian geology of the Dubois Belt, southwestern-central Colorado. Sketched from Olson and Hedlund (1973), Hedlund (1974), Hedlund and Olson (1974, 1975), Olson and others (1975), and Olson (1976).

extraction technique (Clark and Viets, 1979) that measures concentrations of these elements not in silicates. Thus, the concentrations measured are less than a fire or wet chemical assay. This work showed that Cu commonly forms a large dispersion halo, especially in the stratigraphic footwall of the deposits. Pb, Zn, Au, Ag, and Se have narrower halos, being closely restricted to the visibly mineralized horizons (inferred to be the seawater interface at the time of mineralization). Te has different concentration patterns at the different deposits. Cu, Zn, Se, Ag, and Te are the most useful of the elements studied for mineral exploration here.

GENERAL GEOLOGY

There are four major Proterozoic rock types of interest to this study (fig. 1): 1) metamorphosed arkose, greywacke, and siltite with a large percentage of primary feldspar; 2) metamorphosed basalt to andesite water-lain flows and tuffs; 3) metamorphosed dacite to rhyolite tuffs, pyroturbidites, and flows; and 4) syntectonic to late-tectonic granite, granodiorite, and diorite. These rocks are informally referred to here as the "Dubois Belt" after the designation by Hedlund and Olson (1975) at the "Dubois Greenstone Belt." Afifi (this guidebook) and Vance and Blackburn (1981) found a calc-alkalic trend in the region, and Urbani and Blackburn (1974) found a calc-alkalic trend in similar rocks of 20 km NE of this study area.

Between 1730 and 1650 m.y. the region was metamorphosed and intruded by granite to diorite stocks and plutons (Hansen and Peterman, 1968; Wetherhill and Bickford, 1965). This tectonism has been referred to by Hutchinson (1976) as the Boulder Creek Orogeny. Preliminary study of the regional metamorphism indicates a "medium" grade (Winkler, 1976) was produced in much of the region, implying maximum temperatures of 500-525°C (Drobeck, 1979). No systematic study of the variations in metamorphic grade has been completed. The metamorphism was accompanied and followed by folding and faulting. The west part of the Dubois belt is dominated by shallow plunging east-west trending tight to isoclinal folds and the eastern part shows steeply plunging, northwest-trending folds (Drobeck, 1979, Fig. 1; Afifi, this guidebook). Hedlund and Olson (this guidebook) discuss the regional geology in greater detail.

DENVER CITY MINE

General Geology

This area has been geologically mapped by Riesmeyer (1978) (fig. 2), and Afifi (this guidebook) and Olson (1976). The area is dominated by steeply dipping meta-felsic tuffs and pyroturbidites, which commonly contain recrystallized pumice lapilli, and quartz and microcine phenoclasts. Thin, discontinuous purple metachert horizons imply a subaqueous environment. The mineralization is restricted to a quartz-eye rhyolite unit, and in particular, a fragmental facies of this unit (Riesmeyer, 1978; fig. 2). The rocks have been folded into steep southeast-plunging folds, and work by Afifi (this guidebook) indicates this area is on the flank of a large syncline with stratigraphic top to the northeast.

Mineralization

No production records were found pertaining to the Denver City. The deposit was developed by a now inaccessible shaft. The rich sphalerite on the dumps suggests the zinc ore was not shipped.

The mineralization occurs as a stratabound lens parallel to the dip of the host rhyolite. It is composed of massive sulfides intercalated with calcite, quartz, and fine-grained tuffaceous material.

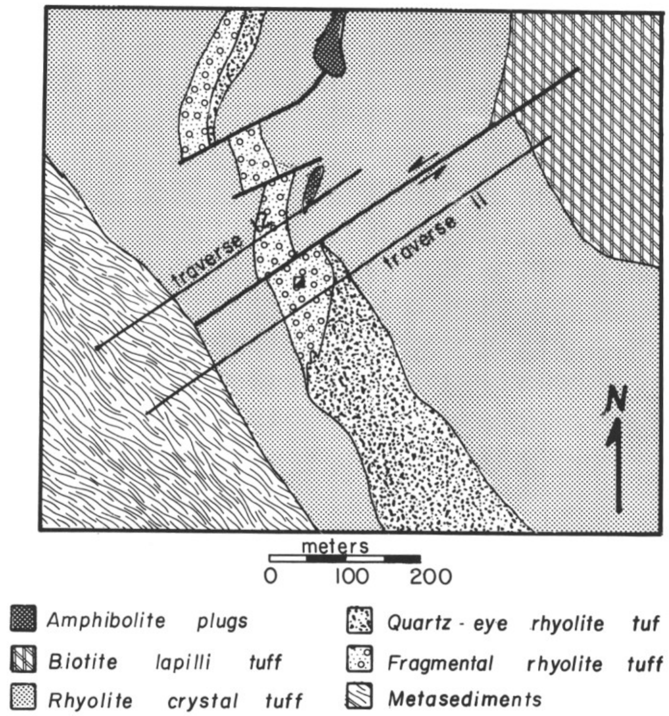

Figure 2. Geologic map of the Denver City Mine area, simplified from Riesmeyer (1978).

The massive ore is 35-45 percent quartz-calcite-muscovite gangue with 30-40 percent black sphalerite, 20-25 percent pyrite, 2-5 percent chalcopyrite, and less than 2 percent pyrrhotite. In general, where greater amounts of massive sulfide occur, the gangue becomes more calcite-rich. In places thin laminae and beds of carbonate were encountered in drilling. One sample of massive sulfide yielded 0.46 oz/T Ag and 0.04 oz/T Au by the partial extraction analysis.

The massive sulfide usually has alternating pyrite-rich and sphalerite-rich laminae, which appear sedimentary in origin. Triple junctions between the four sulfide phases are common, suggesting equilibrium was attained. Sphalerite was the first and last sulfide phase to crystallize, replacing the other phases in the latest stage. This replacement of pyrite and pyrrhotite may be a retrograde metamorphic phenomenon since the sphalerite cell can accept more iron as load pressure decreases (Scott, 1976).

Veinlet-controlled (with minor replacement) quartz-calcite-sericite alteration is restricted to a small area on the northeast side of the massive sulfide lens.

The banded sulfides, the intercalation with tuffaceous material and exhalative carbonate, the obvious metamorphic effects in the sulfides, and the stratabound, stratiform occurrence together clearly imply the deposit was formed cogenetically with the enclosing volcanic rocks.

Trace Element Geochemistry

Analysis of 31 samples on two traverses perpendicular to the strike of the mineralization showed the Cu was enriched two-fold relative to similar rocks elsewhere in the study (an average of 97 ppm versus 41 ppm). These anomalous values occur as much as 300 m from the known mineralized horizon. Directly over the known mineralization Cu concentrations rise to about twice the local background (fig. 3). Pb forms a two order of magnitude anomaly and Zn a one order of magnitude anomaly within 30 m of

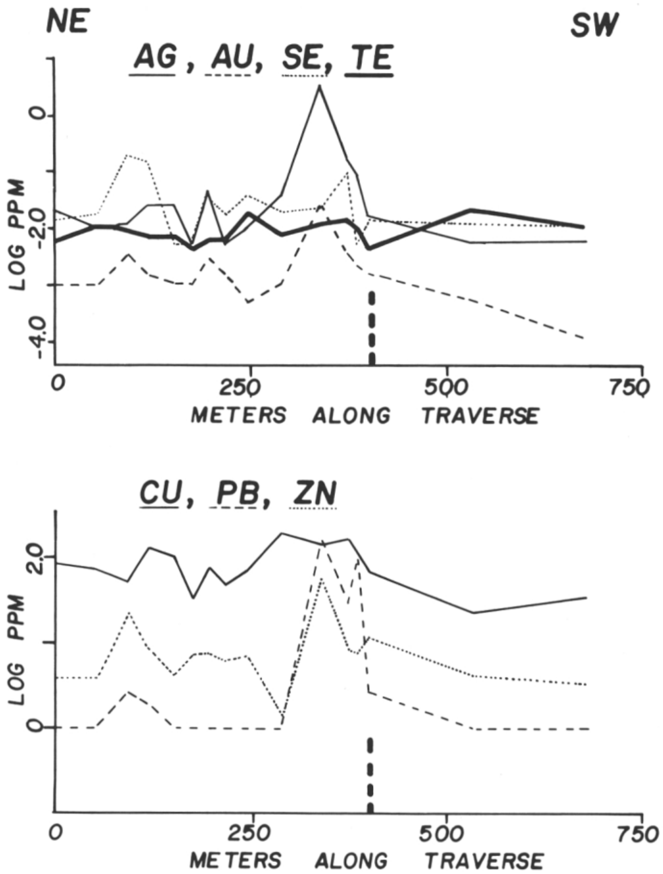

Figure 3. Trace element concentrations in samples from traverse 11 in the Denver City Mine area. Vertical dotted line notes location of mine shaft.

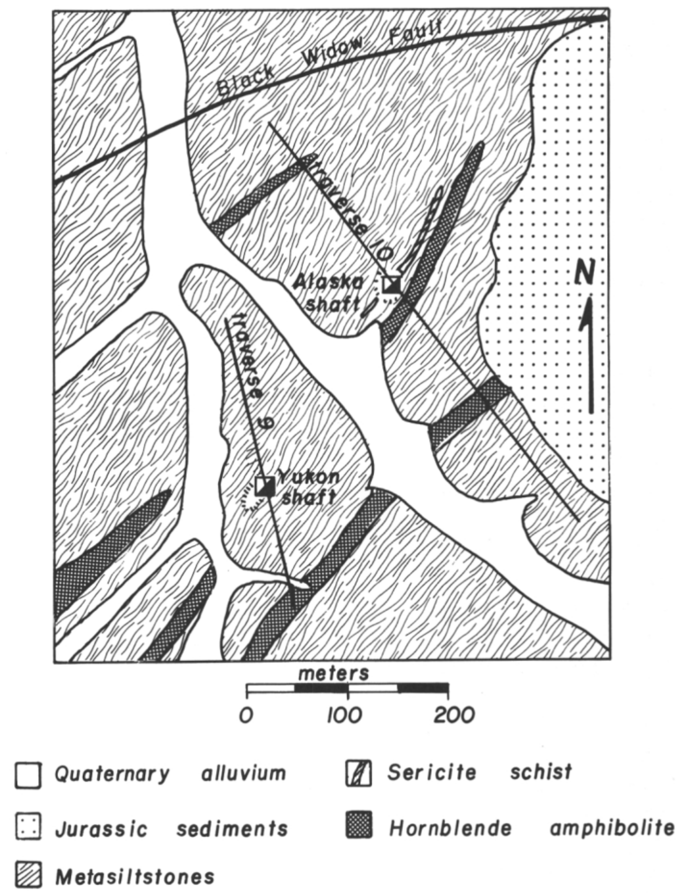

Figure 4. Geologic map of the Yukon and Alaska Mines area, simplified from Beaty and Zahoney (1977).

the known mineralized horizon (fig. 3). Se is only weakly concentrated and Te is not at all concentrated at the known mineralization. Ag forms a two order of magnitude anomaly and Au a one order of magnitude anomaly in one sample. Hence, at this deposit, Cu would have been most useful in delineating the prospect since it is so widely dispersed, and Pb-Zn-Ag are most useful in delineating drill targets. The ratio of Te/Se over the known mineralization is less than one-a characteristic of all the syngenetic mineralization in this study.

YUKON-ALASKA MINES

General Geology

This area was previously mapped by Beaty and Zahoney (1977) (fig. 4). The area is predominantly fine-grained metamorphosed argillites, siltites, and greywackes. Local relict graded bedding sequences and rare cross-beds indicate stratigraphic top is to the southeast. The stratification and foliation strike N. 30-35° E. and dip steeply to the southeast.

A 2-7-m thick horizon of fine-grained quartz-feldspar-muscovite schist occurs in outcrop next to the Alaska shaft and in subsurface on strike with the Alaska shaft. This schist is also abundant on both mine dumps. It has abundant elliptical disc-shaped weathered-out pods of quartz and muscovite 0.5 to 1.5 cm long. Though most of these pods are parallel to stratification, some are skewed to it. Hence, these are interpreted as rip up clasts of a fine-grained facies, implying a disconformity. The mineralization occurs on the stratigraphic top of this surface.

Amphibolite lenses occur throughout the area and are thought to represent sills or discontinuous basaltic flows. Minor thin metachert horizons also occur sporadically. Jurassic sedimentary rocks cover much of the area.

Mineralization

The workings at this deposit are very minor and date to the turn of the century. The Yukon Mine is developed by a presently inaccessible shaft. Reportedly, only five ore cars of 4 to 11 percent Cu ore were produced from the Yukon. The Alaska produced only ten tons of 0.70 oz/T Au ore, 15 tons of 11 percent Cu ore, and four ore cars of 34 percent Zn ore.

The mineralization at both mines occurs as one discontinuous lens of sulfide intermixed with quartz veining and interbedded sericite schist. The massive sulfide occurs as laminae 0.2 to 5 cm thick and has alternating pyrite-rich and sphalerite-rich bands. The ore consists of 25-60 percent quartz-sericite gangue, 20-50 percent sphalerite, 15-25 percent pyrite, trace to 5 percent pyrrhotite, and minor chalcopyrite, covellite, chalcocite, tetrahedrite, and galena. (Drobeck, 1979; Beaty and Zahoney, 1977). Pyrite and pyrrhotite occur as intergrowths in one sample from the Alaska dump. Triple junctions between pyrite, sphalerite, and pyrrhotite are common indicating equilibrium was attained. Broken grains of pyrite, pyrrhotite, sphalerite, and chalcopyrite occur in the gangue-rich bands, suggesting the gangue material flowed over the previously crystallized sulfide crystals and eroded them. Sphalerite was the last sulfide phase to begin crystallizing and it continued to crystallize long after the other sulfide phases, replacing them in places.

The field and textural evidence indicates the sulfides were formed as an integral part of the sedimentary sequence. The mineralization is preceeded by a local disconformity. Subsequently sulfides were precipitated as chemical sediments, becoming interlaminated with minor influxes of fine-grained sediments. The footwall of the Alaska deposit shows very minor potassic alteration (sparse 0.1 to 0.5 cm veinlets of K-feldspar ± quartz). The lack of stronger alteration implies that the fumarolic source of the sulfides was not observed in the study. It was not found along strike, and hence, is believed to occur up-dip or down-dip of the present exposed surface. The lack of associated carbonates and cherts also indicates a distant source.

Later, the deposit was metamorphosed along with the enclosing sediments, forming equilibrium textures among the sulfides. Samples on the dumps have banded sulfide and schist, which have been folded together, indicating the schist and sulfide are cogenetic.

Trace Element Geochemistry

A sampling traverse through the Yukon Mine showed no anomalous element concentrations more than 25 m from the mine itself. This lack of a dispersion halo, or any difference between the footwall and hanging wall imply that the geochemical cell that produced the mineralization was not sampled.

The sampling traverse through the Alaska Mine did show a dispersion halo of several elements. Anomalous Cu concentrations all occur in the stratigraphic footwall of the deposit and are found as much as 100 m in the footwall (fig. 5). The deep footwall Cu anomaly and relative Cu depletion in the hanging wall are characteristics found in many syngenetic massive sulfide deposits (Hutchinson, 1973). The weak anomaly at the Alaska could be a distal equivalent of a copper stringer-ore zone as is sometimes found in the footwall of these deposits (Franklin and others, 1975; Walker and others, 1975). Pb and Zn form one order of magnitude anomalies 65 m into the footwall of the known mineralization. Neither Ag or Au form an anomaly (except the high values from a dump sample). Se and Te show a two times background erratic anomaly associated with the Cu anomaly. Most samples have a Te/Se ratio less than one.

For exploration purposes, Cu, Pb, and Zn would be most useful in finding this mineralization. The footwall-hanging wall assymetry of the dispersion halo further corroborates the syngenetic model for the mineralization here.

GUNNISON AND IRONCAP MINES AREA

General Geology

This area has been mapped in detail by the author (1979) (fig. 6). The area is underlain by complexly folded and faulted Proterozoic metasedimentary and metavolcanic rocks.

The metasediments are predominantly fine-grained arkoses, greywackes, and siltites with minor quartz arenite beds. Interbedded cherts are very rare. Many sedimentary structures have survived the effects of metamorphism. Fining upwards graded bedding, ripple laminations, convoluted beds, flame structures, and rare cross-bed sets were all observed and were useful in determining stratigraphic tops. Some incomplete Bouma sequences were observed (B+C+D±E parts of a typical sequence; Walker and Mutti, 1973). These structures, and the predominance of angular feldspar in the rocks, indicate the sediments were shed from a tectonically active continental margin or island arc. These sediments are the predominant Proterozoic rock type from this locality north

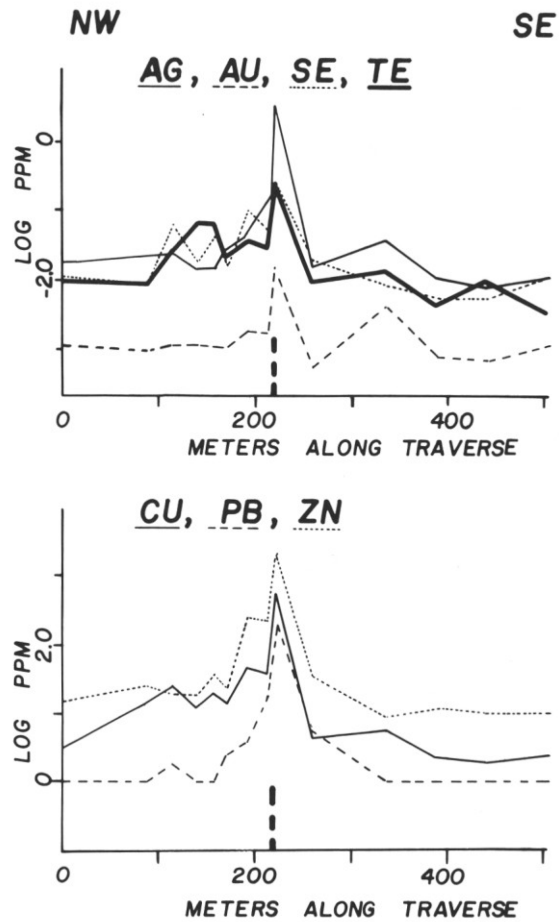

Figure 5. Trace element concentrations in samples from traverse 10 through the Alaska shaft. Vertical dotted line notes location of mine shaft.

to the Gunnison River, suggesting these rocks represent thick coalesced submarine fans.

The metavolcanic rocks in this area are mostly mafic to intermediate flows that are typical of the "Dubois Greenstone" described by other authors (Hartley, 1976; Hedlund and Olson, 1975). One of the earliest flows is a green to bluish-green ultramafic schist consisting of actinolitic tremolite, chlorite, talc, and traces of pyrite, magnetite, and relict olivine phenocrysts. A whole rock analysis of this rock showed it has 46.5 percent SiO_2, 6.2 percent Al_2O_3, 22.0 percent MgO, 8.7 percent CaO, 0.13 percent Na_2O, and 0.013 percent K_2O. Following the classification of Jensen (1976), this rock is an ultramafic komatiite.

The metamorphosed basalt and basaltic andesite flows are mostly younger than the metasediments, except in the east half of the map area where they are time equivalent. Amygdaloidal horizons can sometimes be traced for hundreds of meters. Pillows are rarely formed on top of flows and indicate the sequence was erupted subaqueously. Thin, laterally extensive horizons of fine-grained schist are believed to represent reworked hyaloclastites (Silvestri, 1963). Though most of the basaltic sequence is flows, some laminated tuffs were found in the southern part of the study area.

Metamorphosed chert horizons are common in the metavolcanic rocks. They occur as 0.5 to 10 m thick beds of purplish-black quartzite commonly with sweated-out white bull quartz. Locally

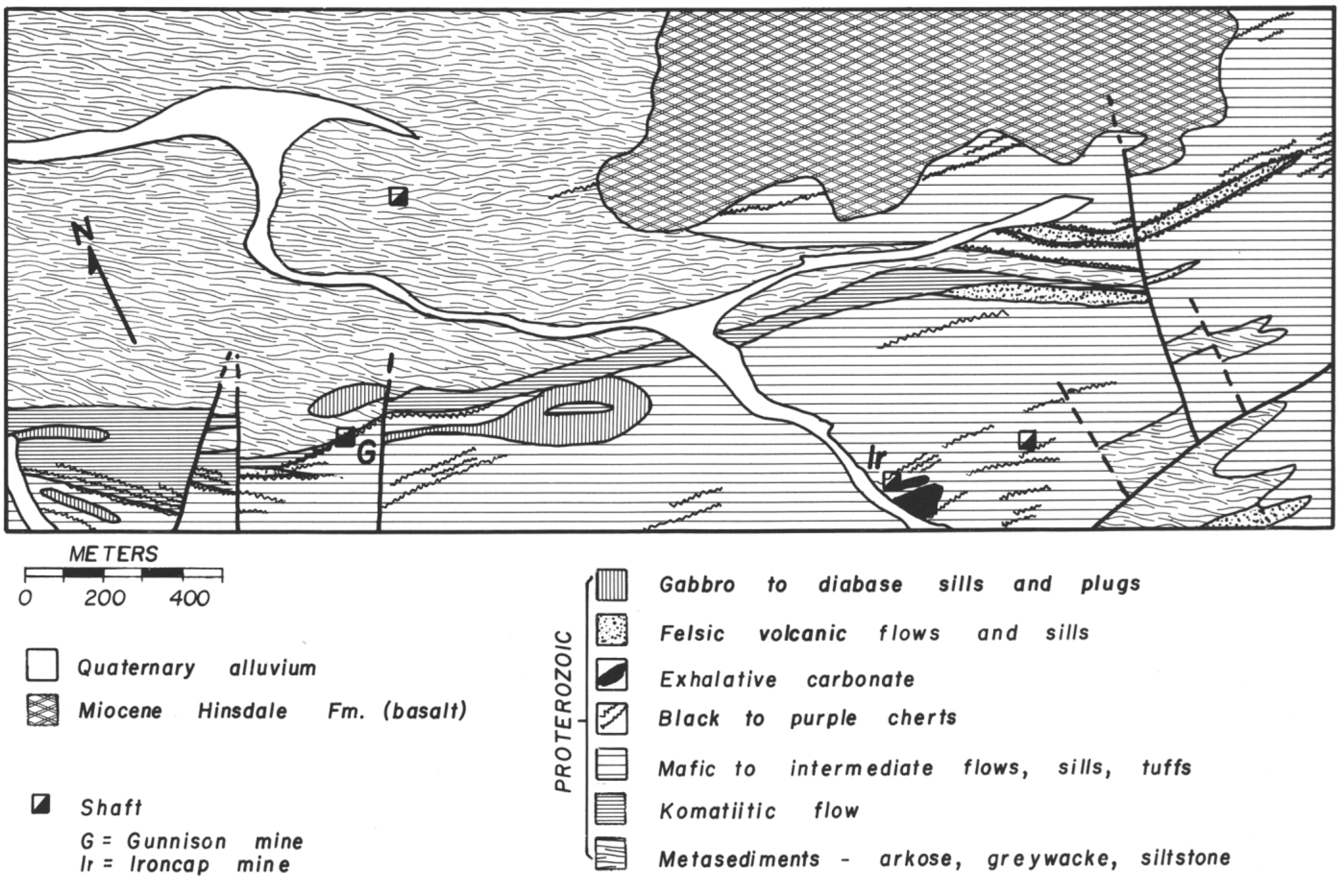

Figure 6. Geologic map of the Gunnison–Ironcap area.

they are highly magnetic, although no true iron formations were found. The cherts are believed to be chemical sediments and are closely related to the mineralization at both the Gunnison and Ironcap deposits. They carry anomalous concentrations of Pb, Ag, Au, and Se.

Carbonate exhalites were also found in the area and are closely associated with the mineralization. They are comprised of brown to white calcite, siderite, epidote, hornblende, quartz, actinolite, and minor sulfides. Well developed calcite alteration of the surrounding rocks is commonly associated with these exhalites and locally with the cherts.

The dominant structures in the area are tight to isoclinal folds plunging gently to the west-northwest. The foliation in the volcanic schists commonly subparallels axial surfaces of the folds, implying metamorphism was synchronous with folding. There are probably more folds than can be mapped since top indicators and marker horizons in the volcanic sequence are generally lacking. North-northeast trending faults cut the folds and are believed to be late Tertiary in age.

Mineralization

The Ironcap Mine has the best show of mineralization in this area. No records of the production were found but it was apparently minor. A caved shaft connects with an adit and an inaccessible winze drops from the adit. Two small shafts approximately 320 m east of the main workings are also inaccessible. They develop a correlative mineralized horizon.

The deposit occurs as an exhalite dome built around a fumarole, which contains jumbled pods of chert and tuffaceous volcanic material. The mafic volcanics are intensely altered to calcite and epidote and commonly have had all the plagioclase destroyed. Where the volcanics are still recognizable, they have numerous small calcite veinlets. The mineralization consists of laminations, veins, and veinlets of sphalerite + pyrite + chalcopyrite + galena in a quartz + calcite + epidote ± actinolite matrix. Banded textures are common. The sulfides exhibit many triple junctions and clearly have been metamorphosed with the gangue. Chalcopyrite commonly has inclusions of sphalerite and also occurs as inclusions within sphalerite. Sphalerite is less abundant in this deposit than the other deposits so far mentioned, and Cu is more abundant. A partial extraction analysis of a 1-m chip sample (representing a minimum value, not an assay) indicated 2.6 percent Cu, 2.0 oz/T Ag and 0.15 oz/T Au.

The shafts east of the main Ironcap workings have kink banded, chlorite-sericite altered volcanics with disseminated pyrite and chalcopyrite. This mineralization is considered cogenetic with, and a distal part of, the Ironcap deposit.

The Gunnison Mine consists of two small shafts sunk in a chert horizon that occurs along the metasedimentary-metavolcanic contact and is associated with a thinned portion of the komatiite flow. The stratigraphic footwall is a soft, deeply weathered biotite siltstone with minor almandite. No massive sulfide was found; only disseminated pyrite and chalcopyrite in remobilized quartz veins occur within the chert. Locally the chert has been brecciated. The chert and the remobilized quartz veins contain anomalous concentrations of Au, Se, and Te.

The stratiform and stratabound occurrences, the association with exhalites, and the obvious metamorphism of the ores indicate that both the Ironcap and Gunnison were formed as chemical sediments contemporaneously with the volcanics.

Trace Element Geochemistry

Lack of outcrop prevented rock sampling traverses perpendicular to strike through the Gunnison and Ironcap mines. A sampling traverse was made 320 m east of the Ironcap, through the weakly mineralized equivalent horizon. Only the sample from the dump on this traverse was highly anomalous in Cu or Zn. Two samples stratigraphically above this dump carried anomalous Pb, Ag, Au, and Se.

Several samples of calcite-altered metabasalt on the hill formed by the Ironcap define a +100 ppm Cu anomaly 150 x 400 m in size. Zn and Se are also highly enriched near this mineralization. The cherts near this deposit contain anomalous concentrations of all the elements analyzed.

Samples from the Gunnison Mine contain anomalous Au, Ag, and Te, but are not strongly anomalous in Cu. This is probably so because the deposit is formed on metasediments, which normally contain much less Cu than metabasalts (in which the Ironcap occurs). The Gunnison deposit is also notably more Te-rich than the Ironcap.

VULCAN-GOOD HOPE MINES

General Geology

Hartley (1976) mapped and described the geology and mineralization of this deposit. Figure 7 is a simplified version of his map. Metabasalt and metaandesite flows and sills are major rock types here and are similar in most respects to those in the Ironcap area. Most are thought to be flows. Quartzo-feldspathic schists and fels (Winkler, 1976) are interpreted as dacite to rhyolite flows, water-laid tuffs, and tuffaceous sediments. Neither the author, nor Hartley (1976) recognized pumice or any textures indicative of ash-flow tuffs or pyroturbidites, as are found in the Denver City area. Cherts are also found in the area, although much less so than in the Ironcap area. Metasedimentary rocks include greywackes, siltites, and argillites which Hartley (1976) suggested were eroded directly from the volcanic pile.

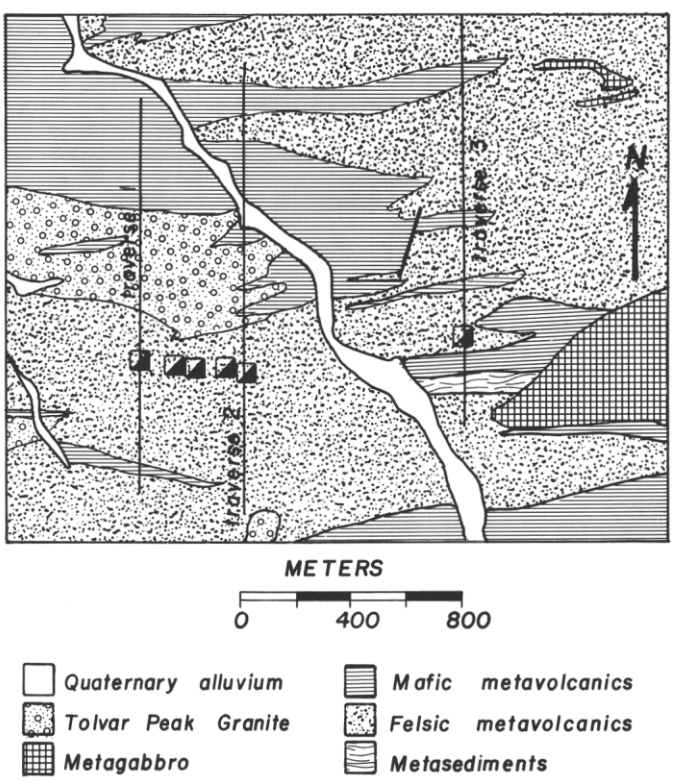

Figure 7. Geologic map of the Vulcan–Good Hope area. Simplified from Hartley (1976).

The texturally and compositionally variable Tolvar Peak Granite outcrops in much of this area. It varies from granite to granodiorite in composition. It is believed to have intruded late during Boulder Creek metamorphism.

Hartley (1976) interpreted the structure in the Vulcan area as a steeply dipping homocline with stratigraphic top to the south.

Mineralization

The Vulcan-Good Hope deposit was the largest producer in the Gunnison Gold Belt. It reportedly produced $500,000 in gold-silver ore (approximately 25,000 gold ounce equivalents) between 1898 and 1902. The actual tonnage mined and average grade are not known. The Colorado Bureau of Mines records show that another 100 tons of 2½ oz/T Au + 12 oz/T Ag were shipped in 1919. Sporadic production continued until the 1930's, including an effort to recover seleniferous sulfur. The deposit is developed by four shafts, the deepest being nearly 200 m deep.

The deposit occurs as a lens of massive sulfide (mostly pyrite) between bleached sericite schists. Within a narrow band of quartz and bleached schist on the hanging wall are opaline chalcedony veinlets which carry silver, gold, and copper tellurides as well as native tellurium (Crawford and Johnson, 1922; Crawford, 1927; Hartley, 1976). The deposit is completely oxidized down to 30 m (water table) where a pencil-shaped body of seleniferous sulfur was found. Below this body is the massive sulfide, which extends to approximately 200 m below the surface when it pinches into low-sulfide sericite schist (Hartley, 1976). The deposit has an intense quartz-sericite-pyrite alteration envelope in which no relict textures of the rock remain. This envelope is partly surrounded by an envelope of quartz-chlorite alteration.

The origin of the massive sulfide mineralization here is believed to be syngenetic with deposition of the volcanic pile (Hartley, 1976). Triple junctions between pyrite, pyrrhotite, and sphalerite, and the coarse grained annealed pyrite imply the sulfides were metamorphased together. The sulfides are sometimes banded into sphalerite and pyrite-rich laminae similar to that described at the Denver City Mine. Hartley (1978) noted sphalerite forms hairline veinlets parallel to foliation and that pyrite grains tend to be elongated parallel to foliation, again indicating metamorphism of the sulfides.

The chalcedony stringer veinlets on the hanging wall, which carry the precious metal values, may be conformable to the foliation in the schists but cut across the massive sulfides (Crawford and Johnson, 1922; Crawford, 1927; Hartley, 1976). The veinlets are distinctly unmetamorphosed, showing delicate replacement textures, which would not have survived metamorphism (Hartley, 1976). A polished section from the dumps showed replacement and brecciation textures with quartz-sericite after pyrite-sphalerite. Hartley (1976) was the first to recognize the two very different mineralization episodes here: the Proterozoic syngenetic massive sulfide mineralization, and the later gold-silver telluride chalcedony veining. He proposed that the chalcedony veining was a much later and unrelated event. Although the age of the second stage is not known, a Miocene age seems most likely since gold-silver telluride deposits of this age are known to the south in the San Juan Mountains.

The spatial coincidence of the two styles of mineralization seems fortuitous. However, D'yachkova and Khodakovskiy (1968) have shown that decreases in oxygen fugacity are the most effective way to precipitate Te from solution (more so than drops in temperature or changes in pH). It seems reasonable that if Miocene mineralizing fluids were percolating through this Proterozoic terrain, a favorable structural discontinuity to follow would be the massive sulfide-metavolcanic contact. Furthermore, these sulfides, being very reducing, would act as a geochemical trap-precipitating tellurides.

Trace Element Geochemistry

Three sampling traverses through the known mineralization were made. These samples clearly define the known mineralization and also outine a strong anomaly 730 m north of the Vulcan-Good Hope, which was also an induced polarization anomaly in Newmon t Mining's 1952 project (Hartley, 1976). Copper is strongly anomalous at both horizons, especially the north anomaly, which is 100 m wide and has four times background Cu concentrations on traverse 2 (fig. 8). No Cu zone was found on traverses 1 or 2 in the footwall of the Vulcan-Good Hope as there was at the Yukon-Alaska. This feature may be due to intrusion of the Tolvar Peak Granite in the footwall. On traverse 3, where the granite has not intruded the footwall, a Cu anomaly was found stratigraphically below the Pb-Zn anomaly (fig. 9). This pattern corroborates the syngenetic model for the massive sulfide mineralization at Vulcan. The most noteable feature of the geochemistry is the high Te

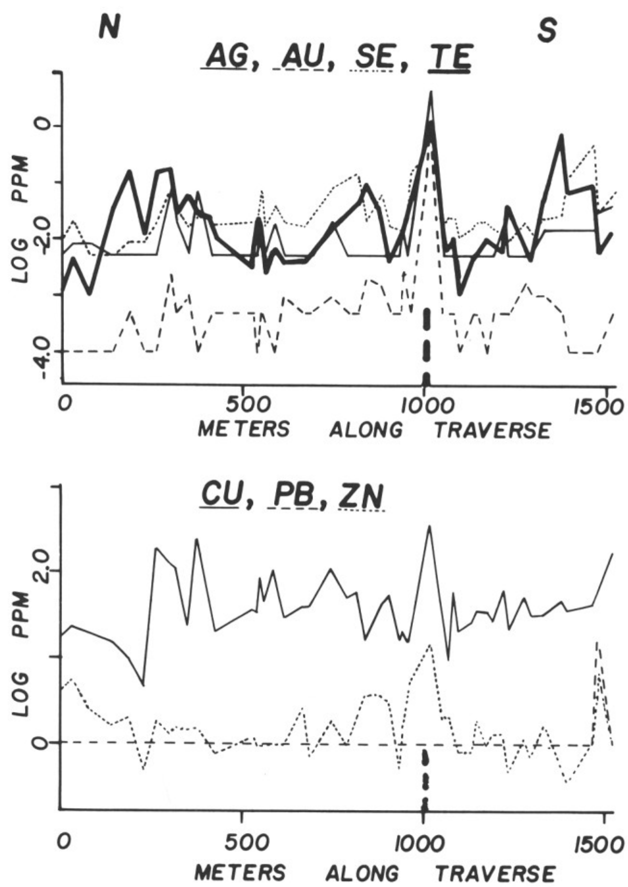

Figure 8. Element concentrations along traverse 2 through the Sulfur shaft, Vulcan–Good Hope area. Vertical dotted line notes location of shaft.

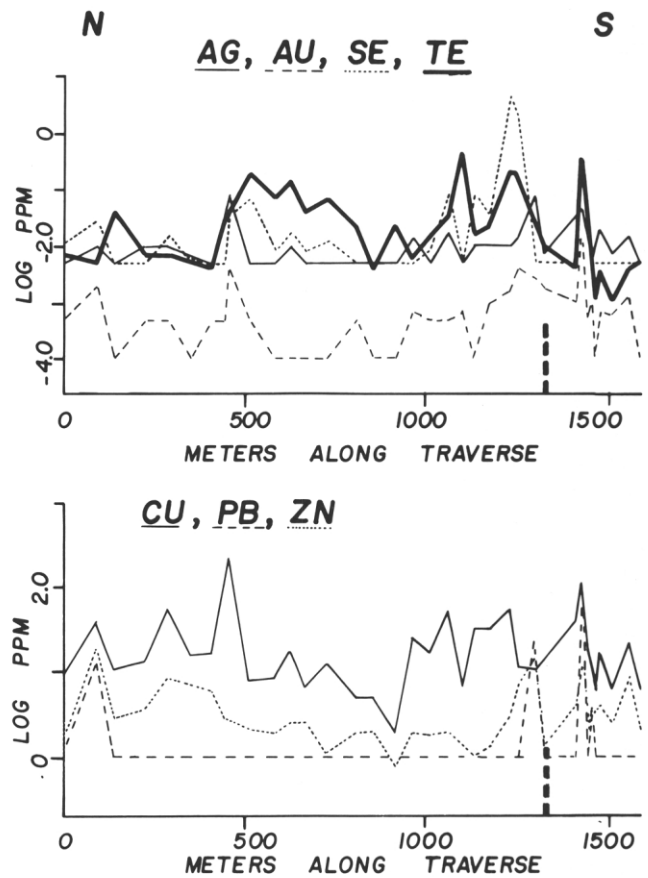

Figure 9. Trace element concentrations along traverse 3 through small shaft east of the main Vulcan–Good Hope workings. Vertical dotted line notes location of shaft.

content. The average Te content of all the samples taken in the Vulcan area is 9.3 times the average of all other samples in this study. Te clearly outlines the known productive zone on all three sampling traverses as well as the northern IP anomaly. At the core of the anomalies, Te rises to 2 orders of magnitude above background (up to 4.7 ppm against a background of 0.016 ppm).

The Te/Se ratio is highly enriched at the Vulcan-Good Hope deposit relative to the other areas studied. In most samples elsewhere in the study, this ratio is less than one and always less than 4.5 (the few samples with greater than one Te/Se all had a deficiency of Se). The ratio is greater than one in a third of the samples in the Vulcan area, even though many of these samples have high Se concentrations. In the cores of anomalies the ratio varies from 5.0 to 206. This unique Te chemistry is attributed to the later epigenetic mineralization at Vulcan, which is so different from mineralization elsewhere in the study. Thus, this ratio divides samples affected only by Proterozoic syngenetic fumarolic mineralization from those affected by Miocene(?) epigenetic mineralization.

CONCLUSIONS

The lenticular massive sulfide deposits of the Gunnison Gold Belt have several common characteristics despite their differing lithologic associations. All those studies are stratiform, stratabound, have well developed metamorphic textures, and have banded fabrics. The Denver City, Ironcap, and probably the Vulcan-Good Hope were formed proximal to fumarolic activity whereas the Yukon-Alaska was not. Both the Denver City and Ironcap are associated with well-developed carbonate exhalite zones and cherts.

Hutchinson (1973) noted that the Proterozoic deposits of syngenetic-volcanogenic origin commonly have associated carbonate exhalites. Therefore, these deposits are all believed to have originated as chemical sediments on the seafloor.

Hutchinson (1973) suggested that volcanogenic syngenetic massive sulfides of Proterozoic age can be expected to have more lead than similar Archean deposits. However, the Jerome deposit in Arizona (Anderson and Creasey, 1958), the deposits of the PyhAsalmi-Pielavasi district in Finland (Huhtala, 1979), and the deposits of the Gunnison Gold Belt have low lead contents-similar to the Archean deposits.

The trace element geochemistry method can be used reliably to outline known deposits and can thus probably be used to locate blind orebodies. Copper was found to have the widest dispersion halo at all the deposits studied and is therefore the most useful in delineating possible project areas. Zn, Pb, Se, and Ag have narrower, and higher contrast anomalies so they can be used in delineating drill targets. It was interesting to find clearly developed footwall Cu enrichment zones, which are believed to be analogous to footwall stringer zones in other deposits. The element Te and the Te/Se ratio can be used to explore for the style of mineralization found at Vulcan and to discriminate between the two different styles of mineralization studied.

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