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ECONOMIC GEOLOGY OF THE SOUTH PASS GRANITE-GREENSTONE BELT, SOUTHERN WIND RIVER RANGE, WESTERN WYOMING

by

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Introduction

The South Pass granite-greenstone terrane (**Figure 1** and **Plate 1, back pocket**) lies near the southern tip of the Wind River Range. This greenstone belt forms a synclinorium of metamorphosed sedimentary, volcanic, and plutonic rock intruded by granitic plutons. The style of structure, stratigraphy, and mineralization at South Pass is similar to Precambrian volcano-sedimentary terranes in the Slave and Superior Provinces of Canada, the Pilbara and Yilgarn blocks of Western Australia, and the eastern and southern African cratons. These latter areas are responsible for more than one-half of the world's gold production and the bulk of the world's nickel ore. The commercial significance of these terranes and their geological similarities to the South Pass granite-greenstone belt supplied the impetus for this project.

Even though the South Pass region has been Wyoming's most important source of gold and iron ore, only a few of the known mineralized structures have been systematically tested. In the past, gold mining was restricted to selective mining in near-surface, high-grade ore shoots. Large strike lengths of several mineralized structures remain untested.

Geologic summary

The South Pass greenstone belt is interpreted to represent a supracrustal belt of Archean (>2.5 Ga) rocks possibly deposited on an ancient continental crust of older Archean basement gneiss and migmatite or on an ancient oceanic crust formed of basalts and ultramafic igneous rocks. The flanks of the greenstone terrane have been intruded by granite and granodiorite, which, with the supracrustal rocks, collectively form the granite-greenstone belt.

The greenstone belt is an elongate belt of Precambrian metamorphic rocks folded into a regional synclinorium with many structural elements paralleling the axis of the synform. Foliation, shear zones, and many lower order fold axes parallel the axis of the belt. The folding style is accordianlike buckle folds with an early isoclinal folding event overprinted locally by a later, relatively open folding event expressed principally by chevron and crenulation geometries.

The greenstone belt has been regionally metamorphosed to greenschist and amphibolite facies and later locally overprinted by a retrogressive greenschist-facies event. Lithologically, the belt is dominated by metagreywacke and mica schist. However, typical of many Archean greenstone belts, the supracrustal rocks include a lower succession of mafic and ultramafic metaigneous rock. This lower succession is overlain by banded iron formation, quartzite, metapelite, and metatholeiite, and capped by a thick metagreywacke unit with interlayered mica schist, graphitic schist, metaconglomerate, metabasalt, meta-andesite, and actinolite schist.

During the Archean, before regional metamorphism, the belt was intruded by mafic sills and tonalite plugs and sills. Following regional metamorphism, the belt was intruded by granite and granodiorite plutons. Later, during the Proterozoic, the belt was invaded by a mafic dike swarm.

Mineralization is varied and includes gold, iron, copper, silver, tungsten, uranium, asbestos, and pegmatite deposits. Lode-gold mineralization is found principally in foliation-parallel shear zones that include ore shoots developed locally in fold closures, shear pinches, and shear intersections, and is associated with quartz, sulfides (pyrrhotite, pyrite, and arsenopyrite), and carbonate and related wallrock alteration. Less common types of mineralization include auriferous quartz veins, crosscutting to conformable cupriferous veins containing elevated gold and silver contents, and copper-silver stockworks. Paleoplacer and placer gold deposits are widespread in and around the greenstone terrane. Paleoplacers consist of Tertiary arkosic boulder and pebble conglomerate and fanglomerate in the Wasatch, White River, and South Pass formations. Placer deposits are often found in Recent and Quaternary stream gravels that cut regional foliation. Nearly all the gold recovered from placers is detrital.

Banded iron formation crops out along the northwestern and southeastern margins of the synclinorium. Along the northwestern flank, the iron formation is structurally thickened by internal folding and plication and is repeated by slippage along axial plane

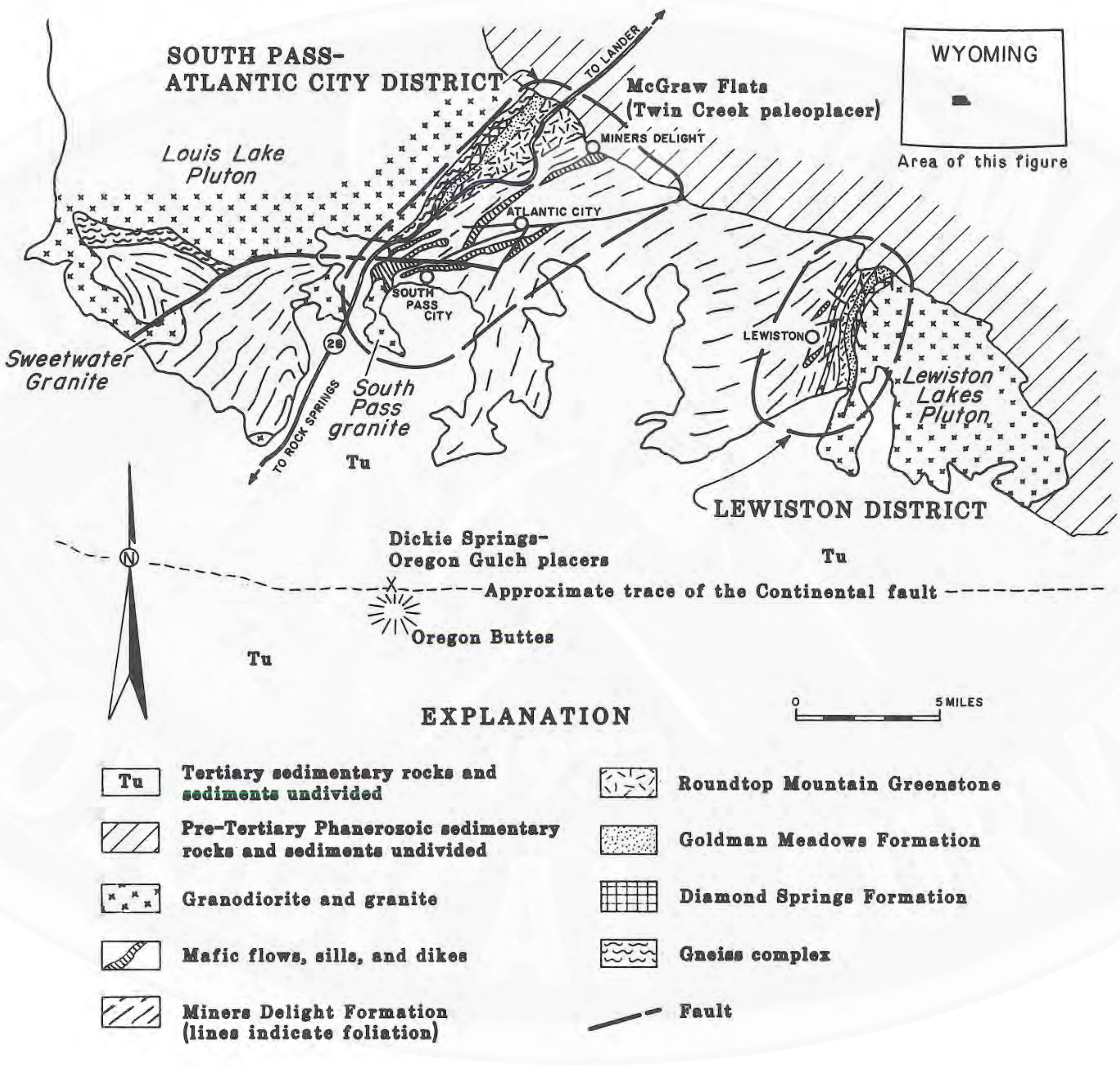

Figure 1. Generalized map of the South Pass granite-greenstone belt showing mining district locations, gold placers and paleoplacers, and simplified Precambrian geology.

cleavage and later faults. This accordianlike folding and repetition by faulting has increased the thickness of the unit nearly fourfold while shortening the strike length.

Tungsten occurs as scheelite in narrow, discrete, foliation-parallel veins and veinlets principally in metagreywacke and related placers. However, no tungsten has been mined commercially.

The pegmatites include feldspar, mica, quartz, and rare tourmaline, tantalite, beryl, and aquamarine. Additionally, gold, copper, silver, arsenic, tungsten, tin, and chromium anomalies have been detected in rocks, soils, and stream sediments of the greenstone belt.

Previous investigations

Early reports on mining and geology at South Pass include papers by Knight (1901), Beeler (1908), Trumbull (1914), Spencer (1916), Bartlett and Runner (1926), and Armstrong (1948). The first detailed maps of the greenstone belt were authored by Bayley (1965a,b,c,d). His 7 1/2-minute quadrangles included the South Pass-Atlantic City district, which was remapped by Hausel (1987c, 1988a,c,e). Bayley also compiled a 1:48,000-scale map of the district including the Anderson Ridge Quadrangle to the west (Bayley and others, 1973). Maps of the greenstone terrane west of the South Pass-Atlantic City district were completed by El-Etr (1963), Hodge (1963), Worl (1963), Markwell (1973), Lipke (1978), and Hausel (1986c, 1988d). The greenstone belt (including the Lewiston district) southeast of the South Pass-Atlantic City district remained unmapped until 1986. It was recently mapped at 1:24,000 scale (Hausel, 1986b, 1988b, 1988f).

Overviews on the geology and mineralization of South Pass were published by Bayley (1968), Bow (1986), Hausel (1986a, 1987a and b, 1989a, 1990), Snyder and others (1989a), and Hausel and Hull (1990). Prinz (1974) examined the possibility of using geochemical surveys to locate deposits in the greenstone belt.

The petrography, geochemistry, and provenance of metagreywacke from the Miners Delight Formation were examined by Condie (1967, 1981). The rare-earth and trace-element geochemistry of various units were interpreted by Wildeman and Condie (1973), Condie and Baragar (1974), and Condie (1976a). Condie (1972) proposed that a back-arc tectonic setting best fit the available data for South Pass. More recently, Harper (1985) suggested the basal ultramafics and metatholeiites of the greenstone belt represented a fragmented ophiolite complex.

Structural studies of the greenstone belt were completed by Hodge and Worl (1965), Yunker (1979), Kalish (1982), and Hull (1988). Site-specific geophysical surveys were conducted by Balsam (1986) and Day and others (1988).

Acknowledgments and dedication

Many individuals contributed to this study by providing geologic, historic, or geographic information; conversation at breakfast or spirits after dinner; or rescue from a quagmire. Although, it is not possible to name all of those who contributed, I must thank Steve Gyorvary, without whose input on geology, history, and geography this study would have fallen short of its goal. Steve also helped in the mapping of several mines in the belt; his only short-coming was his coffee.

Many other people provided information or assistance to the author. In alphabetical order, they are Nick Alexander, Bob Bell, Dean Clark, Barbara Cole, Toni Emerson, Dave Geible, Bob and Dave Haddenham, Phil Halstead, Hank Hudspeth, Jr., Bob Johnson, Bill and Sharon Johnson, Bob Kellie, J. David Love, Krista McGowan, Mike Massie, Gary Nunn, Sam Peterson, Buddy Presgrove, Bart Rea, Jim Rutter, Tony Salazar, and Gerald Stout. My two field assistants, Karl G. Albert and Jon K. King, helped with the mapping of many mines. I would also like to thank Stephen Lipple and others of the Western Australia Geological Survey for leading me through some greenstone terranes in southwestern Australia in 1986. In 1989, Stephen (currently with Geoscience Consulting, Swanbourne, Western Australia) visited Wyoming and provided some helpful input on the structure of the South Pass belt.

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Finally, I would like to dedicate this study to the memory of three people: Richard W. Bayley, whose early mapping of the greenstone belt was instructional and provided me with an excellent foundation for my study; Dave "Shorty" Haddenham, one of the last historic gold miners of the district; and Elmer C. Winters, a close friend and a fellow prospector.

Mining history

Several different mining district names have been applied to the mines of the South Pass granite-greenstone belt and no detailed treatise of these names or origins is intended for this study. Some of the more popular names applied to the districts have included archaic terms such as the Sweetwater district. More site-specific names have included the Atlantic City district, the Atlantic City-South Pass City district, the Lewiston district, the Miners Delight district, the South Pass district, and the Strawberry Creek district. However, this publication conforms to the district names of Harris and others (1985), which recognizes two mining districts in the Precambrian terrane, the South Pass-Atlantic City and Lewiston districts.

Records suggest gold may have been found in the South Pass region as early as 1842. This initial discovery was probably made in the area presently known as the Lewiston district (Hale, 1883). However, no significant developments occurred for more than two decades because of the extremely primitive and hostile environment of the Wyoming territory during the 1800s.

Sometime in 1863, placer gold was discovered in the vicinity of Oregon Buttes along the Overland Trail, a few miles south of the exposed greenstone terrane. Greene (1896) reported this discovery was rich enough to attract a "colony of prospectors" who worked the placers for three months before they were attacked and killed by Indians. Because of increased Indian hostilities following the massacre, the Overland Trail was abandoned for a safer route farther to the south (Greene, 1896). From 1864 to 1882, this region continued to be a battleground, which inhibited prospecting and mining.

In 1867, gold was discovered on Willow Creek 6 to 8 miles north of the Oregon Buttes placers. The source of this gold was traced upstream, which led to the discovery of the Carissa lode. During the ensuing winter, a handful of prospectors worked the lode with primitive hand tools and mortars, recovering more than 400 ozs of gold.

News of the discovery soon infected many immigrants and a gold rush followed. Within a short time the gold camps of Atlantic City, Miners Delight, and South Pass City were established to support hundreds of gold seekers. Nearly overnight, the population of Atlantic City grew to more than 500. Although the exact peak population at Miners Delight is unknown, it certainly numbered in the hundreds, and South Pass City swelled to more than 2,000 inhabitants.

Continued Indian hostilities made prospecting extremely hazardous. Few prospectors dared to stray far from the established gold camps and gold prospecting generally required a minimum of two people—one to dig and another to stand guard. By 1870, the U.S. Army had established Camp Stambaugh, near Smith Gulch between Atlantic City and Miners Delight, to protect the nearby mining camps. Although the district was slow to develop, by 1872 as many as 12 stamp mills were operating with a total of 161 stamps.

Most mills in the district were poorly designed, which resulted in significant losses to the tailings. Combined with the refractory nature of some ores, this often resulted in a significant loss of gold. Flooding was a major problem, affecting several mines developed in highly permeable shear zones that provided good access for ground water. Mining continued for several years, but appears to have declined markedly by 1875. In 1878, the army abandoned Camp Stambaugh but continued to patrol South Pass.

The region known as the Lewiston district, 12 miles southeast of Atlantic City, received some interest, but activities were limited because the district was far removed from the towns. The date when the district was established is unclear. Weis (1974) reported Lewiston was founded in 1879. Pfaff (1978) noted that Martin Lewis discovered placer gold on Strawberry Creek in 1875, which led to the establishment of Lewis Town (later known as Lewiston). Martin Lewis's discovery occurred on the north bank of Strawberry Creek; in the following two years as much as 19,000 ozs of gold may have been recovered from what became known as the Bullion mine (Pfaff, 1978), although this figure appears to be too high.

Gold was found south of Strawberry Creek at Wilson Bar in 1878. According to early reports, some pockets in this placer were extremely rich. The Wilson Bar placer lies at the mouth of Burr Gulch where it intersects the Sweetwater River. Gold from Wilson Bar was traced upstream to the Burr lode, which may have been found as late as 1886 (*The Lewiston Gold Miner*, v. 1, no. 1, 1894). The Hidden Hand lode (located north of the Burr) was probably not discovered until the early 1890s, although early activity on the mine is not well documented. In the 1930s, mining on the Hidden Hand lode intersected a rich shoot that produced several sacks of specimen-grade ore with 75 to 1,650 ozs of gold per ton (Pfaff, 1978) and a few rare specimens that reportedly contained 10 percent gold (3,100 ozs/ton)!

Another period in gold mining activity occurred between 1933 and 1941, when the E.T. Fisher Company dredged 6 miles of Rock Creek (Ross and Gardner, 1935). This operation was continuous until the United States entered World War II.

After the Second World War, only minor amounts of gold were mined as the main focus shifted from gold to iron. Serious exploration of the banded iron formation began in 1954, north of Atlantic City. In August, 1962, U.S. Steel Corporation shipped the first iron pellets from the Atlantic City open pit to Geneva, Utah for smelting (Bayley, 1963). From 1962 until operations ceased in 1983, more than 90 million tons of iron ore were mined (Hausel, 1984).

Gold mining activities were minimal during much of this time. When Congress eliminated the gold standard in 1969, gold prices were free to rise; by the end of the 1970s gold prices were the highest in history and they continued to rise, stimulating lode exploration in the district. A few small placer mines began production, but by the early to middle 1980s, the worldwide economic recession crippled the U.S. mining industry, including activity at South Pass. In 1986, interest in South Pass again picked up, but was soon attenuated by the 1987 stock market panic.

Geography

Located at the southern end of the Wind River Range, the South Pass granite-greenstone belt lies 30 miles south of Lander, a moderate-size Wyoming town with a population of seven to eight thousand. State Highway 28 runs south from Lander, rising to the foothills of the Wind River Range and passing along the northwestern margin of the greenstone belt before continuing another 40 miles southwest to Farson, Wyoming, in the Green River Basin. Northwest of the greenstone belt, the Wind River Range rises sharply to rugged, majestic, perennially snow-covered peaks skirted by alpine glaciers that culminate at Gannett Peak, 13,804 feet above sea level.

The greenstone belt topography is less dramatic — rolling hills on a gradual sloping pediment 8,500 feet above sea level near the foothills and 7,200 feet along the Sweetwater River. Farther south, the greenstone terrane disappears under Tertiary sedimentary cover and eventually terminates at the Continental fault (**Figure 1**). The Green River Basin lies south of this fault.

The foothills of the high mountainous peaks are covered by pine forests and lie within the National Forest. However, much of the greenstone belt to the south lies in public range land supervised by the U.S. Bureau of Land Management. Deeded ranch land and some patented mining claims occur in the area, with local areas blanketed by unpatented mining claims, but much of the region is open to public access.

Graded and unimproved dirt roads enter the greenstone belt from Highway 28. Two villages, Atlantic City and South Pass City, are located in the belt and both towns have dozens of summer cabins and homes. South Pass City hosts the historic South Pass City State Park, a reconstructed mining camp. The historic villages of Miners Delight and Lewiston are ghost towns.

South Pass is a high semidesert. The pediment and south-facing slopes support sparse grass, sagebrush, and prickly pear cactus, and the north facing slopes and creek valleys are covered with sagebrush, grass, willow, aspen, and pine. Most creeks and rivers in the region are perennial, although a few tend to dry by August. Spring runoff in late June to early July makes many streams impassible.

Regional geology and geochronology

The South Pass granite-greenstone terrane is one of several fragmented, metamorphosed, volcano-sedimentary terranes exposed in the cores of Laramide uplifts within the Wyoming Province (**Figure 2**). The geology of the Wyoming Province has been summarized by Condie (1976b), Peterman (1979), Houston and Karlstrom (1979), and Karlstrom and others (1981). The South Pass granite-greenstone belt lies within the south-central portion of the Wyoming Province and forms the southern toe of the Wind River Range.

The Wind River Range is a Precambrian-cored thrust slab. The range was uplifted during the Late Cretaceous-early Tertiary Laramide orogeny and thrust to the west and south along moderately dipping thrust faults. The toe of the Wind River thrust (the basal decollement) is approximately marked at the surface by the Continental fault, located immediately north of Oregon Buttes and south of the greenstone belt (**Figure 1**). The Continental fault, a high-angle normal fault, intersects the buried thrust (**Figure 3**).

Paleozoic and Mesozoic rocks on the eastern flank of the range dip northeast into the Wind River Basin. Paleozoic and Mesozoic rocks on the western flank are buried by syn- and post-Laramide Tertiary rocks. To the south, the Precambrian terrane is buried by Tertiary sedimentary rocks that have a very sinuous contact with the South Pass greenstone terrane.

The core of the Wind River Range is composed of a high-grade metamorphic and igneous complex of migmatite, amphibolite- to granulite-facies orthogneiss, and paragneiss that grades into quartz diorite and granite (Stuckless and others, 1985). Amphibolite-facies orthogneiss in the early crystalline complex yielded a Rb-Sr age of 2.8 to 3.8 Ga (Barker and others, 1979). The northern margin of this felsic gneiss is intruded by granite pegmatite that has Rb-Sr mineral ages of 2,000 to 2,795 Ma (Giletti and Gast, 1961; Bassett and Giletti, 1963) and K-Ar mineral ages of 1,485 to 2,420 Ma (Bassett and Giletti, 1963). Stuckless and others (1985) interpreted these data to mean the original 2.8 Ga pegmatite has been modified by secondary events.

The southern margin of the early crystalline complex of the Wind River Range is intruded by granodiorite of the Louis Lake batholith, which also intrudes the gneiss complex adjoining the South Pass greenstone belt. The Louis Lake batholith is approximately 2,630 ± 20 Ma (Stuckless and others, 1985). The southeastern flank of the greenstone belt lies in fault contact with, and is locally intruded by, granodiorite of the Lewiston Lakes pluton. Magnetic and seismic data show the fault to be steeply dipping (Day and others, 1988). This pluton may be related to the Louis Lake batholith (Day and others, 1988) or possibly to the Granite Mountains batholith to the east (Peterman and Hildreth, 1978).

The Bears Ears pluton [includes (?) Sweetwater and South Pass granites] intrudes the Louis Lake granodiorite (Stuckless and others, 1985). The South Pass and Sweetwater granites intrude and dome metasedimentary rocks of the supracrustal belt near the western margin of the belt, but they were not observed to intrude the Louis Lake granodiorite. Zircon separates from the Bears Ears pluton yielded a 2,565 ± 75 Ma age (Naylor and others, 1970).

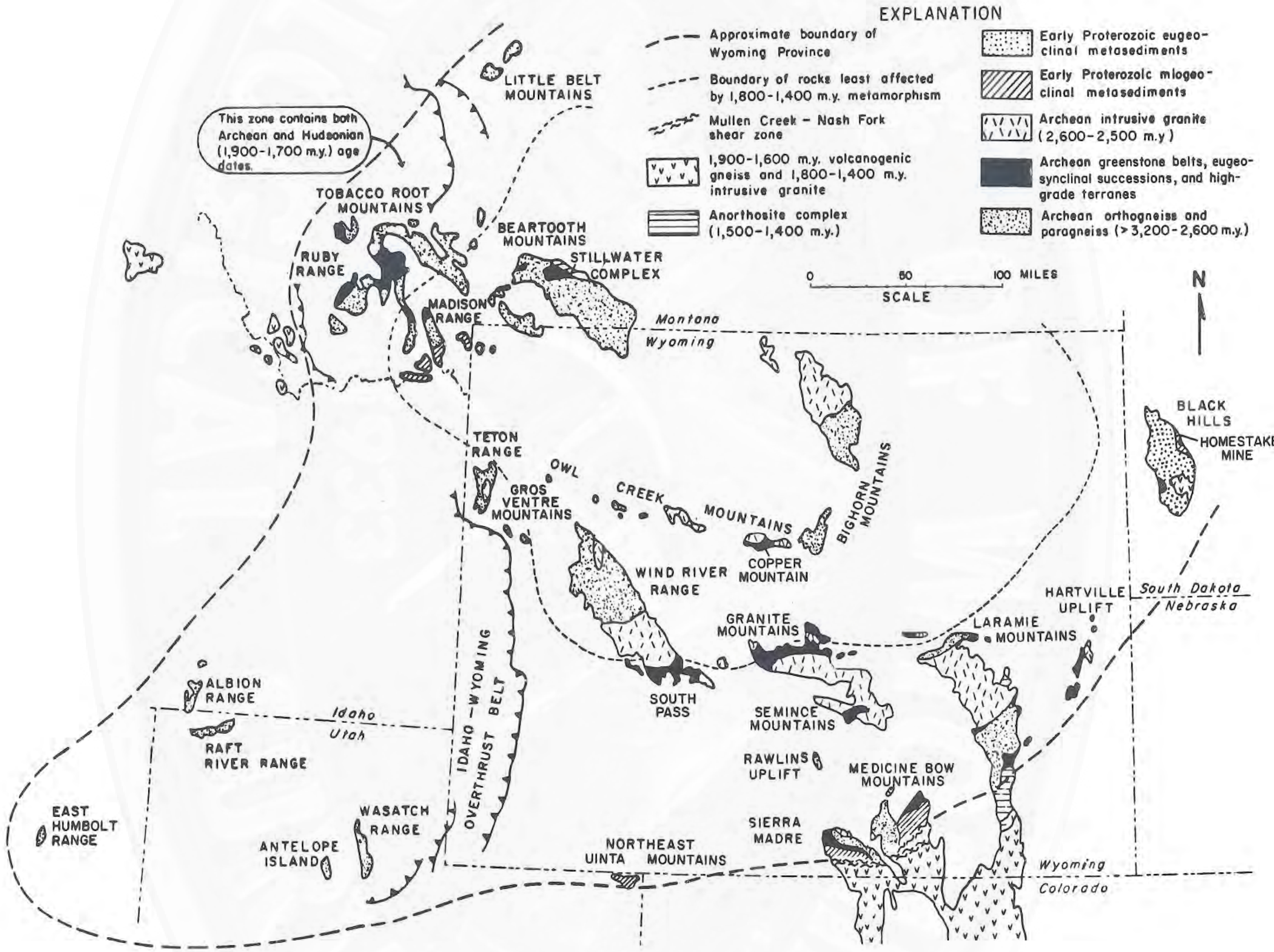


Figure 2. Sketch map of the Wyoming Province, showing the location of the South Pass granite-greenstone belt (modified from Karlstrom and others, 1981).

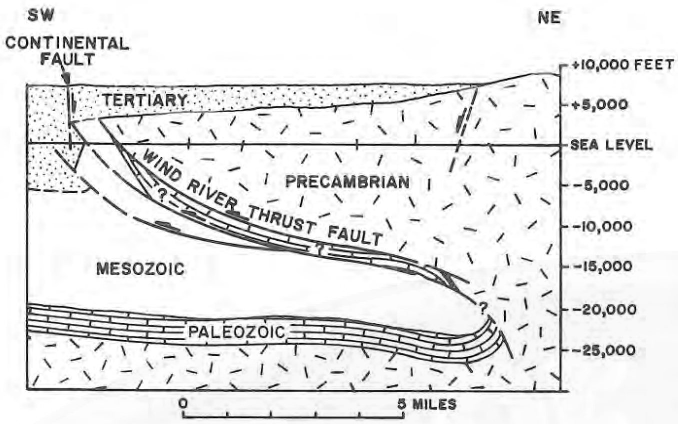


Figure 3. Structural interpretation of a seismic profile (T.29N., R.105W.) west of the South Pass granite-greenstone belt (Big Sandy profile, from Berg, 1983). The Continental fault is shown just intersecting a subsidiary thrust of the Wind River thrust fault. Although this section lies west of South Pass, it illustrates possible fault orientations at the toe of the greenstone belt.

The youngest recorded igneous event in the Wind River Range was the emplacement of a mafic dike swarm of tholeiitic affinity. These dikes have been affected by retrograde metamorphism. Whole-rock ages are 2,010 to 1,270 Ma (Condie and others, 1969). Potassium-argon ages of pyroxenes are restricted to between 1,600 and 1,880 Ma (Spall, 1971).

Following deposition and lithification of the sediments and volcanics of the South Pass greenstone belt, sometime before 2.8 Ga, the entire belt was deformed and tightly folded into a deep synformal structure. Regional metamorphism was contemporaneous with deformation, and the widespread distribution of gold deposits throughout the greenstone belt strongly suggests that metamorphic fluids were responsible for the leaching and transportation of gold.

A Rb-Sr whole-rock isochron for the Miners Delight Formation, the youngest of the Archean supracrustal units, yielded a 2,800 ± 100 Ma age (Z.E. Peterman, written communication to Stuckless and others, 1985). Bow (1986) and Hull (1988) interpreted this date to represent the timing of prograde metamorphism. A model lead age from the Snowbird mine in the Miners Delight Formation also yielded a 2.8 Ga date (Bayley and others, 1973), suggesting a temporal connection may exist between metamorphism and mineralization.

Large regions of the greenstone belt are buried by Tertiary ash falls, sandstones, siltstones, and conglomerates. Possibly as much as one-half of the uplifted greenstone belt is hidden by Tertiary cover. This cover thickens southward, where it reaches a thickness of 2,000 to 4,000 feet north of Oregon Buttes and the Continental fault. South of the Continental fault, more than 20,000 feet of sediments and sedimentary rocks overlie the Precambrian basement (Berg, 1983; Blackstone, 1989) (**Figure 3**).

In the northeast, the greenstone terrane continues under upwarped Paleozoic and Mesozoic sedimentary rocks that dip northeastward into the Wind River Basin. The basal Paleozoic section consists of Cambrian Flathead Sandstone quartzite and conglomerate, which unconformably rests on top of the Precambrian basement.

Two mining districts occur in the Precambrian belt — the South Pass-Atlantic City district, located along the northwestern flank of the South Pass synclinorium, and the Lewiston district, located along the southeastern flank. Auriferous paleoplacers eroded from the greenstone belt occur in Tertiary conglomerates and fanglomerates in the Oregon Buttes area south of the greenstone belt and in the McGraw Flats area northeast of the greenstone belt (**Figure 1**). Paleoplacers are also present within the greenstone terrane.

Rocks of the South Pass granite-greenstone belt

Unraveling stratigraphic successions in Archean terranes presents many problems because units are often thickened, thinned, folded and repeated, truncated, and transposed by multiple episodes of deformation and metamorphism. Distinctive marker beds are rare, good outcrops are uncommon, and metamorphism and deformation tend to modify the original chemistry, mineralogy, and texture. Because of these modifications, protoliths are difficult to recognize and the stratigraphic succession is always debatable.

Bayley (1965c) presented evidence that all major units in the South Pass greenstone belt were upright, although folded into a series of parallel anticlines and synclines. However, Harper (1985, 1986) presented evidence from deformed pillow structures that the Roundtop Mountain Greenstone and Goldman Meadows Formation have been overturned. Mapping by the author (**Plate 1**) agrees with Bayley's interpretation and shows the stratigraphic sequences in both exposed limbs of the synclinorium are upright. Hull (1988) and Hausel (1987c) also supported Bayley's (1965c) facing criteria. The geological evidence appears to be conclusive, but repetition of units along thrust faults and folds is undoubtedly common.

Modification of the original rock chemistry can present problems in interpreting protoliths. In most cases, relatively immobile elements such as titanium, aluminum, selenium, hafnium, zirconium, chromium, nickel, and tungsten are considered reliable indicators of precursors and probably have not been greatly modified except in and adjacent to shear zones. Therefore, metamorphic rocks not associated with shear zones that exhibit whole-rock and trace-element abundances equivalent to unaltered protoliths are assumed to be compositionally similar. For example, many ultramafic schists that have been mineralogically altered and retain no relict textures but are chemically similar to peridotitic komatiite are inferred to be metamorphosed peridotitic komatiite or a similar metamorphosed intrusive.

Very generally, the South Pass greenstone belt is floored by ultramafic and mafic metaigneous rocks that include primitive, alkali-poor, ultramafic lavas and subvolcanics and tholeiitic lavas and sills. This lower unit is overlain by a thin metasedimentary-metavolcanic unit of metatholeiite, metapelite, quartzite, and banded iron formation, which is overlain by a relatively thick metatholeiite unit. The youngest supracrustal unit includes ultramafic, tholeiitic, and calc-alkaline metaigneous rocks capped by a fining-upward metasedimentary sequence. These rocks are intruded by granite, granodiorite, and tonalite, and are intercalated with augen gneiss (gneiss complex) along the northern margin of the belt.

Gneiss complex

The northwestern margin of the greenstone belt is marked by gneiss intruded by granodiorite of the Louis Lake batholith and intermixed with supracrustals of the greenstone belt (**Plate 1**). The gneiss zone, or "mixed margin" of Bayley and others (1973), consists of strongly foliated felsic gneiss and granitic migmatite intruded by weakly to moderately foliated Louis Lake granodiorite. The gneiss and migmatite enclose concordant amphibolite, tonalite gneiss, and ultramafic enclaves (Talpey, 1984) with subordinate metagreywacke, mica schist, fuchsitic gneiss and schist, and rare sillimanite schist and banded iron formation. The felsic gneiss has augen and migmatitic textures of more severely foliated fabric than the granodiorite and supracrustals, indicating that it has been subjected to a more intense strain history (Talpey, 1984).

The gneiss complex is also intercalated with supracrustal rocks of the greenstone belt. For example, near the Atlantic City mine, the complex is interleaved with metasedimentary rocks of the Goldman Meadows Formation. A few miles southwest, gneiss is intercalated with rocks of the Diamond Springs Formation. In the vicinity of the East Sweetwater River near the western extent of the greenstone belt, layers of gneiss and granodiorite are complexly interleaved with metasedimentary rocks of the Miners Delight Formation. Only limited exposures of the gneiss complex occur along the southeastern margin of the greenstone belt, and relationships of the gneiss and supracrustals are ambiguous.

Compared to granodiorite of the Louis Lake batholith, the felsic gneiss is enriched in silica and alumina and depleted in soda. The gneiss is alkali-rich with calc-alkaline composition (**Figure 4** and **Appendix A1**). The mineralogy of the felsic gneiss is dominated by feldspar and quartz with accessory biotite, muscovite, garnet, zircon, and epidote, but lacks sphene, unlike the typically sphene-bearing granodiorite (Talpey, 1984). The gneiss possesses geochemical and mineralogical signatures of a sedimentary precursor and was interpreted by Talpey (1984) to be an S-type gneiss, which differs from the I-type (igneous) granodiorite of the batholith (Talpey, 1984).

The amphibolite enclaves of the gneiss complex also exhibit a more intense tectonic fabric than the amphibolites of the Diamond Springs Formation, at the base of the supracrustal succession. Geochemically, the amphibolite enclaves are slightly enriched in TiO_2 relative to modern mid-ocean ridge basalts (MORB) (Talpey, 1984), and they possess amphibolite- to greenschist-facies mineral assemblages.

Two possible origins for the gneiss complex were considered by Talpey (1984) and Hull (1988): (1) a differentiated border zone of the Louis Lake batholith, and (2) a remnant of an older basement.

The chemistry of the felsic gneiss does not indicate a genetic relationship with the granodiorites of the Louis Lake batholith (Lo, 1970; Talpey, 1984). The gneiss complex is lithologically diverse, and has a

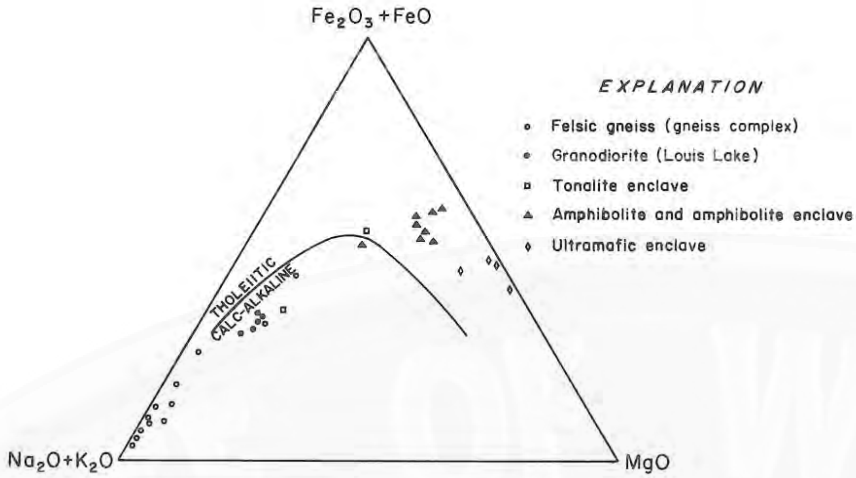


Figure 4. Ternary diagram showing ultramafics, amphibolites, tonalites, and felsic gneisses of the gneiss complex and Louis Lake granodiorite (data from Talpey, 1984; and from the author).

heterogeneous S-type rock assemblage unlike the I-type assemblage of the Louis Lake granodiorite. Thus the gneiss complex is probably not part of a differentiated border zone of the Louis Lake batholith.

Instead, the available isotopic data (Stuckless and others, 1985) suggest the felsic gneiss was derived from an older protolith than the Louis Lake granodiorite (Hull, 1988). Stuckless and others (1985) noted the garnet-bearing felsic gneisses deviated significantly from the Louis Lake Pb-Pb isochron and were probably not related to the granodiorites. This, in combination with the lack of chemical and isotopic similarity to the granodiorite, supports a separate genesis for the gneiss. The data, along with the complex interlayering with the supracrustal units, imply that the most probable origin of the gneiss complex is a ancient basement or earlier supracrustal succession that was tectonically interleaved as thrust splinters into the South Pass supracrustals.

South Pass greenstone belt

A study of the supracrustal rocks of the South Pass greenstone belt and their mineral deposits was the primary objective of this project. Bayley and others (1973) provided the first meaningful investigation of the supracrustals and designated three formations within the greenstone belt (Goldman Meadows Formation, Roundtop Mountain Greenstone, and Miners Delight Formation). The same stratigraphic terminology used by Bayley and others (1973) is used here, although it became apparent during mapping that there is a fourth mappable unit, the Diamond Springs Formation (Hausel, 1986d, 1987b).

The four mappable formations of the greenstone belt (Bayley and others, 1973; Hausel, 1986d, 1987b) (**Plate 1**), have been affected by amphibolite-facies metamorphism and, to a lesser extent, by greenschist-facies metamorphism.

Diamond Springs Formation

The Diamond Springs Formation is named for relatively continuous but poorly exposed outcrops south of Diamond Springs in SW sec. 19, T29N, R97W and in sec. 36, T29N, R98W (Hausel, 1986a, 1987b; 1988b,1988e). This new unit was originally described by Bayley and others (1973) as a distinct group of rocks containing metabasalt, metagabbro, and serpentinite located near Iron Mountain, along the northern margin of the South Pass greenstone belt.

The Diamond Springs Formation is dominated by serpentinite, tremolite-talc-chlorite schist, and amphibolite. These rocks can be chemically separated into three groups—ultramafic (peridotitic) komatiites, basaltic komatiites, and tholeiitic basalts. Rocks with ultramafic compositions include both serpentinites and tremolite-talc-chlorite schists. Those with basaltic komatiite composition include tremolite-talc-chlorite schists and amphibolites. Tholeiites include amphibolites and some chlorite schists.

Rocks of the Diamond Springs Formation were considered by Bayley and others (1973) to be part of a migmatite assemblage interpreted as a remnant of a mafic volcanic basement upon which the South Pass supracrustals were deposited. However, recent mapping (Hausel, 1987b, 1988b,e) indicates these rocks are conformable with the overlying supracrustal succession, are more widespread than previously thought, and should be considered part of the greenstone belt. For example, continuous outcrops of this unit have been mapped for more than 3 miles along the northwestern flank of the greenstone belt (**Plate 1**) and also along much of the exposed length of the southeastern flank of the belt. Unfortunately, only a few localities have good exposures and well-preserved textures, but at these sites, the Diamond Springs schists are conformable with the overlying metasedimentary rocks of the Goldman Meadows Formation.

Serpentinites

Serpentinites of the Diamond Springs Formation form dark green to brownish green, massive, hornfelsic to schistose serpentinites containing abundant serpentine, disseminated magnetite, and minor chlorite and talc. Often these rocks are stained by hematite or contain disseminated hematite pits after magnetite, and may locally contain asbestos (see p. 37). Relict cumulate textures are preserved in some serpentinites. In the cumulates, serpentine occurs as pseudomorphs after olivine and pyroxene (**Figure 5**). The former pyroxene and olivine grains are also commonly outlined by magnetite. Possibly the best cumulate-textured serpentinites occur west of the Atlantic City mine entrance, in the W/2 SE sec. 34, T30N, R100W. Serpentinite contacts are commonly conformable, suggesting these relatively fine-grained rocks are metamorphosed flows or sills (Hull, 1988).

Tremolite-talc-chlorite schists

Tremolite-talc-chlorite schists have varying amounts of amphibole (tremolite/actinolite to anthophyllite), chlorite, talc, serpentine, carbonate, and two generations of opaque minerals (Hull, 1988). These gray-green to gray rocks include plagioclase-actinolite schist, talc-chlorite schist, and tremolite/actinolite-talc-chlorite schist. The rocks often exhibit varying degrees of carbonatization and serpentinization.

Amphibolites

Amphibolites of the Diamond Springs Formation are dark gray to black hornblendic amphibolites with schistose, hornfelsic, diabasic, and gabbroic textures. These rocks are principally hornblende-plagioclase (± quartz) amphibolites with subordinate biotite and chlorite.

Figure 5. Cumulate-textured serpentinite from the Atlantic City mine area. Sample consists of abundant 2- to 4-mm diameter grains of serpentine after olivine and pyroxene in a serpentinized matrix. Photograph taken at locality 23D (Plate 2).

Locally, these rocks have been retrogressively metamorphosed to greenschist facies and include chlorite-sericite-epidote-quartz-feldspar assemblages. Textures vary, but indicate basalt to diabase protoliths. Pillow structures have also been recognized west of the Atlantic City iron mine (Greg Harper, personal communication, 1986), thus both flows and sills are present.

Igneous protoliths

Because primary textures are lacking in most rocks of the Diamond Springs Formation, protolith determinations are often dependent on geochemistry. The geochemistry and mineralogy indicate Diamond Springs Formation rocks had high initial magnesium content and are metamorphosed equivalents of basaltic and gabbroic tholeiites, undepleted peridotites, pyroxenites, and basaltic and peridotitic komatiites (Hausel and Hull, 1990) (**Appendix A2** and **A3**). The relatively fine-grained textures and conformable contacts of many of these rocks suggest they were originally volcanic or subvolcanic, although medium- to coarse-grained intrusive sills are intercalated with the metavolcanics. Chemically, they are similar to mafic and ultramafic volcanic and subvolcanic rocks from Canada, South Africa, Western Australia, and the Seminoe Mountains and Elmers Rock greenstone belts of Wyoming. They can be separated into three groups based on whole rock chemistry: (1) peridotitic komatiite, (2) basaltic komatiite, and (3) tholeiitic basalt.

(1) Rocks with peridotitic (ultramafic) komatiite composition. Ultramafic rocks from the Diamond Springs Formation include serpentinites and tremolite-talc-chlorite schists that have SiO_2 contents ranging from 28.6 to 50.6% (**Appendix A2**). MgO values vary from 18.5 to 38.1%, and the alkali and TiO_2 contents are very low (Na_20 <0.01 to 0.41%; K_20 <0.02 to 0.31%; and TiO_2 from 0.02 to 0.81%). Chromium contents range from a high of 10,100 ppm to a low of 595 ppm. Nickel contents vary from 2,570 ppm to 160 ppm.

In general, the major-oxide chemistries of many of these rocks demonstrate a similarity to ultramafic komatiite, with the exception of some serpentinites that have unusually low $Ca0/Al_2O_3$ ratios. The generally low CaO/Al_2O_3 ratios (0.06 to 0.74) may be the result of CaO depletion with respect to Al_2O_3 during serpentinization (Herrmann and others, 1976; Condie and others, 1977). The CaO/Al_2O_3 ratios for the tremolite-talc-chlorite schists range from 0.6 to 2.8, which in many cases is very close to unity and more characteristic of komatiite.

Some serpentinites (e.g. 12D; **Appendix A2**) are depleted in the olivine-incompatible elements aluminum, titanium, and calcium, which reflects a relatively high modal olivine content. These rocks were collected from an asbestos serpentinite north of the Atlantic City mine and are chemically similar to komatiitic dunites from the eastern Yilgarn Block, Western Australia (sample 8D, **Appendix A2**).

A few ultramafic rocks were partially analyzed for their rare-earth element (REE) chemistry. The preliminary results show these rocks possess flat heavy REE patterns similar to the Western Australian komatiites. Since the light REE data are lacking, no further comparison can be made.

Ultramafic rocks are common hosts for commercial nickel, chromium, platinoids, and gold, but samples from the South Pass greenstone belt showed only weak chromium and gold anomalies and average amounts of platinum, palladium, and nickel (see, p. 36). Typically, ultramafics show increasing amounts of nickel and chromium with increasing MgO content.

(2) Rocks with basaltic komatiite composition. Rocks with chemistries similar to basaltic komatiite (samples 61D-68D, **Appendix A3**) also occur in the Diamond Springs Formation. These rocks are serpentine-chlorite schists, talc-chlorite schists, tremolite-chlorite-talc schists, and tremolite-hornblende-plagioclase amphibolites.

Silica contents for these rocks range from 43.3 to 55.5%; TiO_2 concentrations are relatively low (1.33 to 0.17%); and alkali contents are low (0.35 to 2.95% Na_2O; <0.03 to 1.54% K_2O). MgO varies from 9.16 to 19%, which parallels high chromium (97 ppm to 2,900 ppm) and high nickel (30 ppm to 980 ppm) contents. These rocks have $Ca0/Al_20_3$ ratios between 0.67 and 2.6). One anomalously high $Ca0/Al_20_3$ ratio (65D, **Appendix A3**) is due to carbonate alteration.

The cation percentages for these schists show a distinct suite of rocks with compositions similar to basaltic komatiite, having an apparent compositional gap in the range of 11.5 to 15% MgO (**Figure 6**). This gap could be the result of sampling bias, tectonic removal of a portion of the section, or lack of rocks with MgO content transitional between basaltic komatiite and peridotitic komatiite. Sun and Nesbitt (1978) found a similar compositional gap in the range of 12 to 18% MgO, which was ascribed to a lack of a genetic link between basaltic and peridotitic komatiite.

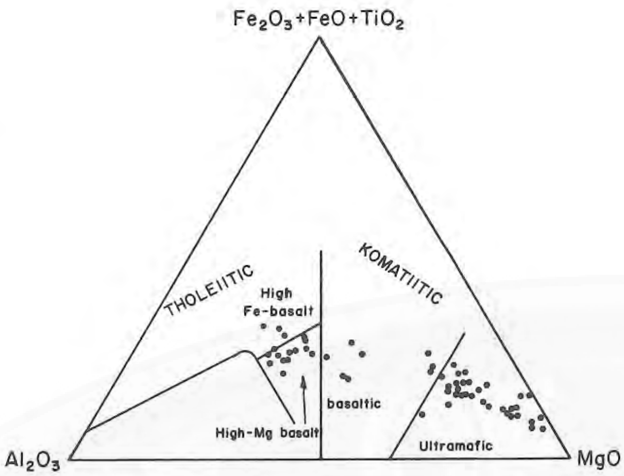


Figure 6. Jensen plot of metaigneous rocks of the Diamond Springs Formation. The major cation percentages of these rocks are similar to basaltic and ultramafic komatiite, and to tholeiitic basalt.

A few samples of basaltic komatiite affinity were partially analyzed for their REE chemistry. These showed relatively high light REE contents and have similar patterns to amphibolites of the Elmers Rock greenstone belt (see Smaglik, 1987) and to spinifex-textured basalts from the Negri volcanics, Australia (see Sun and Nesbitt, 1978).

No significant precious metal anomalies were observed for the rocks with basaltic komatiite chemistry. The chromium and nickel contents of these schists are typical of basaltic komatiites, although samples 63D and 64D (**Appendix A3**) have relatively low chromium and nickel compared to the typical basaltic komatiite, indicating that these rocks are most likely not komatiites and have been altered or fractionated. The rocks with komatiite affinity have been completely recrystallized during metamorphism. Unfortunately, spinifex textures have not been preserved in any rocks with komatiite affinity at South Pass.

(3) Rocks with tholeiitic basalt compositions. A third group of rocks in the Diamond Springs Formation includes amphibolites, metabasalts, and mica schists with tholeiitic affinity.

Rocks of this group have higher alumina and alkali contents and lower magnesium, chromium, and nickel concentrations than komatiites. Silica ranges from 32.4 to 56.8%. Even though the alkali content is higher than in the komatiites, these rocks are still subalkaline. Soda ranges from 1.18 to 3.36%, and potash ranges from 0.9 to 0.08%. Magnesium content, from 9.35 to 5.7% MgO, is high compared to modern terrestrial basalts. The rocks contain from 400 ppm to 20 ppm chromium and 190 ppm to 17 ppm nickel.

Compared to their modern terrestrial counterparts, these rocks have more MgO and Fe_2O_3 and less Al_2O_3. The Ti/V ratios range from 13 to 27, which is higher than ratios for modern island arc tholeiites and modern mid-ocean ridge tholeiites. The magnesium, nickel, and chromium contents are generally higher than modern tholeiites.

One sample of metatholeiite was tested for REE content. In general, the preliminary REE data is similar to other Archean basalts.

For the most part the metabasalt gold contents are not anomalous. Samples yielded < 0.005 to 0.032 ppm gold. The maximum gold content was 19 times higher than the average terrestrial mafic igneous rock.

Geologic setting

Whether or not these rocks are part of a dismembered ophiolite complex, as suggested by Harper (1986), is undetermined. The compositions of the rocks from the Diamond Springs Formation are typical of the basal volcanic members of greenstone belts in other Archean terranes in the world and it is apparent that they represent high-magnesian flows and sills that were erupted on an ancient sea floor of the primitive Archean Earth.

Goldman Meadows Formation

The komatiitic and tholeiitic rocks of the Diamond Springs Formation are overlain by the Goldman Meadows Formation. Rocks of the Goldman Meadows Formation include quartzite, banded iron formation, pelitic schist (metapelite), and amphibolite (metatholeiite).

The Goldman Meadows Formation was named by Bayley (1965d) for exposures northwest of Goldman Meadows in sec. 26, T30N, R100W. The type section described by Bayley and others (1973) included mica-andalusite schist, biotite(chlorite)-garnet schist, quartz-magnetite iron formation, chlorite-amphibole-magnetite-garnet schist, quartz-mica schist, chlorite-amphibole-garnet schist, quartz-mica-andalusite schist, quartzite, and feldspathic quartz-biotite schist. Bayley's type exposures are presently buried by the Atlantic City mine tailings and are submerged under a lake occupying the open pit. However, some good exposures are found approximately 1 mile north-northeast of the mine, in sec. 24. The Goldman Meadows Formation has been an important source of iron ore in the past (see p. 35).

Many of the rock units described in the type section are missing southwest of the Atlantic City mine. The Goldman Meadows Formation is structurally thickened in the vicinity of the iron mine but it thins to the southwest (**Plate 1**). Along the southeastern flank of the greenstone belt, the formation can be traced for nearly 5 miles. It includes mica-andalusite schist, quartz-magnetite iron formation, quartz-hematite iron formation, quartz-mica schist, fuchsitic quartzite, and amphibolite. Metabasalt and hornblendic amphibolite intervene between metasedimentary units east of the Atlantic City mine and in the vicinity of Strawberry Creek and the Sweetwater River along the southeastern flank of the greenstone belt. North of Strawberry Creek, the formation is faulted and fragmented. Farther south, the formation is comprised principally of amphibolite schist with thin units of quartzite, fuchsitic quartzite, porphyroblastic andalusite-muscovite schist, and mica schist. Near the Sweetwater River, the formation is poorly defined by two thin mica schist layers separated by a thick belt of amphibolite. The enclosed amphibolite belt was included in the formation.

Iron formation members

The Goldman Meadows iron formation has been the subject of considerable interest because of the iron deposits that were mined along the northwestern flank of the greenstone belt. However, studies related to the iron formation's potential as a gold host are nonexistent. Lithologically, these rocks are hard, dense, laminated rocks with alternating layers of magnetite and metachert and varying amounts of amphibole. The layers are commonly plicated, 0.1 to 0.5 inch thick, but may be as much as 2 inches thick. The rock is black to dark gray with fine-grained hornfelsic microtexture and is highly magnetic. The siliceous layers, interpreted as recrystallized chert, consist of fine-grained quartz mosaics with intergranular euhedral magnetite and amphibole. The magnetite-rich layers are formed of euhedral magnetite and crystalline magnetite aggregates with minor quartz and amphibole (Bayley and others, 1973).

The average iron content of the quartz-magnetite iron formation in the Atlantic City mine area is about 33.5% (Bayley, 1963). One whole-rock analysis yielded 56.23% SiO_2, 34.96% Fe_2O_3, and 5.67% FeO (Bayley, 1963). Samples collected from the southeastern flank of the greenstone belt (sec. 19, T29N, R97W) yielded a similar iron content (1G, 8G, and 9G, **Appendix A4**).

Well-foliated lenses and selvages of quartz-chlorite schist, chlorite-garnet schist, and chlorite-amphibole-garnet-magnetite schist are interlayered with the iron formation in the vicinity of the Atlantic City mine (Bayley, 1963). These selvages and the iron formation commonly contain conformable quartz lenses and veins that are boudinaged parallel to foliation. Later quartz and carbonate veins and veinlets also cut foliation.

Locally, the iron formation and schist selvages are sulfide bearing. The greatest sulfide concentration was found in SE sec. 26, T30N, R100W, along the highwall of the Atlantic City mine, which is currently submerged under water. Here, the rocks contain 1 to 5 percent sulfides as pyrite euhedra and disseminations, and as sulfide aggregates conformable to foliation. Secondary pyrite and chalcopyrite also coat rock cleavage surfaces that crosscut the primary banding. Samples of the sulfide-bearing iron formation were tested for gold with no detectable precious metal. However, some oxide-facies iron formation yielded weak gold anomalies elsewhere (see banded iron formation, p. 35).

Along the southeastern flank of the greenstone belt, the magnetite-chert banded iron formation grades southward into hematite-quartz iron formation. Within one-quarter mile of the Oregon Trail, the iron formation is intruded by metagabbro and no other iron formation is found south of the metagabbro.

Schist member

The schist member of the Goldman Meadows Formation includes pelitic schists, thin quartzites, and massive to schistose amphibolites. The pelitic schists are principally porphyroblastic, with large andalusite porphyroblasts in fine- to medium-grained muscovite. Many porphyroblasts are replaced by muscovite and quartz. Less common are quartz-muscovite schists, biotite (chlorite) schists, garnet-mica schists, and quartzite. Amphibolite units are generally thin, but at some locations, the amphibolites form relatively thick sections.

Quartzites of the Goldman Meadows Formation are commonly light colored, white, gray, or brown, but some outcrops appear green where fuchsite (chrome-muscovite) colors bedding surfaces. The rock is fine to medium grained, vitreous, and recrystallized, and it exhibits no primary sedimentary structures other than bedding. Quartz mosaics with numerous minute colorless mica flakes and traces of tourmaline are visible in thin section. Chemical analyses (4G, **Appendix A4**) show anomalous chromium (400 ppm) in fuchsitic quartzite and relatively high iron content (8.41% Fe_2O_3) in light reddish brown quartzite (6G, **Appendix A4**).

The few amphibolites collected from the Goldman Meadows Formation for analyses are strongly foliated hornblendic amphibolites. Compositionally, these rocks fall between the more mafic tholeiites of the Diamond Springs Formation and the more iron-rich tholeiites of the Roundtop Mountain Greenstone. Titanium to vanadium ratios average 17 (3G, 5G, and 7G, **Appendix A4**).

Geologic setting

The Goldman Meadows Formation indicates a significant change in the depositional environment of the South Pass belt. The metasedimentary rocks represent a relatively shallow water stable-platform facies, eroded from a nearby shelf that appeared in Goldman Meadows time and shed sediments into a deeper oceanic basin (Hull, 1988). Erosion of the shelf was periodically interrupted by volcanic activity, erupting basalt flows and ejecting iron-silica exhalites.

Roundtop Mountain Greenstone

The Roundtop Mountain Greenstone was named by Bayley (1965c) for exposures on Roundtop Mountain in secs. 30 and 31, T30N, R99W. The formation rests conformably (locally unconformably) on the Goldman Meadows Formation and consists primarily of greenstone, greenschist, and amphibolite. Mica schist, hornblende-mica schist, and metabasalt, with lesser metagreywacke, minor metatuff, tremolite/actinolite schist, chlorite schist, and rare grunerite schist are also present. Exposures of the Roundtop Mountain Greenstone are found in both limbs of the South Pass synclinorium (Hausel, 1987b) (**Plate 1**). Along the northwestern flank, greenstones and greenschists at Roundtop Mountain grade into amphibolites to the southwest. Rocks of the Roundtop Mountain Greenstone in the eastern flank of the synclinorium are entirely amphibolite facies.

Microscopically, the greenstones and greenschists are almost entirely composed of chlorite, actinolite, epidote, and minor apatite. The original plagioclase is entirely sausseritized. The amphibolite-facies rocks are composed of blue-green hornblende, twinned and untwinned plagioclase (oligoclase to andesine), and minor quartz, epidote, and chlorite.

Much of the Roundtop Mountain Greenstone consists of metamorphosed pillow basalts. Where affected by amphibolite-facies metamorphism, these rocks generally possess foliation or related penetrative fabrics that destroy pillow structures and other primary textures. But at Roundtop Mountain and on an adjacent hill north of the Highway Department substation (NW sec. 36, T30N, R100W.), several deformed pillows are preserved (**Figure 7**). The cusp-shaped ellipsoids of the pillows were used as facing criteria to indicate the Roundtop Mountain Greenstone is right side up. However, caution must be exercised when using these ellipsoids because the pillows are deformed and are particularly stretched vertically, which can lead to ambiguous conclusions (Harper, 1985). In addition to pillow basalts, massive vesicular metabasalt and porphyritic metabasalt occur in the formation. Spotted metabasalts south of the Sweetwater River contain large (0.25- to 0.5-inch) porphyroblasts of clinozoisite after feldspar in an aphanitic groundmass.

The Roundtop Mountain Greenstone is dominated by rocks of magnesian- and iron-tholeiite affinity and contains a thin actinolite-chlorite schist member of basaltic komatiite affinity (**Figure 8**). The tholeiites have silica contents ranging from 46.1 to 57.4% SiO_2, and magnesium concentrations of 3.11 to 9.10% MgO. The Ti/V ratios vary from a low of 14 to a high of 44 (averaging 25), indicating these rocks are transitional between modern mid-ocean ridge basalts and island arc tholeiites, although on the average the ratios are more similar to modern mid-ocean ridge basalts. Similar characteristics were also noted for other Archean basalts by Glickson (1971) and Naqvi and Hussain (1973a,b). In general, the Archean metatholeiites differ from the basaltic komatiites by their high TiO_2, Al_2O_3, Na_2O, K_2O, barium, strontium, zirconium, yttrium, Zr/Y and Ti/V, and by lower chromium, nickel, cobalt, and Ni/Co (Condie, 1981). Archean tholeiites have high FeO/Fe_2O_3, FeO, and other transition metals, and lower Al_2O_3 than modern tholeiites.

Partial REE analyses were completed for only two greenstone samples (3R, 13R, **Appendix A5**). The results indicate both samples have REE patterns similar to those described by Condie (1981, p. 98) for Archean tholeiites.

A few samples collected from the Roundtop Mountain Greenstone were magnesium rich, with compositions similar to basaltic komatiite (35R-38R, **Appendix A5**). However, one sample (35R) possessed anomalously low chromium, nickel, and Fe_2O_3, and high

Figure 7. Deformed pillow metabasalts near the Atlantic City iron mine. Hammer handle points southeast to the top of the unit, as interpreted from the pillow cusps.

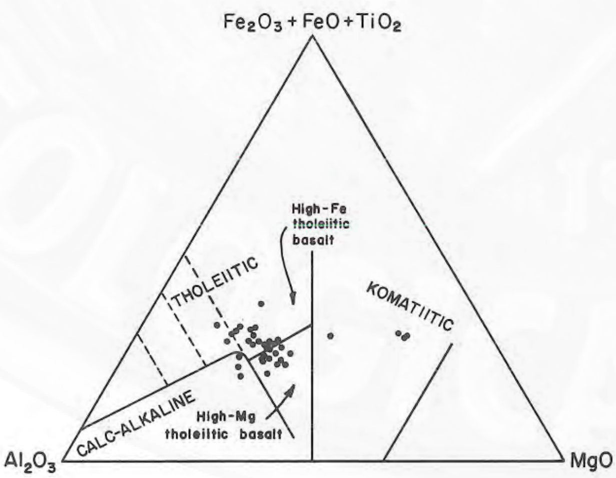


Figure 8. Jensen plot for rocks of the Roundtop Mountain Greenstone, showing a distinct suite with tholeiitic basalt compositions. Actinolite schists have chemistries similar to basaltic komatiite.

barium, strontium, Zr/Y, K_2O, and SiO_2. The chemistry of this sample is atypical for a komatiite. The sample was described texturally as a metadiabase in the field, and based on its appearance and chemistry, this rock is probably an altered tholeiite.

Actinolite schist (36R, **Appendix A5**) collected near the top of the Roundtop Mountain Greenstone, along the northwestern margin of the greenstone belt, yielded major- and transition-metal abundances similar to basaltic komatiite. The partial REE composition shows a similar pattern to the Negri, Australia spinifex-textured basalts, and to the high-magnesium amphibolites from the Elmers Rock greenstone belt in eastern Wyoming.

Metasedimentary rocks are not common in the Roundtop Mountain Greenstone but, near the top of the succession, metagreywacke increases in frequency and is interlayered with metatholeiite. In addition to metagreywacke, a thin grunerite schist layer occurs along the eastern flank of the greenstone belt. This schist has 23% Fe_2O_3 and 62% SiO_2.

The top of the formation is marked by a broad zone of carbonated breccias and intensely folded schists. This deformation zone represents a major break in the geologic record.

Geologic setting

Greenstones and greenschists of the Roundtop Mountain Greenstone represent oceanic basalts with interlayered tuffs cut by numerous basaltic and diabasic sills. The presence of interlayered metagreywacke beds near the top of the formation indicate that volcanic activity was intermittent near the close of Roundtop Mountain time.

Miners Delight Formation

The Miners Delight Formation is well exposed in the vicinity of the historic gold mining camp of Miners Delight (sec. 32, T30N, R99W) (Bayley, 1965c). This formation has a diversified package of lithologies, but is dominated by metagreywacke, which underlies about 90 percent of the exposed region. Unfortunately, the relative ages of the various lithologic units in the Miners Delight Formation have not been determined with any confidence, thus the lithologic column shown on **Plate 1** for this formation is not intended to show age relationships. According to Bayley and others (1973), the Miners Delight Formation is more than 5,000 feet thick (possibly up to 20,000 feet), although the actual thickness is not determinable.

The contact between the Roundtop Mountain Greenstone and the Miners Delight Formation is marked by the Roundtop fault. Rocks adjacent to the fault are mylonitized, brecciated, and strongly folded, locally (Hull, 1988). The hanging wall of the fault consists of the Miners Delight Formation, which contains abundant metagreywacke and mica schist with lesser meta-andesite, metabasalt, amphibolite, actinolite schist, chlorite schist, and graphitic schist.

Metagreywacke

Feldspathic and biotitic metagreywacke interbedded with mica schist (greywacke schist) dominates the Miners Delight Formation. The metagreywacke is generally a fine-grained, bedded turbidite with bedding-parallel foliation. The mica schist is primarily a more micaceous metagreywacke. Both proximal- and distal-facies sediments are present, although distal facies are more common. These rocks are only slightly metamorphosed (below the andalusite isograd) (Condie, 1967).

The distal-facies rocks are gray to dark brown, fine-grained to massive metagreywacke, with individual beds ranging from less than 0.1 inch to more than 5 feet thick. The rock is poorly sorted and consists of angular to subangular quartz, plagioclase (mostly oligoclase), and rock fragments in a recrystallized matrix of biotite, untwinned plagioclase, and quartz, with or without almandine, chlorite, chloritoid, and sericite. Rock fragments, including chert, quartzite, and phyllite, form less than 10 percent of the rock. Igneous rock fragments are uncommon except in metatuff and in metaconglomerate on Peabody Ridge (Bayley and others, 1973). Greenschist-facies metagreywackes show crude alignment of mineral and rock fragments, but amphibolite-facies metagreywackes show pronounced megascopic foliation and have lost most traces of primary textures and structures (Condie, 1967).

At Peabody Ridge (secs. 31 and 32, T30N, R99W), well-preserved fine- to medium-grained, proximal-facies metagreywacke with angular quartz and feldspar grains occurs in a recrystallized matrix. The metagreywacke exhibits primary sedimentary structures including graded beds, crossbeds, and channel structures (John Nold, personal communication, 1987) (**Figure 9**).

Greywacke schist interbeds are similar to metagreywacke but are more micaceous and carbonaceous. Some of these units also have abundant gray to brown, almond-shaped porphyroblasts elongated in the plane of foliation. In all respects, the porphyroblasts resemble andalusite, but are almost entirely replaced by sericite with poikiloblastic quartz and biotite. According to Bayley and others (1973), these porphyroblasts were originally andalusite where found near granitic rocks but, in the vicinity of the Rose mine north of Atlantic City, they exhibit diffraction patterns characteristic of cordierite [x-ray analyses by K.C.Condie *in* Bayley and others (1973)]. The presence of cordierite in the Rose mine area was also confirmed by x-ray diffraction studies by the Geological Survey of Wyoming (Wayne M. Sutherland, personal communication, 1989).

The geochemistry of Miners Delight Formation metagreywackes is similar to other Archean metagreywackes (**Appendix A6**), including those from the Elmers Rock greenstone belt in the Laramie Mountains (Graff and others, 1982; Smaglik, 1987) The compositional range of the metagreywackes varies from granitic to basaltic (**Figure 10**). Compared to Phanerozoic greywackes, they have higher MgO (0.99 to 8.61%), higher chromium (13 ppm to 507 ppm), and higher nickel (40 ppm to 150 ppm) (**Appendix A6**). Gold values in the nonsheared rocks range from < 0.005 ppm to 0.021 ppm. For comparison, average Archean greywackes possess only 0.002 ppm gold (Kerrich, 1983).

The South Pass metagreywackes are enriched in light REE relative to heavy REE by a factor of 1.5 to 2.5

compared to the North American shale composite. These rocks also have a positive europium anomaly (Wildeman and Condie, 1973). Chemical analyses of the metagreywackes indicate contributions have been made by both mafic and felsic source rocks.

Graphitic schist

Graphitic schist is found in narrow beds, pock-marked by numerous prospect pits, along the margins of the mafic amphibolite belt running from South Pass City to Miners Delight (Plate 1). These rocks are black to steel gray and commonly iron stained. The schist is very fine grained, composed of clastic grains with powdery intergranular graphite (Bayley and others, 1973), and severely sheared, with common quartz veins and boudins.

Mafic amphibolite

Mafic amphibolites (hornblende-plagioclase amphibolites) are prominent in a narrow belt that runs from South Pass City to Miners Delight. Locally, these rocks contain up to several percent quartz.

The amphibolites exhibit both extrusive and intrusive characteristics. They are fine- to medium-grained, dense, black, weakly to strongly foliated, equigranular rocks that are locally subophitic and hornfelsic. The presence of both volcanic and subvolcanic textures indicates this unit is a mixture of flows and sills. The metadiabasic to subophitic texture of these rocks and local crosscutting relationships with adjacent rocks led Bayley and others (1973) to interpret the

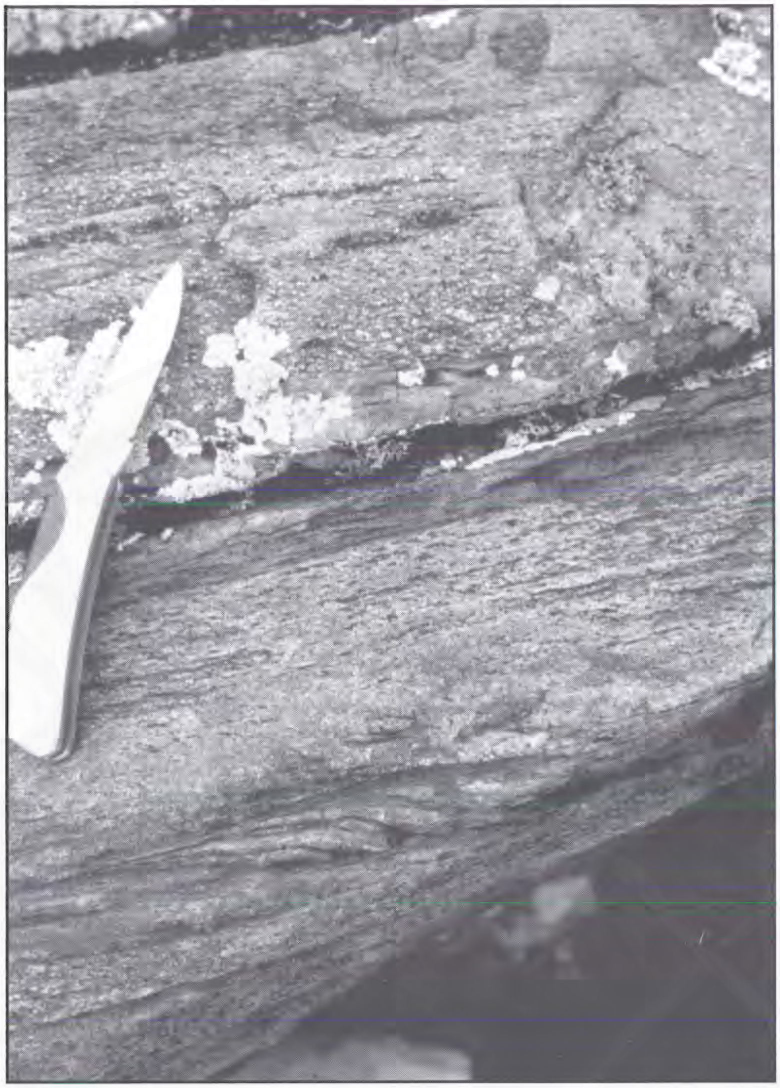


Figure 9. Metagreywacke exposed on the south slope of Peabody Ridge contains fining-upward graded beds (upper half of photo) and truncated crossbeds (bottom half of photo) that give entirely different top solutions. These beds are interpreted to be transposed. The fracture that divides them probably marks the location of a fold axis.

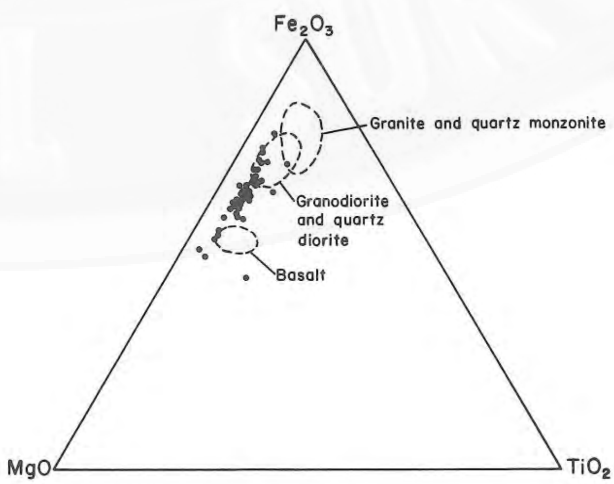


Figure 10. Fe_2O_3-TiO_2-MgO diagram showing the compositional ranges of the South Pass metagreywackes (solid dots) compared to some common igneous rocks (data from Condie, 1967; and the author).

amphibolites to be metamorphosed gabbro dikes and sills. Bow (1986), who was impressed by the common fine-grained to schistose fabric and identified local pillow, vesicular, and variolitic textures, interpreted the amphibolites to be volcanic.

Mixed member

A unit containing diverse lithologies was mapped as the "mixed member" of the Miners Delight Formation by Bayley and others (1973). This unit is about 200 to 1,000 feet thick and includes a variety of interlayered metaigneous and metasedimentary rocks. The rocks include thin beds of metagreywacke, metabasalt, amphibolite, metaconglomerate, tremolite/actinolite schist, chlorite schist, and rare grunerite schist and quartzofeldspathic gneiss. The metagreywacke, chlorite schist, amphibolite, and metabasalt are lithologically indistinguishable from similar rocks found elsewhere in the Miners Delight Formation.

Metaconglomerate occurs sporadically in the "mixed member". Pebbles in the conglomerate are stretched in the plane of foliation and consist of andesite, quartzite, and amphibolite cobbles and pebbles in a micaceous matrix (Bayley and others, 1973). At several locations, the conglomerates have the appearance of volcaniclastics.

Grunerite schist, found in the Diana mine workings and uncommon elsewhere, is a light brown schist composed of strongly oriented grunerite grains. Quartzofeldspathic gneiss, also uncommon, was encountered in the Soules and Perkins mine workings.

The base(?) of the mixed member west of the Soules and Perkins mine is marked by tremolite/actinolite schist, which has a similar composition to basaltic komatiite and is dominated by the actinolite end member. The schist is overlain(?) by five mafic flows interlayered with metasedimentary rocks in this area. The mixed member itself is overlain(?) by hornblende-plagioclase amphibolite of tholeiitic affinity.

The actinolite schist is pervasively sheared and altered, so that no primary textures are preserved to confidently distinguish between a volcanic or intrusive origin. These rocks were probably originally komatiite or a subvolcanic equivalent, but have been altered to actinolite schist with lesser tremolite/actinolite-talc-chlorite schists and talc-chlorite schists with varying intensities of penetrative fabrics. Locally, they have experienced carbonate or calc-silicate alteration (Bow, 1986).

Mixed member actinolite schists conform to the geochemical definition of komatiite. They have MgO contents of 22.73 to about 9%, TiO_2 is low, most are alkali poor, chromium varies from 2,400 ppm to 530 ppm, and nickel varies from 1,100 ppm to 120 ppm. The CaO/Al_2O_3 ratios average 1.5, which is considerably higher than the komatiitic rocks in the Diamond Springs Formation. However, these higher ratios are partially due to carbonate metasomatism. One carbonated actinolite schist (46M; **Appendix A7**) plots within the basaltic komatiite field on the Jensen diagram yet it has only 5.44% MgO. LOI (loss on ignition) measures 12.2% and CaO is very high (22.4%), indicating the rock has suffered appreciable carbonatization as well as probable MgO leaching. The chromium and nickel contents of this rock are characteristic of high-magnesium rocks (1,300 ppm Cr and 280 ppm Ni) and it has a chondrite-normalized REE profile similar to the high-magnesium tremolite/actinolite schists from the Miners Delight Formation. It is tempting to suggest this rock unit originally possessed basaltic komatiite chemistry that was severely modified by carbonatization and MgO leaching. Actinolite schists with REE profiles similar to the carbonated actinolite schist (44M and 50M; **Appendix A7**) possess considerably higher MgO contents (20.84% and 22.0%, respectively). These samples also carry relatively high chromium (1,900 ppm and 2,400 ppm) and nickel (680 ppm and 440 ppm) contents. The MgO contents of these rocks are characteristic of peridotitic komatiites, but the REE contents are high.

Metachert (cherty metagreywacke)

Some metagreywackes are texturally similar to cherts. These rocks occur near the Mint mine in the Lewiston district and along the southern flank of Peabody Ridge. Portions of these rocks appear to be sheared and recrystallized while other portions are weakly silicified. The "cherty" metagreywacke is hard, banded, massive, dark gray to black rock that fractures conchoidally and rings when struck by a hammer (John Nold, personal communication, 1987). Microscopically, some possess fine-grained mosaics of quartz with minor muscovite, chlorite, and feldspar in a preferred orientation. Samples from the Lewiston district (see 33M, **Appendix A6**) also possess accessory carbonate, which is reflected by high CaO content. Other samples are indistinguishable from metagreywacke in thin section. Chemically, the "cherty" metagreywackes show little variation from the average metagreywacke except that they have generally higher average silica content (commonly 5-10% more SiO_2 than the average metagreywacke).

Locally, the "cherty" metagreywacke possesses mylonitic to ultramylonitic texture and, for the most part, may be the result of mylonitization accompanied by silicification. In thin section, the mylonite exhibits angular mineral grains and quartz, feldspar, and mica augen in a crushed groundmass. The groundmass is so fine grained in some samples that individual grains are generally not recognizable except under high magnification. Samples of the mylonite were analysed for gold but none contained anomalous gold values. The lack of mineralization in the mylonites could be due to their development after the main episode of mineralization or to the lack of matrix permeability.

Marble

Marble (metacarbonate) was identified at only one locality in the greenstone belt (31M, **Appendix A6**), south of the Mary Ellen mine in SW sec. 14, T29N, R100W. There, the marble is intensely folded and ranges from fine-grained metacarbonate to medium-grained marble. Locally, the rock is sulfide bearing and has been prospected by shallow pits. This rock is interpreted as metamorphosed travertine.

Meta-andesite

The meta-andesites interfinger with metaconglomerates and metatuffs. These rocks occur as massive flows, porphyries, and ellipsoidal and vesicular rocks with dominant calc-alkaline chemistry. Bayley and others (1973) interpreted the massive meta-andesite to be a porphyry or glomeroporphyry with altered plagioclase (oligoclase) and amphibole phenocrysts in a fine-grained matrix of plagioclase, amphibole, biotite, and quartz. The trachytic meta-andesite porphyries consist of white plagioclase (oligoclase) phenocrysts (up to 1 inch long), which are oriented parallel to the strike of the flows, in a dark green to gray matrix. Hornblende phenocrysts occur with plagioclase in a dense microlitic groundmass. The groundmass consists of biotite, hornblende, feldspar, and quartz (Bayley and others, 1973). The metatuffs and metaconglomerates are composed of fine- to coarse-grained, well-foliated, lenticular andesitic material.

Metadacite

Metadacite mineralogically resembles the meta-andesite and is difficult to separate without chemical analyses. Petrographically, the primary minerals in the rock are plagioclase and green hornblende. Megascopically, the rocks are dense and black with white plagioclase aligned as in trachyte, parallel to the strike of the flows (Bayley, 1965c). Locally, these rocks are nearly holocrystalline, with a salt-and-pepper appearance (Bayley and others, 1973).

Trace elements and mineralization

Metaigneous rocks of the Miners Delight Formation form a unit of mixed rocks with calc-alkaline, tholeiitic, and komatiitic affinities (**Figure 11**). The lithologies include hornblende-plagioclase amphibolite, metagabbro, massive and vesicular metabasalt, metadacite porphyry, ellipsoidal and vesicular meta-andesite, trachytic meta-andesite porphyry, meta-agglomerate, actinolite schist, tremolite/actinolite-chlorite schist, and chlorite schist. All three suites are present in a narrow mineralized belt that runs from South Pass City to Miners Delight.

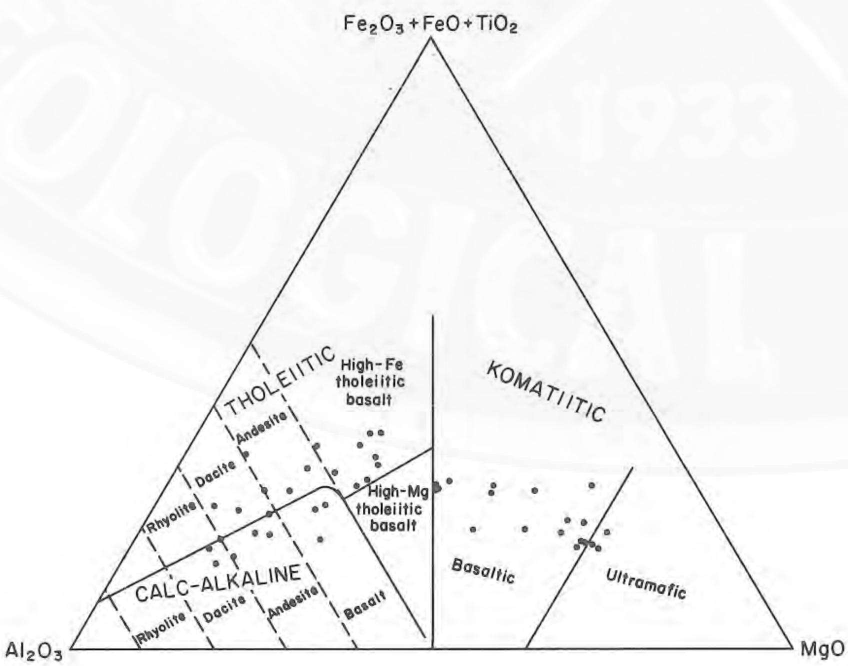


Figure 11. Jensen plot of Miners Delight Formation metaigneous rocks.

The gold content of some metaigneous rocks of the Miners Delight Formation is anomalous. Gold values range from < 5 ppb to 430 ppb for the komatiitic suite, <5 ppb to 219 ppb for the tholeiitic suite, and <5 ppb to 70 ppb for the calc-alkaline suite (**Appendix A7**). According to Kerrich (1983), primary unmineralized ultramafic and mafic igneous rocks average only 0.8 ppb and 1.7 ppb gold, respectively. For the most part, the samples from the Miners Delight Formation were selected for whole-rock analyses because of apparent lack of shearing, quartz stringers, or intense alteration; however, it is obvious they have all been affected by varying degrees of metasomatism, deformation, and metamorphism. Thus, the anomalous gold content of some of these rocks is assumed to be epigenetic and secondary, which further suggests the possibility of gold mineralization not only in well-defined shear zones, but also in wallrock with penetrative foliation.

Bow (1986) suggested there was a genetic relationship between gold and the ultramafic rocks with compositions similar to komatiite in the Miners Delight Formation. Although the ultramafic suite undoubtedly contributed to the total gold budget, it is unlikely it was a unique source. Recent studies by Spry and McGowan (1989) support a greywacke rather than ultramafic source for the gold. However, the marked association of gold with shear zones and fractures in a variety of host rocks suggests these structures focused metamorphic fluids that leached the precious metal from a variety of source rocks deep within the supracrustal pile.

Geologic setting

Most of the Miners Delight Formation consists of fine-grained, finely bedded, distal-facies metagreywacke. But coarser grained proximal-facies metagreywacke with channels and crossbedding occurs locally. The presence of both distal- and proximal-facies rocks implies a moderately deep oceanic basin with contributions from a shallow-water fan along the edge of the basin.

Miners Delight Formation metaigneous rocks include rocks with komatiite, tholeiite, and calc-alkaline chemical compositions. The spatial association of calc-alkaline volcanics with proximal-facies metagreywacke implies an island arc or similar crustal feature was located in that region of the greenstone belt by Miners Delight time, whereas, most of the remaining area underlain by Miners Delight Formation rocks was probably an oceanic basin, in which tholeiitic basalts, distal facies greywacke, komatiite, and carbonaceous sediments were deposited.

Archean granitic intrusives

Three Archean episodes of granite emplacement occurred at South Pass. The initial episode produced small tonalitic stocks and quartz diorite dikes, which intruded along shear zones in the supracrustal terrane prior to regional metamorphism. The second event was a cratonization event involving the emplacement of large granodiorite plutons along the margin of the greenstone belt. The third event generated dome-like granitic plutons and associated pegmatites that intruded the supracrustal pile principally in the western portion of the greenstone belt.

First granitic event

Rocks of the first granitic event (Archean tonalite, **Plate 1**) include light colored, metamorphosed leucodacite porphyry, quartz diorite, and tonalite dikes and plugs intruded along shear zones in the South Pass supracrustal rocks. These rocks are not abundant. They are found north of the Highway Department substation (sec. 36, T30N, R100W) intruding rocks of the Roundtop Mountain Greenstone, along the South Pass-Atlantic City mineralized belt intruding the mixed member of the Miners Delight Formation both east and west of Atlantic City, and most extensively along the eastern edge of the Lewiston district. Chemical analyses of these rocks are in **Appendix A8**.

At two locations, the leucocratic rocks are mineralized. Bayley and others (1973) reported a sheared metaleucodacite porphyry dike in sec. 36, T30N, R100W contains quartz stringers in joints with some disseminated arsenopyrite. One sample yielded 0.343 ppm (0.01 oz/ton) gold and 0.343 ppm (0.01 oz/ton) silver. The Mary Ellen stock southwest of Atlantic City (sec. 14, T29N, R100W.) intrudes mixed member rocks. This stock includes a prominent northwest dipping quartz vein that carries visible gold. The vein trends north before making a distinct bend to the northwest, following the trend of conjugate fractures in the tonalite. It is not known if the gold in the tonalites represents a separate gold mineralizing event or if the tonalites acted as a heat source for the remobilization of nearby gold deposits. Field evidence indicates the tonalite-hosted vein at the Mary Ellen mine is younger than the shear-zone mineralization. Because of the rarity of tonalites in the supracrustal belt, their contribution to the overall gold budget could not have been great.

Second granitic event

Rocks of the second granitic event include the 250-square-mile Louis Lake batholith along the northwestern greenstone belt margin and the similar 40-square-mile Lewiston Lakes pluton along the eastern flank of the greenstone belt (Archean granodiorite, **Plate 1**). In view of the large volumes of magma generated, the second and third events are considered to represent a significant cratonization event.

Chemically, these rocks are dominantly quartz diorite and granodiorite with subordinate granites. The Louis Lake batholith is composed of peraluminous granodiorite with lesser quartz monzonite and granite (Lo, 1970). According to Bayley and others (1973) the batholith has rather uniform granodioritic composition. The rock is dominantly plagioclase with lesser microcline, quartz, biotite, hornblende, sphene, and magnetite. Plagioclase is commonly sericitized and sparsely sausseritized and the mafic minerals are partly chloritized. Epidote is often disseminated in the granodiorite as well as in veinlets. The Lewiston Lakes pluton is chiefly pinkish white to salmon colored biotite granodiorite. Pegmatites are noticeably absent in this pluton; the rock has medium-grained hypidiomorphic granular texture with autoliths of dark gray hornblende-biotite tonalite (Day and others, 1988).

Isotopic studies show the Louis Lake batholith formed about 2,630 ± 20 Ma from a >3.5 Ga tonalite protolith (Hull, 1988). The exact age of the Lewiston Lakes pluton is unknown, but is probably similar to the Louis Lake batholith.

Mineralization is noticeably absent in both granodiorite plutons. Copper silicates and carbonates occur in a shear zone adjacent to a mafic dike in the Louis Lake pluton (locality 23A, **Plate 2**), but this type of mineralization appears to be uncommon. At another location in the batholith (in Rock Creek west of the Atlantic City mine), placer gold is reported, but the source of the gold is unknown (Wilson, 1953).

Third granitic event

The third (?) granitic event emplaced two plutons that intrude Miners Delight metasedimentary rocks in the western part of the greenstone belt (Archean granite, **Plate 1**). Considerable confusion has arisen over the names of these granites, but since Bayley and others (1973, p. 18) named the pegmatitic granite west of South Pass City the South Pass pluton this name is retained here (see also Hausel, 1988a). Farther west, along the Sweetwater River and Lander Creek (sec. 35, T29N, R102W), is a fine- to medium-grained leucocratic granite that is referred to as the Sweetwater granite in this report (see also Hausel, 1986c). These two plutons may be part of the larger Bears Ears pluton described by Stuckless and others (1985), who reported ages from 2,504 ± 40 to 2,575 ± 50 Ma.

The South Pass pluton is dome shaped. The rock is weakly foliated with porphyritic texture and grades into garnet-bearing pegmatitic granite (Proctor and El-Etr, 1968).

The Sweetwater granite is fine to medium grained with crosscutting aplite dikes. This is a leucocratic, light gray to white granite composed of quartz, biotite, plagioclase, and microcline with numerous crosscutting quartz-feldspar aplite dikes. The foliation in the country rock xenoliths rafted into the granite conforms to regional foliation and exhibits no rotational component. Age relationships between the Sweetwater granite and the Louis Lake granodiorite to the north could not be determined in the field.

The initial isotopic ratios of the Bears Ears pluton indicate it is not cogenetic with the Louis Lake batholith. Instead, evidence suggests the Bears Ears pluton was derived from a protolith that first crystallized around 3.2 Ga (Stuckless and others, 1985). The emplacement of these late plutons appears to have commenced about 2,500 to 2,575 Ma, following cessation of the second granitic event.

Rocks of the third granitic event are distinguished geochemically from second-event rocks on the basis of lower K/Na ratios, higher K/Rb ratios, and lower Rb/Sr ratios. Third-event rocks generally have higher initial Sr^{87}/Sr^{86} ratios than the first and second granitic event rocks, possibly because many if not all of these plutons were derived from the reworking of pre-existing sialic (tonalitic to granitic) crust (Stuckless and others, 1985).

Metal deposits associated with the third-event granites are notably absent. However, pegmatitic mineralization is common (see p. 37).

Proterozoic dikes

The Archean terrane is cut by a swarm of dominantly northeast to east trending Proterozoic mafic dikes that show chilled selvages. These dikes form conspicuous ridges in the Louis Lake batholith and Lewiston Lakes pluton but are less conspicuous in the supracrustal rocks. The dikes are 10 to 200 feet wide and some can be followed several miles along strike. The rocks are fine- to medium-grained tholeiitic basalts and diabases with equigranular, porphyritic, and pilotaxitic textures. Mineralogically, the dikes consist of plagioclase, chlorite, carbonate, and uralite replacement of augite, with some epidote, iron oxide, and leucoxene (Bayley and others, 1973). Locally, portions of the dikes are pervasively replaced by epidote. These rocks have been dated at about 2,060 Ma (Condie and others, 1969; Snyder and others, 1989b).

Mineralization is notably lacking in the dikes. However, a mafic dike on Rennecker Peak (north of the map area of Plate 1), contains pods of massive pyrite (Elmer C. Winters, personal communication, 1985).

Phanerozoic sedimentary rocks

The South Pass greenstone belt continues northeastward off the map area of **Plate 1** under a relatively complete Phanerozoic section, which dips northeasterly into the Wind River Basin. However, only those Phanerozoic units with a potential for economic metal deposits are considered in this discussion.

Flathead Sandstone

The base of the Phanerozoic section is marked by salmon to reddish brown, crossbedded arkosic quartzites, sandstones, and conglomerates of the Flathead Sandstone (Middle Cambrian), which unconformably overlie the Precambrian basement. These rocks are as much as 250 feet thick and contain rounded quartz and chert pebbles up to 1/4 inch in diameter.

The Flathead is considered to be a potential gold and REE exploration target on the basis of its fluvial character and similarities to the Deadwood auriferous conglomerate in the Black Hills and Flathead auriferous and monazite-bearing conglomerate at Bald Mountain in the Bighorn Mountains. The Flathead at South Pass has been prospected only locally. Reconnaissance paleocurrent studies along the northeastern edge of the greenstone belt indicate stream flow during deposition of the Flathead was southwesterly into the greenstone belt rather than out of the belt (Tom J. Mitko, personal communication, 1985), indicating this portion of the conglomerate was probably derived from a gold-poor granite-gneiss source terrane. However, additional paleocurrent studies are needed to determine if any Cambrian paleodrainages can be identified to exit from the gold-rich greenstone terrane.

At least one mine and a few prospects were driven into the Flathead along the northeastern edge of the greenstone belt (34A, **Plate 2**) north of Miners Delight in search of gold (see Diamond Development adit, p. 49). Samples of the conglomerate collected from this region yielded no gold.

Tertiary sedimentary rocks

Tertiary sedimentary units within and along the margins of the South Pass greenstone belt locally contain gold. Considerable confusion has arisen in the nomenclature and correlation of the syntectonic Tertiary rocks because of lithologic similarities and numerous erosional unconformities (Steidtmann and Middleton, 1986).

Gold-bearing conglomerates have been reported in the Eocene Wasatch Formation (Love and others, 1978), the Oligocene White River Formation (Antweiler and others, 1980), the basal Arikaree Formation (Oligocene?, Miocene?) (Zeller and Stephens, 1969), and the South Pass Formation (Oligocene?, Miocene?, Pliocene?). The age of the South Pass Formation was originally reported by Denson and others (1965) as late Miocene to middle Pliocene; however recent work by Steidtmann and Middleton (1986) suggest an older age of late Oligocene or early Miocene. The South Pass Formation covers large regions of the greenstone belt and contains auriferous conglomerates (Elmer C. Winters, personal communication, 1985; Fred Groth, personal communication, 1988), thus the unit has potential commercial value and needs to be defined and mapped in detail.

All of these conglomerates contain varying amounts of Precambrian material characteristic of their source terranes, and a few conglomerates provide evidence of some rich source areas (Love and others, 1978; Antweiler and others, 1980). Some of these paleoplacers represent sizable, low-grade, gold deposits.

Structure and metamorphism

The supracrustal rocks of the greenstone belt have been affected by a long and complex deformation history that yielded structures favorable for epigenetic mineralization (Hausel and Hull, 1990). Recognition of the structural style most favorable for a given mineral deposit, in particular gold, is complicated by overprinting of later structural and metamorphic events. At least three episodes of deformation and metamorphism are recognized.

The first major episode of deformation and metamorphism began with classic synclinorial folding in response to compression, resulting in northeast trending, tight, upright or isoclinal folds (**Figure 12a**). Continued deformation and downwarping produced regional foliation, shearing, and transposed layering parallel to the original bedding. In many places, the original bedding was obliterated and overprinted by foliation. Isoclinal axial fold surfaces parallel regional foliation, suggesting the foliation formed during development of the isoclinal folds. Locally, some isoclines were refolded.

Foliation-parallel shear zones focused gold-bearing solutions during the initial stage of deformation. In the Lewiston district, the shears appear to be relatively simple, paralleling the limb of a regional fold. In the South Pass-Atlantic City district, the majority of the shears are more complex, paralleling foliation along or adjacent to lithologic contacts with rocks of contrasting competency.

This initial episode of deformation was accompanied by regional metamorphism at about 2.8 Ga (Bow, 1986), during which the metamorphic fluids may have leached gold and other metals from the supracrustal pile and focused them into shear zones. Nearly all of the rocks of the belt were raised to amphibolite grade, except for a small region surrounding Roundtop Mountain along the northern margin of the greenstone belt that was raised to greenschist facies. Amphibolite-facies metagreywackes and pelitic schists are represented by the assemblage oligoclase-quartz-biotite-garnet-andalusite (or cordierite). The andalusite is typically replaced by sericite and quartz. Greenschist-facies metatholeiites on Roundtop Mountain are represented by the common chlorite-grade assemblage, chlorite-actinolite-albite-epidote.

During a second phase of deformation, the original folds of the synclinorium were strongly deformed into broad synform-antiform arches (Bayley and others, 1973). The folding style associated with this event is typically open folding with fold axes nearly perpendicular to the first-stage fold hinges. Many small-scale folds related to this event plunge steeply southeast to southwest and have chevron geometries (**Figure 12b**).

This second phase of deformation was synchronous with the emplacement of granodiorite and isolated dome-like granite plutons (second and third granitic event plutons) and was accompanied by local contact metamorphism and metasomatism. Secondary microcline replaces primary feldspar and some sillimanite developed in the gneiss adjacent to the Louis Lake batholith north of Anderson Ridge. Minor remobilization of gold may have occurred at this time. A similar style of deformation occurred in response to movement along some Archean structures (i.e. Roundtop fault). This stage of deformation may have been synchronous with secondary folding and contact metamorphism.

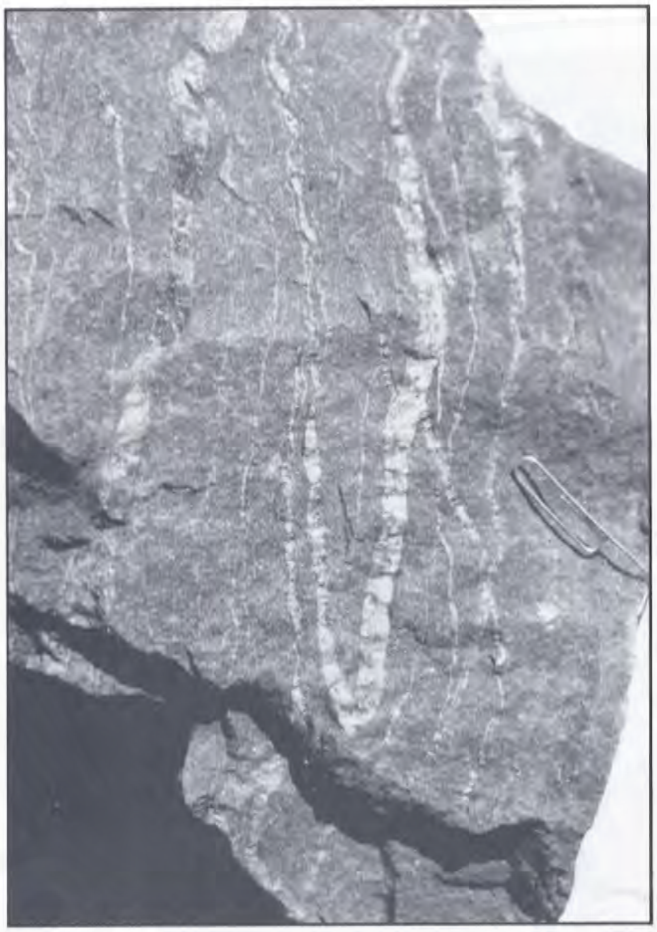
A retrograde metamorphic event occurred at 1.4 Ga. Biotite interpreted to have formed from metamorphic fluids in a fault zone in granite west of Iron Mountain yielded a 1.4 Ga K-Ar date (Bayley and others, 1973). This event produced broad areas of secondary epidote and chlorite in the Louis Lake batholith. Lower Proterozoic mafic dikes that cut the batholith exhibit some actinolite-chlorite-epidote alteration, and rocks of the bordering gneiss complex are sericitized and chloritized (Bayley and others, 1973).

A third deformational event produced brittle fracturing in response to the uplift of the South Pass region during the Laramide orogeny. Structures of this event are quite distinct from the earlier ductile fault or shear zone systems that predominantly parallel isoclinal fold hinges and foliation. These much later brittle faults bear no obvious relationship to the older structural fabric in most cases (Kalish, 1982). Many Laramide structures cut regional foliation and bedding at high angles.

A few Archean structures were reactivated at this time. Reactivated Archean structures are best viewed along the Roundtop and Anderson Ridge faults. The top of the Roundtop Mountain Greenstone is marked by the Roundtop fault (**Plate 1**) (Bayley and others, 1973), which separates the underlying Roundtop Mountain Greenstone from the overlying Miners Delight Formation. The fault has been reactivated since the Archean. Archean deformation extends over a broad zone adjacent to the fault and produced buckle folds with chevron and kink geometries. This early-stage ductile deformation has been modified by subsequent brittle Laramide deformation, marked by carbonated mylonites and breccias that overprint the earlier folds (Hull, 1988).

Near the fault on the northwestern flank of the greenstone belt, graded bedding and crossbeds in metagreywackes of the Miners Delight Formation south of the fault consistently provide top orientations to the north, whereas pillows of the Roundtop Mountain Greenstone north of the fault consistently provide top orientations to the south. Thus, these two terranes appear to be facing one another.

Mylonites are relatively common in the greenstone belt. Hull (1988) mapped ultramylonite zones to the north, near the Roundtop Mountain fault, Jon K. King (personal communication, 1986) recognized mylonites at the Outpost mine, and Stephen Lipple (personal communication, 1989) recognized rocks with mylonitic texture in the vicinity of the Snowbird mine. Various intensities of mylonitic texture are common throughout the greenstone belt.



a.

b.

Figure 12. (a) Isoclinally folded quartz vein in metagreywacke at the Carissa mine. (b) Chevron fold in metagreywacke.

South Pass compared to other greenstone belts

Precambrian cratons, or continental cores, typically consist of scattered greenstone belts and other supracrustal fragments rafted in a sea of granite and gneiss. Granite and gneiss form greater than 75 percent of the cratons, while the remainder is formed of greenstone belts and similar supracrustal terranes. Typically, greenstone belts are linear to irregularly shaped, synformal supracrustal successions with fold axes and major Archean faults parallel to the axial trend of the synclinoria. Unlike most other greenstone belts in the world, the South Pass belt also has major post-Archean crosscutting and foliation-parallel tear faults generated by the Cretaceous Laramide orogeny.

Greenstone belts typically possess greenschist- and amphibolite-facies mineral assemblages, although the metamorphic grade often increases near contacts with some late-intruding plutons. The predominantly amphibolite-grade South Pass greenstone belt is somewhat anomalous. It contains a small enclave of greenschist-facies rocks at the northeastern edge of the belt adjacent to the Atlantic City iron mine that is enclosed to the north, west, and south by amphibolite-facies rocks. The metamorphic grade further increases in the western part of the belt, where sillimanite schist and gneiss crop out in the bordering gneiss complex near the East Branch of the Sweetwater River.

It has been suggested that the predominantly amphibolite-grade metamorphism at South Pass is due to a deeper level of erosion at South Pass. However, South Pass is not unique in its metamorphic grade. Similar grades are reported in a number of greenstone belts throughout Wyoming as well as in the Southern Cross and Murchison provinces of the Yilgarn block of Western Australia. Unfortunately, the greater metamorphic intensity has destroyed many primary rock textures and has mobilized varying amounts of major-element oxides and trace elements, making rock-precursor interpretations more difficult.

Greenstone belts form tripartite successions of metamorphosed sedimentary, volcanic, and plutonic rocks. The sedimentary and volcanic rocks are interpreted to be of dominantly submarine origin, deposited on an abyssal plain, in a submerged rift, or in an island arc. Very generally, the basal unit of the stratigraphic succession is often formed of ultramafic to mafic metavolcanic rocks that include rocks of komatiitic and tholeiitic compositions. In most greenstone belts, the volcanic component tends to grade into more felsic rocks higher in the stratigraphic succession, with increasing amounts of sedimentary rock.

Komatiite

The presence of komatiite in Precambrian greenstone belts is of particular significance since these primitive lavas are uncommon in other terrestrial environments. Komatiites are classified as basaltic (mafic), with MgO contents of 9 to 18%, and peridotitic (ultramafic), with MgO contents greater than 18%. Peridotitic komatiites are a product of melting of the primitive mantle and have not been found in rocks younger than Archean. Other characteristics of komatiites are relatively high CaO/Al_2O_3 ratios and low TiO_2 and alkali contents.

In low-grade metamorphic terranes, such as in the Kalgoorlie district in Western Australia, some komatiites display diagnostic textures. Peridotitic komatiites in the Hannans Lake Serpentinite, Kalgoorlie, possess well-preserved spinifex textures (**Figure 13a**). Where preserved, these textures occur at flow tops and grade downward into fine-grained equigranular (aphyric) flows to cumulate-textured rock at the flow base.

At higher metamorphic grades, the olivine- and pyroxene-bearing komatiites alter to serpentine, talc, chlorite, magnesite, anthophyllite, and tremolite/actinolite assemblages. These minerals tend to yield to cataclasis and develop penetrative foliation. In amphibolite-facies terranes, spinifex textures may be destroyed by recrystallization. However, some relatively well-preserved spinifex textures are seen in amphibolites of the Bradley Peak ultramafics in the Seminoe Mountains greenstone belt of central Wyoming (**Figure 13b**) (Klein,1981; Snyder and others,1989a).

Sun (1984) distinguished two groups of komatiites on the basis of Al_2O_3 content — aluminum-depleted and aluminum-undepleted. He examined the Al_2O_3/TiO_2 ratios of komatiites from several greenstone terranes and found most were undepleted in aluminum, producing comparable ratios to chondrite (20.4). Most samples from South Pass are also undepleted. One major exception noted by Sun (1984) was the komatiites from the Barberton greenstone belt in South Africa, which yielded ratios of 10.2. These results indicate the Barberton komatiites were depleted in aluminum before extrusion.

Other lithologies

Other metavolcanic rocks in greenstone belts include fine-grained, massive, vesicular, and pillow-textured basalts and andesites. Many of the basalts found in the greenstone belts exhibit geochemical similarities to modern mid-ocean ridge basalts (tholeiitic).

The upper stratigraphic levels of greenstone belts commonly include greywacke-argillite (turbidite) beds with subordinate chert. The earliest formed greywackes of greenstone belts indicate a rapid rate of sedimentation. Banded iron formation and chert reflect periods of low detrital sedimentation and tectonic quiescence, but such sediments form only a small portion of most greenstone belts. Limestone and dolomite are rare. Some sedimentary units contain

a.

b.

Figure 13. (a) Spinifex-textured peridotitic komatiite from the Hannans Lake Serpentinite, Kalgoorlie, Western Australia. The dark radiating skeletal crystals are aggregates of serpentinized olivine grains formed in response to supercooling of the ultramafic lava. (b) Spinifex-textured basaltic komatiite from the Bradley Peak ultramafics, Seminoe Mountains, Wyoming. These radiating crystals consist of tremolite/actinolite aggregates after pyroxene (Klein, 1981).

conglomerate and quartzite, which are interpreted as part of an alluvial outwash plain (for example, in the Elmers Rock greenstone belt in Wyoming and the Moodies Group in the Barberton greenstone belt, South Africa).

Vertical extent

The vertical extent of greenstone belts may be relatively great. On the basis of gravity and seismic studies, greenstone belts are interpreted to have depths from 2 to 9 miles. Archibald and others (1978) suggested the maximum depth of belts in the Eastern Goldfields province of Western Australia is nearly 9 miles. The Barberton belt in South Africa is estimated to have a minimum depth of 2 or 2.5 miles and a maximum depth of about 3.5 miles. The Abitibi belt in the Timmins district of the Superior Province, Canada, has a shallow depth of only 2 to 3 miles (Gupta and others, 1982). The depth of the supracrustal rocks in the South Pass greenstone belt is not known.

Economic importance of greenstone belts

Greenstone belts are important host and source terranes for precious and base metals and a number of nonmetallic mineral deposits. Such belts are frequently termed "gold belts" because of the ubiquitous occurrence of gold in shear zones and veins. The vertical extent of the auriferous shear zones is usually unknown, but probably is relatively deep. For example, auriferous shear zones have been followed to depths of nearly one mile in some terranes. Gold in some greenstone belts is closely associated with banded iron formation, albite-bearing feldspathic dikes and plugs, carbonatized ultramafics, and quartz-carbonate rocks (Pearton, 1980).

The occurrence of many significant gold deposits in greenschist-facies rocks in the world has led some researchers to imply greenschist-facies rocks are more favorable hosts than amphibolite-facies rocks. However, significant gold deposits have been discovered in amphibolite-grade greenstone terranes (i.e. Groves and others, 1985; Phillips, 1985).

Commercially mineable nickel deposits occur in ultramafic rocks near the bases of some greenstone belts. In particular, ultramafic komatiites with MgO contents greater than 36% may be enriched in nickel. In the Kalgoorlie district, Western Australia, commercially mineable nickel sulfide mineralization occurs in the cumulate-textured bases of some of the magnesium-rich flows. Komatiite is also considered a potential source rock for gold by a few researchers.

Asbestos deposits are notable in greenstone belts of the southern African craton and occur in serpentinized olivine or olivine-pyroxene cumulates at the base of layered intrusives. Some minor asbestos deposits occur in serpentinite cumulates at South Pass.

Copper-zinc massive sulfide deposits are important in some Canadian greenstone belts, although no massive base-metal sulfide deposits are known in the Wyoming greenstone terranes. These deposits are commonly associated with calc-alkaline metavolcanics, but rocks with calc-alkaline affinity are uncommon in the Wyoming belts.

Banded iron deposits occur in both the sedimentary and volcanic successions in many greenstone belts. At South Pass, large iron deposits occur in the metasedimentary succession near the base of the greenstone belt. In the Seminoe Mountains greenstone belt of central Wyoming, banded iron formation occurs in both the metavolcanic and the metasedimentary sections.

Pearton (1980) reported rare occurrences of antimony and mercury in the Murchison greenstone belt, South Africa. Antimony and mercury are generally regarded as characteristic of much younger epithermal gold deposits and no primary antimony or mercury mineralization has been recognized in the South Pass greenstone belt. However, antimony mineralization (as berthierite) was recently identified with arsenopyrite and gold in the Sellers Mountain supracrustal belt, eastern Wyoming (Hausel, 1989).

Other deposits, occurrences and anomalies identified in the South Pass belt, such as tungsten, tin, aquamarine, feldspar, and uranium, occur in many other greenstone terranes. These are often, but not exclusively, associated with granite intrusives.

Economic geology

The South Pass greenstone belt has been divided into two mining districts, the South Pass-Atlantic City district along the northwestern flank and the Lewiston district along the southeastern flank (**Plate 1**). Between these two districts, lode mineralization is uncommon. However, auriferous South Pass Formation conglomerates (Elmer C. Winters, personal communication, 1984; Fred Groth, personal communication, 1988) fill in part of the gap between the two districts. Some pegmatite deposits also occur in the Anderson Ridge area west of the South Pass-Atlantic City district, and some gold and tungsten occur in the Crows Nest area east of the South Pass-Atlantic City district. Outside the greenstone belt, auriferous placers and paleoplacers derived from the greenstone belt occur in the Oregon Buttes and McGraw Flats areas.

Recorded and estimated production

Gold and iron ore have been recovered from the South Pass greenstone belt in the past. Additionally, a small amount of silver and copper were recovered as a by-product of gold mining; a small amount of cross-fiber asbestos was mined between 1919 and 1921 from the Fire King deposit located along the northern edge of the Atlantic City open pit mine; some feldspar was mined from pegmatite in the Anderson Ridge area before 1960; and a minor tonnage of uranium ore was recovered from granite-gneiss at the Pard mine near the eastern edge of Prospect Hills at the extreme western tip of the granite-greenstone belt. A small amount of placer scheelite (tungsten), some road metal, and at least one large crystal of aquamarine beryl (approximately 1 foot long) have also been recovered from the granite-greenstone belt. There is one unverified report of a diamond found in the Beaver placers (*The Lewiston Gold Miner*, 1894); however, the diamond potential of the region was not evaluated during this project.

Considerable iron ore was produced from the Atlantic City open pit mine along the northern edge of the greenstone belt between 1962 and 1983. During this period, U.S. Steel Corporation brought the Atlantic City iron mill to full capacity of about 5.5 million tons of ore per year. When mining operations terminated in 1983, more than 90 million tons of ore had been pelletized. Operations ceased in 1983 because of foreign competition and high operating costs, leaving a huge iron resource in place. Even though large amounts of iron ore were mined from the greenstone belt, there is no record of gold being recovered from the iron deposit or any evidence that the iron formation was ever examined for gold during mining operations.

Total gold production from the South Pass region is unknown because production records were not kept except in a few cases. Production estimates for the South Pass-Atlantic City district are in considerable disagreement and range from a low of 70,000 ozs (Koschmann and Bergendahl, 1968) to more than 325,000 ozs (Hausel, 1980, 1987b). Estimates are inadequate for the Lewiston district, the other principal mining district in the greenstone belt, and for the Tertiary paleoplacers and Recent placers of the McGraw Flats and Oregon Buttes areas. **Table 1** was compiled from the available records, historic estimates, and field examination to provide an estimate of gold production of approximately 348,600 ozs.

Ore tenor

The tenor of most veins and placers in the greenstone belt is not well established, and many historic reports are unrealistic because early mining operations concentrated on near-surface, enriched, oxidized ore shoots, ignoring lower grade zones (<6.86 ppm or 0.2 oz/ton gold). Typically, the auriferous shear zones have a trace to low-grade gold contents along much of their strike lengths, with local enriched ore shoots.

The tenor of ore recovered from the Lewiston district was reported to have ranged from a trace to 106,000 ppm (3,100 oz/ton) gold. However, the extremely enriched specimen-grade ore (from the Hidden Hand mine) was quite rare. Little information is available on average ore grades, although one zone in the Burr mine averaged 17.15 ppm (0.5 oz/ton) gold and an ore sample collected from the Mint Mine for metallurgical tests averaged 20.9 ppm (0.61 oz/ton) gold (Knight, 1893).

The tenor of ore recovered from the South Pass-Atlantic City district ranged from a trace to 8,920 ppm (260 oz/ton) gold. Average ore grades ranged from 10.3 ppm (0.3 oz/ton) to 68.6 ppm (2.0 oz/ton) gold (**Table 2**). Recent sampling in some of the mines shows variance to the historic reports, which undoubtedly is due to selective mining techniques of the historic mine operations and to exaggerated promotions.

The average gold content of the placers varies considerably. Gravels range from a trace of gold to better than 1.0 oz/yd^3. At the Stout placer mine on Rock Creek, gravels are estimated to average 0.01 oz/yd^3 (Gerald Stout, personal communication, 1987). The gravels dredged by the E.T. Fisher Company from 1933 to 1941 on Rock Creek averaged 0.012 oz/yd^3 (Ross and Gardner, 1935). Recent exploration on Smith Gulch yielded gravels with an average gold content of 0.1 oz/yd^3 (Hank Hudspeth, Jr., personal communication, 1987).

Gold geochemistry and metallurgy

One of the dilemmas of the historic mine operations was the lack of metallurgical information and proper ore treatment tests. This remains a problem. Based on historic information and samples collected during this project, the gold ranges from microscopic grains to coarse leafs or pellets. The gold generally is about 0.850 to 0.900 fine, with much of the remaining alloy occurring as silver. Near-surface ores are oxidized and associated with limonite-, hematite-, and scorodite-stained quartz and cataclastics. At shallow depths (often within a few feet of the surface) primary sulfides (arsenopyrite, pyrite, and/or pyrrhotite) occur in small amounts (generally less than 5%).

The gold occurs as leaves filling fractures in quartz and has been identified in scorodite, limonite, hematite, arsenopyrite, pyrite, and pyrrhotite. Gold values have also been obtained from chloritized metagreywacke, although the mode of occurrence was not determined. Knight (1901) reported wires and pellets of gold were found in schist.

The trace-element geochemistry of gold from the South Pass-Atlantic City district was investigated by Antweiler and Campbell (1977) and Love and others (1978). According to Antweiler and Campbell (1977), Au/Ag and Au/Cu ratios of gold samples from the Diana mine in the South Pass-Atlantic City district are characteristic of hypothermal (high pressure and temperature) veins. Typically, the Au/Ag ratios are relatively high compared to veins formed at shallower depths, and the Au/Cu ratios (445 to 6,740) are relatively low. Trace elements (Bi, Pb, As, Sb, Sn, V, Mo, W, B, Nb, Cr, Zn, Co, Ni) are typical for Archean greenstone mineralization reported elsewhere in the world.

Table 1. Estimated and reported gold production for the South Pass greenstone belt.

Mine name	Location	Gold production (ounces)	Discussion
SOUTH PASS-ATLANTIC CITY DISTRICT			
Alpine	SW NE sec. 20, T29N, R100W	Unknown	The Alpine mine developed a thick (6 to 8 ft) anastomosing vein in metagreywacke. Sixteen samples collected from the mine yielded a trace to 101 ppm Au.
Atlantic Gulch placer	Secs. 6 and 7, T29N, R99W	750	Estimate from Jamison (1911).
Arthur	Sec. 1, T29N, R100W	Unknown	---
B & H (Empire State)	SW sec. 22, T29N, R100W	450	Estimate from Armstrong (1948).
Beaver Creek placer	T29N, R100W	500	Estimate from Jamison (1911).
Big Atlantic Gulch adit	NW sec. 6, T29N, R99W	Unknown	Consists of 220 ft of workings, thus only small amount of gold could have been produced.
Big Chief	SE sec. 11, T29N, R100W	2,000	Estimate based on volume of mined rock and historic ore grades.
Blackbird	Sec. 6, T29N, R99W	Unknown	---
Blanch May	SE sec. 1, T29N, R100W	Unknown	---
Caribou	SE sec. 1, T29N, R100W	25,000	Estimate from Jamison (1911).
Carissa	NW sec. 21, T29N, R100W	50,803	Production based on Jamison (1911) estimate and actual production recorded after 1911 (Hausel, 1980). Other figures suggest more than 180,000 oz may have been recovered, although this is believed to be unlikely (Hausel, 1989).
Carrie Shields	SE sec. 21, T29N, R100W	1,750	Estimate from Jamison (1911).
Charles Dickenson	Unknown	Unknown	---
Cleveland	NW sec. 21, T29N, R100W	Unknown	---
Clipper	Unknown	Unknown	---
Cuba	NE sec. 20, T29N, R100W	Unknown	Very minor production, if any.
Dexter Tunnel	SE sec. 2, T29N, R100W	Unknown	Historic reports indicate the Dexter Tunnel was driven 1,400 to 1,500 ft in metagreywacke across regional structure. Probably minor production.
Diamond Development	SW sec. 29, T30N, R99W	Unknown	Short adit and winze in Flathead conglomerate. Minor production.
Diana	SW sec. 1, T29N, R100W	500	Estimate from Jamison (1911).
Doc Barr	SW sec. 15, T29N, R100W	850	Estimate from Jamison (1911).
Duncan	NW sec. 14, T29N, R100W	3,790	Estimate (750 oz) from Jamison (1911), and 3,040 oz of actual production after 1911 (Hausel, 1980).
Europe	Unknown	350	Estimate from Jamison (1911).
Exchange	NE sec. 15, T29N, R100W	1,000	Estimate from Jamison (1911).
Franklin	SW sec. 20, T29N, R100W	15,000	Estimate from Jamison (1911).
Garfield (Buckeye)	NE sec. 11, T29N, R100W	21,000	Estimate from Jamison (1911).
Gold Dollar	SW sec. 32, T30N, R99W	Unknown	The mine was driven 1,350 ft across regional structure. Possibly minor production.
Gould and Curry	Unknown	1,000	Estimate from Jamison (1911).
Groundhog	SW sec. 11, T29N, R100W	1,500	Estimate from Jamison (1911).
Homestake	Sec. 21, T29N, R100W	Unknown	---
Independence	Unknown	75	Estimate from Jamison (1911).
Kenyon	SE sec. 15, T29N, R100W	Unknown	---
Klondike	Unknown	125	Estimate from Jamison (1911).
Lone Star	NW sec. 35, T30N, R100W	2,000	Estimate from Jamison (1911).
Lucky Boy	Unknown	150	Estimate from Jamison (1911).
Mars	NW sec. 21, T29N, R100W	Unknown	---
Mary Ellen	NE sec. 14, T29N, R100W	6,250	Estimate from Jamison (1911).
Meadow Gulch placers	Sec. 29, T30N, R99W	50,000	Estimate from Jamison (1911).
Midas (1914)	SW sec. 1, T29N, R100W	1,380	Armstrong (1948) reported production for 1934. No other production data available.
Mill Hill hydraulics	SW sec. 12, NW sec. 13, T29N, R100W	10,500	Estimate from Spencer (1916).
Miners Delight	Sec. 32, T30N, R99W	60,000	Estimate from Jamison (1911).
Monarch	NE sec. 21, T29N, R100W	Unknown	Mine consists of two adits with total of 480 ft of workings. Samples collected in mine yielded a trace to 0.25 oz/ton Au. Little to no gold produced.
Monte Carlo	NW sec. 32, T30N, R99W	Unknown	---
Mormon Crevice	Sec. 11, T29 N, R100W	150	Estimate from Jamison (1911).
Old Hermit	NW sec. 13, T29N, R100W	Unknown	---

Table 1, continued.

Mine name	Location	Gold production (ounces)	Discussion
Outpost	NW sec. 18, T29N, R99W	Unknown	Mine consists of about 1,400 ft of drifts. No estimates available.
Payrock	Unknown	100	Estimate from Jamison (1911).
Peacock	Unknown	250	Estimate from Jamison (1911).
Promise Gulch placer	Sec. 5, T29N, R99W	1,500	Estimate from Jamison (1911).
Rocky Bar adit	SW sec. 15, T29N, R100W	Unknown	29 samples taken in the 400-ft tunnel driven across regional structure assayed no gold to 0.03 oz./ton Au. Minor to no production.
Rock Creek adit	NE sec. 11, T29N, R100W	Unknown	---
Rock Creek placer	T29N, R99-100W	11,500	Reported production (Hausel, 1980).
Rose	SE sec. 2, T29N, R100W	250	Estimate from Jamison (1911).
Smith Gulch adit	SE sec. 6, T29N, R99W	Unknown	Minor to no production.
Snowbird (Rosella)	Sec. 6, T29N, R99W	375	Estimate from Jamison (1911).
Soules and Perkins (Victoria Regina)	NE sec. 11, T29N, R100W	25,000	Estimate from *Lewiston Gold Miner* (1894). Jamison estimated production at 17,500 oz.
Spring Gulch placer	NE sec. 33, T30N, R99W	1,500	Estimate from Jamison (1911).
St. Louis	NW sec. 13, T29N, R100W	375	Estimate from Jamison (1911).
Tabor Grand	NE sec. 14, T29N, R100W	2,400	Estimate from Hausel (1987).
Tornado	SE sec. 30, T30N, R99W	Unknown	Minor Cu, Au, Ag production.
Wyoming Copper	Sec. 18, T29N, R100W	Unknown	Minor Cu, Au, Ag production.
Wyoming Mica and Metals	T30N, R100W	Unknown	---
Yankee Gulch placer	SW sec. 28, T30N, R99W	25,000	Estimate from Jamison (1911).
Yellow Jacket	Sec. 25, T30N, R100W	Unknown	Minor to no production.
Young American	Unknown	1,000	Estimate from Jamison (1911).
TOTAL PRODUCTION	326,123 ounces		
LEWISTON DISTRICT			
Bullion (Jumbo)	Sec. 5, T28N, R98W	21,000	Reported production by Pfaff (1978).
Burr	NW sec. 8, T28N, R98W	Unknown	---
Full Hand	N/2 sec. 34, T29N, R98W	Unknown	Little to no production.
Goodhope	SW sec. 34, T29N, R98W	Unknown	---
Helen G	NE sec. 5, T28N, R98W	Unknown	---
Hidden Hand	S/2 sec. 5, T28N, R98W	Unknown	---
Iron Duke	E/2 sec. 5, T28N, R98W	Unknown	---
Lone Pine	SE sec. 9, T28N, R98W	Unknown	---
Mint-Goldleaf	SE sec. 33, T29N, R98W	Unknown	---
Morris	SE sec. 5, T28N, R98W	Unknown	---
Big Nugget placer	W/2 sec. 33, T29N, R98W	Unknown	---
Strawberry Creek	N/2 sec. 5, T28N, R98W	Unknown	---
Two Johns Gulch	Unknown	Unknown	---
Wilson Bar placer	NW sec. 16, T28N, R98W	391	Reported production (*Lewiston Gold Miner*, 1894).
Wolf (Ruby)	SE sec 22, T29N, R98W	Unknown	---
TOTAL PRODUCTION	21,391 ounces		
TWIN CREEK			
Red Canyon placers	Sec. 31, T31N, R98W and sec. 36,T30N, R99W	1,060	Estimate from Jamison (1911).
Smith placer	Sec. 2, T30N, R98W	Unknown	See Antweiler and others (1980).
Wilson placer	NE sec. 13, T30 N., R98 W	Unknown	Estimate from Jamison (1911).
TOTAL PRODUCTION	1,060 ounces		
DICKIE SPRINGS-OREGON GULCH			
Dickie Springs placer	Sec. 15, T27N, R101W	Unknown	See Love and others (1978).
Oregon Gulch placer	Secs. 20 and 21 T27N, R100W	Unknown	---
Oregon Buttes	T27N, R101W	Unknown	---
CROWS NEST	Sec. 11, T290N, R99W	Unknown	---
ANDERSON RIDGE	T29N, R101W	Unknown	---

Table 2. Reported average gold ore tenor (in oz/ton) from lode mines in the South Pass-Atlantic City district, comparing historic records and recent sampling.

Mine name	Average tenor–historic sampling	Average tenor-recent sampling
Alpine	---	0.22
B&H (Empire State)	0.75	---
Big Chief	2.0	---
Burr	0.5	---
Carissa	0.3	---
Carrie Shields	1.0	---
Diana	0.7	0.13
Doc Barr	1.7	---
Mary Ellen	0.4	---
Soules & Perkins	0.58	---
Tabor Grand	0.5	0.23
Lone Star	---	0.06

The majority of the lode deposits are dominated by gold, but in a few cases, such as the B & H mine, silver forms a significant portion of the ore. Armstrong (1948) reported the Au/Ag ratio for the B & H averaged 0.5. Most of the lode deposits are depleted in base metals, although a few, such as the Exchange lode and the Tornado mine, are enriched in copper. The overall lack of copper and zinc in most of the South Pass lodes is favorable for gold recovery by conventional cyanidation. However, the apparent coarseness of some of the gold is not favorable for conventional cyanidation.

Historic tests conducted by Knight (1901) on ores from several mines in the district showed variable success in extracting gold by free milling (crushing and amalgamation). Fine grinding was necessary, and mills using 40-mesh screens could not save (on average) even 50% of the gold values. After free milling, the tailings were treated with cyanide and assayed. The raw ores were also treated by chlorination and the tailings assayed.

Free milling at several mines from the South Pass-Atlantic City district recovered between 62.3 and 95% of the assay value. Cyanide treatment of the tailings recovered nearly all of the remaining gold in most tests. Chlorination of the raw ores recovered from 56.5 to 100%. The high recovery was from oxidized ores and the low recovery from sulfide-bearing ores that could not be successfully handled by chlorination without first roasting the sulfides (Knight, 1901).

Samples tested from three mines in the Lewiston district demonstrated the ore to be refractory. Ore samples from the Mint, Midget (location unknown), and Spotted Horse (location unknown) mines all contained significant gold values, assaying 20.99 ppm (0.612 oz/ton), 33.5 ppm (0.977 oz/ton), and 13.72 ppm (0.4 oz/ton), respectively. Free-milling tests recovered only 57, 58, and 79% of the respective samples. After treatment with cyanide, the free-milling tailings assayed 4.8 ppm (0.14 oz/ton), 6.86 ppm (0.2 oz/ton), and 6.17 ppm (0.18 oz/ton) gold, indicating poor recovery (Knight, 1901).

Chlorination tests were also unsuccessful. The tails from chlorination of the Mint ore assayed 12.35 ppm (0.36 oz/ton) gold. Chlorination of the Midget ore extracted only 13% of the assay value, and tests on the Spotted Horse ore were not better (Knight, 1901). These poor results suggest much of the gold occurs in sulfides and as coarse pellets.

The importance of grinding these ores to increase the available surface area was recently emphasized on mine dump material collected on a heap-leach pad between the Diana and 1914 mines in the South Pass-Atlantic City district. Material from the dump yielded good assay values (Hank Hudspeth Jr., personal communication, 1985), but the waste was not crushed before cyanidation, resulting in no gold recovery.

Types of deposits

Auriferous shears and veins

Much of the lode gold recovered from the greenstone terrane was in shear-zone structures. Quartz veins have also been productive, but are less common. Essentially all of the mines in the Lewiston district and many in the South Pass-Atlantic City district are developed in metagreywacke-hosted shear zones, however, there is a variety of other host rock types in the South Pass-Atlantic City district including hornblende-plagioclase amphibolite, meta-andesite, graphitic schist, and metatonalite. The variety of host rock types is contrary to the concept of a single source rock.

In general, the shear zones are narrow (±5 feet), ductilely and brittlely deformed, cataclastic zones that dip steeply and strike parallel to the grain of the country rock. Strike lengths vary from tens of feet to a few thousand feet, but their downdip extents have not been determined. The Carissa shaft, the deepest gold mine in the greenstone belt, was sunk to a depth of 400 feet. The mineralized shear pinches and swells downdip, but the lower workings are still within mineralized rock. Anaconda Minerals Company drilled this shear in 1974 and intersected the mineralized zone 930 feet below the collar of the shaft, proving the shear continues to at least that depth. If comparisons can be made with other greenstone terranes worldwide, then these shears may be continuous to greater depths (more than 1 mile), even where strike lengths are relatively short (e.g. Groves and others, 1985).

Wider mineralized zones are also present. These include a minimum 100-foot-wide, low-grade, auriferous envelope of fractured and rehealed metagreywacke enclosing the Carissa shear; a 40-foot-wide gold-bearing shear splay at the Duncan mine; and some 15- to 100-foot-wide mineralized shears elsewhere in the greenstone belt. Additionally, there are a number of relatively wide untested zones of country rock with common discrete veins and veinlets.

Quartz and carbonate are relatively common in the shear zones. The quartz occurs in veins and lenses, as stretched boudins, and as sheared lenses parallel to wallrock foliation. Continuous uninterrupted veins are rare and have been mapped in only a few mines (Alpine, Carrie Shields, Diana, and Mary Ellen). The quartz is milky or light to dark gray translucent (the dark quartz being blackened by abundant microscopic tourmaline). Some mines also have more than one generation of cherty quartz. Some later generations of quartz include crosscutting veins, quartz breccias, and vuggy, singly terminated quartz prisms. Carbonate occurs as massive calcite replacements and rhombs.

Localization of ore shoots in the shear zones is not well understood. Generally, the shear structures are weakly to poorly mineralized along much of their strike length with occasional ore shoots. Armstrong (1948) described some shoots at intersections, pinches, and splits, and along attitude changes of mineralized structures. Ore shoots also occur in fold closures. Control by chemically receptive wallrock is not apparent.

Mines with ore shoots developed at shear intersections are common in the greenstone belt, for example, at the B & H (Empire State), Caribou, Hidden Hand, and Kenyon mines. The Caribou and Hidden Hand shoots were particularly well mineralized due to the increased permeability produced by several intersecting shear structures. There are also examples of ore shoots developed at Archean shear and Laramide(?) fault intersections (e.g., Bullion mine). But if the auriferous solutions are assumed to be Archean, these shoots could only have developed in one of two ways; (1) the Laramide structure could represent a reactivated Archean structure, or (2) the intersection of the two structures could have sufficiently increased the permeability to allow for supergene enrichment of the ore body. Miners in the region insist supergene enrichment was important to the development of some shoots at the water table (Dave Haddenham, personal communication, 1986).

Ore shoots at pinches in structures are best typified by the Mary Ellen vein; where the vein pinches from 3 feet to 6 inches, gold values are generally elevated (Steve Gyorvary, personal communication, 1986). Another vein, in the Diana mine, is complexly folded. The vein strikes nearly perpendicular to regional foliation, rolls over, changes attitude parallel with the regional grain, and rolls over a second time, suggesting that it lies in a complex refolded drag fold. Elevated gold values occur at attitude changes in the vein. At the Alpine mine, gold enrichment occurs in the nose of an open fold.

Fold closures appear to have localized some shoots, particularly on the stope scale. In addition to the Alpine and Diana shoots, the Miners Delight shaft was sunk in a folded shear. Folds localized shoots in the Carissa and Franklin mines (Bow, 1986) and controlled the location of shoots at the Duncan mine and in several other mines in the region. A channel sample taken in a quartz lens in a fold closure at the Duncan mine yielded many times the average gold value of the remainder of the exposed mineralized shear zone (46A, **Plate 2**).

The gold-bearing shears in the South Pass-Atlantic City district commonly follow amphibolite-metagreywacke contacts but also penetrate the adjacent metagreywacke and amphibolite. Additionally, a number of shears occur in graphitic schist, chlorite schist, and tremolite/actinolite-chlorite schist adjacent to the amphibolite. The spatial association of the auriferous shears with a narrow east-northeast trending belt of diverse assemblages of metaigneous and metasedimentary rock is structural. The contrasting rock competencies of this assemblage provided a favorable environment for the subsequent development of shears during regional folding and metamorphism.

In the Lewiston district, the shears appear to be less complex and are concentrated near the apex of a large regional fold. These shears parallel the fold limb and contain numerous small sweat veins. Ore shoots in these shears are controlled by intersecting structures.

Most shears in the greenstone belt are strike shears that parallel regional foliation, bedding, and isoclinal fold hinges and only locally crosscut the rock fabric at low angles. The age of the auriferous shears and mineralization is interpreted to be synmetamorphic on the basis of the congruence of a model lead age for galena (~2.8 Ga) from the Snowbird mine (Bayley and others, 1973) and a 2.8 Ga Rb-Sr whole-rock isochron for the Miners Delight Formation (Stuckless and others, 1985).

Wallrock alteration associated with the mineralized shears in the South Pass-Atlantic City district varies in intensity. Generally, wallrock alteration is weak, defined by narrow SiO_2- and K_2O-enriched zones manifested by secondary sericite and quartz. Locally, pre-existing feldspar is replaced by untwinned microcline. Accessory calcite, chlorite, and tourmaline, and secondary biotite may occur. Some shears are more intensely chloritized and hematitized.

In the Lewiston district, wallrock alteration is megascopically apparent as light greenish to reddish stained rock that extends several feet from the shear zones. These altered rocks and septa within the shears are partially replaced by chlorite, hematite, and quartz and accessory tourmaline, calcite, epidote, and biotite.

The mineral assemblage associated with wallrock alteration indicates the temperature of the mineralizing fluids was relatively high but not much higher than the temperature of the contemporaneous amphibolite-grade regional metamorphism that affected large portions of the greenstone belt. The mineralogy suggests recrystallization near the low-temperature limit of the amphibolite facies, at about 400°C (Bayley and others, 1973).

Sulfides in shear zones include pyrite, pyrrhotite, and arsenopyrite, which oxidize to hematite, limonite, and scorodite. Paragenetic studies have been neglected. In most samples with visible gold, gold fills fractures in quartz and occurs in arsenopyrite and iron sulfides.

The occurrence of gold in fractures in chemically inert quartz suggests some deposition resulted from changes in pH and oxygen fugacity linked to temperature. Gold also occurs in sulfides, indicating some precious metal may have been carried in gold-sulfide complexes. Locally, mineralized structures are carbonatized, which also points to CO_2-enriched fluids.

Placer deposits

Gold in placers is concentrated at or near bedrock and in some layers above bedrock on impermeable clay. Most nuggets recovered in recent years are irregular to flat, often having rounded to jagged edges. For the most part, these nuggets give the impression of mechanical transport. Microscopic gold from Wilson Bar in the Lewiston district was reported by Day and others (1988, p. 9) to be of two types: (1) rounded to irregular shaped gold suggestive of mechanical transport, and (2) wire gold derived from a nearby lode or geochemically precipitated. All of the placer gold examined during this study appeared to have been mechanically transported and there was no evidence of low-temperature geochemical precipitation or biologically induced growth of gold.

Historical information on recovered nuggets is notably lacking, but the available reports describe nuggets weighing up to 5 ozs (Hausel, 1989). Two samples found on Rock Creek before 1905 are of particular interest. One was described as a fist-size piece of gravel covered and filled with about 24 ozs of gold, suggesting it was a nugget with mixed country rock. The other rock specimen reportedly contained an estimated 630 ozs (nearly 40 pounds!) of gold (*Wyoming Industrial Journal*, 1905, v. 6, no. 12, p. 18).

Gold amalgamated with mercury is found in several placers. The mercury was probably introduced by prospectors during the historic past; no attempt was made to determine if any natural mercury sources occur in the greenstone belt.

Other heavy minerals, scheelite and cassiterite, were identified in concentrates from the Stout placer on Rock Creek. Scheelite also occurs in the Crows Nest placers east of Atlantic City (Jim Rutter, personal communication, 1984), and both scheelite and cassiterite were identified in placers in the Lewiston district (Day and others, 1988).

Cupriferous lodes and stockworks

Chalcopyrite-bearing quartz veins containing silver and gold, and calcite gangue occur in strike shears, in breccia zones of some major faults, and in cross fractures oblique to foliation. These veins are less common than the auriferous strike shears and in a few locations can be demonstrated to displace the auriferous shears, therefore representing a later episode of mineralization (Bayley and others, 1973). These veins are Precambrian but their precise age is unknown. Three relationships suggest that at least some copper is syn-to post- Louis Lake and Lewiston Lakes granodiorites (~2.6 Ga): (1) a concentration of copper deposits near the margins of the greenstone belt within short distances of the plutons suggests possible derivation and introduction from the granodiorite; (2) a cupriferous shear is exposed in the Louis Lake granodiorite at the Burnt Meadow prospect; and (3) a cupriferous stockwork is located along the margin of the Louis Lake batholith near the northwestern edge of the greenstone belt.

The veins are generally narrow, discordant quartz veins that pinch and swell along strike. Copper carbonate locally stains fault breccias at some localities, for example near Gold Creek on the Anderson Ridge fault in the vicinity of Anderson Ridge (21A, **Plate 2**) and on Willow Creek, also along the Anderson Ridge fault (69A, **Plate 2**).

Cupriferous stockworks (26A, **Plate 2**) with crosscutting milky quartz veins and veinlets contain copper with elevated precious metal values. The stockwork lies within a mixed zone of border gneiss complex and Louis Lake granodiorite. A similar but unmineralized stockwork occurs northeast of the Atlantic City mine in an unsurveyed portion of the national forest (~sec. 24, T30N, R100W). This stockwork is in granodiorite intruded into the gneiss complex.

Most cupriferous deposits in the South Pass granite-greenstone belt are too small and narrow to be considered commercially significant, but the stockwork is worthy of closer inspection. Only one sample from the stockwork was assayed (26A, **Appendix B**) and it yielded 3.23% copper, 3.2 ppm (0.09 oz/ton) silver, and 0.16 ppm (0.005 oz/ton) gold. The precious metal content is anomalous, and more samples are needed to characterize the deposit.

Banded iron formation

Banded iron formation, or taconite, was commercially recovered by open pit mining between 1962 and 1983, at the Atlantic City mine along the northwestern flank of the greenstone belt. More than 90 million tons of ore were recovered during this period.

The iron formation is a member of the Goldman Meadows Formation, a predominantly metasedimentary unit of quartzite, metapelite, mafic amphibolite, and iron-bearing schist (see p. 14). The Goldman Meadows iron formation is principally a hard, dense, black schist consisting of bands of alternating magnetite- and quartz-rich layers. Most of the rock is formed of magnetite and quartz (about 90%), with lesser amphibole, chlorite, and garnet. The average iron content is 33.5%, with silica averaging 50% (Bayley and others, 1973). Locally, samples include pyrite and chalcopyrite. The iron formation is relatively thin, but has undergone structural thickening at the Atlantic City mine site, making it amenable to open-pit mining.

During this study, the banded iron formation was examined along the northwestern greenstone belt flank and iron deposits were discovered elsewhere in the greenstone belt. These previously unreported iron deposits are located and described below:

(1) Along the southeastern limb of the belt, banded magnetite-quartz iron formation occurs in a structurally complex region near Diamond Springs (SW sec. 19, T29N, R97W). The main body of this iron formation crops out in a large fault block. From here, the iron-bearing schist continues to the south as sheared hematitic-quartz iron formation.

(2) A thin grunerite schist outcrop in the Roundtop Mountain Greenstone (sec. 25, T29N, R98W) contains 23.3% total iron as Fe_2O_3. Grunerite schist was also identified in the Diana mine in the Miners Delight Formation and does not appear to be extensive.

(3) Magnetite-quartz banded iron formation occurs in the gneiss complex between the Sweetwater and East Sweetwater Rivers near the western margin of the greenstone belt (sec. 22, T29N, R102W).

The iron deposit northeast of the Lewiston district is relatively small compared to the Atlantic City deposit. This is probably the same iron formation reported by Harrer (1966, p. 36) to be in sec. 5, T29N, R98W. However, Harrer's location places the iron formation in the Phanerozoic section (the Lewiston iron formation is Archean and partially located in sec. 19, T29N, R97W, along the southeastern margin of the greenstone belt more than 4 miles southeast of Harrer's location) (**Plate 1**). This deposit has never been mined, but it may be feasible to operate a satellite open pit to supplement reserves at the Atlantic City mine if operations ever resume.

No systematic search for gold in the iron formation has been undertaken, although a few samples of banded iron formation were collected to test for gold (**Appendix B**). Samples of sulfide-bearing iron formation collected from the Atlantic City open pit mine (37A, **Plate 2**) contained <0.01 oz/ton gold. Banded iron formation collected from a shallow prospect adjacent to Highway 28 (24A, **Plate 2**) contained 1.3 ppm (0.03 oz/ton) gold. Quartz from this same prospect yielded 0.40 ppm (0.01 oz/ton) gold (**Appendix B**). Samples of iron formation collected south of Diamond Springs (17A and 18A, **Plate 2**) yielded no detectable gold to 0.02 oz/ton gold.

Nickel-chromium and precious metal anomalies in ultramafic rocks

Except for a brief mention of chromite in Rock Creek, nickel and chromium anomalies have never been reported in the South Pass greenstone belt. However, the presence of cumulus serpentinites and other similar ultramafic rocks in the South Pass region points to the need for detailed investigations, particularly for nickel. For instance, some South Pass serpentinites show geochemical similarities to the Western Australia nickeliferous komatiites (see p. 12).

The nickeliferous komatiites of Western Australia are characterized not only by high MgO (> 36%), but also by CaO/Al_2O_3 ratios of about 1, Al_2O_3/TiO_2 ratios of about 20, and flat heavy REE patterns. These Australian rocks are undepleted in aluminum and depleted in TiO_2 and light REE (Marston and others, 1981). The South Pass ultramafics show similar geochemical characteristics, although the REE distributions are not well known.

Two types of nickel deposits occur in Western Australia: (1) volcanic-hosted deposits of komatiite affinity, and (2) dunite-hosted deposits. Examples of komatiitic nickeliferous host rocks from Western Australia are presented in **Appendix A2** (6D-9D) for comparison. Note that serpentinites from South Pass (10D-13D, **Appendix A2**) have comparable compositions to the Australian rocks, and samples 10D through 15D all exceed 36% MgO, but the nickel values are not anomalous. Much nickel in the Western Australian deposits occurs as the nickel sulfide pentlandite, which is concentrated near the base of cumulate-textured serpentinites or talc-magnesite schists (Groves and Hudson, 1981; Naldrett and Campbell, 1982). The commercial nickel deposits in Western Australia have average grades of 0.8 to 4.1% nickel (Groves and Hudson, 1981). The South Pass MgO-rich serpentinites and cumulate-textured serpentinites yielded MgO concentrations of 36.3 to 38.1% and nickel concentrations only as high as 2,570 ppm (0.26%).

Dunite-hosted (intrusive) nickel deposits have high average MgO compositions (49-50%). These rocks have similar ore grades to the volcanic-associated deposits, although tonnages are normally greater. The Mt. Keith deposit, in the Eastern Goldfields province of the Yilgarn block, Western Australia, is reported to contain 290 million tons of 0.6% nickel (Groves and Hudson, 1981, p. 312). Rocks with extreme MgO enrichment comparable to dunites were not identified in South Pass.

The only known report of chromium in the South Pass greenstone belt prior to this study was a brief mention of chromite recovered on Rock Creek by Dietz (1932, p. 93). The location of this discovery was not given, although it was implied to have been near the asbestos prospects at Iron Mountain along the northern edge of the Atlantic City iron mine. Samples collected during this study from the Stout placer mine, located a few miles downstream from Iron Mountain on Rock Creek, were tested for chromium by emission spectrometry but none was found.

Some ultramafic rocks of the Diamond Springs Formation contain anomalous chromium. Chromium contents as high as 10,100 ppm (1.01%) were detected in some South Pass serpentinites, but these values are considerably lower than the chromium deposits mined in the Soviet Union. For example, podiform chromite deposits in the Ural Mountains have grades of 28 to 44% (280,000 to 440,000 ppm) Cr_2O_3. The average ultramafic rock has about 1,600 ppm (0.16%) chromium (Kerrich, 1983).

Precious metal contents of ultramafic rocks from South Pass are unimpressive. The average terrestrial ultramafic rock contains 0.0008 ppm gold, 0.06 ppm silver, 0.009 ppm palladium, and 0.011 ppm platinum (Kerrich, 1983). South Pass ultramafics analyzed during this study ranged from <0.005 ppm to 0.016 ppm (0.0005 oz/ton) gold, but most samples contained below detectable gold content (<0.005 ppm). However, the maximum detected gold content (0.016 ppm) represents a 20-fold enrichment compared to the average ultramafic rock. Silver was detected (6 ppm) in only one sample, which represents a 100-fold enrichment over the average ultramafic rock. Palladium values ranged from <0.002 ppm to 0.010 ppm, and platinum ranged from <0.015 to 0.025 ppm (0.0007 oz/ton), indicating the South Pass ultramafics do not exhibit anomalous platinoid contents.

Tungsten-tin anomalies

Tungsten occurs on a number of properties at South Pass. For instance, the Burr mine in the Lewiston district contains scheelite in association with the primary auriferous shear zone (Wilson, 1951). Disseminated scheelite also occurs in discrete veins and veinlets in the Crows Nest region and elsewhere in the Lewiston district. Placer scheelite has been identified in stream-sediment concentrates from the Lewiston district (Day and others, 1988), from Rock Creek in the South Pass-Atlantic City district, and in the Crows Nest placers between the South Pass-Atlantic City and Lewiston districts.

Traces of cassiterite (tin oxide) were detected in some stream-sediment samples in the Lewiston district by Day and others (1988) and at the Stout placer on Rock Creek. The source of the tin was not determined.

Miscellaneous mineralization

A number of additional mineral resources occur in the South Pass granite-greenstone belt. Pegmatites in the Anderson Ridge area are enriched in microcline and were selectively mined after the Second World War for feldspar. These coarse-grained granites also contain minerals of interest to collectors, such as schorl tourmaline, green tourmaline, aquamarine beryl, green beryl, tantalite, arsenopyrite, and almandine garnet (Proctor and El-Etr, 1968; Harris and Hausel, 1986).

Crossfiber chrysotile asbestos is found in some serpentinites near the Atlantic City mine. The asbestos occurs in narrow (1/16th- to 1/2-inch-wide) subparallel veinlets (12D and 27D, **Plate 2**) along the northeastern highwall of the open pit mine (N/2 sec 26, T30N, R100W) and also west of the mine entrance near Slate Creek (S/2 sec 34, T30N, R100W). The asbestos is restricted to a few outcrops.

Uranium mineralization does not appear to be extensive in the greenstone belt; however, no systematic study of radioactive deposits was undertaken. During mapping of the Halls Meadow Spring Quadrangle, samples of uraniferous granite gneiss were collected from the Pard mine, located near the western edge of the greenstone terrane in the adjacent granite gneiss (NW sec 35, T29N, R103W). The Pard mine is a small open pit (essentially a prospect pit), from which a minor amount of yellowcake was recovered in the 1950s. Samples collected from the pit were examined by x-ray diffraction, yielding two lead-bearing uranium oxide mineral phases, kivuite and renardite.

The historic report of a diamond recovered from a placer deposit in the greenstone belt and the report of a large diamond found in the central Wind River Range to the north (J.D. Love, personal communication, 1986), as well as the presence of kimberlitic indicator minerals in other Wyoming Archean greenstone belts (e.g. Elmers Rock and the Seminoe Mountains belts) (Hausel and others, 1988, and personal field notes), suggest that diamond exploration projects in this region should be considered. However, diamonds were not investigated for this report due to an insufficient number of personnel to conduct geophysical and geochemical surveys.

South Pass-Atlantic City district

The northwestern margin of the greenstone terrane is intensely fractured along a narrow east-northeast trending belt of metamorphosed sedimentary and igneous rock of the Miners Delight Formation. The frequency of mineralized shears and veins diminishes away from this belt, which runs from South Pass City through Atlantic City to the ghost town of Miners Delight (**Figure 14**).

The great majority of the mines in the district are localized in strike-trending structures. These shears penetrate structurally competent amphibolite and also occur along contacts between rocks of contrasting competency (i.e. metagreywacke-amphibolite contacts), in rocks with well-developed penetrative fabrics such as ultramafic and chlorite schist, and in metagreywacke and graphitic schist.

Five styles of primary precious-metal mineralization are evident in the South Pass-Atlantic City district. They include (1) auriferous strike-trending shears, (2) auriferous quartz veins, (3) argentiferous (Ag-As-Au) veins and shears, (4) chalcopyrite-dominated (Cu-Au-Ag) veins and shears, and (5) copper-silver stockworks. Secondary mineralization includes gold placers and paleoplacers.

Most gold-bearing structures are dominated by gold with minor silver. Gold/silver ratios are generally high, typical of Archean gold deposits, although a few are relatively low. For example, Armstrong (1948) reported ore from the B & H mine yielded nearly twice as much silver as gold.

Other gold-bearing structures in the district include copper-dominated lodes. These chalcopyrite-bearing structures carry gold and silver with Au/Ag ratios generally much lower than the Au/Ag ratios for the primary gold-dominated systems. The gold-bearing structures are narrow crosscutting quartz-calcite veins and cataclastics of major faults. Because the faults displace the auriferous shears, these copper-dominated lodes represent a later episode of mineralization.

Individual mines

The South Pass granite-greenstone belt includes hundreds of lode and placer mines and prospects. Essentially all of these were examined by the author during this project, but only a few are described below. Locations of the mines and prospects are shown on **Plate 1** and **Figure 14**. Additional information can be obtained from the Geological Survey of Wyoming.

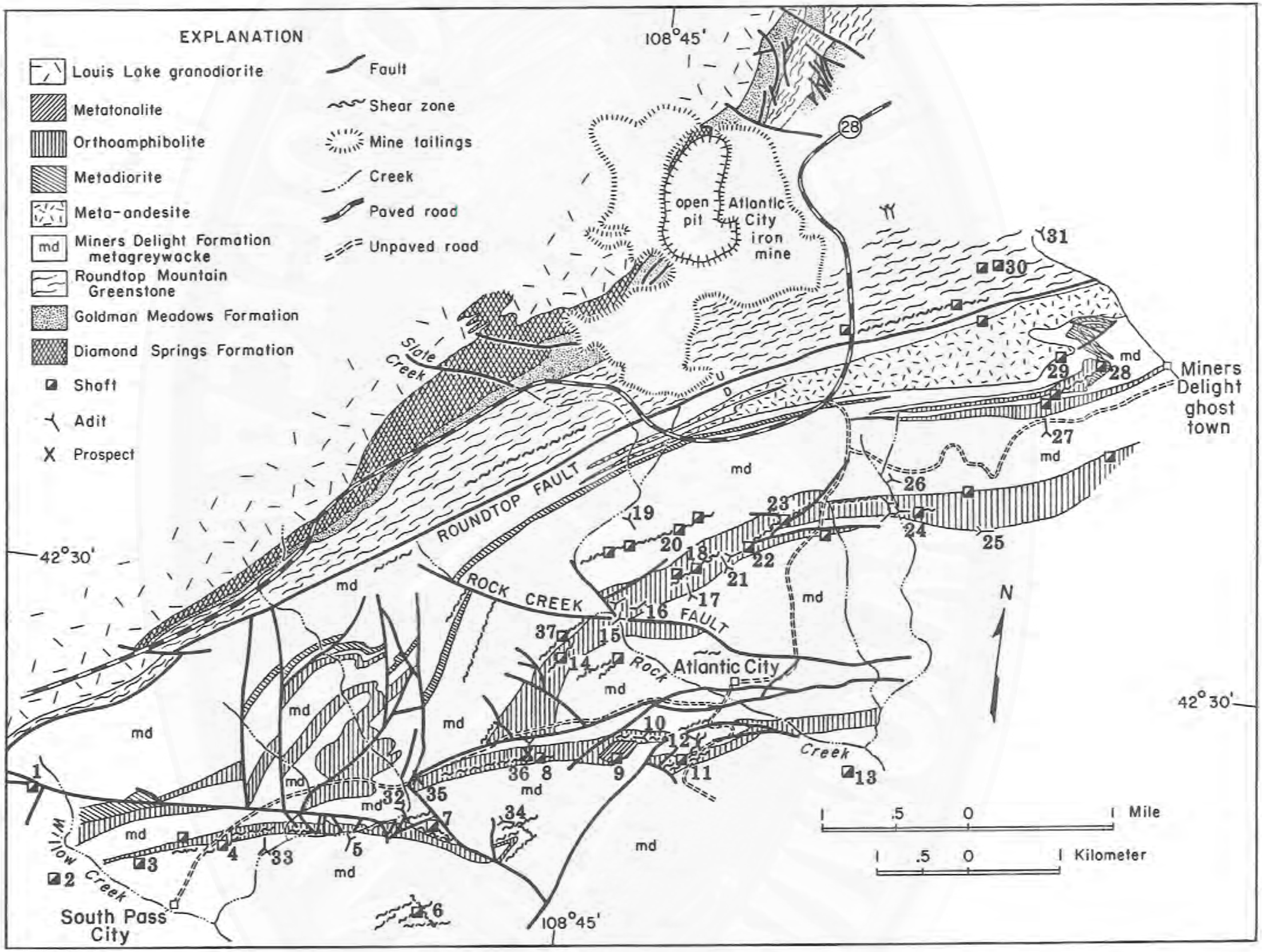

EXPLANATION
Louis Lake granodiorite
Metatonalite
Orthoamphibolite
Metadiorite
Meta-andesite
md Miners Delight Formation metagreywacke
Roundtop Mountain Greenstone
Goldman Meadows Formation
Diamond Springs Formation
Shaft
Adit
Prospect
Fault
Shear zone
Mine tailings
Creek
Paved road
Unpaved road
108°45'
42°30'
open pit
Atlantic City iron mine
28
Slate Creek
ROUNDTOP FAULT
ROCK CREEK FAULT
Rock Creek
Atlantic City
Miners Delight ghost town
South Pass City
Willow Creek
Creek
md
N
1 .5 0 1 Mile
1 .5 0 1 Kilometer
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

Figure 14 (opposite). Generalized geologic map of the South Pass-Atlantic City district (modified from Hausel and Hull, 1990). Thirty-seven mines and prospects described in the text are located according to the list below.

Mines and prospects:

1. Wyoming Copper Mining Company
2. Franklin
3. Alpine
4. Carissa
5. Monarch
6. B & H (Empire State)
7. Doc Barr
8. Duncan
9. Mary Ellen
10. Tabor Grand
11. St. Louis (Jim Dyer)
12. Old Hermit
13. Outpost
14. Groundhog
15. Big Chief
16. Rock Creek adit
17. Soules and Perkins (Bucks Tunnel, Brittana, Victoria Regina)
18. Garfield (Buckeye)
19. Dexter Tunnel
20. Rose
21. Diana
22. Midas (1914, McGrath, Sullivan)
23. Caribou
24. Snowbird (Rosella)
25. Smith Gulch adit
26. Big Atlantic Gulch adit
27. Gold Dollar
28. Miners Delight
29. Monte Carlo
30. Tornado
31. Diamond Development Company adit
32. Rocky Bar adit
33. Homestake
34. Kenyon
35. King Solomon
36. Exchange
37. Wareagle

Alpine mine; W/2 NE sec. 20, T29N, R100W, located near South Pass City (**Plate 1** and **Figures 14** and **15**). This inclined shaft was developed on a 30° to 35°N dipping, gray, anastomosing, translucent quartz vein in metagreywacke of the Miners Delight Formation. The vein cuts regional foliation and lies within a sequence of isoclinally folded metasedimentary rocks.

Chip samples of the vein and sheared metagreywacke were taken in the mine back and ribs on 10-foot intervals (**Figure 15** and **Table 3**). Samples of sheared metagreywacke yielded 0.1 ppm to 2.3 ppm (0.003-0.067 oz/ton) gold, and the vein yielded values of 0.17 ppm to 101 ppm (0.005-2.94 oz/ton) gold. The greatest gold values were obtained from a narrow ore shoot formed in the nose of an open fold with fold axis oblique to regional foliation (Samples 4 and 5, **Table 3** and **Figure 15**). The average gold content of 16 samples collected in the mine was 7.4 ppm (0.22 oz/ton).

Table 3. Assay values (ppm) of samples collected in 1987 from the Alpine mine. Locality numbers refer to Figure 15.

Locality number	Sample number	Au	Ag	Locality number	Sample number	Au	Ag
1	AP 1-87	0.08	0	9	AP 9-87	2.3	1.0
2	AP 2-87	0.17	0	10	AP10-87	0.58	0
3	AP 3-87	0.41	0	11	AP11-87	0.85	0
4	AP 4-87	101.0	2.7	12	AP12-87	0.18	0
5	AP 5-87	9.8	0	13	AP13-87	0.29	0
6	AP 6-87	0.22	0	14	AP14-87	0.61	0
7	AP 7-87	0.10	0	15	AP15-87	0.34	0
8	AP 8-87	1.3	0	16	AP16-87	0.36	0

Two diamond drill holes drilled by Consolidated McKinney Resources in 1989 on the Alpine property yielded only traces of gold (de Quadros, 1989). These results agreed with Phillips (1911), who described the property as a low-grade lode, and with samples collected by the author in the Alpine mine, which showed the vein to be low grade with a narrow, localized, high-grade ore shoot (**Table 3**).

Atlantic City iron mine; SE T30N, R100W. This large open pit was developed on banded iron formation (BIF) of the Goldman Meadows Formation north of Atlantic City (**Plate 1** and **Figure 14**). The BIF averages less than 150 feet wide, but is thickened nearly fourfold by faulting and internal plication and folding.

The BIF is a hard, dense, laminated, dark rock composed of alternating layers of magnetite and quartz with varying amounts of amphibole. The rock is very fine grained and hornfelsic, with an average iron content of 33.5% (150 samples). Silica averages about 50%, titanium averages 0.025%, phosphorus averages 0.046%, and sulfur averages 0.011% (Bayley, 1968).

Sulfides are present locally in the iron formation. No gold was detected in six sulfide-bearing samples collected in the open pit (Hausel, 1986a). The mine was operated from 1962 to 1983, yielding more than 90 million tons of iron ore (Hausel, 1984) but no known gold was recovered. Although gold was not reported in the iron formation at the mine site, Bayley (1963) described an auriferous quartz vein adjacent to the BIF (see Lone Star mine).

B & H (Empire State) mine; (sec. 22, T29N, R100W), located between South Pass City and Atlantic City (**Plate 1** and **Figures 14** and **16**). The B & H shaft was sunk on a narrow, N80°E trending, near-vertical shear in metagreywacke of the Miners Delight Formation. A few yards east of the shaft, a glory hole was dug on an ore shoot formed at the intersection of the N80°E trending shear with a N35°W trending shear. The shaft was sunk 105 feet with 255 feet of drifts on three levels (**Figure 16**). According to Armstrong (1948), at least 600 tons of ore were mined that averaged 25.7 ppm (0.75 oz/ton) gold. Jamison (1911a) estimated production at 240 ozs of gold.

The B & H lode consists of sheared quartz and metagreywacke containing some pyrite, arsenopyrite, tourmaline, and gold. Bane (1929) reported samples yielded good values (**Table 4**).

Table 4. Descriptions and assay values for samples from the B & H mine (dash = not determined; n.d. = not detected).

Sample number	Description	Au (oz/ton)	Ag (oz/ton)
1	A composite of 12 samples from a 3-foot vein collected from the 100-foot level (Bane, 1929).	1.09	--
2	Four samples from a 4-foot vein at the surface on the Ellen M.C. no. 1 claim (Bane, 1929).	0.33	--
3	A composite of five samples from an 8-foot vein on the surface of the Caroline no. 1 claim (Bane, 1929).	0.28	--
4	A composite of three samples from a 6-foot wide vein on the surface of the Ellen M.C. no. 3 claim (Bane, 1929).	0.34	--
5	A composite sample collected from a 3-foot vein exposed in shallow 30-foot shafts near the center of the Emma claim (Bane, 1929).	0.76	--
6	A composite of two samples from a 6-foot vein collected from the discovery shaft on the Gold Nugget claim (Bane, 1929).	0.81	--
7	A composite sample of scorodite-stained quartz from the mine dump (Hausel, 1989).	n.d.	0.16

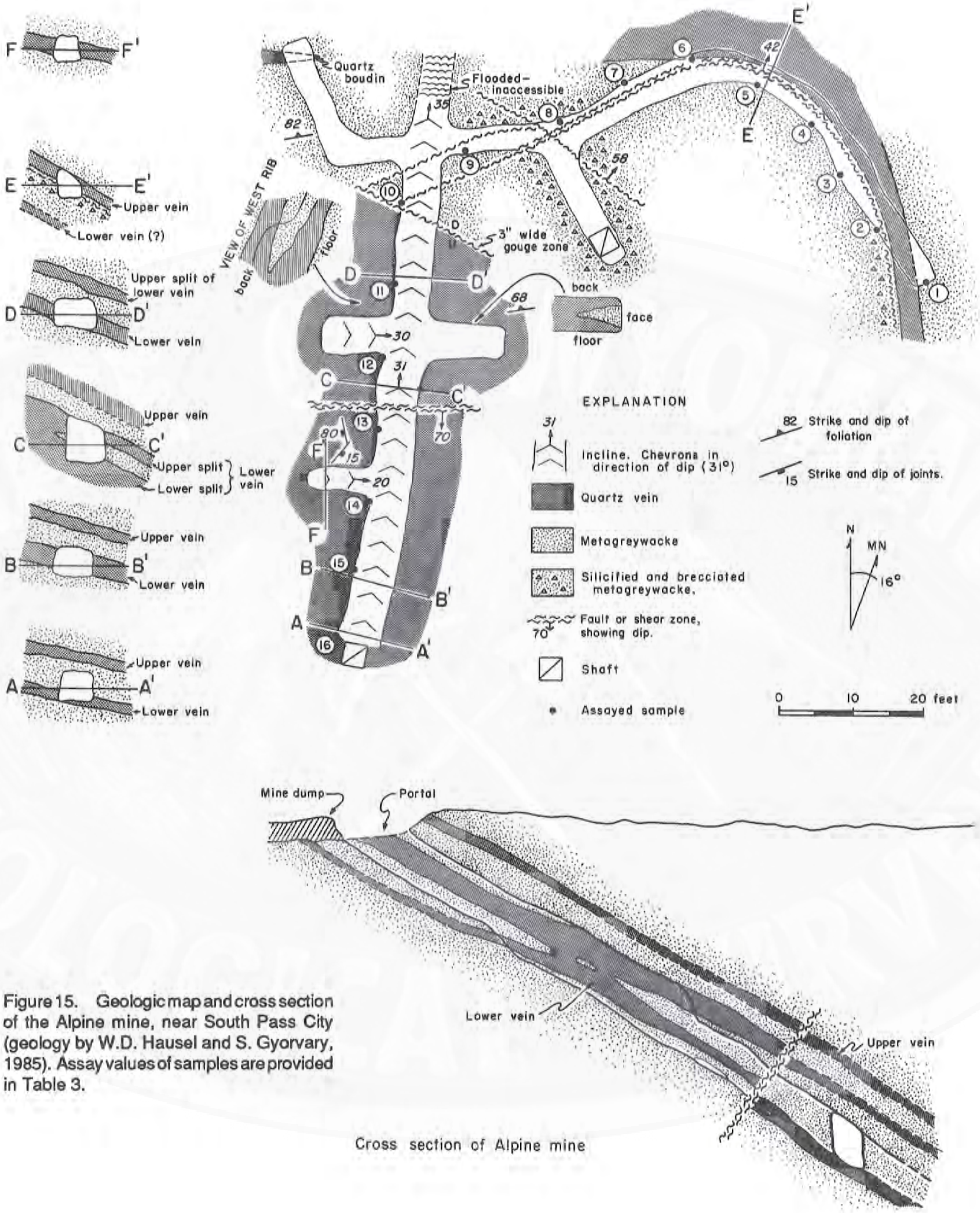


Figure 15. Geologic map and cross section of the Alpine mine, near South Pass City (geology by W.D. Hausel and S. Gyorvary, 1985). Assay values of samples are provided in Table 3.

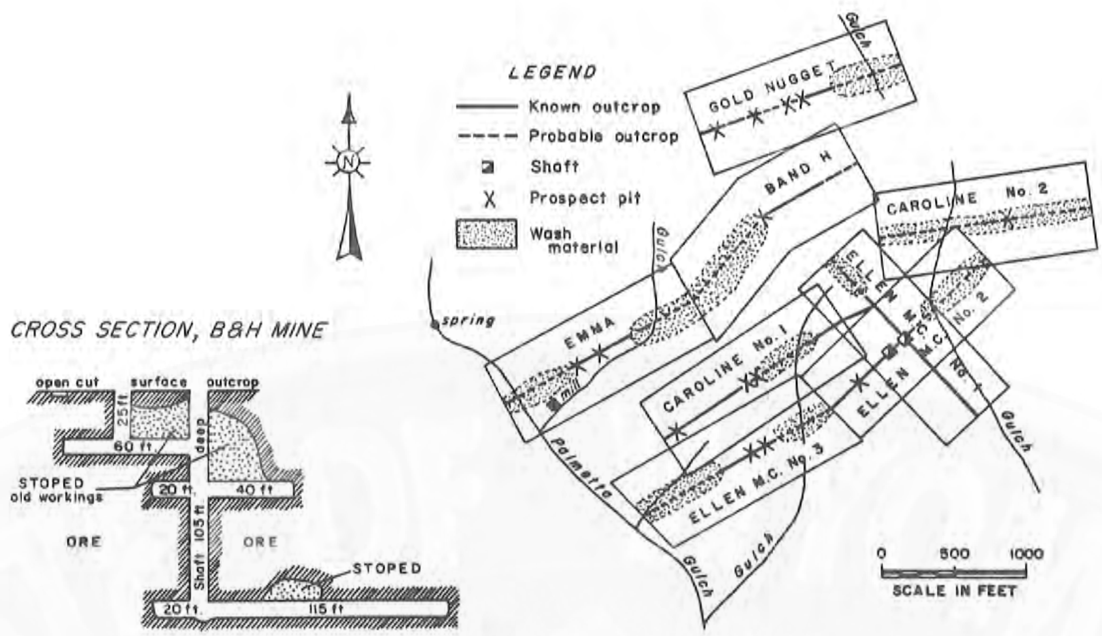


Figure 16. Claim map and cross section of the B & H mine (after Bane, 1929).

The B & H ore has an unusually low Au/Ag ratio. Armstrong (1948) reported the ratio as 0.5 (about twice as much silver as gold) and Love and others (1978) reported the Au/Ag ratio to average 2.5. The high silver content of this deposit is somewhat enigmatic but not unusual, since silver-dominated systems have been identified elsewhere in the greenstone belt. Some arsenopyrite-bearing veins and many of the cupriferous veins elsewhere in the greenstone belt are enriched in silver compared to gold.

A traverse by Prinz (1974) identified a 700-foot-wide weak arsenic soil geochemical anomaly west of the shaft. About 1/2 mile southeast, Prinz (1974) identified another 900-foot-wide arsenic soil geochemical anomaly over metagreywacke. One geochemical sample collected for arsenic also yielded 0.1 ppm gold.

Big Atlantic Gulch mine; NW sec. 6, T29N, R99W (**Figure 14**). The Big Atlantic Gulch adit was driven 30 feet to the east in Miners Delight Formation metagreywacke before branching into two tunnels (**Figure 17**). The drift running northeast cut a narrow graphitic schist bed and shear zone in metagreywacke country rock. The drift to the southeast intersected two narrow (less than 5 inches wide) shears in metagreywacke. Near the junction of the drifts are numerous quartz-filled fractures (less than .25-inch wide) in metagreywacke. No samples were taken in this mine.

Big Chief mine; SE sec. 11, T29N, R100W (**Figure 14**). The portal is hidden in willows on the west bank of Rock Creek northwest of Atlantic City. The adit was driven on a southwest trending shear in metagreywacke of the Miners Delight Formation. The mine dump extended from the portal on the stream bank into Rock Creek. Much of the dump was redistributed by the Fisher dredge in the 1930s.

According to Jamison (1911b), at least 1,000 feet of drifts were dug, and a 100-foot shaft was sunk on the shear zone. Jamison's report implies there is more than one level in the mine, since the adit level mapped during this project has only 650 feet of drifts and crosscuts (**Figure 18**). The westernmost extent of the mine was blocked by a muck pile, but slight airflow was detected during mapping of the mine in 1984 at this point, indicating that a raise lies beyond the pile and continues to the surface.

The ore grade was reported by Jamison (1911a) to average about 68.6 ppm (2.0 oz/ton) gold, and historic newspaper accounts reported ore from the Big Chief to run as high as 858 ppm (25 oz/ton) gold. Two samples collected from the mine dump in 1984 assayed <0.343 ppm (<0.01 oz/ton) gold with 0.686 ppm (0.02 oz/ton) silver, and 1.23 ppm (0.036 oz/ton) gold.

The average ore grade reported by Jamison (1911a) unquestionably represents selectively mined ore. Mineralization occurs in well-developed shears, with

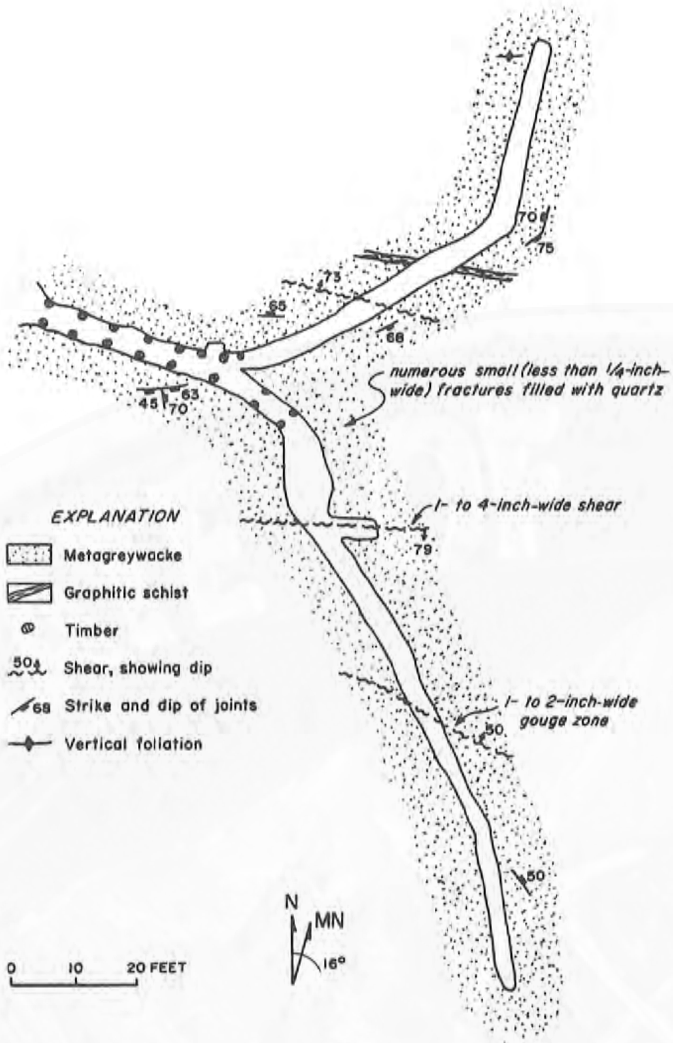


Figure 17. Geologic map of the Big Atlantic Gulch adit (by W.D. Hausel and J.K. King, 1985). Mapped at waist level.

localized ore shoots. At one point in the mine, a strike shear is projected to intersect a cross shear within 20 feet of the east face of a short crosscut. This shear intersection could represent an untested ore shoot. Gold production from the mine is estimated to be less than 2,000 ozs (Hausel, 1987b).

Caribou mine; S/2 sec. 1, T29N, R100W, located between Atlantic City and the Atlantic City iron mine (**Plate 1** and **Figure 14**). The Caribou shaft was one of the principal producers in the greenstone belt, with estimated production of 24,000 ozs of gold (Jamison, 1911a). Detailed large-scale mapping by the author identified five separate intersecting faults and shears at the mine site. The ore shoot apparently occurs where a well-developed N50°E trending shear is intersected by an east-west cross fracture. The host rock for the ore includes amphibolite and banded graphitic schist of the Miners Delight Formation. (Similar auriferous graphite schists in the Abitibi belt, Canada, have been interpreted by Springer (1985) to represent exhalites.) Samples collected from the dump in 1983 included limonite-stained quartz that assayed 11.3 ppm (0.33 oz/ton) gold. A 6-foot channel sample, cut into sheared metagreywacke west of the shaft, assayed 1.99 ppm (0.058 oz/ton) gold with 0.99 ppm (0.029 oz/ton) silver (**Appendix B**).

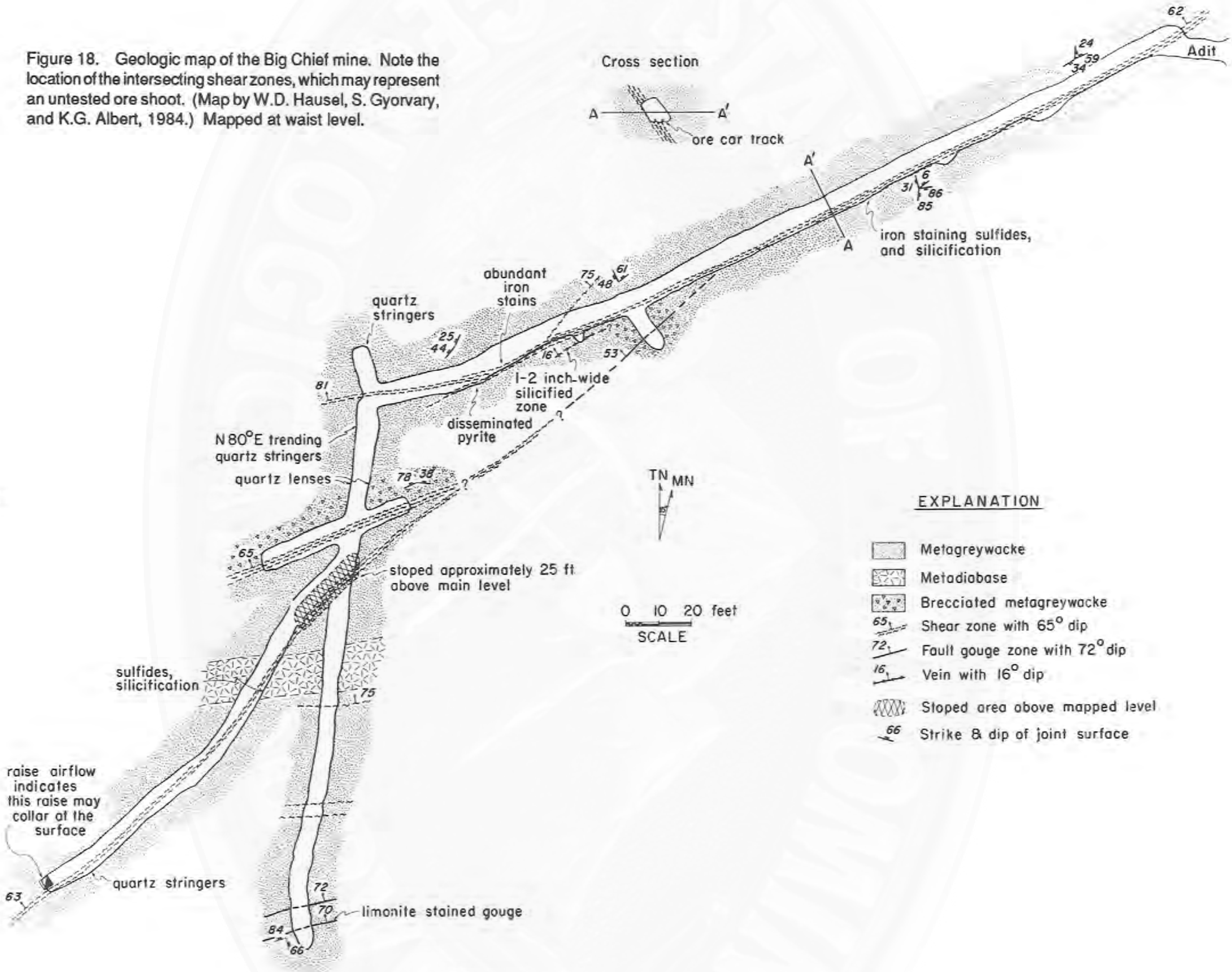
Carissa mine; NW sec. 21, T29N, R100W, located near South Pass City (**Plate 1** and **Figure 14**). According to Jamison (1911a), early gold production from the Carissa mine may have been about 50,000 ozs, although combined figures from the *Wyoming Industrial Journal* and U.S. Bureau of Mines (see Hausel, 1989), indicate more than 180,500 ozs were recovered from the mine over a period of five years. This latter figure may be too high, based on the volume of rock mined and the average reported ore grade.

The mine workings were dug in a N70°E trending strike shear in Miners Delight metagreywacke adjacent to carbonatized tremolite/actinolite chlorite schist and amphibolite. The shear (**Figure 19a**) averages about 6 feet wide at the surface and is enclosed by a 100- to 300-foot-wide envelope of fractured wallrock. The wallrock contains common quartz veins and veinlets and secondary chlorite, hematite, and biotite. The veins are stretched and boudinaged in the plane of foliation and isoclinally folded. Late quartz veins and quartz breccia veins crosscut foliation (**Figure 19b**).

The primary shaft of the Carissa mine was sunk to the fourth level at a depth of 350 feet and a winze continued to the fifth level, 400 feet below the collar of the shaft. More than 2,300 feet of drifts were driven over a total strike length of at least 750 feet. Some of the drifts were extended after Curran's (1926) map was completed (Steve Gyorvary, personal communication, 1985) (**Figure 19c**), thus this map is not up to date. This map indicates a large block of unmined mineralized rock may lie in a vertical plane between mine levels. Underground, the width of the shear plane averages 6.3 feet and swells to 50 feet locally (Curran, 1926). Evidence suggests a few ore shoots were controlled by folds on the stope level (Bow, 1986). The ore ranged from a trace to 89 ppm (2.6 oz/ton) gold and averaged 10.29 ppm (0.3 oz/ton). Some rare specimen-grade ore assayed 8,920 ppm (260 oz/ton) gold (Beeler, 1908).

The early mining operations concentrated on recovering high-grade ore from the shear zone and

Figure 18. Geologic map of the Big Chief mine. Note the location of the intersecting shear zones, which may represent an untested ore shoot. (Map by W.D. Hausel, S. Gyorvary, and K.G. Albert, 1984.) Mapped at waist level.



avoided low-grade mineralization. Historic reports and some samples collected by the author indicate this mine may contain a large-tonnage, low-grade, untapped gold deposit that extends from the shear zone into the adjacent wallrock. The wallrock is fractured and rehealed over a width of 200 to 300 feet (Beeler, 1908; Curran, 1926). Samples of wallrock taken in crosscuts over an aggregate width of 300 feet assayed 0.686 ppm to 1.7 ppm (0.02 to 0.05 oz/ton) gold (Curran, 1926). More recently, composite samples collected on the surface by Hausel (1989) show a 97-foot-wide mineralized zone in the wallrock containing an average of 0.80 ppm (0.023 oz/ton) gold (**Appendix B**). Another 30-foot composite sample collected north of the shear contained 2.4 ppm (0.07 oz/ton) gold (Hausel, 1989).

The horizontal and vertical extent of the mineralized shear has been only partially determined. For example, Curran's (1926) map (**Figure 19c**) shows the mine faces on all levels to have terminated in mineralized rock. Also, drilling by Anaconda Minerals Company in 1974 detected traces of gold in cores recovered several hundred feet west of the shaft. The continuation of the shear at depth was also tested. At about 650 to 700 feet below the surface, Anaconda drill hole DDH-1 intersected 16.1 feet of sheared metagreywacke that averaged 4.46 ppm (0.13 oz/ton) gold. A 0.4-foot section in this zone assayed 54.9 ppm (1.6 oz/ton) gold (de Quadros, 1989). At depths of 700 to 930 feet, mineralized rock was intersected in four other drill holes (de Quadros, 1989) (**Table 5**).

a.

b.

Figure 19. (a) View of the Carissa shear exposed in the glory hole and (b) late quartz breccia vein exposed in the glory hole (19c next page).

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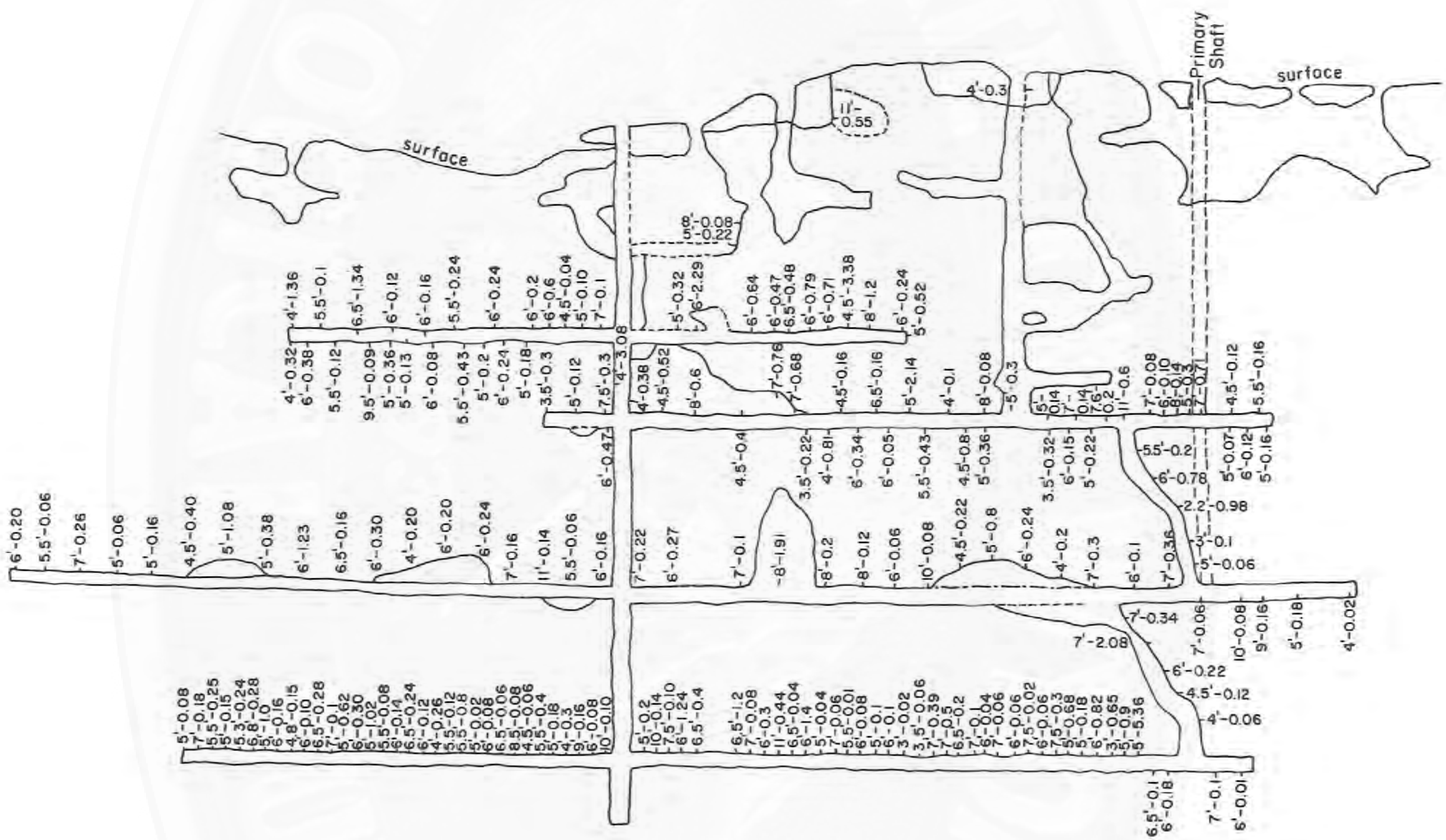

Figure 19. (c) Assay map and cross section of the Carissa mine (after Curran, 1926). All workings are projected to a single plane. Numbers represent sample width and gold assay in oz/ton. (1 inch = about 100 feet) (' = foot)

Table 5. Drill hole and assay information for the Carissa mine. (Data from Anaconda Minerals Company collection document 56102.07, American Heritage Center, University of Wyoming.)

Drill hole number	Width of mineralized shears		Gold (oz/ton)
DDH-1		16.1 feet	0.13
DDH-1A		2.3 feet	0.36
DDH-4	(Zone 1)	7.4 feet	0.14
	(Zone 2)	3.0 feet	0.14
DDH-5		11.9 feet	0.12
DDH-6	(Zone 1)	7.4 feet	0.11
	(Zone 2)	8.3 feet	0.18

Recently, Consolidated McKinney Resources, Ltd. of Vancouver drilled eight holes on the Carissa property into an anomalous gold-bearing zone that ranged up to 80 feet wide. The assays from the core ranged from 1.06 ppm (0.031 oz/ton) to 87.1 ppm (2.54 oz/ton) gold (de Quadros, 1989).

The auriferous shear at the Carissa is apparently continuous downdip to at least 930 feet. The strike length of the mineralized shear is open on both ends for an unknown distance, although it may play out several hundred feet to the west. The mine also appears to include a large-tonnage, low-grade mineralized zone that has remained untapped and untested. About 1,000 feet south of the Carissa shaft is a 600-foot-wide belt filled with discrete quartz veins, veinlets, and stringers in metagreywacke that produced a weak arsenic geochemical anomaly (Prinz, 1974). This anomaly also remains untested.

Drilling on the property has been sparse, so reserve estimates are limited. However, de Quadros (1989) reported that H.S. MacFarlane, with Carissa Gold, Inc., calculated the following reserves using a cut-off grade of 0.299 oz/ton gold:

1.	Original lode content (775' by 400' by 10')	248,000 tons	- -
2.	Mine excavation	40,000 tons	- -
3.	Unmined content	208,000 tons	@ 0.343 oz/ton
4.	Sample reserve	7,405 tons	@ 0.850 oz/ton
5.	Geological reserve	37,000 tons	@ 0.850 oz/ton

The close association of the Carissa shear with the nearby carbonatized tremolite/actinolite chlorite schist of komatiitic affinity led Bow (1986) to suggest the schist represented the primary source for gold in the Carissa shear. Recent fluid-inclusion and stable-isotope studies of samples taken in the Carissa mine, however, support a metagreywacke source for the gold in this deposit (Spry and McGowan, 1989).

Carrie Shields mine; SE sec. 21, T29N, R100W, located on the east bank of Willow Creek nearly 1 mile east of South Pass City (**Plate 1 and Figure 20**). The lower adit was driven on a N60°E trending, 52°SE dipping vein in Miners Delight Formation metagreywacke. The shear averages 3 feet wide and encloses a 1- to 2-foot-wide vein. From the lower adit level, the vein-shear zone was extensively stoped updip and a short distance downdip. In addition to this adit, two other portals enter the mine workings; one is a shaft on top of the hill east of Willow Creek, about 220 vertical feet above the lower level, and the other is an adit located halfway up the hill.

Jamison (1911a) estimated early gold production from the Carrie Shields was about 1,750 ozs. The average grade of the ore was reported as 34.3 ppm (1.0 oz/ton) (Armstrong, 1948).

Christina Lake placer. One of the more enterprising operations during the early history of the district was the Granier Mining Company's Christina Lake placer. The company constructed a network of miles of flumes and ditches, which ran from the headwaters of the Popo Agie River to the South Pass-Atlantic City district. The first clean up in 1891 yielded 6,720 ozs of gold (*Engineering and Mining Journal*, 1891, v. 52, p. 463).

Dexter Tunnel; S/2 sec. 2, T29N, R100W, located on the east bank of Rock Creek south of the iron mine (**Figure 14**). This adit was driven partially through a ridge separating Rock Creek and Atlantic City. Initially, plans called for a 2,800-foot-long tunnel to explore for hidden lodes. The ridge is formed of Miners Delight Formation metagreywacke, graphitic schist, and amphibolite. Operations terminated 1,400 to 1,500 feet from the portal after intersecting six blind leads of unknown tenor and width (*Wyoming Industrial Journal*, 1905, v. 6, no. 12, p. 5). Beeler (1908, p. 11) reported three of the leads contained low-grade ore. If driven in a straight line, the tunnel should have intersected the Rose lode, 900 to 1,000 feet from the portal, at about 250 to 300 feet below the surface. This may have been one of the blind leads reported by Beeler.

When examined by the author in 1986, the mine entrance was caved and inaccessible. One grab sample collected from the mine dump assayed 0.343 ppm (0.01

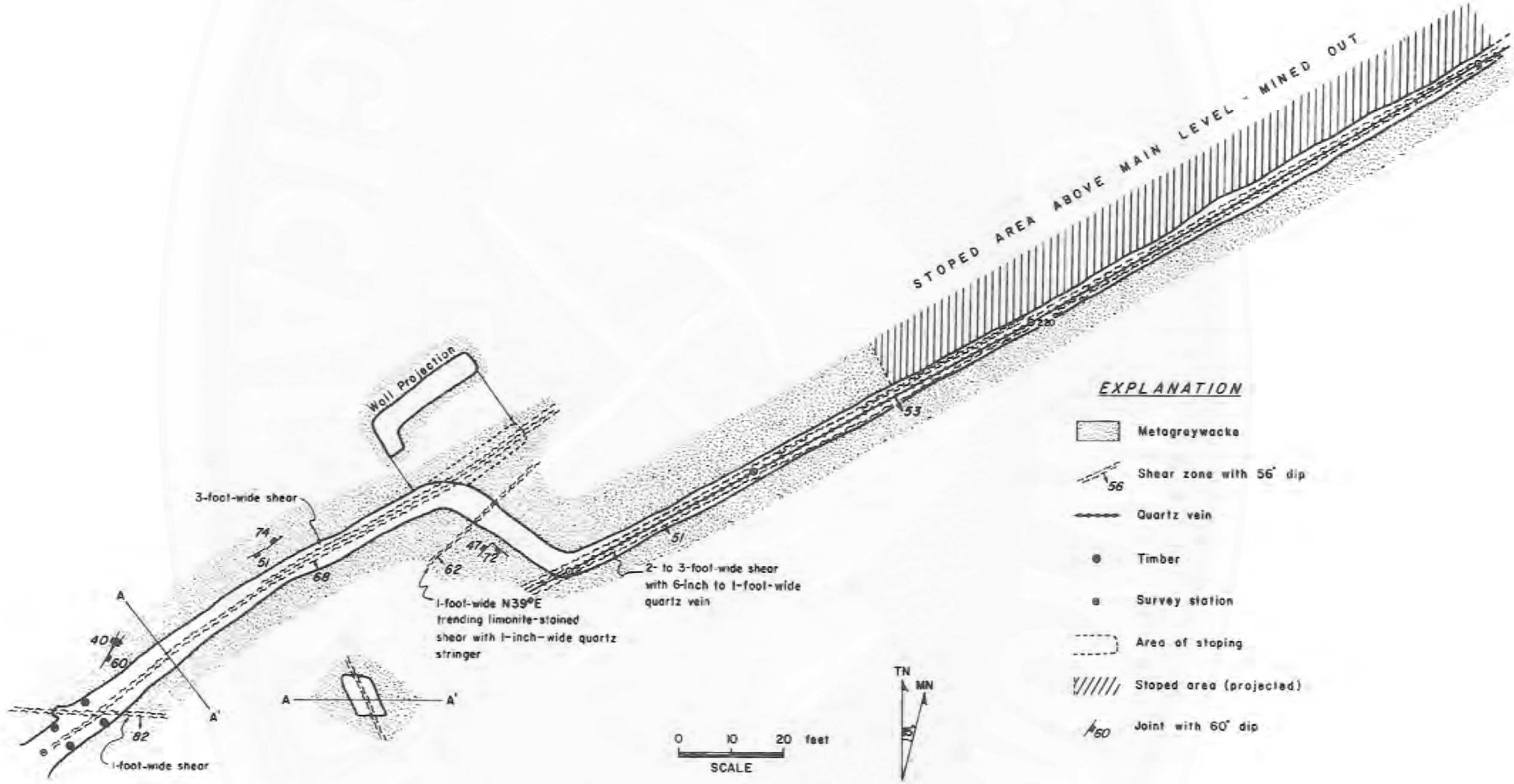

Figure 20. Geologic map of the lower Carrie Shields adit (by W.D. Hausel and K.G. Albert, 1983). Mapped at waist level.

oz/ton) gold and 0.686 ppm (0.02 oz/ton) silver (74A, **Appendix B**).

Diamond Development Company adit; W/2 W/2 sec. 29, T30N, R99W (**Figure 14**). This is a short tunnel driven into crossbedded quartz-pebble conglomerate of the Flathead Sandstone (Cambrian) east of the Atlantic City mine (**Figure 21**). At 35 feet from the portal, a winze (estimated to be 50 to 100 feet deep) was sunk through the conglomerate into underlying metatholeiites of the Roundtop Mountain Greenstone. It is not known if any lower levels were established.

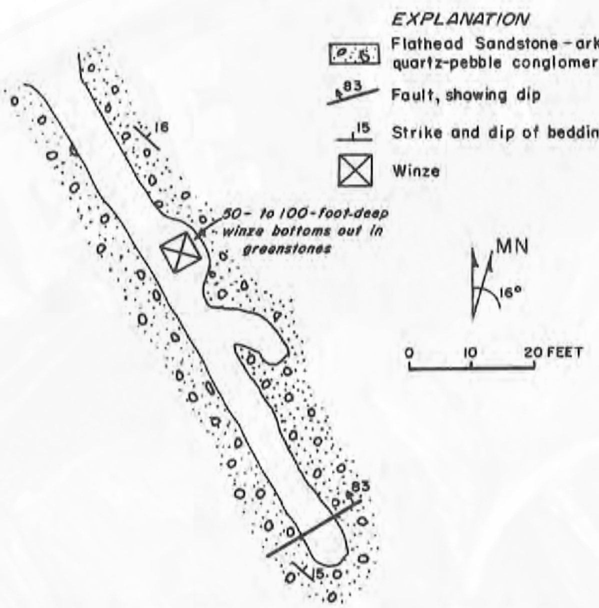

Figure 21. Geologic map of the Diamond Development Company adit (by W.D. Hausel, 1987). Mapped at waist level.

Available reports suggest some gold was recovered from the Flathead conglomerates, but the mine workings indicate the greenstones were the primary target. Samples of Flathead conglomerate were collected, crushed, and panned but yielded no visible gold. However, the underlying greenstones contain chalcopyrite-pyrite-bearing milky quartz (34A, **Plate 2** and **Appendix B**) and specimens of the quartz have rare visible gold (Steve Gyorvary, personal communication, 1987). A small amount of ore was milled on the property before the Diamond Development Company mill was dismantled and moved to the Mary Ellen shaft south of Atlantic City (Steve Gyorvary, personal communication, 1987).

Diana mine (Tom McGrath); NW sec. 12 and SW sec. 1, T29N, R100W, located north of Atlantic City (**Plate 1** and **Figure 14**). Seven hundred feet of crosscuts and drifts were developed on the main level, with a winze connecting to lower levels. The mine workings cut Miners Delight Formation metagreywacke, graphitic schist, amphibolite, grunerite schist, and tremolite/actinolite schist (**Figure 22**).

The Diana mine is one of the most structurally complex mines in the district. Attitude changes along the vein have provided favorable sites for the localization of gold. The principal mineralized zone is a steeply dipping quartz vein that trends northwest (perpendicular to regional foliation), rolls over, and makes a nearly right-angle bend near the winze. Unfortunately, the ground surface above the mine is buried by eluvium and soil, making it difficult to formulate a three-dimensional model to explain the right-angle bend in the vein, although a drag fold with the fold axis running nearly east-west through the winze is postulated based on measured rock foliations in the mine workings.

From their analysis of geochemical data, Antweiler and Campbell (1977) concluded the Diana vein was a typical hypothermal vein. A chemical analysis of gold from the mine produced 92.5% gold, 7.4% silver, 0.05% copper, with traces of arsenic, bismuth, nickel, and lead. The Au/Ag ratio is relatively high (12.5), and the Au/Cu ratio is relatively low (1,850) compared to gold samples from other mines in the Rocky Mountain region (Antweiler and Campbell, 1977).

Mine production is estimated to be about 500 ozs of gold (Jamison, 1911a). The Diana ore was reported to average about 24 ppm (0.7 oz/ton) gold and run as high as 98 ppm (2.85 oz/ton) gold (Wilson, 1951). Recent sampling yielded an average of 4.46 ppm (0.13 oz/ton) gold, ranging from a trace to 24 ppm (0.71 oz/ton) gold and a trace to 8.9 ppm (0.26 oz/ton) silver (**Table 6**). The better values were obtained where the vein changes strike near the winze. A grab sample of quartz collected from the mine dump by Prinz (1974) assayed 26 ppm (0.76 oz/ton) gold and 450 ppm arsenic.

In the early 1980s, a small heap-leach pad was constructed adjacent to the Diana and Midas mines. Tailings from some mines in the area were piled on the pad and treated with cyanide. However, the rock pile was not crushed (boulders up to 1 foot in diameter were placed on the pad) and the material was compacted, destroying much of its permeability and resulting in no gold recovery (Hank Hudspeth, Jr., personal communication, 1986).

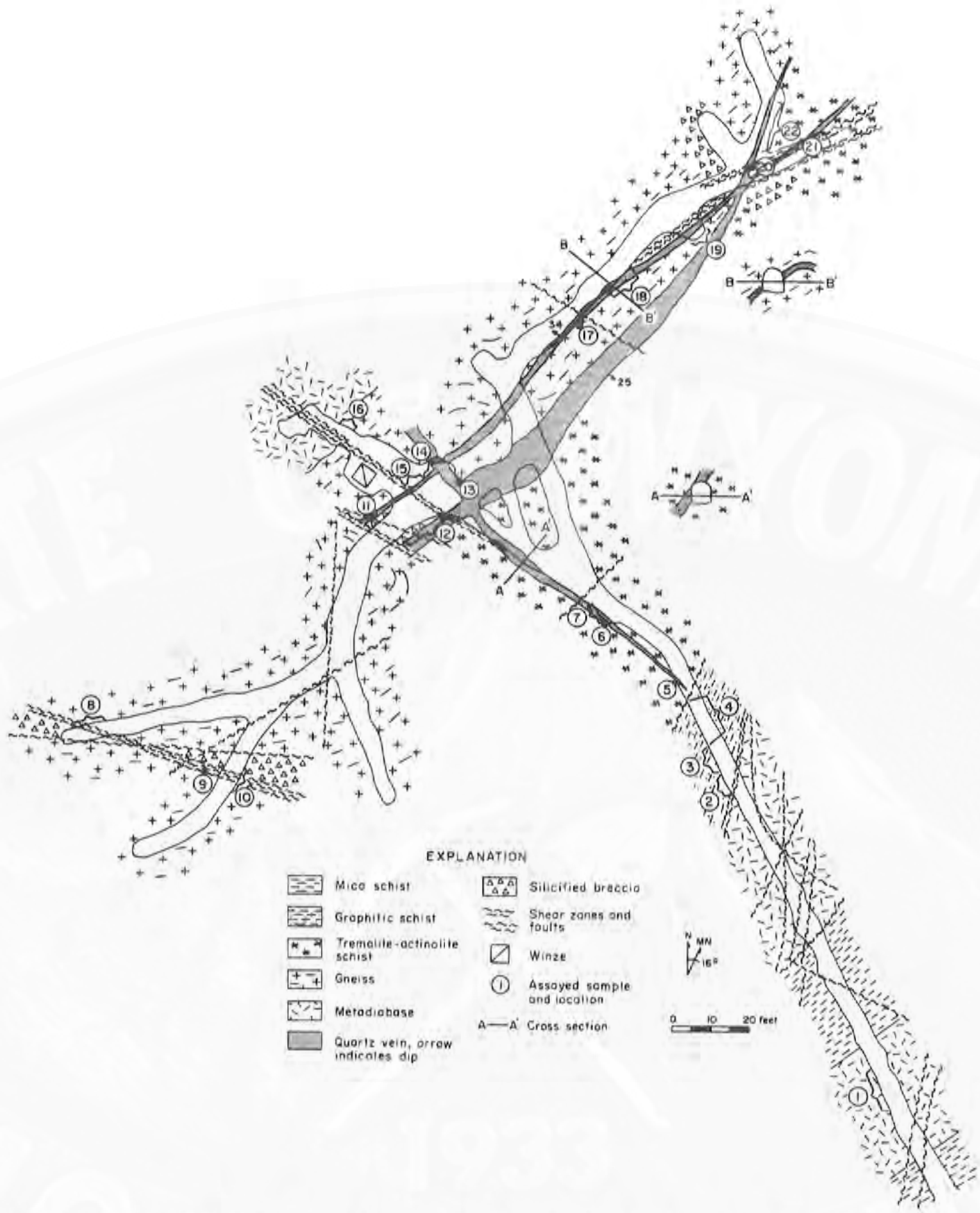

Figure 22. Geologic map of the Diana mine showing sample locations (by W.D. Hausel and S. Gyorvary, 1984). Mapped at waist level. Assay values of samples are provided in Table 6.

Doc Barr mine; sec. 22, T29N, R100W (**Figure 14**). Numerous pits, shafts and some adits surround this location, thus it is difficult to determine which workings belong to the actual Doc Barr mine (see also Rocky Barr adit). Jamison (1911b) reported a 65-foot-deep shaft was sunk and a 150-foot-long tunnel was driven 200 feet west from the bottom of the shaft to work the Doc Barr vein. The vein is 2.5 feet wide and contains an average of 58.3 ppm (1.7 oz/ton) gold. It was offset by a fault at the bottom of the shaft and lost. The ore was stoped to the surface along the full length of the drift (Jamison, 1911b).

The vein offset is not surprising because the area around the Doc Barr is structurally complex, with numerous faults (see Hausel, 1988a). The continuation of the Doc Barr vein may be a worthy exploration target, especially if the ore grade reported by Jamison can be verified. Jamison (1911a) estimated 820 ozs of gold were recovered from the mine.

Table 6. Assay results of samples collected in the Diana mine, South Pass-Atlantic City district (courtesy of U.S. Borax). Locality numbers refer to Figure 22.

Locality number	Description	Assay values (ppm)				
		Au	Ag	W	As	Cu
1	Chip sample	0.09	1.2	7.0	195.0	41.0
2	Chip sample	0.08	2.5	4.0	651.0	269.0
3	Chip sample	<0.02	2.2	5.0	1,290.0	113.0
4	Chip sample	0.06	1.9	12.0	1,930.0	91.0
5	5 ft of vein footwall	0.14	1.7	6.0	917.0	112.0
6	Vein	<0.02	1.2	8.0	190.0	147.0
7	Hanging-wall sample	<0.02	0.7	3.0	171.0	44.0
8	6-ft chip sample	0.89	0.5	4.0	779.0	107.0
9	2-ft sample of silicified breccia	0.74	0.7	5.0	488.0	58.0
10	5-ft sample of shear zone	0.27	1.0	6.0	836.0	142.0
11	2-ft chip sample of quartz vein	23.7	0.5	8.0	326.0	13.0
12	Composite chip sample	10.5	1.2	7.0	1,030.0	65.0
13	Chip sample across 18 in of quartz vein	0.93	0.5	4.0	180.0	13.0
	5-ft sample of footwall below vein	0.92	0.5	3.0	133.0	38.0
14	7-ft channel in northeast portion of muck pile	24.0	8.9	25.0	1,640.0	77.0
	3-ft hanging wall sample	13.2	4.1	20.0	1,320.0	70.0
15	7-ft channel in southwest part of muck pile	3.11	1.4	11.0	444.0	59.0
16	3-ft channel along contact	4.41	1.0	32.0	2,830.0	84.0
17	2-ft chip sample of vein	1.37	0.2	4.0	2,490.0	31.0
	5-ft sample of footwall	0.06	0.5	4.0	498.0	83.0
18	Sample along strike of 1-ft wide vein	1.71	<0.2	2.0	178.0	15.0
19	Sample across 18-in quartz vein	5.66	2.2	5.0	362.0	16.0
	4-ft footwall sample below vein	0.84	1.4	6.0	1,150.0	50.0
20	5-ft oblique sample across quartz vein	0.62	0.7	5.0	134.0	22.0
21	3-ft sample in sheared actinolite schist in back	0.05	1.0	3.0	388.0	152.0
22	2-ft sample across swell in quartz vein	0.31	1.21.0	3.0	467.0	30.0
	2-ft sample across footwall breccia	0.03	1.0	7.0	714.0	66.0

Duncan mine; W/2 W/2 sec. 14, T29N, R100W, located 1 mile southwest of Atlantic City (**Plate 1** and **Figure 14**). The main strike shear (N80°E strike) is hosted by Miners Delight Formation hornblende-plagioclase amphibolite, which is intruded by a small, weakly foliated, metatonalite plug at the western edge of the property. The primary shear continues eastward a short distance and wraps around to a N65°W trend in a tight drag fold, producing a splay. Initial studies indicated two separate shear zones intersected at the shaft (Armstrong, 1948), but recent more detailed mapping indicates a single folded shear zone. A shaft was sunk and a glory hole quarried in the ore shoot of this fold closure. Samples collected by the author in the glory hole (**Table 7**) revealed enhanced mineralization in the fold nose, enclosed by a splay of low-grade mineralization in the adjacent fractured and rehealed wallrock. A 2-foot channel sample collected from a quartz boudin in the fold nose assayed 33 ppm (0.96 oz/ton) gold. A composite of 37 feet of channel samples taken across a splay of fractured wallrock, excluding the quartz boudin, averaged 2.52 ppm (0.073 oz/ton) gold.

Table 7. Channel-sample assays from the Duncan glory hole.

Sample number	Description	Au (ppm)	Ag (ppm)
DUN1-87	2-ft channel, west end of shear	3.0	2.2
DUN2-87	2-ft channel across quartz boudin in shear	33.0	6.0
DUN3-87	5-ft channel, east of boudin	1.8	1.8
DUN4-87	10-ft channel, east of DUN3	6.6	2.7
DUN5-87	10-ft channel, east of DUN4	0.71	7.4
DUN6-87	10-ft channel, east of DUN5	0.53	1.0
Average of 39 ft		2.66	2.27

The extent of the underground workings of the Duncan mine is not known, although Jamison (1911b) reported 1,255 feet of drifts were driven from the 250-foot-deep shaft before 1911. The Duncan shaft is currently inaccessible and the adit that connects into the lower mine workings from Little Beaver Creek to the northwest is also caved at the portal.

Jamison (1911a) reported the ore tenor to range from 8.58 ppm to 180 ppm (0.25 to 5.25 oz/ton) gold. High-grade ore was confined to pockets and it is doubtful any low-grade ore was seriously pursued.

Anaconda Minerals Company drilled four locations on the Duncan property in 1974 (**Table 8**). One hole (DDH-10) was not completed. The drill hole data indicate the Duncan mine includes an incompletely explored 925-foot-long mineralized shear from 0.7 feet to 7 feet wide.

Table 8. Reported drill hole intercepts at the Duncan mine. (From Anaconda Minerals Company report document 56102.07, 1974, American Heritage Center, University of Wyoming.)

Drill hole number	Description	Width of shear zone	Au (oz/ton)
DDH-9	Intersected two mineralized zones	Zone 1 averaged 7 ft Zone 2 averaged 2.1 ft	0.18 0.11
DDH-10A	Drilled 375 ft west of DDH-9	Zone 1 Zone 2 averaged 0.7 ft	trace 0.17
DDH-11	Collared 550 ft west of DDH-10A	Zone 1 Zone 2 averaged 5.7 ft	trace 0.025

Estimated and actual gold production figures show at least 3,800 ozs of gold were mined from the property (Jamison, 1911a; Hausel, 1980). Historical data indicate rich ore was discovered on the Duncan property in 1911. From 1911 until the mine first closed in 1914, about 1,900 ozs of gold were recovered and 1,500 feet of underground workings completed (Weis, 1974). The mine reopened in June, 1933 and operated intermittently until early January, 1936. During this period, several gold shipments were made to the U.S. Mint in Denver, and some rich concentrates were shipped to the smelter at Murray, Utah. A minimum of 1,200 ozs of gold was recovered during this period (Turelle, 1981). The mine reopened in 1946 and an unknown amount of ore was processed. Ten years later, in 1956, the mine was again active and the small town adjacent to the mine was filled with miners. This town included more than a dozen cabins, a store, and a two-story dormitory/mine-office complex (Weis, 1974, p. 213-214). (See cover photo)

Two factors are important to any interpretation of a gold source in the Duncan shear. First, the mineralized zone is completely enclosed by amphibolite adjacent to a thin actinolite schist in metagreywacke. Second, a small metatonalite plug intruded the Duncan shear adjacent to the ore shoot. These relationships suggest a possibility the plug partially influenced development of the fold in the shear and acted as a heat engine, upgrading the precious metal content of the shear.

Exchange lode; E/2 sec. 15 and W/2 sec. 14, T29N, R100W, adjacent to and west of the Duncan mine (**Figure 14**). The Exchange lode includes a narrow, N63°E strike shear in Miners Delight Formation amphibolite near the contact with metagreywacke. A 2-foot channel taken across the Exchange shear in the back of a short adit yielded 2.1 ppm (0.06 oz/ton) gold and 1.2 ppm (0.035 oz/ton) silver. A sample of cupriferous milky quartz collected west of the adit assayed 18.1% copper, 0.73 ppm (0.02 oz/ton) gold, and 27 ppm (0.79 oz/ton) silver (45A, **Appendix B**). Jamison (1911a) estimated gold production from this property at 1,000 ozs, which is much too high considering the lack of mine development.

The Exchange vein lies adjacent to sheared, limonite-stained, graphitic schist. In the Abitibi-belt, Canada, an important direct relationship between carbon and gold was recognized in some mines, indicating a possible link between the graphite and gold. Coarse free gold was often found at vein margins where the quartz cut carbonaceous strata (Springer, 1985). Although the schist near the Exchange shear has been prospected at various locations, it deserves another look based on the reported associations in the Abitibi greenstone belt.

Franklin mine; W/2 SW sec. 20, T29N, R100W, 1/2 mile west of South Pass City (**Plate 1** and **Figure 14**). The Franklin shaft was sunk in mineralized Miners Delight Formation metagreywacke invaded by South Pass granite pegmatite. The intricate intermixing of granite with the metagreywacke may have resulted in some gold remobilization and enrichment.

Folding of the rocks exposed on the surface of the property may have exerted some control on ore shoots. The first-stage folds are foliation-parallel, isoclinal to tight folds that have been refolded by open cross folds with chevron geometries.

A grab sample of vein material collected from the mine dump assayed 17.15 ppm (0.5 oz/ton) gold (79A, **Appendix B**). Production was estimated by Jamison (1911a) at 15,000 ozs.

Garfield (Buckeye) mine; NE NE sec. 11, T29N, R100W (**Figure 14**). The Buckeye shaft of the Garfield mine was sunk in 1870 on a strike shear in Miners Delight Formation amphibolite to a depth of 140 feet. At that time, the mine was producing 2,500 ozs of gold annually. The shear is traceable for 1,000 feet and may continue farther to the northeast under eluvial cover. It is not possible to determine how much farther the structure continues without drilling, trenching, or geophysical surveys. The Diana tunnel (see Diana mine) terminated operations just short of the projected Garfield shear zone.

The extent of mine development is unknown, but a sizable dump suggests the workings are extensive. Total gold production was estimated at 20,000 ozs (Jamison, 1911a).

Gold Dollar mine; SW sec. 32, T30N, R99W (**Plate 1** and **Figure 14**). The Gold Dollar adit was driven 1,300 feet across regional foliation through Miners Delight Formation metagreywacke, amphibolite, and metadacite (**Figure 23**). At about 1,210 feet from the portal, three N40°W to N50°W trending veins and cherty metagreywacke were intersected in the tunnel. A raise was collared to the surface from the veins. The veins are 0.5 to 2.0 feet thick and contain minor sulfides.

The adit was developed to intersect the western extent of the Miners Delight lode, but at this location the Miners Delight lode is poorly defined, represented by narrow quartz veins. Since there was very little mining of the veins, only a small amount of gold could have been recovered from the mine.

Samples collected from the Gold Dollar dump contained no detectable gold, but one sample collected by Prinz (1974) from the Gold Dollar shaft assayed 17.5 ppm (0.51 oz/ton) gold and 60 ppm arsenic (35A and 36A, **Appendix B**). Surface mapping indicates the Gold Dollar vein continues 2,200 feet northeastward to the Miners Delight mine (Hausel, 1987c).

Groundhog mine; SW sec. 11, T29N, R100W, west of Atlantic City (**Plate 1** and **Figure 14**). The Groundhog mine was developed on two parallel N30°E trending shears in Miners Delight Formation hornblendic amphibolite near a contact between metagreywacke and the amphibolite. Two shafts, 40 to 100 feet deep with at least 200 feet of drifts, were developed in the parallel shear zones. The average ore grade was reportedly between 8.58 ppm and 13.72 ppm (0.25 to 0.4 oz/ton) gold. Production was estimated at 1,450 ozs (Jamison, 1911a).

A 2-foot channel sample of mixed quartz and amphibolite collected by Prinz (1974) assayed 47.3 ppm (1.38 oz/ton) gold with 250 ppm arsenic (66A, **Appendix B**). Prinz (1974) also outlined a weak 2,000-foot-wide arsenic soil geochemical anomaly near the Groundhog mine.

Homestake mine; NW sec. 21, T29N, R100W, located on the northeastern edge of the Hermit Gulch reservoir east of the Carissa mine (**Figure 14**). This adit cuts metagreywacke of the Miners Delight Formation and intersects a belt of actinolite schist 500 feet north of the portal. The entrance was caved when examined in 1986. Silicified metagreywacke and minor actinolite schist occur on the dump. Some metagreywacke samples were mineralized with arsenopyrite.

A 10-pound sample taken by Knight (1901) from the Homestake mine for metallurgical tests assayed 31.56 ppm (0.92 oz/ton) gold. Two samples collected from the dump of a shaft sunk on a quartz vein north of the Homestake mine yielded 0.2 ppm and 10.9 ppm (0.32 oz/ton) gold (Prinz, 1974) (63A, **Appendix B**). Prinz (1974) also identified a strong arsenic soil geochemical anomaly associated with the vein. This area needs work to more thoroughly test the Homestake vein and shear and to test a zone of discrete quartz veins northwest of the mine area (see Hausel, 1988a).

Kenyon mine; SE SE sec. 15, T29N, R100W (**Figure 14**). The Kenyon mine consists of four adits located on shears in Miners Delight metagreywacke

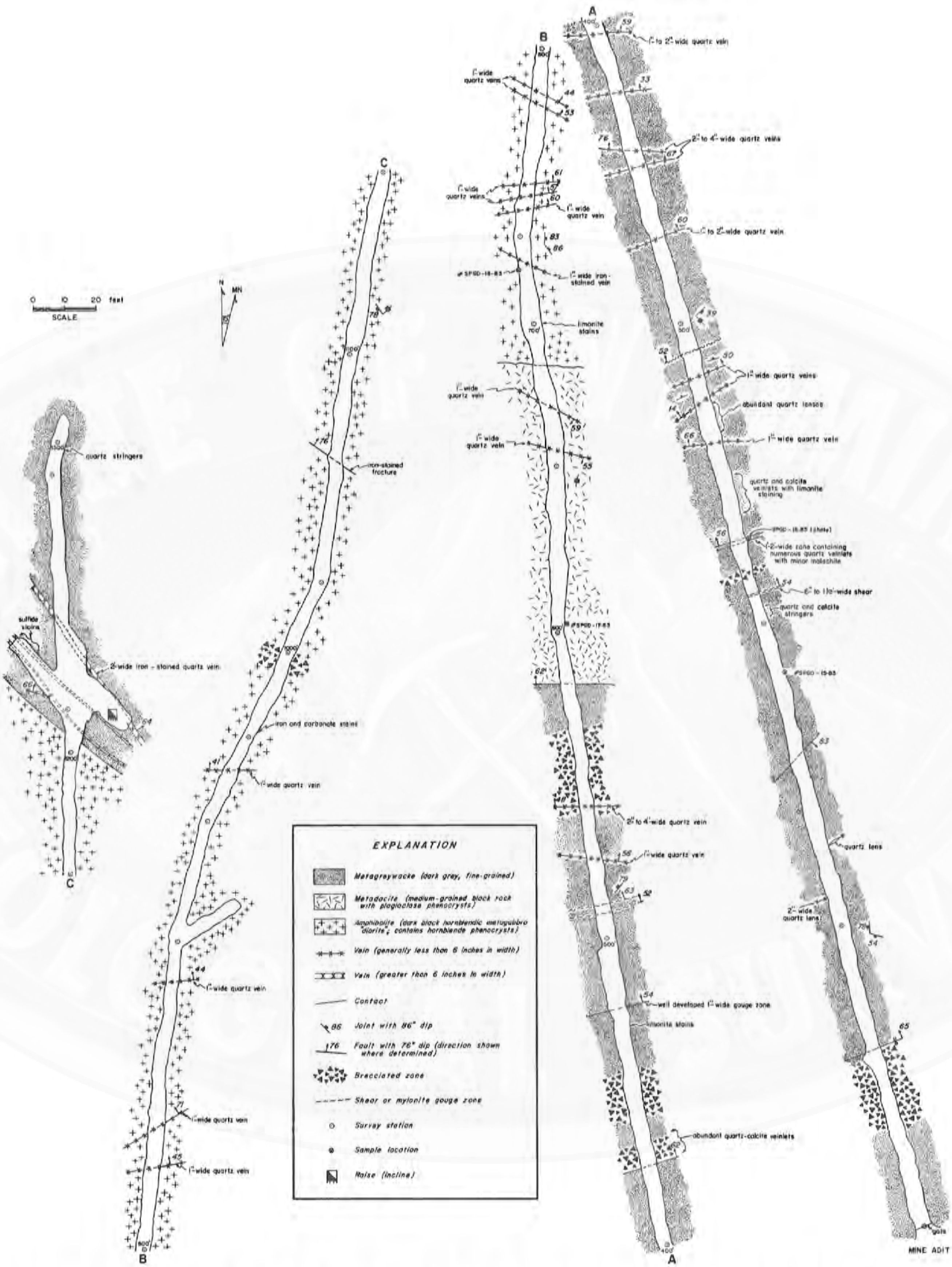

Figure 23. Geologic map of the Gold Dollar mine (by Hausel and Albert, 1983). Mapped at waist level. (scale 1:240)

(Hausel, 1988a). About 400 to 500 feet east of the portals, a narrow N65°E trending, 75°NW dipping shear intersects a N62°W trending, 82°SW dipping shear, forming a possible ore shoot. This area is isoclinally folded with rock foliations paralleling both shears. Two other shears roughly parallel the N65°E trending shear and may intersect the N62°W trending shear farther to the southwest.

Prinz (1974) identified a weak arsenic geochemical anomaly over the shears, and two of the geochemical samples assayed 3.43 ppm (0.1 oz/ton) gold. One of the samples also had elevated barium (1,000 ppm).

King Solomon prospect; SW sec. 15, T29N, R100W (**Figure 14**). A group of prospect pits and a short adit were dug into brecciated and sheared Miners Delight Formation amphibolite and graphitic schist on the east bank of Hermit Gulch. One sample collected by Knight (1901, p. 28) assayed 5.49 ppm (0.16 oz/ton) gold, but a geochemical survey by Prinz (1974) did not identify any unusual anomalies.

Lander Belle; location unknown. The mine was reportedly developed on a 200-foot-wide, silicified quartz porphyry dike between schist and granite. Assays ranged from 4.46 ppm to 8.58 ppm (0.13 to 0.25 oz/ton) gold (Jamison, 1911a).

Lone Star mine; W/2 sec. 35, T30N, R100W. The Lone Star occurs in schist of the Goldman Meadows Formation. Bayley (1963) reported the shaft was sunk on a quartz vein adjacent to banded iron formation. The vein averaged 2.06 ppm (0.06 oz/ton) gold (Bayley, 1963). The Lone Star is buried by the tailings from the Atlantic City iron mine. About 2,000 ozs of gold were produced before 1911 (Jamison, 1911a).

Lucky Boy; NE sec. 11, T29N, R100W. The Lucky Boy is a shallow shaft sunk on a sheared contact between Miners Delight Formation graphitic schist and amphibolite west of the Garfield mine. Jamison (1911a) estimated 150 ozs of gold were recovered from the property.

Mary Ellen mine; NE sec. 14, T29N, R100W, southwest of Atlantic City (**Plate 1** and **Figures 14** and 24). The Mary Ellen property was developed by a 240-foot incline that followed the dip of a 6-inch to 3-foot wide vein in metatonalite porphyry. The vertical depth from the surface to the bottom of the shaft is only about 90 feet, due to the relatively shallow dip of the vein. The porphyry forms a small intrusive stock, which was emplaced along a strike shear at the contact between amphibolite and actinolite schist.

The N35°E-trending vein was developed by a minimum of 1,300 feet of drifts on five levels and has been extensively stoped between levels. The vein is continuous throughout the mine but disappears in the northern face on the 209-foot level. Otherwise, the vein is continuous beyond the present mine workings as well as downdip to an unknown depth, although the vein narrows to less than 6 inches on the 209-foot level. Gold mineralization is generally enhanced where the vein narrows.

Prinz (1974) indicated a parallel unexplored vein crops out a short distance east of the Mary Ellen vein. Both veins are hosted by the porphyry and strike nearly perpendicular to regional foliation, with shallow dips compared to other auriferous systems in the greenstone belt. North of the shaft, the Mary Ellen vein abruptly changes strike to the northwest, following the trend of a conjugate fracture. The trend of the vein and the intrusive nature of the tonalite implies that the Mary Ellen vein represents a later episode of gold mineralization than the strike shears found elsewhere in the greenstone belt.

The average grade of ore recovered from the Mary Ellen vein was reported as 13.72 ppm (0.4 oz/ton) gold (Jamison, 1911a), with a tenor of 8.58 ppm (0.25 oz/ton) to 180 ppm (5.25 oz/ton) gold and local high-grade pockets running up to 1,715 ppm (50 oz/ton) gold (Anonymous, 1916). Samples collected in 1983 for assay on the 32-foot level and on the 59-foot level yielded no detectable gold to 20.25 ppm (0.59 oz/ton) gold; however, composite chip samples collected later from these levels ranged from a 2.5-foot sample with 0.686 ppm (0.02 oz/ton) gold to a 1.2-foot sample with 42.5 ppm (1.24 oz/ton) gold (Steve Gyorvary, personal communication, 1984).

Several samples of milky quartz with visible gold have been found on the mine dump in recent years. The gold averages 0.891 in fineness with 89.1% gold, 10.7% silver, and 0.2% copper. Characteristic trace elements include bismuth, boron, lead, arsenic, antimony, tin, vanadium, molybdenum, tungsten, niobium, and zinc. The Au/Ag ratios average 8.3 and the Au/Cu ratios average 445 (Love and others, 1978).

Total production from the mine is unknown, but Jamison (1911a) estimated early production at 6,050 ozs of gold. In 1895, some mine tailings were sold and treated with cyanide, yielding 340 ozs of gold (*Engineering Mining Journal*, 1895, v. 60, p. 452).

Midas (1914, McGrath, Sullivan) mine; S/2 SW sec. 1, T29N, R100W (**Figure 14**). The Midas was

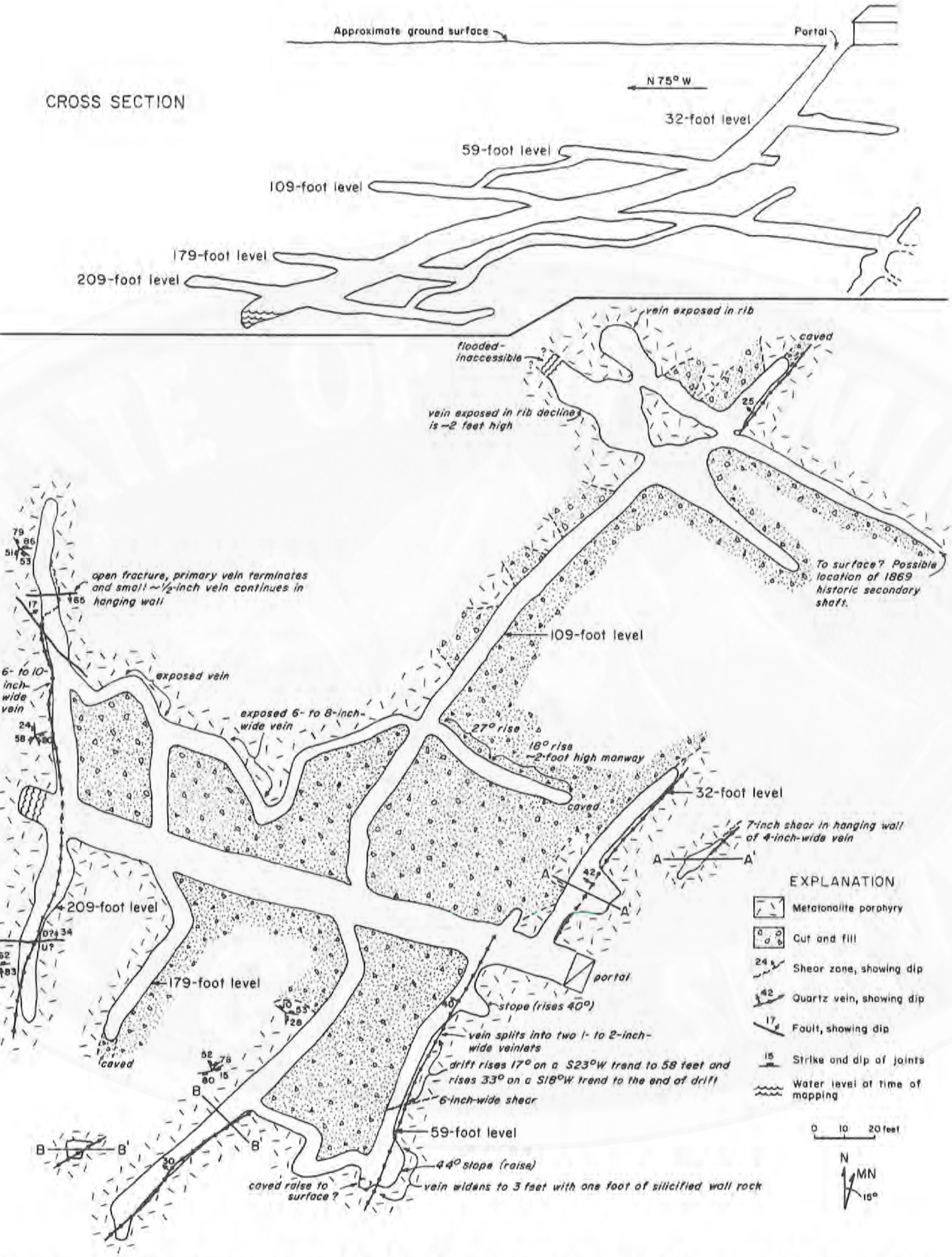

Figure 24. Geologic map and cross section of the Mary Ellen mine (by W.D. Hausel, S. Gyorvary, and J.T. Roberts, 1984).

developed in Miners Delight Formation graphitic schist. Four samples collected in the schist from an open cut located between the 1914 adit and Midas shaft yielded 0.095 ppm (0.003 oz/ton) to 0.405 ppm (0.01 oz/ton) gold (90A, **Appendix B**). A sample of sheared, limonite-stained schist assayed 2.8 ppm (0.08 oz/ton) gold with 1,200 ppm arsenic (Prinz, 1974). Microscopic studies of some ore specimens from the mine led Bane (1929) to identify both gold and arsenopyrite filling fractures in quartz.

The Midas shaft was sunk to a depth of 300 feet with 1,500 feet of drifts on the 100- and 200-foot levels (Bartlett and Runner, 1926). The 100-foot level was intersected by the 1914 adit. Total gold production from the mine is not known although Armstrong (1948) reported 1,380 ozs of gold were recovered in 1934.

Mill Hill hydraulic placer; immediately south of Atlantic City flanking the south bank of Rock Creek. Hydraulic mining, employed from 1890 to 1892, recovered between 10,000 and 11,000 ozs of gold (Spencer, 1916, p. 25).

Miners Delight mine; center sec. 32, T30N, R99W, west of Miners Delight ghost town (**Plate 1** and **Figure 14**). The Miners Delight mine occurs in Miners Delight Formation metavolcanic rocks near the northeastern margin of the greenstone terrane and includes metabasalt, meta-andesite, and metadacite porphyry with cherty metagreywacke and metagreywacke. The shear is folded along an east-northeast fold axis. Thus, at the shaft, the 3- to 16-foot-wide shear trends N58°E but abruptly swings to a N17°E trend a short distance east of the shaft.

The shear is traceable for more than 2,000 feet southwest to the Gold Dollar mine and continues another 500 feet northeast, where it disappears under alluvial cover. Gravels along the projected trend to the northeast are enriched in gold, leading to speculation that the lode may be continuous even farther to the north. Gravels downstream from the Miners Delight shaft in Spring Gulch are also auriferous and were placer mined in the late 1800s, yielding an estimated 1,500 ozs of gold (Jamison, 1911a).

Gold is reported to fill fractures in the shear zone and to occur in the host rock matrix. Three recent channel samples taken across the shear yielded gold values ranging from 0.40 ppm (0.01 oz/ton) to 12.38 ppm (0.36 oz/ton)(73A, **Appendix B**). The wallrock was not sampled.

The reported ore tenor was from $7 to $3,800/ton (Prospectus of the Miners Delight Mining Company, undated). Because no date was given for the gold prices in the prospectus, the original dollar values are presented (at $20.67 per oz, the tenor would range from 0.34 to 184 oz/ton; at $35 per oz, the tenor would be 0.2 to 109 oz/ton). The prospectus reports more than 2,400 feet of drifts occur in the mine, and the property was developed from two operating shafts (**Figure 25**).

The mine map (**Figure 25**) is apparently incorrectly oriented. This map indicates much of the lode continues roughly north-south, when in reality, much of the exposed lode trends N58°E. The Miners Delight shaft was developed on three levels (250, 150, and 115 feet) and the Miners Delight East shaft had one level at 90 feet below the surface (**Figure 25**). Bartlett and Runner (1926) reported the main shaft was sunk to 175 feet deep, but Kyner's (1907) map clearly indicates the Miners Delight shaft was 250 feet deep and the Miners Delight East shaft was an incline sunk to 90 feet. A manway also ran to the surface from the 115- and 150-foot levels.

The Miners Delight gold averages 0.872 in fineness. The raw gold contains an average of 87.2% gold, 12.7% silver, and 0.02% copper. Metal ratios for the gold average: Au/Ag=6.9, Au/Cu=4,360, and Ag/Cu=640. Trace elements include bismuth, lead, tin, vanadium, and boron (Love and others, 1978).

Other than some very early mining history, little is known about the operation of the mine. It was a significant producer for at least a few years; Jamison (1911a) estimated the mine contributed 60,000 ozs of gold. Some production may have occurred after 1911, but no records are available.

Monarch mine; NE sec. 21, T29N, R100W (**Figure 14**). Two adits were driven into a N50°E trending, foliation-parallel shear in metagreywacke (**Figure 26**). Sixty feet into the lower portal, a crosscut to the west intersected a contact vein between Miners Delight Formation actinolite schist and metagreywacke and drove along the vein for 20 feet. A 1-foot channel sample of the limonite-stained quartz from the mine back (roof) yielded 8.76 ppm (0.26 oz/ton) gold and 0.2 ppm (0.006 oz/ton) silver. Elsewhere in the tunnel, samples taken every 10 feet yielded 0.13 ppm (0.004 oz/ton) gold to 3.14 ppm (0.09 oz/ton) gold (**Table 9**). The better gold values were obtained within the first 30 feet of the portal. The upper adit is only 140 feet long (compared to 280 feet for the lower adit) and was not sampled.

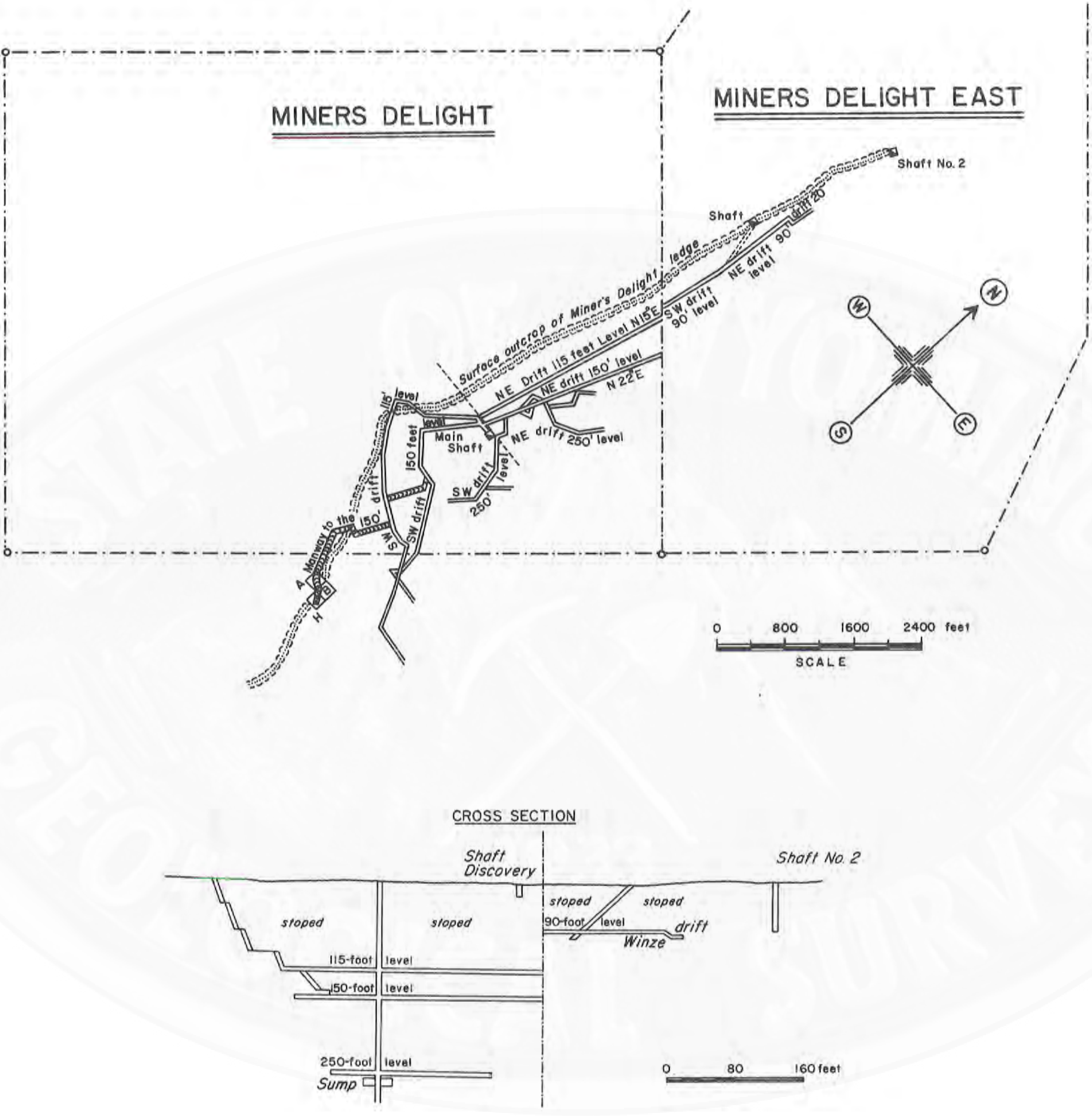

Figure 25. Plan view and cross section of the Miners Delight mine workings (after Kyner, 1907).

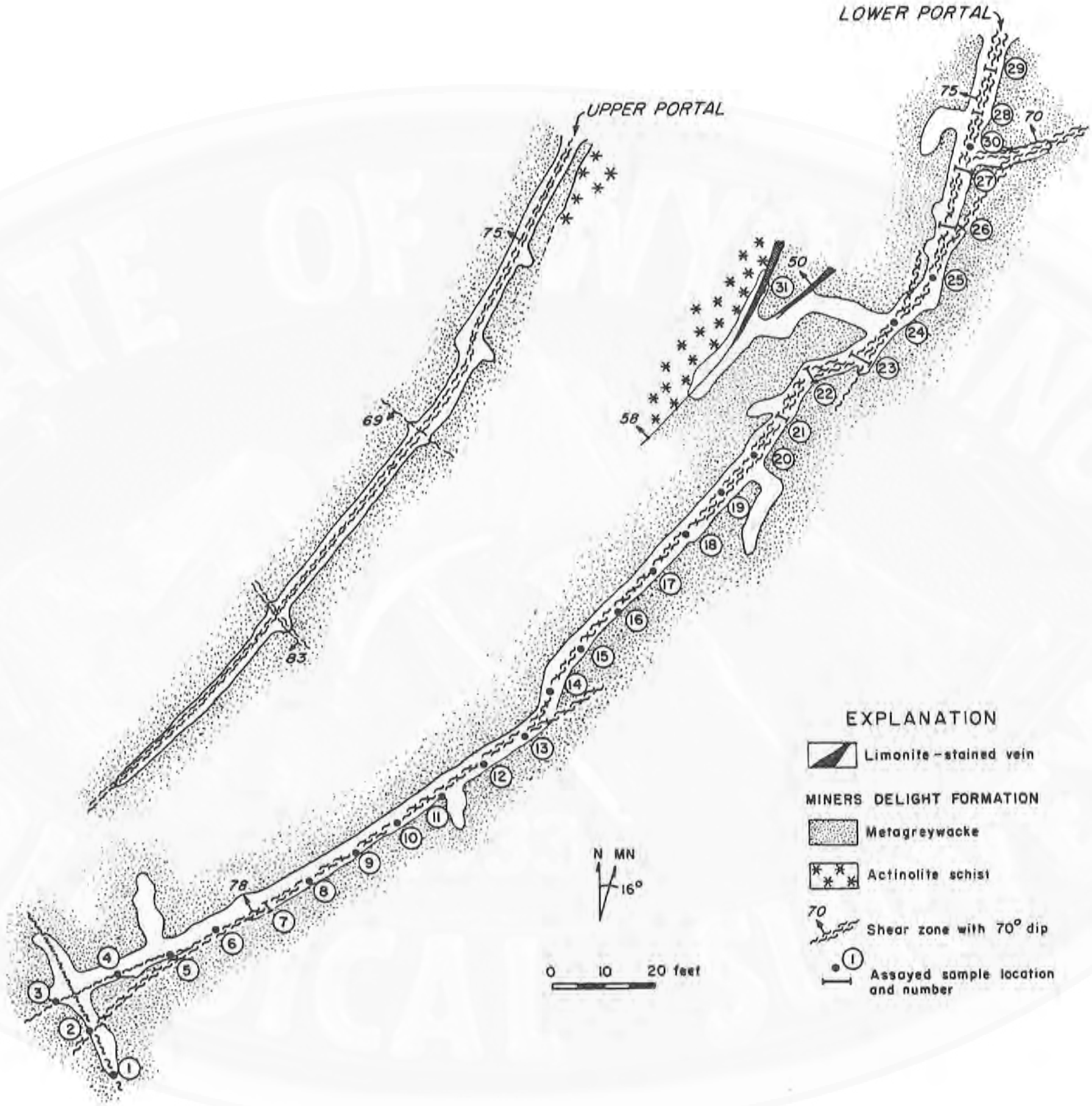

Figure 26. Geologic map of the Monarch upper and lower adits with sample locations (by W.D. Hausel and J.K. King, 1985). Assay values of samples are provided in Table 9.

Table 9. Assays of samples collected in the lower portal of the Monarch (Mars) tunnel. Locality numbers refer to Figure 26.

Locality number	Description	Assay values (ppm)	
		Au	Ag
1	6-in channel at face	0.13	0.0
2	1-ft channel	0.14	0.0
3	1-ft channel at face	0.19	0.0
4	Chip sample from back	0.17	0.0
5	Chip sample from back	0.17	0.0
6	8-in channel from back	0.16	0.0
7	2-ft channel from back	0.16	0.0
8	1-ft channel from back	0.13	0.0
9	1-ft channel from back	0.14	0.0
10	1-ft channel from back	0.19	0.0
11	6-in channel from back	0.16	0.0
12	8-in channel from back	0.24	0.0
13	6-in channel from back	0.21	0.0
14	Chip sample from back	0.13	0.0
15	1-ft channel from back	0.15	0.0
16	Chip sample from back	0.19	0.0
17	10-in channel from back	0.15	0.0
18	Chip sample from back	0.15	0.0
19	Chip sample from back	0.36	0.0
20	Chip sample from back	0.22	0.0
21	2-ft channel from back	0.18	0.0
22	3-ft channel from back	0.22	0.0
23	4-ft channel from back	0.24	0.0
24	14-in channel from back	0.26	0.0
25	18-in composite chip from back	0.36	0.0
26	3-ft channel from back	0.74	0.0
27	3-ft channel from back	2.29	0.0
28	1-ft channel from back	2.19	0.0
29	1.5-ft chanel from back	3.14	0.0
30	Chip from shear intersection	1.09	0.0
31	Limonite-stained metagreywacke	8.76	0.2

The results of the assays indicate this mine did not produce any significant quantities of gold, but that gold enrichment occurs along the actinolite schist-metagreywacke contact and locally in parallel shears near this contact. Nearly 1,000 feet of a parallel actinolite schist-metagreywacke contact is projected to continue under the stream gravels in Hermit Gulch, west of the portal.

Old Hermit mine; NW sec. 13, T29N, R100W (**Figure 14**). The Old Hermit adit is 340 feet long. The mine was developed in carbonate-cemented metagreywacke breccia and hornblendic amphibolite of the Miners Delight Formation (**Figure 27**). The tunnel was driven S10°E across regional foliation through the brecciated metagreywacke. The breccia is post-mineralization. The St. Louis shear was intersected 120 feet into the mine and was followed 100 feet to the southwest.

A channel sample of carbonate-cemented metagreywacke taken 150 feet from the portal contained no detectable gold or silver. A chip of limonite-stained metagreywacke at 170 feet from the portal yielded 0.08 ppm gold and no silver (Hausel, 1989).

Oswego prospect; NE sec. 31, T30N, R99W. In 1916, two shafts 40 and 70 feet deep were sunk. Visible gold was found in a quartz vein in the shafts (Anonymous, 1916).

Outpost mine; W/2 NW sec. 18, T29N, R99W (**Figure 14**). Two adits were driven south from an unnamed aspen-filled gulch. The adits may have intersected an incline shaft 400 to 500 feet south of the portals. However, it is not known if the adits intersected the shaft or if they even connect, since they are caved near the shaft. More than 1,500 feet of drifts and crosscuts were cut into hematitic fault gouge in Miners Delight Formation metagreywacke in these tunnels.

The east adit (**Figure 28**) was driven to the southwest and cut several shears and veins before intersecting the iron-stained crosscut fault. Drifts continued along the fault to the southeast and northwest. The west adit (**Figure 29**) exposes a shear in a narrow amphibolite, which was followed by a drift for 180 feet to the southwest. The principal target was the iron-stained fault that cuts the strike shear a short distance from the portal.

Limonitic metagreywacke collected from the east mine dump contained only traces of gold. A chip sample of limonitic quartz from the back of the Outpost (east) adit assayed 0.87 ppm (0.025 oz/ton) gold with 8.2 ppm (0.24 oz/ton) silver. A sample of hematitic breccia collected from the rib in the Outpost west adit yielded 1.33 ppm (0.039 oz/ton) gold (43A, **Appendix B**).

Peacock mine; SE sec. 25, T30N, R100W. This location places the mine in the Roundtop Mountain Greenstone. Jamison (1911a) estimated 240 ozs of gold were recovered from this property.

Rock Creek adit; NE sec. 11, T29N, R100W (**Figure 14**). This is an unnamed adit located about a mile above Atlantic City on the east bank of Rock

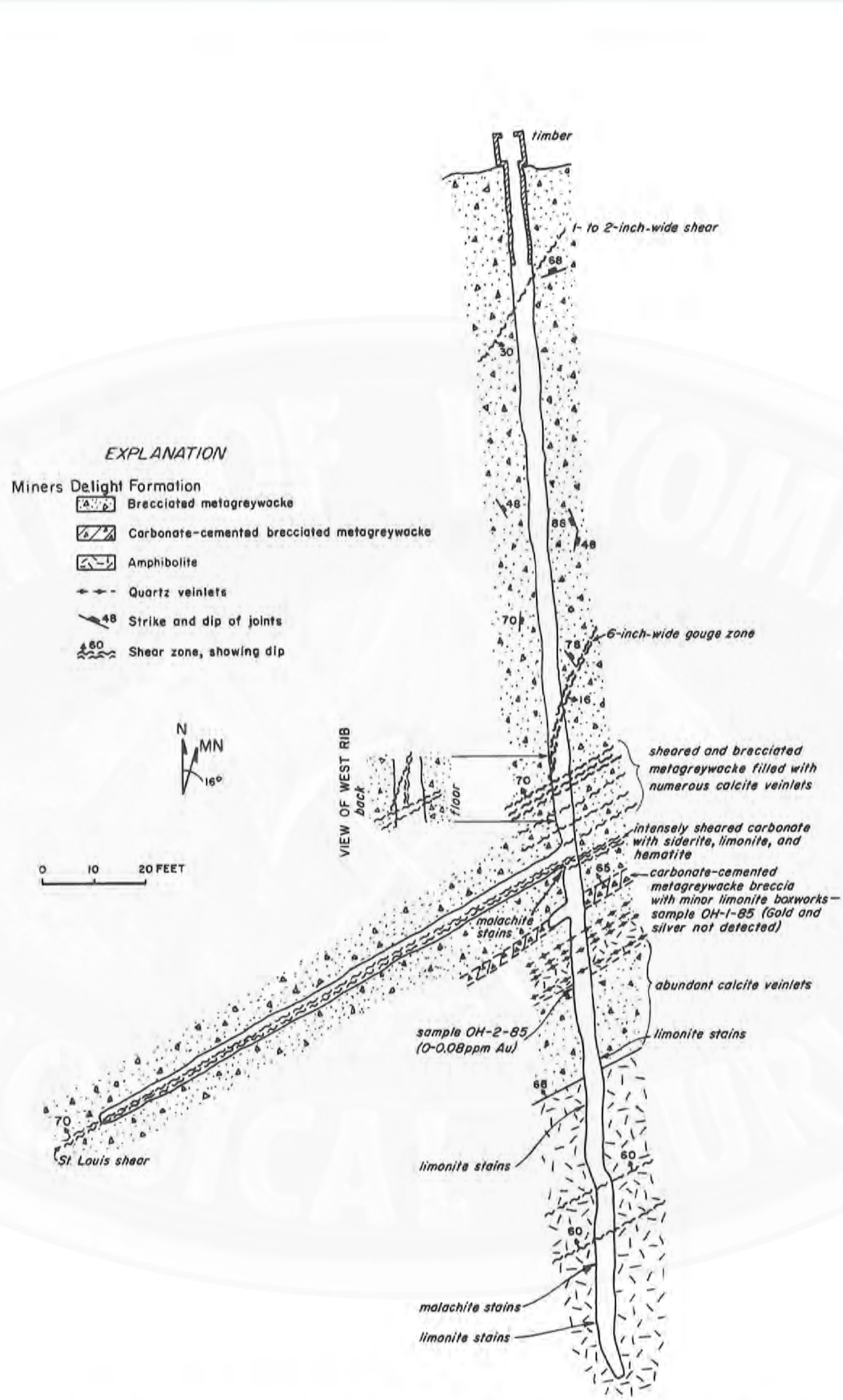

Figure 27. Geologic map of the Old Hermit mine (by W.D. Hausel and J.K. King, 1985).

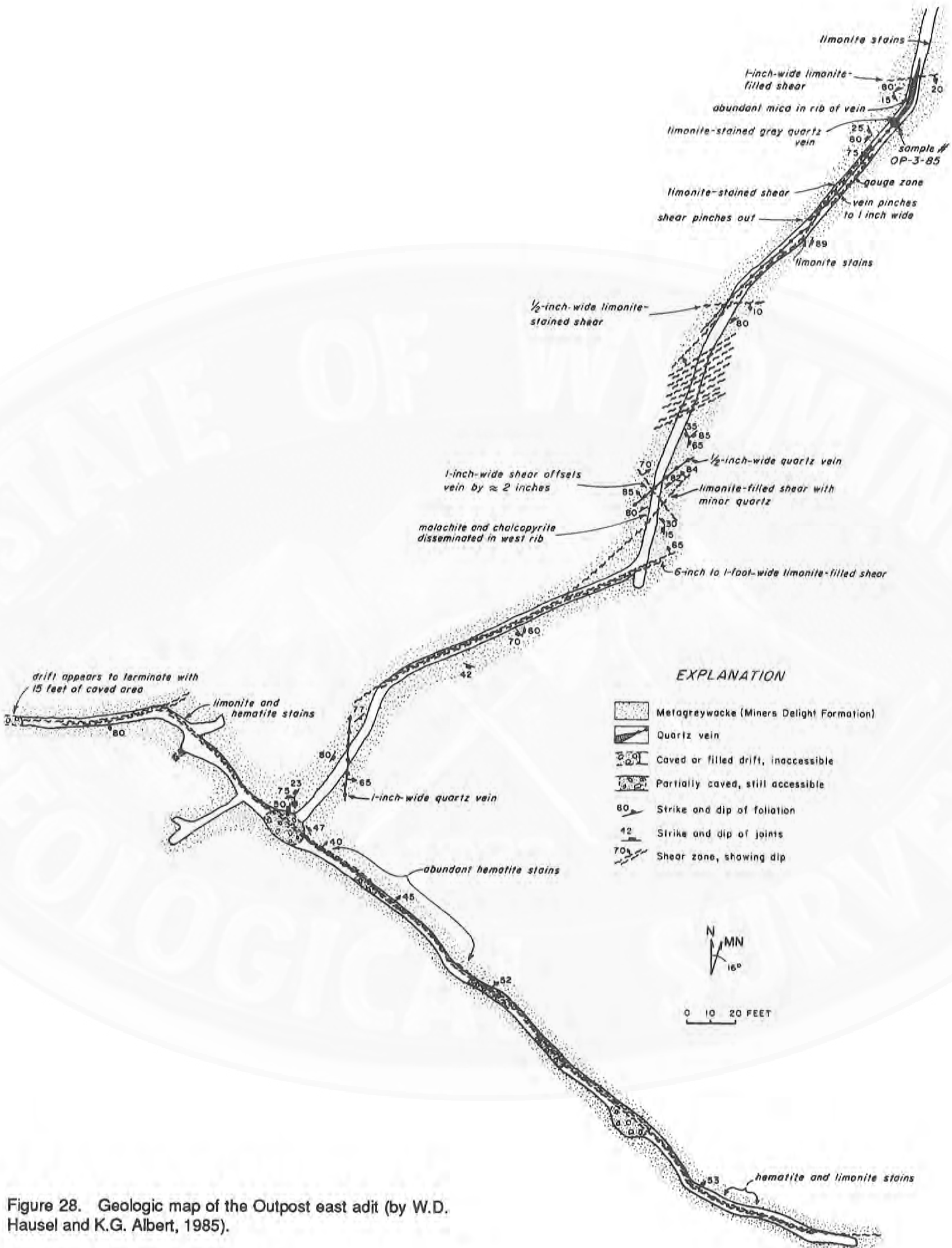

Figure 28. Geologic map of the Outpost east adit (by W.D. Hausel and K.G. Albert, 1985).

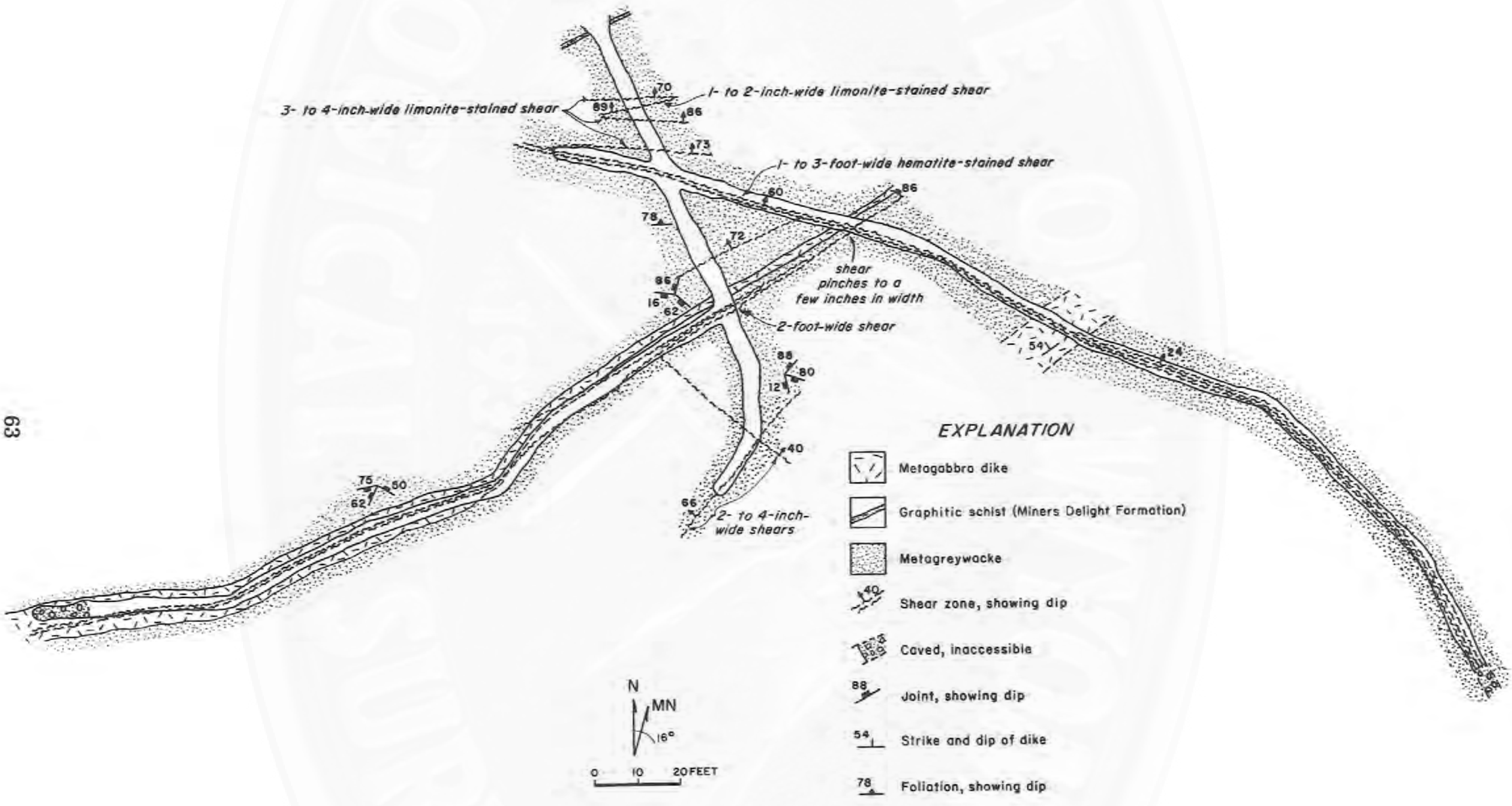

Figure 29. Geologic map of the Outpost west adit (by W.D. Hausel and J.K. King, 1985).

Creek. The tunnel was driven 155 feet northeast into the Miners Delight Formation mixed member, cutting metagreywacke and amphibolite (**Figure 30**). At 75 feet from the portal, the tunnel cut a 15-foot-wide shear zone.

Two samples were taken. A chip of hematite-stained metagreywacke contained 0.03 ppm gold, and a grab sample of quartz-bearing metagreywacke from the mine dump yielded 0.04 ppm gold.

Rock Creek placers. A 6- to 6.5-mile stretch of Rock Creek between the Rock Creek fault and the Oregon Trail (**Plate 1**) was dredged from 1933 to 1941 and three million cubic yards of gravel averaging 0.012 oz/yd^3 were processed by the E.T. Fisher Company. According to production records, 11,500 ozs were recovered, but the average grade and volume processed suggest that three times as much gold may have been recovered.

The Rock Creek channel is 100 to 250 feet wide, with an average depth of 10 feet. Seventy-five percent of the gold was found within 1 to 3 feet of bedrock. The gold occurred as flakes with rounded edges and as uncommon nuggets. One nugget recovered in 1934 weighed 3.4 ozs; larger nuggets were probably recovered after 1934 but not reported. The gold fineness ranged from 0.840 to 0.900 (Ross and Gardner, 1935). Some of the richest gravel was mined 1 mile below Atlantic City where a fault crosses Rock Creek (Wilson, 1953).

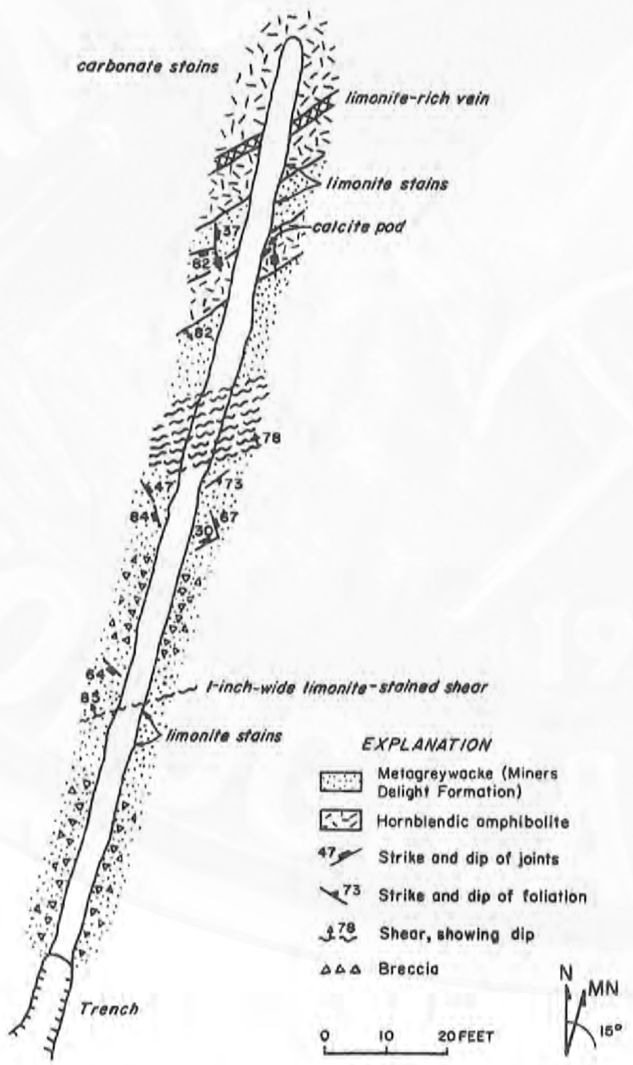

Figure 30. Geologic map of the Rock Creek adit (by W.D. Hausel and J.K. King, 1986).

Some early reports suggest large nuggets were found on Rock Creek. For instance, the *Wyoming Industrial Journal* (1905, v. 6 no. 12, p. 18) reported a fist-size piece of gravel containing 24 ozs of gold was found near the turn of the century, and a boulder reportedly containing an estimated 630 ozs of gold was also recovered about the same time. Neither of these eyewitness accounts seem unreasonable, since the gold in the shear zones is known for forming sporadic rich pockets separated by segments of weakly mineralized rock.

Rocky Barr adit; SW sec. 15, T29N, R100W. The tunnel was driven to the southeast from Big Hermit Gulch, cutting across foliation and bedding, to test a fault intersection 400 to 500 feet southeast of the portal. At 195 feet from the portal, the workings intersected a narrow unmineralized shear in Miners Delight Formation metagreywacke that was followed nearly 95 feet in a crosscut to the east (**Figure 31**). The main tunnel continues another 85 feet beyond this drift before it ends 100 to 200 feet short of the projected fault intersection.

Twenty-nine samples were collected in the mine and assayed. Nearly all were unmineralized to poorly mineralized. Assay values ranged from no detectable gold to 1.1 ppm (0.03 oz/ton) gold (**Table 10**).

Rose (W. J. Bryan) mine; SE sec. 2, T29N, R100W, located north of Atlantic City (**Plate 1 and Figure 14**). The Rose shaft was sunk on a 2- to 3-foot-wide, N60°E trending,

Figure 31. Geologic map of the Rocky Barr mine (by W.D. Hausel and K.G. Albert, 1984). Mapped at waist level. Assay values of samples are provided in Table 10.

Table 10. Assay results of samples collected in the Rocky Bar mine. Locality numbers refer to Figure 31. [n.d. = Au not detected (less than 0.1 ppm). Ag not detected in any sample (less than 2.0 ppm).]

Locality number	Au (ppm)	Locality number	Au (ppm)
1	0.13	16	n.d.
2	0.23	17	n.d.
3	0.14	18	n.d.
4	n.d.	19	n.d.
5	n.d.	20	n.d.
6	n.d.	21	0.55
7	n.d.	22	0.25
8	n.d.	23	1.1
9	n.d.	24	0.24
10	n.d.	25	n.d.
11	n.d.	26	n.d.
12	n.d.	27	n.d.
13	n.d.	28	n.d.
14	n.d.	29	n.d.
15	n.d.		

80°SE dipping shear in Miners Delight Formation metagreywacke and porphyroblastic (cordierite) schist. The shear is continuous for 4,500 feet and was tested by a series of shafts and prospect pits at various points.

Samples collected from the Rose mine were poorly mineralized. The richest sample (a 2-foot channel in sheared metagreywacke) yielded only 0.65 ppm (0.019 oz/ton) gold (59A, **Appendix B**). However, a grab sample collected from another mine dump, 2,000 feet to the southwest on the Rose shear, assayed 15.4 ppm (0.45 oz/ton) gold (60A, **Appendix B**). South of the location of this grab sample are common rehealed fractures parallel to foliation in metagreywacke (see Hausel, 1987c). These veins and veinlets were not sampled.

Jamison (1911a) estimated gold production from the mine was about 250 ozs. There may also have been some production after 1911.

St. Louis (Jim Dyer) mine; W/2 NW sec. 13, T29N, R100W, located south of Atlantic City on Mill Hill (**Plate 1** and **Figure 14**). A 160-foot-deep incline shaft and a 300-foot tunnel were driven on the St. Louis shear (**Figure 32**). The tunnel cut through a 20-foot-wide contact shear between Miners Delight Formation metagreywacke and amphibolite (metadiabase) and followed a narrow 2- to 3-foot-wide shear in amphibolite. At approximately 180 feet into the adit, the workings exposed a fracture filled with gold that quickly played out (Dave Haddenham, personal communication, 1985). Jamison (1911a) estimated 360 ozs were mined from this property. There was some production after 1911 (Bob Haddenham, personal communication, 1986).

Silent Friend prospect; S/2 sec. 14, T29N, R100W. The vein on the property was 10 to 50 feet wide and contained anomalous copper and gold. Some of the ore ran 3.43 ppm (0.1 oz/ton) gold (Anonymous, 1916).

Snowbird (Rosella) mine; sec. 6, T29N, R99W (**Figure 14**). This mine was developed by a shaft and an adit on a narrow shear in Miners Delight Formation metagreywacke, and in a 30- to 50-foot-wide quartz-carbonate-sulfide breccia vein in hornblendic amphibolite (metabasalt), tuffaceous metagreywacke, and metagreywacke (**Figure 33**).

The shaft (not shown on the figure) was sunk on a narrow shear hosted by an isoclinally folded, carbonated, mylonitic metagreywacke of the mixed member of the Miners Delight Formation. A calcite-quartz vein grab sample collected from the dump on this shear by Prinz (1974) assayed 4.5 ppm (0.13 oz/ton) gold. Other samples collected in the mine from the calcite-quartz-sulfide breccia vein to the north yielded only weak gold anomalies (Hausel, 1989).

The breccia vein located in the northern portion of the mine consists of massive calcite, pyrite, uncommon chalcopyrite, two generations of quartz, and country rock clasts and is traceable on the surface for 3,500 feet. West of the mine, across Big Atlantic Gulch, the vein is hosted by graphitic schist. Bayley and others (1973) reported galena from the mine yielded a model lead date of 2.8 Ga.

Smith Gulch mine; SE sec. 6, T29N, R99W, on the east bank of Smith Gulch (**Figure 14**). A 200-foot tunnel was driven a short distance along the contact between Miners Delight Formation graphitic schist and actinolite schist and then cut southward across foliation through the graphitic schist to intersect a 5-foot-wide shear before terminating in metagreywacke (**Figure 34**). Samples from the mine include a chip of sulfide-bearing quartz vein that assayed 2.28 ppm (0.066 oz/ton) gold with 216.4 ppm (6.31 oz/ton) silver, and limonite-stained actinolite schist that assayed 0.080 ppm gold, 0.4 ppm silver, and 356 ppm nickel (Hausel, 1989).

Smith Gulch placer; sec. 6, T29N, R99W, along Smith Gulch south of the Smith Gulch adit. Gravels mined in 1987 averaged 0.1 oz/yd^3 gold (Hank Hudspeth, Jr. and Buddy Presgrove, personal commu-

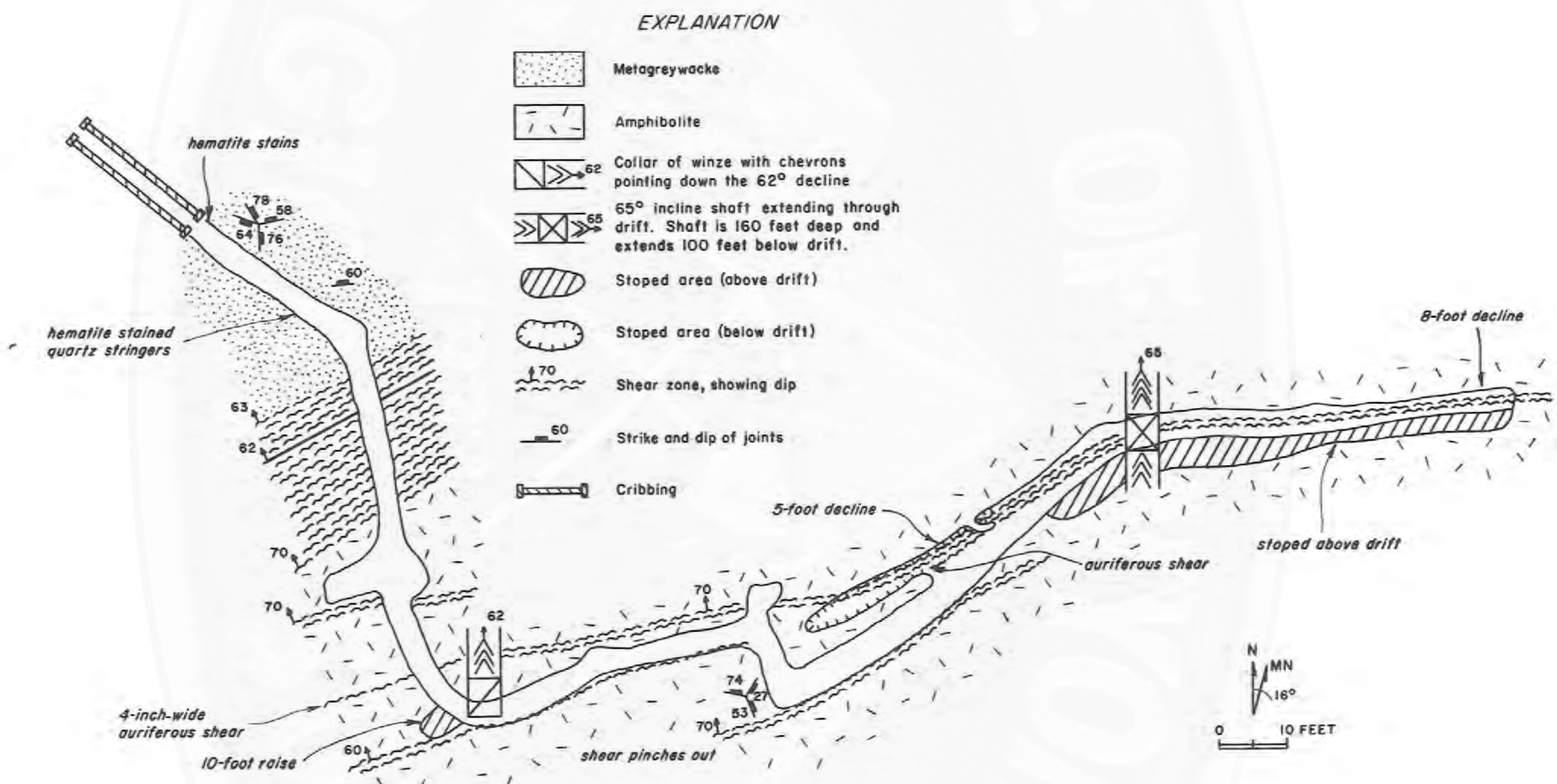

Figure 32. Geologic map of the St. Louis mine (by W.D. Hausel and J.K. King, 1985).

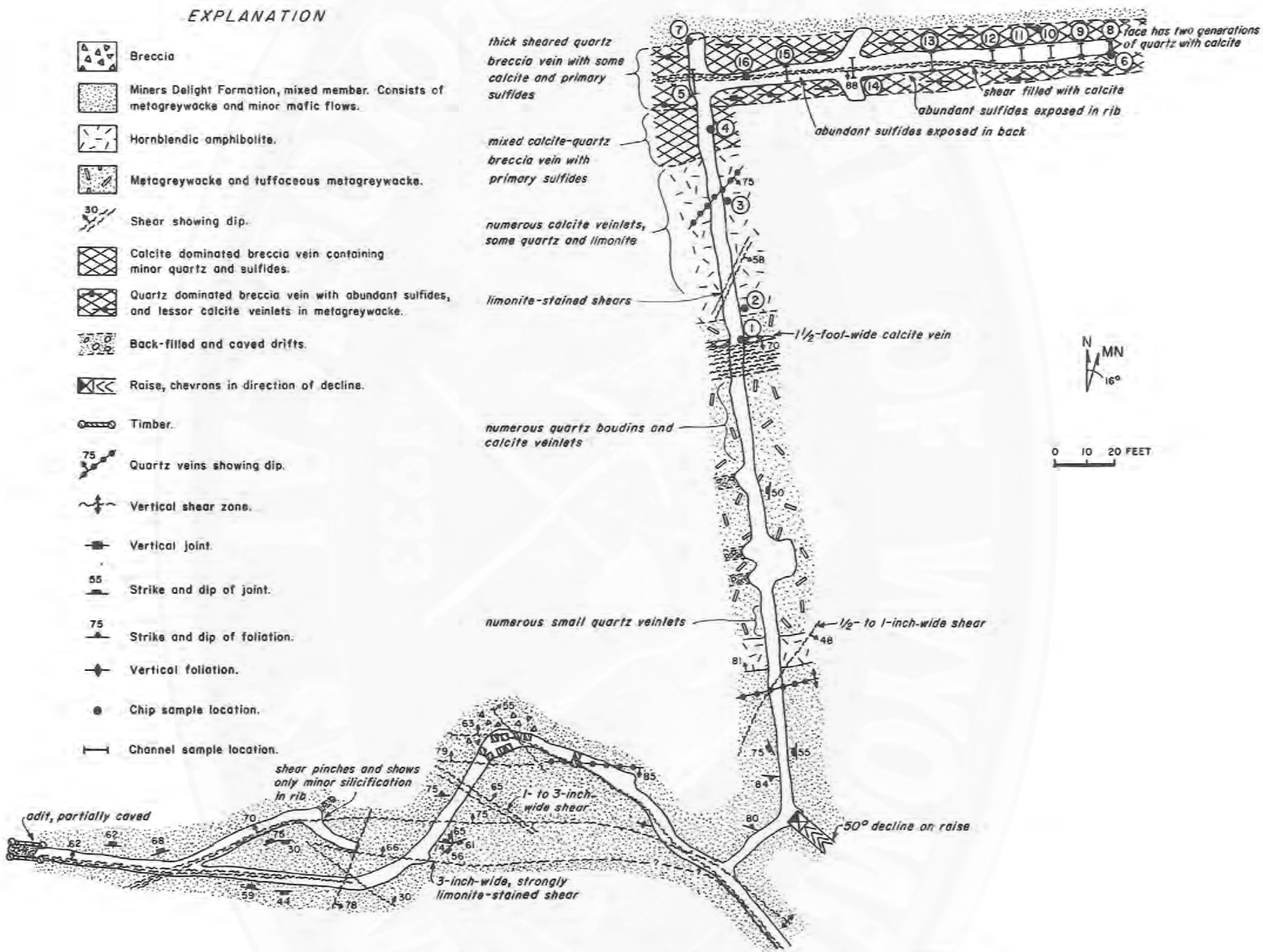

Figure 33. Geologic map of the Snowbird mine (by W.D. Hausel and J.K. King, 1985).

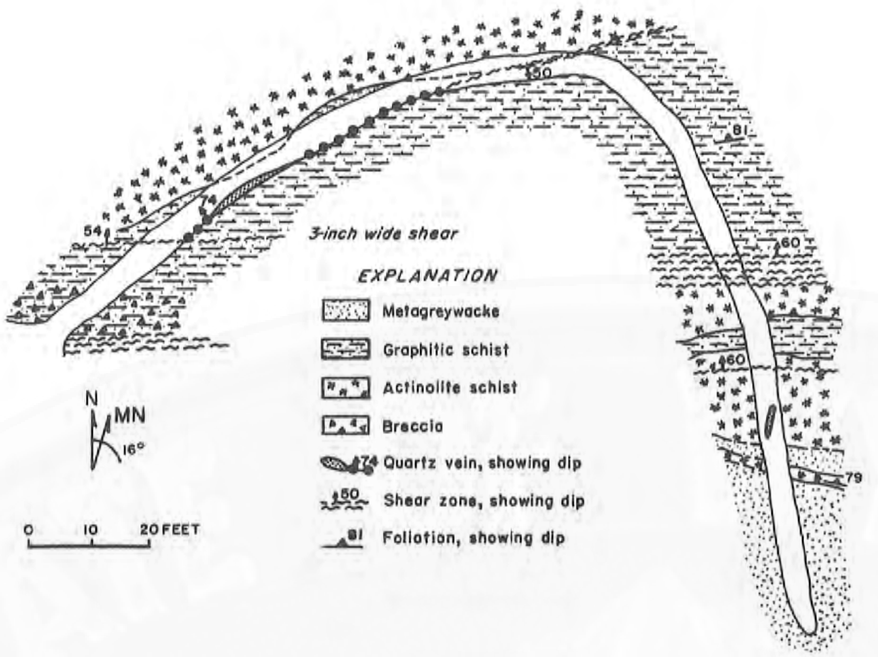

Figure 34. Geologic map of the Smith Gulch adit (by W.D. Hausel and J.K. King, 1985).

nication, 1987). Much of the gold occurred as flatten flakes and nuggets near bedrock and in sandy layers overlying thin clay-rich units.

Soules & Perkins (Bucks Tunnel, Britanna, Victoria Regina) mine; E/2 NE sec. 11, T29N, R100W (**Figure 14**). The Soules and Perkins mine has more than 500 feet of workings and stopes driven across regional foliation through Miners Delight Formation quartzofeldspathic gneiss, amphibolite, metagreywacke, and metaconglomerate (**Figure 35**). At 210 feet from the portal, the mine intersected a narrow 2-foot-wide cross vein and shear zone in the amphibolite. This lode was reported to have an average gold tenor of 19.89 ppm (0.58 oz/ton) (*Engineering and Mining Journal*, 1883, v. 35, p. 228).

Gold production from the mine was estimated at about 25,000 ozs by *The Lewiston Gold Miner* (1894) and about 17,000 to 18,000 ozs by Jamison (1911a).

Unexplored targets in the mine include zones of silicification, quartz veinlets, and a stretched-pebble conglomerate near the mine face. Similar metaconglomerates in other greenstone belts are generally unproductive; however, Anhaeusser (1976) reported some Archean conglomerates in greenstone terranes in southern Africa have yielded gold.

Tabor Grand mine; NE sec. 14, T29N, R100W, located southwest of Atlantic City (**Plate 1** and **Figure 14**). Named after the historic Tabor Grand Hotel in Leadville, Colorado, the Tabor Grand mine was driven along a 3- to 10-foot-wide shear zone in Miners Delight Formation amphibolite. Approximately 500 feet of drifts were cut on the 120-foot level of the mine, with stopes reaching to the surface (**Figure 36**). According to Armstrong (1948), two shafts were sunk 180 and 160 feet, respectively, but development below the 120-foot level was minimal.

Armstrong (1948) reported the average grade of the mined ore to be 17.15 ppm (0.5 oz/ton) gold. Samples recently collected in the mine ranged from a trace to 58 ppm (1.69 oz/ton) gold (**Table 11**). A 260-foot-long mineralized zone is postulated, based on these samples. Mapping and sampling also demonstrate a parallel mineralized zone lies 15 to 30 feet south of the principal shear. This zone is unexplored except in two short crosscuts separated by 300 feet.

The Tabor Grand shear continues 700 to 800 feet east from the adit before it is offset by a Laramide fault. This portion of the shear is also mineralized and an 8-foot channel sample collected from a prospect pit at the eastern extent of the shear contained 3.8 ppm (0.11 oz/ton) gold with 1.7 ppm (0.05 oz/ton) silver (29A, **Appendix B**). The Tabor Grand shear also continues a few hundred feet west from the mine face; thus, the Tabor Grand shear is more than 1,000 feet long.

Tornado mine; S/2 SE sec. 30. T30N, R99W, located east of the Atlantic City mine (**Plate 1** and **Figure 14**). This mine was developed along a narrow, shallow-dipping, sheared, cupriferous vein in the Roundtop Mountain Greenstone (**Figure 37**). Elsewhere in the greenstones, samples of discrete veins in sec. 4, T29N, R100W yielded 9.5 ppm (0.277 oz/ton) gold.

The Tornado vein strikes N20°W to N, and dips 12°SW. It is formed of siderite and calcite gangue with

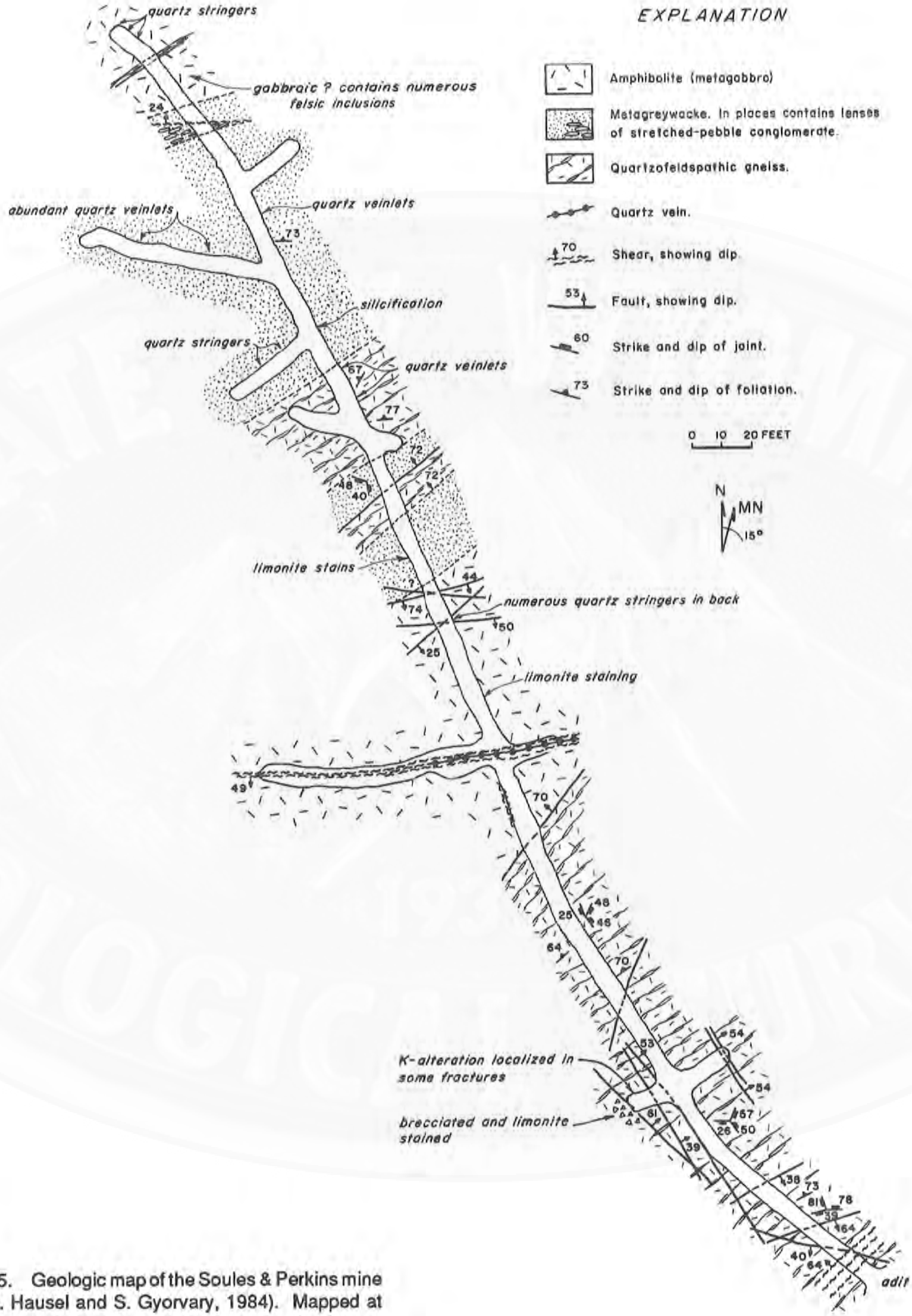

Figure 35. Geologic map of the Soules & Perkins mine (by W.D. Hausel and S. Gyorvary, 1984). Mapped at waist level.

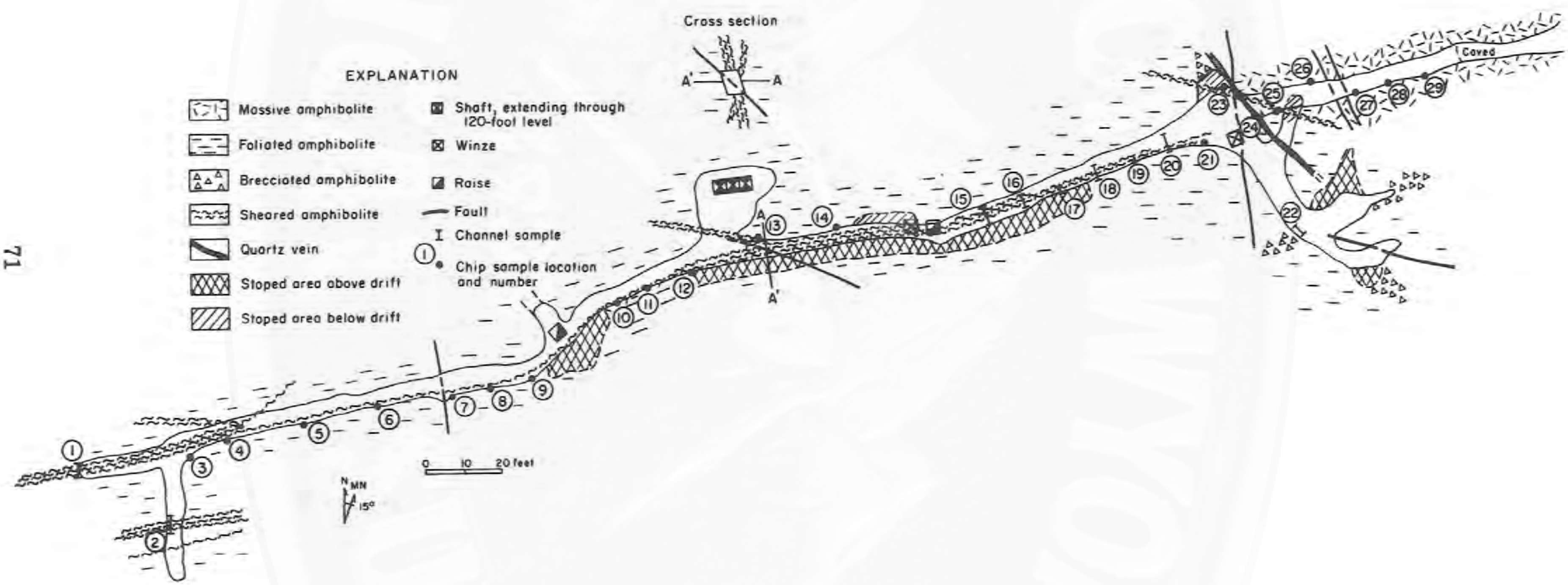

Figure 36. Geologic map of the 120-foot (adit) level of the Tabor Grand mine (by S. Gyorvary and W.D. Hausel, 1984). Mapped at waist level. Assay values of samples are provided in Table 11.

chalcopyrite and malachite. A suite of samples taken in the mine assayed 0.01 to 3.5% copper, none to 37 ppm (1.08 oz/ton) gold, and none to 19 ppm (0.55 oz/ton) silver with traces of lead, nickel, and zinc (**Table 12**).

Table 11. Assays from the 120-foot level of the Tabor Grand gold mine, South Pass, Wyoming. Locality numbers refer to Figure 36.

Locality number	Sample description	Assay values (ppm) Au	Ag
1	3-ft channel across face	0.06	0
2	4-ft channel across shear	1.7	0
3	Chip sample of gouge from south rib	0.07	0
4	Chip from south rib	0.05	0
5	Chip from south rib	2.2	0
6	Chip from south rib	0.81	0
7	Mylonite from south rib	8.6	2.5
8	Mylonite from south rib	58.0	4.7
9	Massive amphibolite	0.10	0
10	Chip of massive amphibolite with milky quartz veinlets	0.12	0
11	Chip, contains milky quartz in massive amphibolite	0.74	0
12	Chip from south rib, contains some quartz	3.0	0
13	Chip from north rib, contains some quartz	4.6	0
14	Chip sample from north rib	2.3	0
15	4-ft channel across mine back	9.1	0
16	3.5-ft channel sample across mine back, includes 2-in wide quartz vein	14.0	0
17	3-ft channel in back	4.4	0
18	4-ft channel in back	8.7	0
19	1-ft channel in back	1.9	0
20	5-ft channel across back includes both blocky massive and sheared amphibolite	2.1	0
21	Chip sample across narrow gouge zone in back	5.2	0
22	3-ft channel sample	7.0	0
23	Chip sample across shear in north rib	5.3	0
24	2-ft channel across 2-ft wide gray quartz vein	22.0	0
25	1-ft wide channel across limonite-stained shear in foliated orthoamphibolite	3.6	0
26	Chip sample from north rib	0.15	0
27	Channel sample in south rib	0.09	0
28	Chip sample from south rib	0.68	0
29	Chip sample from south rib	0.09	0

Wareagle mine; sec. 11, T29N, R100W (**Figure 14**). A shaft with adits was developed to test a 1,000-foot-long strike shear in Miners Delight Formation metagreywacke. This shear parallels the Groundhog shear to the east.

Two grab samples collected from the mine dump by Prinz (1974) assayed 0.3 ppm and 0.2 ppm gold.

Wyoming Copper Mining Company mine; possibly located in sec. 18, T29N, R100W, on the west bank of Willow Creek (**Figure 14**). Spencer's (1916) reported location, in S/2 sec. 13, N/2 sec. 24, T29N, R101W, is probably not correct. Instead this may be the same mine that is located along Willow Creek in S/2 SE sec. 18, T29N, R100W (Steve Gyorvary, personal communication, 1986) (**69A, Plate 2**). This shaft was sunk on a ubiquitous breccia in Miners Delight Formation metagreywacke, and is locally mineralized with milky quartz impregnated with chalcopyrite. The mineralized zone was described as 40 feet wide, developed by a 500-foot-deep shaft.

Table 12. Assays of samples taken in the Tornado mine. Locality numbers refer to Figure 37.

Locality number	Au (ppm)	Ag (ppm)	Cu (%)	Ni (ppm)	Pb (ppm)	Zn (ppm)
1	n.d.	1.7	.019	34	n.d.	66
2	n.d.	n.d.	.011	10	n.d.	37
3	n.d.	n.d.	.022	41	n.d.	n.d.
4	0.39	n.d.	.31	27	2	40
5	0.23	1.0	.18	17	n.d.	50
6	17.0	1.3	.37	n.d.	n.d.	48
7	0.28	n.d.	.10	n.d.	n.d.	160
7a	25.0	6.7	1.8	14	3	93
8	0.13	n.d.	0.25	34	n.d.	71
9	8.4	n.d.	.174	10	6	16
10	3.4	2.2	3.5	67	78	140
11	37.0	19.0	1.1	n.d.	26	97
12	9.1	6.1	1.4	26	3	47

n.d. = not detected; detection limits were: Au less than 0.1 ppm
Ag less than 1.0 ppm
Ni less than 10 ppm
Pb less than 2.0 ppm
Zn less than 10 ppm

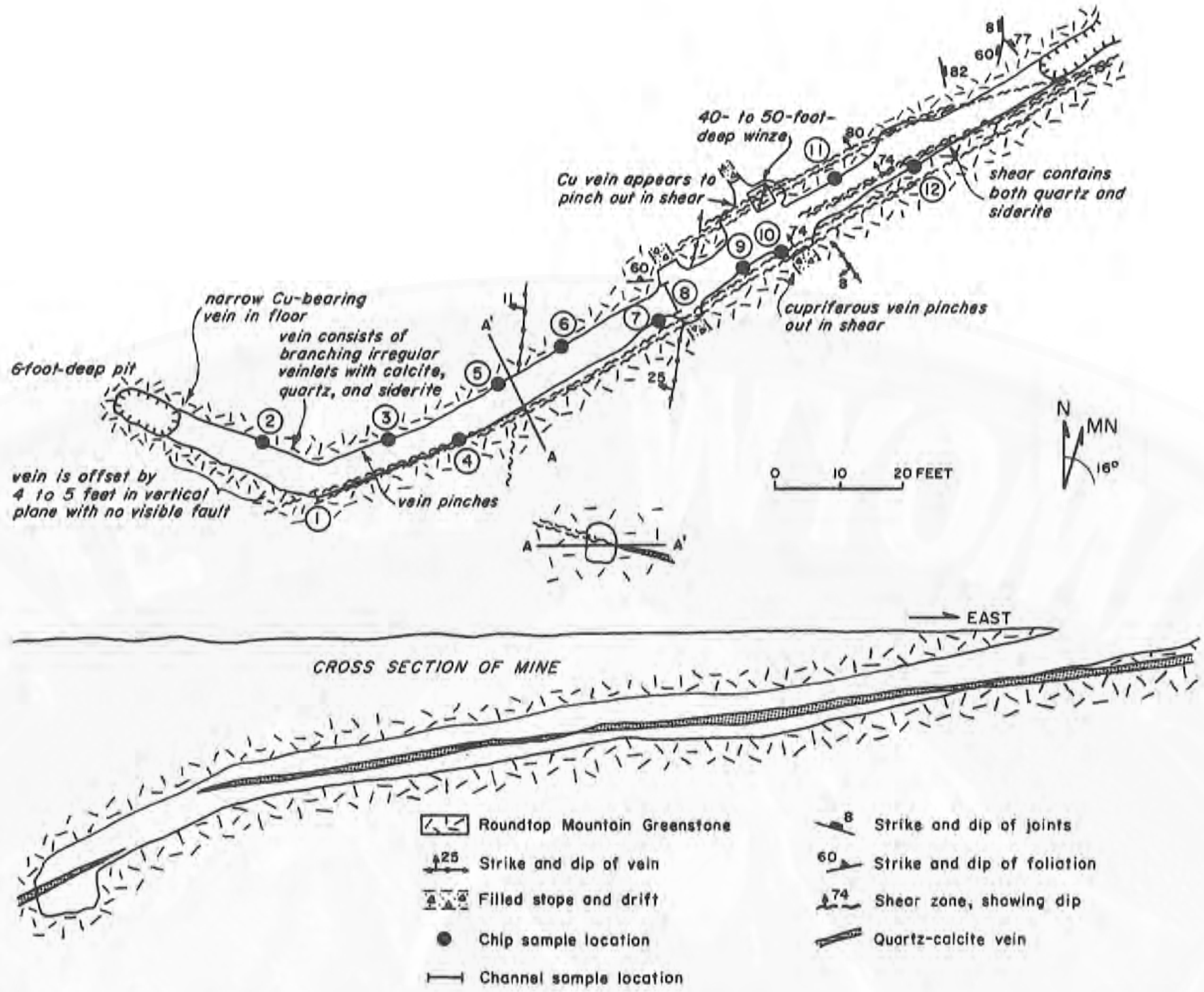

Figure 37. Geologic map of the Tornado mine (by W.D. Hausel and S. Gyorvary, 1985). Mapped at waist level. Assay values of samples are provided in Table 12.

Spencer (1916) reported a quartz vein in schist yielded ore samples containing 4 to 16% copper, 3.43 ppm to 17.84 ppm (0.1 to 0.52 oz/ton) gold, and 51.5 ppm to 1,370 ppm (1.5 to 40 oz/ton) silver. Some lead was also reported in the mine (Anonymous, 1916).

Wyoming Mica & Metals Corporation placer; S/2 secs.20, 21, and 22 and N/2 secs. 27, 28, and 29, T30N, R100W, located on Rock Creek above the Atlantic City iron mine. This location puts it within the Louis Lake granodiorite. The placer contains abundant mica with native gold. Gold values average about 0.016 oz/yd^3 with some pay streaks running as high as 1.17 oz/yd^3 (Wilson, 1953).

XL Dredging (Company) placer. This placer consisted of 1,440 acres of ground on Smith, Big Atlantic, Promise, O'Meara, and Long gulches in the South Pass greenstone belt. A 2-foot-deep, 6-mile-long ditch was constructed to supply water for hydraulic mining and sluicing (Anonymous, 1910).

According to the 1910 company prospectus, values in the lower gravel ran from 0.002 oz to 0.02 oz of coarse gold to the pan, and the topsoil produced values of 0.07 oz/yd^3. Nuggets from 0.07 oz to about 1.0 oz were found on bedrock.

Other mines; Many other mines and prospects are mentioned in the literature, for which no locations are given. Some of these are the Young American, Independence, Gold Dust, McKinley, Rustler, Harrison, Little Bee, Big Copper, Midget, Prixley, Charles Dickens, Klondike, Payrock, Chipper, and Poiree Estate (Knight, 1901; Spencer, 1916).

Other placers; The South Pass-Atlantic City district includes many undocumented placers. During the course of mapping in the district, some of these placers attracted my attention either because of historic workings, or because the surrounding geology was favorable for placer development. Some of these are discussed below.

Deep Gulch; NE NE sec. 22 and sec. 23, T29N, R100W. Deep Gulch is a deeply incised linear drainage, which may follow a crosscutting Laramide(?) fault. The drainage also lies downstream from a group of fault intersections, strike shears, and a mafic-ultramafic amphibolite belt, which are considered potential sources of gold. However, the gradient of the gulch is relatively steep and the gulch contains a relatively small volume of gravel.

Little Beaver Creek; N/2 sec. 14 and NW sec. 13, T29N, R100W. Placer gravels lie downstream from a group of strike shears, fault intersections, and the principal mafic-ultramafic amphibolite belt, which contains many auriferous shears.

North Big Hermit Gulch; NW sec. 9, T29N, R100W. Fragments of a wooden sluice and rocker were found in the willows northwest of Highway 28, suggesting that these gravels were worked for gold.

NW NW sec. 15, T29N, R100W. A relatively small area in an aspen grove is underlain by gravel that lies on amphibolite and metagreywacke of the Miners Delight Formation. The western margin of the drainage is bordered by a cross fault of probable Laramide age. Hidden within the grove are the remains of a cabin, sluice, and other placer equipment.

South Big Hermit Gulch; SW SW sec. 15, NW NW sec. 22, and N/2 NE sec. 21, T29N, R100W. This stretch of Big Hermit Gulch, from the Rocky Barr mine to the confluence with Little Hermit Gulch, lies downstream from several auriferous strike shears and fault intersections and is underlain by amphibolites and ultramafic schists in the Miners Delight Formation.

Below the confluence of Big Hermit Gulch and Willow Creek in W/2 sec. 21, T29N, R100W, gravels lie downstream from several auriferous strike shears, including the Carissa shear, and an area with numerous parallel quartz veins and veinlets. Meanders in the stream also provide favorable conditions for placers.

Willow Creek; N/2 N/2 sec. 28, T29N, R100W. Dredge tailings surround the entrance of the lower Carrie Shields adit. The amount of gold recovered from these gravels is unknown. Vast regions of Willow Creek below South Pass City are unmined. (Rock Creek, which contains numerous pay zones, parallels Willow Creek to the east and cuts the same group of rocks.)

Lewiston district

Gold-bearing shear zones in the Lewiston district are associated with a major district-wide fold in metagreywacke of the Miners Delight Formation (**Figure 38**). The shears parallel the fold limbs and probably formed in response to stress release during regional folding. For the most part, the auriferous shears parallel regional foliation, although they locally cut foliation at oblique angles and lie near the apex of the fold. In some cases, there is evidence that ore shoots were developed at shear intersections and pinches.

Most strike shears are weakly mineralized in gold with sporadic rich ore shoots, whereas most cross shears and faults are unmineralized and are interpreted to be Laramide structures. Cross veins consisting of copper-stained milky quartz with minor gold and silver represent a late(?) Archean copper-dominated mineralizing event. These veins are more common near the eastern margin of the district and cut the earlier gold-bearing shear zones.

The strike shears have been traced on the surface for hundreds of feet to a few thousand feet. For example, the Mint and Bullion shear zones were traced approximately 10,000 and 11,500 feet, respectively, during the mapping of the district using shear exposures, quartz float, altered wallrock, and aerial photography. Either one of these could be an offset extension of the Hidden Hand shear, which would add an additional 7,000 feet of strike length to the structures.

Large intervals of these shears, as well as large areas in the district, are hidden by a thin veneer (usually less than few feet deep) of eluvial debris and silt, which could hide dozens of ore shoots and strike shears. This was emphasized by the author's discovery of a 17-foot-wide blind mineralized shear on the Lone Pine claims in 1987. In addition to hidden shears, there are thousands of feet of exposed shears, veins, boudins, and crosscutting faults that are unexplored.

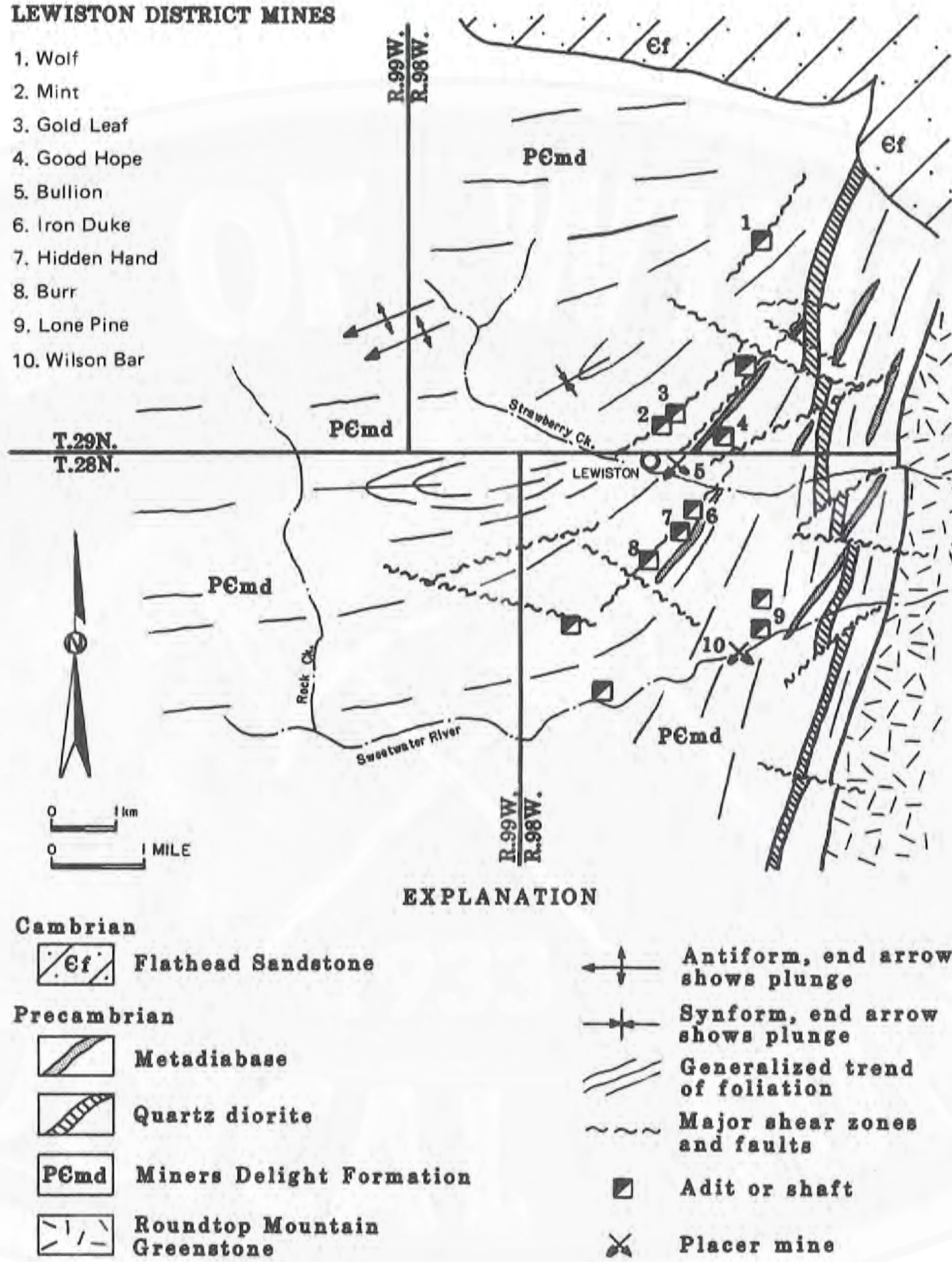

Figure 38. Generalized geologic map of the Lewiston district (modified from Hausel, 1986b).

Most mines in the district are inaccessible because of caving at the portal or because of reclamation efforts by the Wyoming Department of Environmental Quality. In addition, none of the mines are believed to be much deeper than 100 feet and there has not been any deep drilling, thus the continuation of the shears downdip is untested. By comparison with other Archean greenstone belts, these structures are expected to continue to greater depths. The shear widths vary from 2 to 40 feet wide.

Gold occurs in fractures in quartz and in association with pyrite and pyrrhotite. Wallrock alteration includes secondary hematite and chlorite with weak sericitic alteration and local tourmalinization. Arsenopyrite is less common in the Lewiston district than in the South Pass-Atlantic City district. Although arsenopyrite is uncommon in the district, some massive arsenopyrite occurs in parallel quartz veins in a cliff 200 to 300 feet east of the Lone Pine adit along the Sweetwater River east of Wilson Bar. The arsenopyrite is silver-bearing and possesses high Ag/Au ratios (16A, **Appendix B**).

Scattered reports show the gold tenor of the Lewiston mines ranged from a trace to as much as 3,100 ozs/ton (Pfaff, 1978). Samples taken in shear structures often produce anomalous gold values, but the district has not been systematically sampled. In addition to gold, silver, copper, tungsten, and tin anomalies have been identified within the district (Hausel, 1987b; Day and others, 1988), and iron and chromium anomalies have been identified along the eastern edge of the district (Hausel, 1987b).

Mines and occurrences

Anaconda mine; W/2 SW sec. 34, T29N, R98W. At the junction of the Oregon Trail with a north-south jeep trail, a shallow shaft was sunk on a N31°E trending, vertical shear. Very little, if any, ore was produced. One thousand feet south, the shear intersects a N72°E trending crosscut shear. The intersection is unexplored.

Big Nugget (Giblin) placer; secs. 31, 32, and 33, T29N, R98W. Haff (1944) reported five "good-size" nuggets were found in this placer. *The Wyoming State Journal* (March 23, 1932) reported nuggets weighing 5.3 and 5.2 ozs were also found.

Bullion (Jumbo) mine; N/2 sec. 5, T28N, R98W (**Figure 38**). The Bullion mine was developed by a series of open cuts on a strike shear and in eluvium on the north bank of Strawberry Creek adjacent to the former Lewiston town site. The Bullion ore shoot formed at the intersection of a N46°E-trending strike shear with a N80°E-trending (Laramide) cross fault in metagreywacke and ranged from 0.3 to 3.0 oz/ton gold (Barlett and Runner, 1926). Pfaff (1978) reported at least 21,000 ozs were recovered from the mine, which appears to be excessive.

Burr Gulch; N/2 sec. 8 and W/2 sec. 9, T28N, R98W (**Plate 1**). Apparently, Burr gulch was the site of the 1879 gold discovery that led to the establishment of the Lewiston district (*The Lewiston Gold Miner*, 1894). It was reported that gold-bearing quartz float found in the gulch led to the discovery of the Burr lode.

Burr mine; N/2 sec. 8, T28N, R98W (**Plate 1** and **Figure 38**). According to *The Lewiston Gold Miner* (1894), the Burr lode was the first significant deposit found in the district. The mine is located at coalescing and intersecting shear zones, which produced intense fracturing and brecciation. A N49°E trending, 78°NW dipping shear is intersected by a N73°W trending cross shear at the Burr adit. A few hundred feet west, the Amanda incline was sunk on the intersection of the N73°W trending cross shear with a N40°E trending strike shear that coalesces with a N56°E trending shear. South of the Burr mine, another prominent cross fault may intersect the Burr shear near the Irish Jew prospect.

Sporadic rich pockets were mined that yielded 858 ppm to 8,580 ppm (25 oz/ton to 250 oz/ton) gold (*The Lewiston Gold Miner*, 1894) with some rare specimen-grade material that assayed as high as 57,970 ppm (1,690 oz/ton) gold (*Wyoming Industrial Journal*, 1901, v. 2, no. 11, p. 320). One 16-foot-wide zone was reported to have averaged 17.15 ppm (0.5 oz/ton) gold (*The Lewiston Gold Miner*, 1894). In 1893, a small pocket of ore was intersected that yielded nearly 2,900 ozs of gold (*Engineering and Mining Journal*, 1893, v. 56, p. 406).

In addition to gold, the mine contains tungsten. Wilson (1951) reported scheelite occurs in stringers, veinlets, lenses, pods, and specks conformable to the gold horizon on the 25-foot level (**Figure 39**). Samples yielded from 2.5 to 70% WO_3 and the mineralized zone was estimated to average 5% WO_3. Wilson (1951) indicated conditions in this region were favorable for a low-grade, large-tonnage, tungsten deposit.

Goodhope mine; SW sec. 34, T29N, R98W (**Plate 1** and **Figure 38**). A shallow shaft was sunk on a 2-

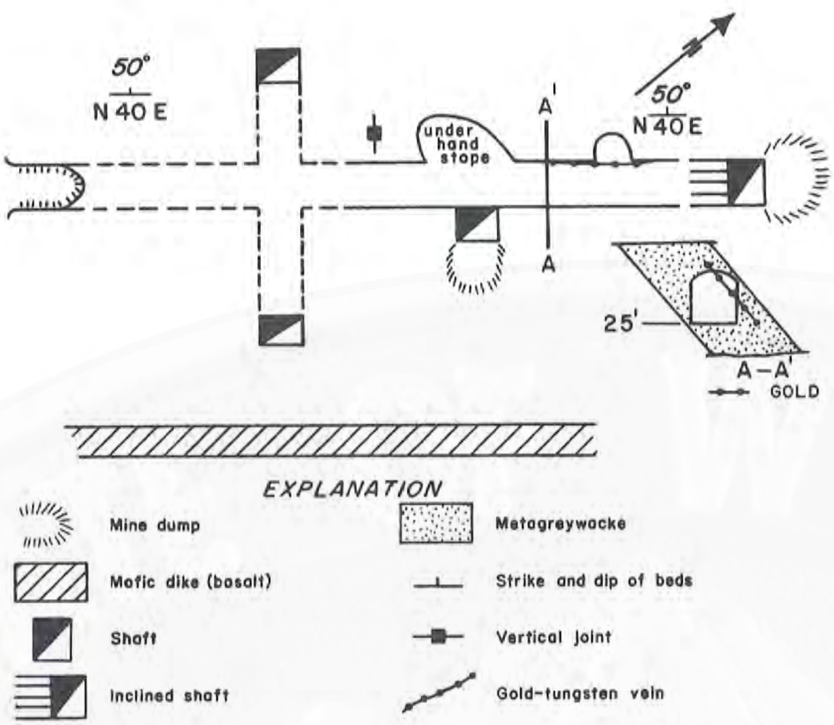

Figure 39. Sketch map of the upper level of the Burr mine (Wilson, 1951).

foot-wide, N45°E trending, vertical, chloritized shear zone in metagreywacke. South of the shaft, the shear was trenched for nearly 100 feet, exposing sheared quartz lenses carrying visible gold.

One grab sample of quartz collected from the trench assayed 1.18 oz/ton gold. Two 2-foot-long channel samples dug across the shear zone assayed 0.11 oz/ton gold and 0.35 oz/ton gold (8A, **Appendix B**). Another 2-foot channel sample collected in the trench assayed 0.63 oz/ton gold (James E. Bond, II, personal communication, 1986). Much of the shear is unexplored.

Hidden Hand mine; SE sec. 5, T28N, R98W (**Plate 1** and **Figure 38**). The Hidden Hand shaft was sunk on a 10- to 30-foot-wide, N40°E trending, 62°NW dipping shear in chloritized, hematitic metagreywacke. The shaft was sunk 110 feet deep and the shear zone explored by at least 640 feet of drifts prior to 1926 (Henderson, 1926).

Ore mined from the 30-foot level assayed as high as 75 oz/ton gold. In 1916, about 1,000 tons of ore with an average grade of 4 oz/ton gold were stockpiled (Anonymous, 1916). One rich shoot yielded specimen-grade ore that assayed up to 106,330 ppm (3,100 oz/ton) gold (Pfaff, 1978). Samples of altered metagreywacke collected from the mine dump contained no gold to traces of gold (7A, **Appendix B**).

Iron Duke mine; SE sec. 5, T29N, R98W (**Figure 38**). North of the Hidden Hand mine, coalescing shears intersect at the Iron Duke shaft. The shaft was sunk on a relatively wide shear in altered metagreywacke. Secondary hematite, chlorite, quartz, and minor sericite and epidote replace portions of the sheared rock and wallrock. A short distance east of the Iron Duke mine is an unexplored shear zone with distinct chloritic and hematitic alteration.

A sample of silicified metagreywacke taken from the Iron Duke shear assayed 7.2 ppm (0.21 oz/ton) gold (6A, **Appendix B**), and a 6-foot-wide channel sample taken across the shear yielded 1.23 ppm (0.036 oz ton) gold (James Bond, personal communication, 1986).

Lewiston Iron Formation; SW sec. 19, T29N, R97W. Banded oxide-facies iron formation was discovered south of Diamond Springs (Hausel, 1988a). The iron formation is banded magnetite and silica with minor amphibole similar to the iron formation at the Atlantic City open pit in the South Pass-Atlantic City district. To the west, the iron formation is oxidized to hematite, possibly because of shearing, and contains some quartz veins with minor copper.

Samples of the iron formation collected for assay yielded < 0.343 ppm to 1.37 ppm (<0.01 to 0.04 oz/ton) gold and < 0.343 ppm to 3.43 ppm (<0.01 to 0.10 oz/ton) silver. A sample of hematitic iron formation collected in the N/2 NE sec. 25, T29N, R98W assayed 0.686 ppm (0.02 oz/ton) gold, 1.72 ppm (0.05 oz/ton) silver, and 0.55% copper (17A and 18A, **Appendix B**).

Lone Pine mine; SE sec. 9, T28N, R98W (**Plate 1** and **Figures 38** and **40**). The adit was driven 470 feet on a N67°W azimuth across regional foliation from the

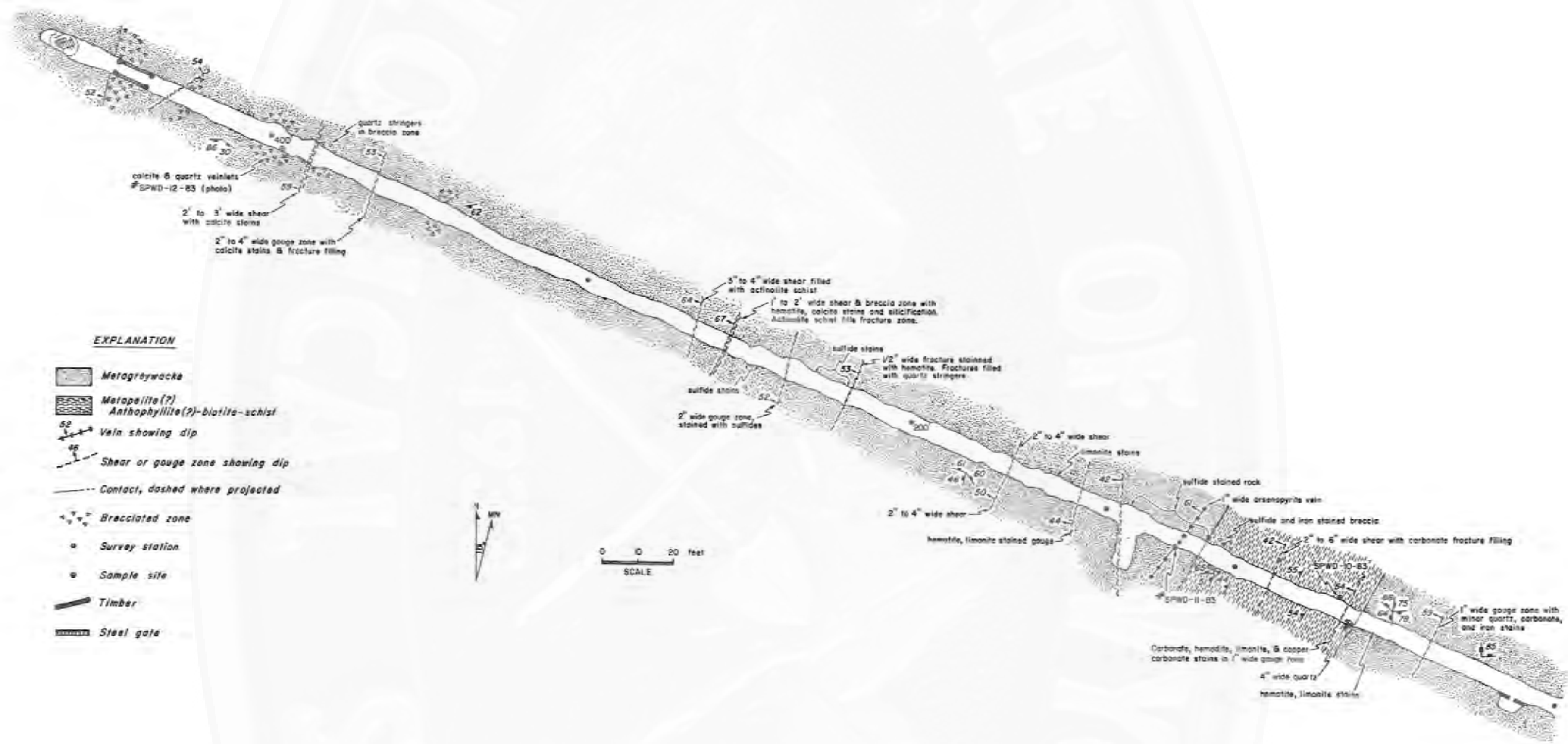

Figure 40. Geological map of the Lone Pine adit (by W.D. Hausel and K.G. Albert, 1983) (" = inch/inches, ' = foot/feet). Mapped at waist level.

north bank of the Sweetwater River. Several narrow shears, faults, and breccia zones were cut, and one narrow (~ 1-inch wide), arsenopyrite-bearing vein was intersected. A sample collected from the vein assayed 20.9 ppm (0.61 oz/ton) silver and no detectable gold (13A, **Appendix B**).

The apparent target of the mine was a crosscutting quartz vein located 1,200 feet (~ 700 feet from the mine face) northwest of the portal. A shaft sunk at the projected intersection of the tunnel with the vein was reclaimed in the early 1980s, obscuring the geologic relationships. In 1987, two trenches were dug perpendicular to the discordant vein and to regional foliation to look for a possible ore shoot at the buried shaft. The trench perpendicular to the vein demonstrated the vein pinched out just short of the shaft, even though it is traceable for more than 3,000 feet to the northeast. In the trench perpendicular to regional foliation, a hidden 17-foot-wide chloritized shear zone with common quartz stringers was discovered. A channel sample taken across the width of the shear averaged 1.6 ppm (0.047 oz/ton) gold and 2.9 ppm (0.085 oz/ton) silver (12A, **Appendix B**). The extent of this blind shear was not determined. The discovery suggests that other hidden, undiscovered shears may be present in the area.

Mint-Gold Leaf mine; SE sec. 33, T29N, R98W (**Plate 1** and **Figure 38**). Two shafts located 500 feet apart were sunk on a N53°E trending, vertical, silicified shear in Miners Delight metagreywacke. This poorly explored shear, traceable over a distance of nearly 10,000 feet, has fewer than two dozen prospects and shafts along its length (Hausel, 1986). At the Mint mine, the shear zone is well exposed in a shallow trench with shafts located at both ends of the trench. The southern shaft was recently filled with waste material by the Wyoming Department of Environmental Quality, and the northern shaft was covered. The shear is 2.5 feet wide at the northern end of the trench and about 6 feet wide at the southern end. Several samples containing visible gold were collected from this trench in recent years. The Gold Leaf shaft is shallow with little development. It appears to lie west of the main shear.

Channel samples were collected across the shear zone at the Mint mine to test this apparently rich shoot (15A, **Appendix B**). A 2.5-foot channel sample collected near the northern shaft assayed 44.2 ppm (1.29 oz/ton) gold (Hausel, 1987b). Another 2.5-foot channel sample assayed 104.6 ppm (3.05 oz/ton) gold (James E. Bond II, personal communication, 1986). Additionally, Knight (1901) collected an ore sample from the Mint shaft that assayed 20.9 ppm (0.61 oz/ton) gold. Cyanide extraction tests on this sample had only a 77% gold recovery rate.

Wilson Bar adit; SW sec. 9, T28N, R98W (**Figures 38** and **41**). A 180-foot-long tunnel was driven perpendicular to regional foliation to test a 2- to 3-foot wide cupriferous milky quartz vein in metagreywacke. The tunnel cut several narrow shears, fractures, and veins and terminated in a 15-foot-wide breccia without intersecting the primary target. The quartz vein apparently pinched out northeast of the tunnel and the controlling structure is expressed as a breccia in the mine face.

Wilson Bar placer; SW sec. 9 and NW sec. 16, T28N, R98W (**Figure 38**). The Burr and Hidden Hand lodes drain into Burr Gulch, which continues south to the Sweetwater River. The mouth of Burr Gulch is known as Wilson Bar. The Wilson Bar placer has been worked several times during the past. During the early history of the Lewiston district, this placer proved to be exceptionally rich. For example, *The Lewiston Gold Miner* (1894) reported the placer was discovered following several pannings that yielded 0.2 to 0.9 ozs of gold to the pan. It was also reported that 370 ozs were recovered from a 500-foot strip of gravel. Wilson Bar was dredged before World War II, although the amount of gold produced at this time is unknown. Recently, (1987-1988), the Steiner placer mine operated along the eastern edge of Wilson Bar.

Wolf (Ruby) mine; SE sec. 22, T29N, R98W (**Plate 1** and **Figure 38**). Three shafts less than 100 feet deep were sunk on the 4,500-foot-long, hematite-stained, chloritized Wolf shear. The shear is not well exposed and may be greater than 100 feet wide. The footwall of the 78°NW dipping shear is silicified. One grab sample of gray quartz with altered metagreywacke assayed 0.68 oz/ton gold (2A, **Appendix B**).

7605 Incline; S/2 sec. 7, T28N, R98W. This incline was sunk approximately 100 feet deep on a N36°E trending, 42°NW dipping shear in metagreywacke. The iron-stained shear is approximately 10 feet wide and contains scattered quartz boudins and pods. One grab sample of quartz from the mine dump assayed 0.05 oz/ton silver and no gold.

SE sec. 9, T28N, R98W, on the north bank of the Sweetwater River, a few hundred feet east of the Lone Pine mine. Two parallel quartz veins carry considerable arsenopyrite. Samples collected from the veins assayed no gold and 0.13 oz/ton silver (Hausel, 1989); 0.85 ppm gold, 130 ppm silver, and 0.16% copper; and

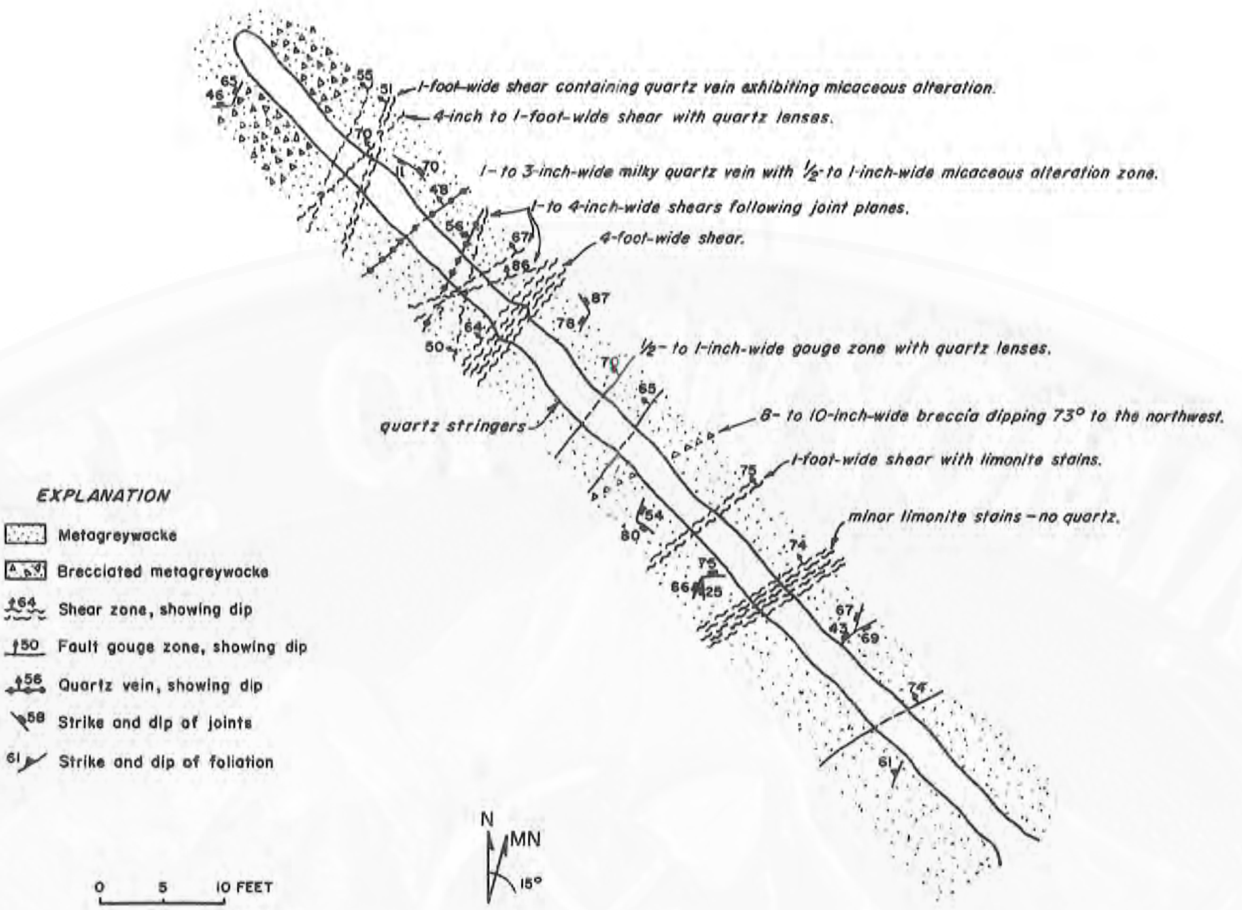

Figure 41. Geological map of the Wilson Bar adit (by W.D. Hausel, K.G. Albert, and S. Gyorvary, 1984). Mapped at waist level.

1.73 ppm gold, 24 ppm silver, and 0.28% copper (16A, **Appendix B**).

SE sec. 23, T29N, R98W. Disseminated scheelite occurs in quartz veinlets and in the adjacent metagreywacke of the Miners Delight Formation.

Anderson Ridge area

Anderson Ridge lies west of the South Pass-Atlantic City district between two granite domes. Metamorphic rocks in this region are principally metagreywacke, mica schist, porphyroblastic mica schist, and almandine mica schist. The porphyroblasts consist of sericite and quartz after andalusite and/or cordierite and are generally rounded grains, less than 1/2 inch in diameter.

The Anderson Ridge area is complexly folded and faulted. The northern edge is juxtaposed against Louis Lake granodiorite along the Anderson Ridge fault, and the supracrustal rocks are extensively invaded by pegmatitic granite and pegmatite.

Concordant and disconcordant pegmatites vary considerably in size. At least five mineralogical types of pegmatite were identified by Proctor and El-Etr (1968): (1) magnetite-bearing pegmatite, (2) graphic granite, (3) tourmaline-garnet (± beryl) pegmatite, (4) garnet pegmatite, and (5) biotite-bearing pegmatite. All of these pegmatites contain potassium and alkali feldspar, perthite, mica, and quartz. Some accessory minerals include arsenopyrite, columbite-tantalite, green beryl, rare aquamarine beryl, lepidolite, spodumene, and sky-blue tourmaline (Bayley and others, 1973; Harris and Hausel, 1986).

Anderson Ridge fault; sec. 21, T29N, R101W (**Plate 1**). The Anderson Ridge fault zone swells to several hundred feet wide in sec. 21 and contains minor localized copper and manganese stains in cataclastic rocks and fault breccia of the Miners Delight Formation. At one point, a shallow shaft was sunk on the copper-stained rock and the fault breccia was trenched perpendicular to the fault trend.

One sample of copper-stained rock assayed 1.86% copper and 175 ppb gold. A second sample of manganese-stained rock from the trench yielded 2.27 ppm (0.066 oz/ton) gold. Eight samples collected on a spacing of 10 feet in the western trench yielded no gold (21A, **Appendix B**). James E. Bond, II (personal communication, 1986) collected a sample of manganese-stained breccia from the western trench that assayed 0.02 oz/ton Au.

Aquamarine pegmatite; SW sec. 26, T29N, R101W. A rare gem-quality aquamarine beryl crystal and some green beryl crystals were found in a pegmatite of the South Pass granite along Fish Creek. The aquamarine was more than 1 foot long (Elmer C. Winters, personal communication, 1985).

Burnt Meadow prospect; NW sec. 17, T29N, R101W. Sheared Louis Lake granodiorite adjacent to a Proterozoic mafic dike is stained with copper carbonate. A short adit was driven through the unmineralized dike into the granodiorite. One sample of cupriferous granodiorite collected from a pit north of the adit assayed 2.75% copper, 104 ppm (3.03 oz/ton) silver, and 4.03 ppm (0.12 oz/ton) gold (23A, **Appendix B**).

NE sec. 24, T29N, R101W. A pegmatite with a narrow central zone of blue tourmaline, spodumene, and lepidolite was reported at this location (Bayley, 1965a).

NW sec. 32, T29N, R101W. A shallow incline shaft sunk in sheared metagreywacke of the Miners Delight Formation contains minor cupriferous quartz. One selected sample collected from the mine dump yielded 1.54% copper, 4.4 ppm (0.13 oz/ton) silver, and 3.4 ppm (0.1 oz/ton) gold (22A, **Appendix B**).

Crows Nest area

The Crows Nest is a small region between the South Pass-Atlantic City and Lewiston districts. The principal host rock is Miners Delight Formation metagreywacke. Gold and tungsten occur in a small number of strike shears, clusters of discrete quartz veins, and placer deposits. The placers are notable for abundant scheelite (Jim Rutter, personal communication, 1984), and some veins and shears carry scheelite in minor to trace amounts.

Crows Nest; sec. 11, T29N, R99W (**Plate 1**). Gold from this placer is typically rough and coarse, and 2-oz nuggets were occasionally recovered (Spencer, 1916). Scheelite is so abundant that it commonly plugs riffles, making gold recovery inefficient (Jim Rutter, personal communication, 1984).

Maxwell prospect (location unknown). Scheelite is erratically distributed in the country rock as disseminations, seams, and small pockets. A drift from a 40-foot shaft exposed scheelite in the ribs of the mine (Hagner, 1942a).

Metterling prospect; near the Maxwell prospect. A 30-foot shaft was sunk on a scheelite-bearing vein in diorite ranging from a few inches to a few feet wide, with an average width of 1.5 feet. The scheelite is fairly uniform throughout the deposit (Hagner, 1942b).

Dickie Springs-Oregon Gulch district

The Dickie Springs-Oregon Gulch area is located along the southern margin of the South Pass granite-greenstone belt north of Oregon Buttes (**Figure 1**). Oregon Buttes forms a prominent set of buttes on the skyline south of the greenstone belt. From Lander, the area is reached by 41 miles of paved Highway 28 and 6 miles of graded light-duty dirt road.

During the Tertiary, the mountains of the Laramide orogeny were intensely eroded, producing extensive alluvial fans and stream alluvium. Fanglomerates and fluvial conglomerates eroded from greenstone terranes often redistributed large amounts of gold. At South Pass, several gold-bearing conglomerates were deposited within and along the margins of the greenstone terrane.

Gold placers in the Dickie Springs-Oregon Gulch region were discovered along the historic Overland Trail in 1863. But, because of hostilities between the Whites and Indians, the Overland Trail was abandoned between 1864 and 1882, but was later reopened in 1882 after the signing of the Treaty of Five Nations (Greene, 1896). Following the reopening of the trail, gold mining from the alluvial deposits resumed; however, the total amount of gold extracted is not known. The total contained resource in the alluvial gravels may be significant. For instance, Greene (1896) reported the placer gravels contained a resource of about 2.2 million ozs of gold.

Reports by both Greene (1896) and Love and others (1978) suggest that the district, which includes both modern placers and Tertiary paleoplacers, contains significant amounts of gold. However, three factors have restricted development: (1) much of the gold in this region is finely disseminated throughout a boulder-conglomerate facies of the Eocene Wasatch Formation, (2) the district lacks surface water except during the spring (the nearest water source is the Sweetwater River, 6 miles to the north), and (3) no effort has ever been made to systematically sample and run district-wide magnetometer surveys in an effort to identify pay streaks.

The district was examined and sampled by Love and others (1978) and only briefly looked at by the author. Therefore, the original paper by Love and others (1978) should be consulted for details and the following summary is principally abstracted from that paper.

The Dickie Springs-Oregon Gulch district contains rocks of Tertiary age unconformably overlying the Precambrian terrane. Boulder conglomerates of the Wasatch Formation and Recent alluvium eroded from the Wasatch Formation are significant gold-bearing units. The conglomerate facies is separated into a western and an eastern lobe by nearly 2 miles of sandstone and siltstone also of the Wasatch Formation.

The conglomerate facies contains giant boulders in a brown arkosic matrix. The boulder conglomerate is interpreted to represent a large alluvial fan eroded from uplifted Precambrian rocks north of the Continental fault (a boundary fault at the south end of the Wind River Range). The boulders, cobbles, and pebbles found in the conglomerate are typical of the rock types that would be found along the edge of the granite-greenstone belt in a dominantly granitic terrane. Compositions of igneous rocks vary from granitic to ultramafic (mafic and ultramafic rocks are uncommon). Fragments of gneiss and schist are also common. Pebbles and cobbles of metagreywacke typical of the Miners Delight Formation also occur in the conglomerate, but not in great abundance. Some boulders in the conglomerate are as large as a pickup truck and many gold flakes are relatively coarse (averaging about 0.1 inch in diameter), suggesting minimal transport distances. The minimum stratigraphic thickness of the conglomerates is 1,300 feet, with a combined areal extent of 8 square miles.

The paleo-uplift north of the Continental fault has long since readjusted and downfaulted and is now partially buried under the extensive Tertiary cover overlying much of the southern portion of the South Pass granite-greenstone belt. The source area may be under this blanket of Tertiary sediment, or it may be somewhere to the north. Love and others (1978) reported gold-bearing drill cuttings were recovered from a depth of 6,500 to 7,000 feet from an oil well drilled about 0.5 mile north of the fault, suggesting a possible source terrane in that region.

The signature geochemistry of gold from the conglomerate indicates two separate terranes or mineral systems supplied the gold to the conglomerates. Love and others (1978) proposed the gold was eroded from the Precambrian rocks to the north. Geochemical and trace element studies of the Dickie Springs-Oregon Gulch gold suggest it originated from hydrothermal veins in a predominantly granitic terrane (Love and others, 1978). This conclusion suggests that the gold was primarily derived from a region other than the South Pass-Atlantic City district, where the gold is principally associated with metagreywacke and metagabbro rather than granite.

Some of the higher gold concentrations of the Dickie Springs-Oregon Gulch district are found in alluvial deposits north of the Continental fault. These deposits were derived from erosion of the Wasatch boulder conglomerate facies and average only about 0.00105 oz/yd^3 gold (Love and others, 1978). Green (1896) estimated 5,843 acres of placer ground in this area averaged 0.039 oz/yd^3 gold, with local areas of gravel running from as high as 0.73 oz/yd^3 to as low as 0.003 oz/yd^3 gold. The gold is relatively coarse, and many flakes average 0.2 inch in diameter (Love and others, 1978).

Radically different gold concentrations led Love and others (1978) to suggest that the conglomerate to the west, in the Pacific Butte area, was derived from a different source region than the conglomerate east of Dickie Springs. The conglomerate facies on the western end of the district has a very low gold content, with values from <0.00003 to 0.0019 oz/yd^3 gold, whereas the eastern facies averages 0.0026 oz/yd^3 gold and ranges from 0.00002 to 0.1038 oz/yd^3 gold (Love and others, 1978). Considering the grades (even though low) and the vast extent of the conglomerate, the total gold resource must be tremendous. The total gold content estimated in these conglomerates may exceed 28.5 million ozs (Love and others, 1978).

Big Placer paleoplacer; southern portions of secs. 21, 22, 23, and 24, T27N, R100W. Immediately north of the Continental fault and east of Dickie Springs, the Big Placer claims were staked on the basal conglomerate of the Arikaree Formation (Miocene). This is a gold-bearing paleoplacer (Zeller and Stephens, 1969; and unpublished Anaconda Minerals Company report document 56105.28, American Heritage Center, University of Wyoming).

Mcgraw Flats area (Twin Creek paleoplacers)

These paleoplacers are located in T31N, Rs98 to 99W and T30N, Rs98 to 100W (**Figure 1**). Antweiler and others (1980) reported Oligocene gold-bearing conglomerates of the White River Formation located immediately northeast of the South Pass greenstone belt. More than a billion cubic yards of gold-bearing gravel and conglomerate are estimated to occur in this region (Antweiler and others, 1980).

Samples of the White River conglomerate collected by Antweiler and others (1980) averaged 0.0047 oz/yd^3 gold. Some reworked placers contain greater gold concentrations, but like the Oregon Buttes area, no systematic magnetometer surveys have been used to locate potential pay streaks in these paleoplacers.

The conglomerate is interpreted to represent a portion of a giant alluvial fan eroded from the northeastern edge of the greenstone belt. The conglomerate hosts boulders and pebbles of granite and banded iron formation in considerable amounts, with lesser slate, mafic rocks, and Paleozoic rocks (Antweiler and others, 1980). Prospectors generally use the banded iron formation pebbles as a guide to the richer portions of the conglomerate (Hank Hudspeth, Jr., personal communication, 1986). Thus, a magnetometer survey may prove to be valuable in locating high-grade pay streaks.

The source area for the conglomerates was the ancestral headwaters of Twin Creek, which was captured by Beaver Creek (Antweiler and others, 1980). The ancestral headwaters area lies east of the Atlantic City iron mine and is underlain by Louis Lake granodiorite, banded iron formation, and other metasedimentary rocks of the Goldman Meadows Formation, and by metatholeiites of the Roundtop Mountain Greenstone. This 2-square-mile region is presently concealed by White River Formation and stream gravels (see Bayley, 1965c; Hausel, 1987c).

The important implication of this gold-bearing conglomerate is that it may have been derived from a small but very rich undiscovered lode. According to Antweiler and others (1980):

The probability that the source area is still there but is now buried by the White River strata rather than having been completely eroded away during Oligocene time is suggested by (1) the calculated less-than-100-feet of erosion within the drainage basin necessary to provide the volume of debris from the fan, and (2) the decrease in gold content in the White River Formation above the basal conglomerate.

The conglomerates were mined hydraulically in the early 1900s (J. David Love, personal communication, 1986) and probably during the late 1800s. Gold production may have totaled several thousand ozs, but no production records exist. The amount of gold remaining in the conglomerate far exceeds the amount mined (Antweiler and others, 1980).

Red Canyon placers; sec. 36, T31N, R99W, and sec. 31, T31N, R98W. Historical reports suggest the Red Canyon placers may have been salted and their value greatly exaggerated. The placers consist of small isolated outcrops of White River Formation conglomerates (part of the Twin Creek paleoplacers) and are probably gold bearing (see Antweiler and others, 1980, p. 228).

The gravel reportedly averaged about 0.05 oz/yd^3 gold (*The Mining Reporter*, 1907, v. 56, p. 227). Jamison (1911a) estimated about 1,000 ozs of gold were recovered from these placers by hydraulic mining.

Ore genesis

The available data show the South Pass gold deposits to be epigenetic. When the timing of regional metamorphism (2.8 Ga based on the Rb/Sr whole-rock isochron for the Miners Delight Formation, as reported by Z.E. Peterman *in* Stuckless and others, 1985) is considered with the age of mineralization (2.8 Ga based on a model lead date reported by Bayley and others, 1973) it points to a metamorphic gold source for these shear-zone deposits. The copper-sulfide mineralization represents a later event, possibly related to the 2.5 to 2.6 Ga thermal event associated with emplacement of the Louis Lake batholith or other granitoids.

The source of the gold was considered by Bow (1986) to be the east-northeast trending belt of ultramafic schists that extend from South Pass City to the Miners Delight ghost town. Bow's interpretation is based on an intimate relationship between gold content in nearby shear zones and the thickness of the ultramafic schist belt.

Recently, Spry and McGowan (1989) examined the stable isotopes and fluid inclusions associated with some shear structures in the South Pass greenstone belt. The sulfur-isotope analyses were consistent with many other Archean gold deposits worldwide, indicating a deep crustal source. The carbon- and oxygen-isotope ratios for calcite in the shear zones were among the lightest ever recorded for an Archean gold deposit. These data, along with the oxygen and hydrogen isotope data obtained from fluid inclusions in lode quartz, were used to infer that the gold solutions originated either by mixing of meteoric water with a metamorphic component, or from evolved seawater or connate water brine. The compositions of fluid inclusions support the latter. The most likely explanation for the formation of the lode deposits based on this information would be for the transporting fluids to have been derived by dewatering from the Miners Delight Formation greywackes during compaction (Spry and McGowan, 1989).

Unfortunately, these source-rock concepts do not explain why:

(1) Gold is ubiquitous in the greenstone belt and is not confined to the Miners Delight Formation, nor to zones in or immediately adjacent to the ultramafic rocks. For example, gold anomalies have been detected throughout the greenstone belt, although there is a noted paucity of gold in the Diamond Springs Formation. This lack of measurable gold in the Diamond Springs Formation could be partially due to insufficient sampling density, although no mines and very few prospect pits occur in this unit.

(2) Auriferous shear zones are not confined to any particular rock type but occur in a variety of rock types, including metagreywacke, amphibolite, meta-andesite, graphitic schist, actinolite schist, chlorite schist, and greenstones. Auriferous quartz veins occur in metagreywacke, actinolite schist, and metatonalite porphyry.

(3) More than one gold-mineralizing event affected the greenstone belt and each exhibits different signatures.

The variety of host rocks containing gold-bearing shear structures suggests the greenstone belt was invaded by mineralizing fluids that were channeled by permeable shear zones. It is possible that the main gold mineralization event occurred during regional metamorphism and deformation, when gold was secreted from the lower levels of the greenstone belt and carried into permeable fractures parallel to foliation and bedding. Portions of the fractures were locally upgraded along favorable structures (folding, shear intersections, etc.).

More than one gold-mineralization event appears to have affected the greenstone terrane. In addition to the initial gold-dominated event, a later predominantly discordant copper-sulfide mineralizing event with associated gold and silver occurred in the belt. Although the source of this mineralization is unknown, it is noteworthy that these deposits are more common near the margins of the greenstone belt. Similar mineralization is found in stockworks at the granodiorite-greenstone contact and in a narrow shear structure in the Louis Lake granodiorite along the northwestern margin of the belt. Thus, this later event may have been related to the final stages of crystallization of the granodiorite.

Localized areas of the greenstone belt were overprinted by greenschist-facies assemblages related to the 2.6 Ga granodiorite and granite. Epidotization related to this event may have mobilized some gold as well as copper. Condie and others (1977) reported progressive epidotization is accompanied by increases of gold as well as copper.

Bayley and others (1973) reported a late Precambrian retrograde metamorphic event (1.4 Ga). Mineralization has not been tied to this event. However, there is a possibility of redistribution of gold during the Late Cretaceous-Early Tertiary Laramide orogeny. For example, some ore shoots occur at intersections of Laramide faults with Archean shears. These shoots may document supergene enrichment as a result of greater fracture permeability. Such shoots would be localized at the ground-water level.

Suggestions for exploration

This project resulted in the recognition of many geochemical anomalies in several areas of the greenstone belt. Follow-up studies on these anomalies are needed to fully evaluate the potential for ore deposits.

During mapping and sampling of the gold anomalies and deposits, several important relationships were observed. For example, the greenstone belt includes several previously undescribed areas that contain common discrete foliation-parallel veins and veinlets. The importance of these as potential low-grade gold deposits was emphasized by samples chipped from the Roundtop Mountain Greenstone, which yielded 9.5 ppm (0.277 oz/ton) gold (92A, **Appendix B**). Many of these veins remain unsampled, and many other inadequately sampled gold anomalies occur in the region.

Some deposits that need additional sampling include:

(1) Envelopes of low-grade mineralization that may be potential large-volume deposits. These types of deposits, identified at the Carissa mine, the Duncan mine, the Lone Pine mine, and the Wolf mine during this study, may be relatively common in the belt.

(2) High-grade ore shoots occurring within fold closures, pinches, and shear-zone intersections. Examples of these were seen at the Mint mine, where 2.5-foot channel samples containing up to 104.6 ppm (3.05 oz/ton) gold were collected at a pinch in a regional shear; at the Duncan mine, where enhanced gold values of 33.0 ppm (0.96 oz/ton) were detected in a fold closure; and at the Hidden Hand mine, where shear intersections reportedly yielded samples that contained more than 10% gold.

I also recommend the use of geophysical and remote-sensing surveys designed to detect hidden permeable shear zones containing disseminated sulfides. Our discovery of the hidden auriferous shear at the Lone Pine mine suggests similar buried structures occur in the belt.

The search for base metals in the belt offers some potential. The copper-silver stockwork discovered west of the Atlantic City iron mine is poorly exposed in an aspen-filled drainage, thus the size and extent are unknown. Banded iron formation in the vicinity of the Atlantic City mine occurs as a sizable resource of millions of tons of taconite supplemented by a smaller resource south of Diamond Springs. Although no significant chromium or nickel occurrences are reported in the district, the high-magnesium schists in the Diamond Springs Formation may indicate some potential for these metals. Nickel prospectors should concentrate on gossans near the base of ultramafic flows, since mineable nickel occurs as a sulfide.

The search for commercial tungsten deposits in the greenstone belt should be confined to large-tonnage, low-grade deposits with supplemental gold values. No such deposit is known to occur in the greenstone belt, but possibilities occur in areas with abundant veins and veinlets. Initial exploration should be geared to areas where known scheelite deposits are found, at Crows Nest and Lewiston.

Finally, prospecting for gems requires detailed examination of a variety of rocks. Aquamarine and tourmaline are confined to pegmatites in the Anderson Ridge area. Nephrite jade is commonly associated with ultramafic and mafic rocks and has been reported in the Prospect Mountains, near the western margin of the greenstone belt. Although no kimberlite intrusives have been reported in the greenstone belt, one diamond was reportedly recovered from a placer deposit in the 1800s. Diamondiferous kimberlite could occur anywhere in the granitic, gneissic, or supracrustal terrane. Exploration for diamond deposits requires labor-intensive sediment-sampling surveys to search for satellite indicator minerals or remote sensing surveys to search for anomalous structures similar to those recognized in the Colorado-Wyoming State Line district.

Conclusions

The petrologic, geochemical, and structural features of the South Pass granite-greenstone belt are characteristic of an Archean greenstone belt that has been subjected to greenschist- and amphibolite-grade regional metamorphism. The belt consists of a tripartite succession of metamorphosed plutonic, sedimentary, and volcanic rock that has been folded into a regional synclinorium displaying many parallel structural elements. Metaigneous rocks include rocks with komatiitic, tholeiitic, and calc-alkaline chemistry, and metasedimentary rocks include pelites, banded iron formation, and arenites. However, the entire section is dominated by metagreywacke similar to some metasedimentary subprovinces in the Canadian Shield. Known mineral deposits in the belt are typical of those found in similar greenstone terranes in the world.

It will require adequate exploration of the South Pass greenstone belt to prove the presence or absence of commercial mineral deposits. This study has identified many encouraging anomalies. These anomalies, coupled with the favorable geological setting, suggest the potential for discovery of significant mineral deposits is considerable. There is a possibility for several small commercial placer and lode-gold deposits, as well as potential for one of more world-class deposits.

References cited

Anhaeusser, C.R., 1976, The nature and distribution of Archean gold mineralization in Southern Africa: Mineral Science and Engineering, v. 8, no. 1, p. 46-84.

Anhaeusser, C.R., 1981, Barberton excursion guidebook — Archean geology of the Barberton Mountain Land: Geological Society of South Africa Geocongress '81, 78 p.

Anonymous, 1910, Syndicate company number one — XL Gold Dredging Company: Geological Survey of Wyoming mineral files (unpublished prospectus), 8 p.

Anonymous, 1916, South Pass district—greatest gold mining camp in the state being developed: Geological Survey of Wyoming mineral files (unpublished), 1 p.

Antweiler, J.C., and Campbell, W.L., 1977, Application of gold compositional analyses to mineral exploration in the United States: Journal of Geochemical Exploration, v. 8, p. 17-29.

Antweiler, J.C., Love, J.D., Mosier, E.L., and Campbell, W.L., 1980, Oligocene gold-bearing conglomerate, southeast margin of the Wind River Range, Wyoming: Wyoming Geological Association 32nd Annual Field Conference Guidebook, p. 223-237.

Archibald, N.J., Bettenay, L.F., Binns, R.A., Groves, D.T., and Gunthorpe, R.J., 1978, The evolution of Archean greenstone terrains, eastern Goldfields Province, Western Australia: Precambrian Research 6, p. 103-131.

Armstrong, F.C., 1948, Preliminary report on the geology of the Atlantic City-South Pass mining district, Wyoming: U.S. Geological Survey Open File Report [48-1], 64 p.

Arndt, N.T., 1976, Ultramafic rocks of Munro Township: economic and tectonic implications: Geological Association of Canada Special Paper 14, p. 617-657.

Arndt, N.T., and Nisbet, E.G., 1982, What is a komatiite?, *in* Arndt, N.T., and Nisbet, E.G., editors, Komatiites: George Allen & Unwin, London, p. 19-27.

Balsam, R.C., Jr., 1986, Geology and geophysics of the South Pass area, Fremont County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 100 p.

Bane, J.R., 1929, Report on the B & H Mining Company: Geological Survey of Wyoming Mineral Report 29-2 (unpublished), 10 p.

Barker, F., Millard, H.T., Jr., and Lipman, P.W., 1979, Four low-K siliceous rocks of the western U.S.A., *in* Barker, F., editor, Trondhjemites, dacites, and related rocks: Elsevier, Amsterdam, p. 415-433.

Bartlett, A.B., and Runner, J.J., 1926, Atlantic City, South Pass gold mining district: Geological Survey of Wyoming Bulletin 20, 23 p.

Bassett, W.A., and Giletti, B.J., 1963, Precambrian ages in the Wind River Range, Wyoming: Geological Society of America Bulletin, v. 74, p. 209-212.

Bayley, R.W., 1963, Preliminary report on the Precambrian iron deposits near Atlantic City, Wyoming: U.S. Geological Survey Bulletin 1142-C, 23 p.

Bayley, R.W., 1965a, Geologic map of the South Pass City Quadrangle, Fremont County, Wyoming: U.S. Geological Survey Geologic Quadrangle Map GQ-458, scale 1:24,000.

Bayley, R.W., 1965b, Geologic map of the Atlantic City Quadrangle, Fremont County, Wyoming: U.S. Geological Survey Geologic Quadrangle Map GQ-459, scale 1:24,000.

Bayley, R.W., 1965c, Geologic map of the Miners Delight Quadrangle, Fremont County, Wyoming: U.S. Geological Survey Geologic Quadrangle Map GQ-460, scale 1:24,000.

Bayley, R.W., 1965d, Geologic map of the Louis Lake Quadrangle, Fremont County, Wyoming: U.S. Geological Survey Geologic Quadrangle Map GQ-461, scale 1:24,000.

Bayley, R.W., 1968, Ore deposits of the Atlantic City district, Fremont County, Wyoming, *in* Ridge, J.D., editor, Ore deposits of the United States, 1933-1967: American Institute of Mining Engineers, p. 589-604.

Bayley, R.W., Proctor, P.D., and Condie, K.C., 1973, Geology of the South Pass area, Fremont, County, Wyoming: U.S. Geological Survey Professional Paper 793, 39 p.

Beeler, H.C., 1908, A brief review on the South Pass gold district, Fremont County, Wyoming: Office of the State Geologist, miscellaneous printed report, Cheyenne, Wyoming, 23 p.

Berg, R.R., 1983, Geometry of the Wind River thrust, Wyoming, *in* Lowell, J.D., editor, Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists, p. 257-262.

Blackstone, D.L., Jr., 1989, Precambrian basement map of Wyoming: outcrop and structural configuration: Geological Survey of Wyoming Map Series 27, scale 1:1,000,000.

Bow, C.S., 1986, Structural and lithologic controls on Archean greywacke-hosted gold mineralization in the Sweetwater district, Wyoming, U.S.A., *in* Keppie, J.D., Boyle, R.W., and Hanes, S.J., editors, Turbidite-hosted gold deposits: Geological Association of Canada Special Paper 32, p. 107-118.

Condie, K.C., 1967, Geochemistry of early Precambrian greywackes from Wyoming: Geochimica et Cosmochimica Acta, v. 31, p. 2135-2149.

Condie, K.C., 1972, A plate tectonics evolutionary model of the South Pass Archean greenstone belt, southwestern Wyoming: Proceedings of the 24th International Geological Congress, p. 104-112.

Condie, K.C., 1976a, Trace element geochemistry of Archean greenstone belts: Earth Science Reviews, v. 12, p. 393-417.

Condie, K.C., 1976b, The Wyoming Province in the western United States, *in* Windley, B.F., editor, The early history of the Earth: John Wiley & Sons, New York, p. 499-510.

Condie, K.C., 1981, Archean greenstone belts: Elsevier, Amsterdam, 434 p.

Condie, K.C., and Baragar, W.R., 1974, Rare-earth element distributions in volcanic rocks from Archean greenstone belts: Contributions to Mineralogy and Petrology 45, p. 237-246.

Condie, K.C., Leach, A.P., and Baadsgaard, H., 1969, Potassium-argon ages of Precambrian mafic dikes in Wyoming: Geological Society of America Bulletin, v.80, p. 899-906.

Condie, K.C., Macke, J.E., and Reimer, T.O., 1970, Petrology and geochemistry of early Precambrian greywackes from the Fig Tree Group, South Africa: Geological Society of America Bulletin, v. 81, p. 2759-2776.

Condie, K.C., Viljoen, M.J., and Kable, E.J.D., 1977, Effects of alteration on element distributions in Archean tholeiites from the Barberton greenstone belt, South Africa: Contributions to Mineralogy and Petrology 64, p. 75-89.

Curran, H.T., 1926, Report on the Carissa mining property: Geological Survey of Wyoming Mineral Report 26-1 (unpublished), 9 p.

Day, W.C., Hill, R.H., Kulik, D.M., Scott, D.C., and Hausel, W.D., 1988, Mineral resources of the Sweetwater Canyon Wilderness study area, Fremont County, Wyoming: U.S. Geological Survey Professional Paper 1757-D, 22 p.

Denson, N.M., Zeller, H.D., and Stephens, E.V., 1965, South Pass Formation on the southwest flank of Wind River Range, Wyoming; U.S. Geological Survey Bulletin 1224-A, p. 27-29.

de Quadros, A.M., 1989, Report on the diamond drill program, July-August 1989, at the Carissa mine property, South Pass City, Fremont County, Wyoming: Property report for Consolidated McKinney Resources, Limited, Vancouver, British Columbia, Canada, 76 p.

Dietz, C.S., 1932, Electrometallurgical resources of the North Platte River Basin, Wyoming: Geological Survey of Wyoming Bulletin 23, 235 p.

Donaldson, M.J., Lesher, C.M., Groves, D.I., and Gresham, J.J., 1986, Comparison of Archean dunites and komatiites associated with nickel mineralization in Western Australia: implications for dunite genesis: Mineralium Deposita 21, p. 296-305.

El-Etr, H.A., 1963, Pegmatites of the Anderson Ridge Quadrangle, Fremont County, Wyoming: M.S. thesis, University of Missouri-Rolla, 102 p.

Giletti, B.J., and Gast, P.W., 1961, Absolute age of Precambrian rocks of Wyoming and Montana: New York Academy of Science Annals, v. 91, p. 454-458.

Glikson, A.Y., 1971, Primitive Archean element distribution patterns: chemical evidence and geotectonic significance: Earth and Planetary Science Letters, v. 12, p. 309-320.

Graff, P.J., Sears, J.W., Holden, G.S., and Hausel, W.D., 1982, Geology of the Elmers Rock greenstone belt, Laramie Range, Wyoming: Geological Survey of Wyoming Report of Investigations 14, 22 p.

Greene, E.A., 1896, Oregon Butte placer mines, Fremont County, Wyoming: University of Wyoming Archives (unpublished), 27 p.

Groves, D.I., and Hudson, D.R., 1981, The nature and origin of Archaean strata-bound volcanic-associated nickel-iron-copper sulphide deposits, *in* Wolf, K.H., editor, Handbook of strata-bound and stratiform ore deposits: Elsevier Publishing Company, New York, p. 305-409.

Groves, D.I., Phillips, G.N, Ho, S.E., and Houstoun, S.M., 1985, The nature, genesis, and regional controls of gold mineralization in Archean greenstone belt of the western Australian shield: a brief review: Transactions of the Geological Society of South Africa 88, p. 135-148.

Gupta, V.K., Thurston, P.C., and Dusanowskyj, T.H., 1982, Constraints upon models of greenstone belt evolution by gravity modelling, Birch-Uchi greenstone belt, northern Ontario: Precambrian Research 16, p. 233-255.

Haff, J.C., 1944, Big Nugget gold placer claims: Geological Survey of Wyoming Mineral Report 44-1 (unpublished), 2 p.

Hagner, A.F., 1942a, Maxwell tungsten claims at Lewiston: Geological Survey of Wyoming Mineral Report 42-32 (unpublished), 1 p.

Hagner, A.F., 1942b, Field notes on the Metterling scheelite claim: Geological Survey of Wyoming Mineral Report 42-33 (unpublished), 1 p.

Hale, William, 1883, Report of the Governor of Wyoming, *in* Report of the Secretary of Interior to the 48th Congress, 1st Session, Executive Document 1, part 5: Washington, D.C., p. 589-599.

Harper, G.D., 1985, Dismembered Archean ophiolite, Wind River Range, Wyoming (USA): Ofioliti, v. 10, p. 297-306.

Harper, G.D., 1986, Dismembered Archean ophiolite in the southeastern Wind River Mountains, Wyoming—remains of Archean oceanic crust, *in* DeWit, M.J., and Ashwal, L.D., editors, Workshop on tectonic evolution of greenstone belts: Lunar and Planetary Institute LPI Technical Report 86-10, p. 108-110.

Harrer, C.M., 1966, Wyoming iron-ore deposits: U.S. Bureau of Mines Information Circular 8315, 112 p.

Harris, R.E., and Hausel, W.D., 1986, Wyoming pegmatites, *in* Modreski, P.J., editor, Colorado pegmatites: Colorado Pegmatite Symposium, Colorado Chapter, Friends of Mineralogy, Denver, p. 101-108.

Harris, R.E., Hausel, W.D., and Meyer, J.E., 1985, Metallic and industrial minerals map of Wyoming: Geological Survey of Wyoming Map Series 14, scale 1:500,000.

Hausel, W.D., 1980, Gold districts of Wyoming: Geological Survey of Wyoming Report of Investigations 23, 71 p.

Hausel, W.D., 1984, Tour guide to the geology and mining history of the South Pass gold mining district, Fremont County, Wyoming: Geological Survey of Wyoming Public Information Circular 23.

Hausel, W.D., 1986a, Preliminary report on the geology and gold mineralization of the South Pass greenstone belt, Wind River Range, Wyoming: Society of Mining Engineers of AIME, Preprint 86-15, 10 p.

Hausel, W.D., 1986b, Geologic map of the Lewiston gold district, Radium Springs Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 86-25, scale 1:24,000.

Hausel, W.D., 1986c, Geologic map of the Anderson Ridge Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 86-26, scale 1:24,000.

Hausel, W.D., 1986d, Preliminary report on the geology and gold mineralization of the South Pass granite-greenstone terrane, Wind River Range, western Wyoming (U.S.A.), *in* deWit, M.J., and Ashwal, L.D., editors, Workshop on tectonic evolution of greenstone belts: Lunar and Planetary Institute Technical Report 86-10, p. 114-115.

Hausel, W.D., 1987a, Structural control of Archean gold mineralization within the South Pass greenstone terrain, Wyoming (U.S.A.), *in* Hurst, R.W., Davis, T.E., and Augustithis, S.S., editors, The practical applications of trace elements and isotopes to environmental biogeochemistry and mineral resources evaluation: Theophrastus Publications, Athens, Greece, p. 199-216.

Hausel, W.D., 1987b, Preliminary report on the gold mineralization, petrology, and geochemistry of the South Pass granite-greenstone belt, Wind River Range, Wyoming: Wyoming Geological Association 38th Annual Field Conference Guidebook, p. 287-304, 1 plate.

Hausel, W.D., 1987c, Revised geologic map of the Miners Delight Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 87-10, scale 1:24,000.

Hausel, W.D., 1988a, Revised geologic map of the South Pass City Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 88-2, scale 1:24,000.

Hausel, W.D., 1988b, Preliminary geologic map of the Lewiston Lakes Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 88-3, scale 1:24,000.

Hausel, W.D., 1988c, Revised geologic map of the Atlantic City Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Map Series 28, scale 1:24,000.

Hausel, W.D., 1988d, Reconnaissance geologic map of the Halls Meadow Springs Quadrangle, Fremont and Sublette Counties, Wyoming: Geological Survey of Wyoming Open File Report 88-8, scale 1:24,000.

Hausel, W.D., 1988e, Revised geologic map of the Louis Lake Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 88-12, scale 1:24,000.

Hausel, W.D., 1988f, Geologic map of the Radium Springs Quadrangle (including the Lewiston gold district), Fremont County, Wyoming: Geological Survey of Wyoming Map Series 26, scale 1:24,000.

Hausel, W.D., 1989, The geology of Wyoming's precious metal lode and placer deposits: Geological Survey of Wyoming Bulletin 68, 248 p.

Hausel, W.D., 1990, Archean gold mineralization within the South Pass greenstone terrain, Wyoming, *in* Hollister, V.F., editor, Case histories of mineral discoveries, vol. 2: Discoveries of valuable minerals and precious metals deposits related to intrusions and faults: Society of Mining, Metallurgy, and Exploration, Inc., of AIME, Littleton, Colorado, 438 p.

Hausel, W.D., and Hull, J., 1990, Guide to gold mineralization and Archean geology of the South Pass greenstone belt, Wind River Range, Wyoming, *in* Roberts, Sheila, editor, Geologic field tours of western Wyoming and parts of adjacent Idaho, Montana, and Utah: Geological Survey of Wyoming Public Information Circular 29, p.179-191.

Hausel, W.D., Sutherland, W.M., and Gregory, E.B., 1988, Stream-sediment sample results in search of kimberlite intrusives in southeastern Wyoming: Geological Survey of Wyoming Open File Report 88-11, 11 p.

Henderson, C.W., 1926, Gold, silver, and copper in Wyoming: U.S. Bureau of Mines Minerals Yearbook, 1925, p. 623-624.

Henderson, J.B., 1972, Sedimentology of Archean turbidites at Yellowknife, Northwest Territories:

Canadian Journal of Earth Sciences, v. 9, p. 882-902.

Herrmann, A.G., Blanchard, D.P., Haskin, L.A., Jacobs, J.W., Knake, D., Koroter, R.L., and Brannon, J.C., 1976, Major, minor, and trace element compositions of peridotitic and basaltic komatiites from the Precambrian crust of southern Africa: Contributions to Mineralogy and Petrology, 59, p. 1-12.

Hodge, D.S., 1963, Polymetamorphism of Precambrian rocks in the southwestern Wind River Range, Fremont County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 49 p.

Hodge, D.S., and Worl, R.G., 1965, Multiple metamorphic episodes of Precambrian rocks near South Pass City, Wyoming: Contributions to Geology, University of Wyoming, v. 4, no. 2, p. 51-57.

Houston, R.S., and Karlstrom, K.E., 1979, Uranium-bearing quartz-pebble conglomerates — exploration model and United States resource potential: U.S. Department of Energy Open File Report GJBX-1(80), 510 p.

Hull, J.M., 1988, Structural and tectonic evolution of Archean supracrustals, southern Wind River Range, Wyoming: Ph.D. thesis, University of Rochester, New York, 280 p.

Jamison, C.E., 1911a, Geology and mineral resources of a portion of Fremont County, Wyoming: Geological Survey of Wyoming Bulletin 2, Series B, 90 p.

Jamison, C.E., 1911b, The South Pass gold district, Wyoming: Mining Science, v. 64, p. 575-576.

Kalish, R.S., 1982, Structural geology and petrology of a portion of the Miners Delight Quadrangle, Wyoming: M.A. thesis, University of Missouri-Columbia, 62 p.

Karlstrom, K.E., Houston, R.S., Flurkey, A.J., Coolidge, C.M., Kratochvil, A.L., and Sever, C.K., 1981, A summary of the geology and uranium potential of Precambrian conglomerates in southeastern Wyoming, v. 1: U.S. Department of Energy Open File Report GJBX-139(81), 541 p.

Kerrich, R., 1983, Geochemistry of gold deposits in the Abitibi greenstone belt: Canadian Institute of Mining and Metallurgy Special Volume 27, 75 p.

Kerrich, R., 1986, Archaean lode gold deposits of Canada, part 2, Characteristics of the hydrothermal systems and models of origin: Economic Geology Research Unit Information Circular 183, University of Witwatersrand, Johannesburg, South Africa, 34 p.

Klein, T.L., 1981, The geology and geochemistry of the sulfide deposits of the Seminoe district, Carbon County, Wyoming: Ph.D. thesis, Colorado School of Mines, Golden, 232 p.

Knight, W.C., 1893, Notes on the mineral resources of the state: University of Wyoming Experimental Station Bulletin 14, p. 103-212.

Knight, W.C., 1901, The Sweetwater mining district, Fremont County, Wyoming: Bulletin of the University Geological Survey of Wyoming, the School of Mines, University of Wyoming, Laramie, 35 p.

Koschmann, A.H., and Bergendahl, M.H., 1968, Principal gold producing districts of the United States: U.S. Geological Survey Professional Paper 610, 283 p.

Kyner, T., 1907, Report on the geology of the Miners Delight Group: Geological Survey of Wyoming Mineral Report 07-4 (unpublished), 10 p.

The Lewiston Gold Miner, 1894: Lewiston, Wyoming, v. 1, no. 1, 8 p.

Lipke, A.C., 1978, Geology and petrology of the northeastern quarter of the Anderson Ridge Quadrangle, Wyoming: M.A. thesis, University of Missouri-Columbia, 79 p.

Lo, H.H., 1970, Geochemistry of the Lewis Lake pluton, southwestern Wyoming: Ph.D. thesis, Washington University, St. Louis, Missouri, 123 p.

Love, J.D., Antweiler, J.C., and Mosier, E.L., 1978, A new look at the origin and volume of the Dickie Springs-Oregon Gulch placer gold at the south end of the Wind River Range: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 379-391.

Ludden, J.N., and Gelinas, L., 1982, Trace element characteristics of komatiites and komatiitic basalts from the Abitibi metavolcanic belt of Quebec, *in* Arndt, N.T., and Nisbet, E.G., editors, Komatiites: George Allen & Unwin, London, p. 331-346.

Markwell, K.E., 1973, Petrology and structure of the northwest quarter of the Anderson Ridge Quadrangle, Wyoming: M.A. thesis, University of Missouri-Columbia, 44 p.

Marston, R.J., Groves, D.I., Hudson, D.R., and Ross, J., 1981, Nickel sulfide deposits in Western Australia: a review: Economic Geology, v. 76, no. 6, p. 1330-1363.

Naldrett, A.J., and Campbell, I.H., 1982, Physical constraints on genetic models for komatiite-related Ni-sulphide deposits, *in* Arndt, N.T., and Nisbet, E.G., editors, Komatiites: George Allen & Unwin, London, p. 423-434.

Naqvi, S.M., and Hussain, S.M., 1973a, Geochemistry of Dharwar metavolcanics and composition of the primeval crust of the peninsular India: Geochimica et Cosmochimica Acta, v. 37, p. 159-164.

Naqvi, S.M., and Hussain, S.M., 1973b, Relation between trace and major element composition of the Chitaldrug metabasalts, Mysore, India, and the Archean Mantle: Chemical Geology 11, p. 17-30.

Naylor, R.S., Steiger, R.H., and Wasserburg, G.J., 1970, U-Th-Pb and Rb-Sr systematics in 2,700 ± 106-year-old plutons from the southern Wind River Range, Wyoming: Geochimica et Cosmochimica Acta, v. 34, p. 1133-1159.

Nesbitt, R.W., Sun, S., and Purvis, A.C., 1979, Komatiites: geochemistry and genesis: Canadian Mineralogist, v. 17, p. 165-186.

Pearton, T.N, 1980, The geochemistry of the carbonate and related rocks of the Antimony Line, Murchison greenstone belt, with particular reference to their genesis and to the origin of stibnite mineralization: Ph.D. thesis, University of Witwatersrand, Johannesburg, South Africa, 270 p.

Pearton, T.N, 1982, Gold and antimony mineralization in altered komatiites of the Murchison greenstone belt, South Africa, *in* Arndt, N.T., and Nisbet, E.G., editors, Komatiites: George Allen & Unwin, London, p. 459-475.

Peterman, Z.E., 1979, Geochronology and the Archean of the United States: Economic Geology, v. 74, p. 1544-1563.

Peterman, Z.E., and Hildreth, R.A., 1978, Reconnaissance geology and geochronology of the Precambrian of the Granite Mountains, Wyoming: U.S. Geological Survey Professional Paper 1055, 22 p.

Pfaff, B.C., 1978, Atlantic City nuggets: Baroil, Wyoming, 155 p.

Phillips, G.N, 1985, Interpretation of the Big Bell/Hemlo-type gold deposits: precursors, metamorphism, melting, and genetic constraints: Transactions of the Geological Society of South Africa, v. 88, p. 159-173.

Prinz, W.C., 1974, Map showing geochemical data for the Atlantic City gold district, Fremont County, Wyoming: U.S. Geological Survey Miscellaneous Investigations Map I-865, scale 1:24,000.

Procter, P.D., and El-Etr, H.A., 1968, Layered pegmatites, southern Wind River Range, Fremont County, Wyoming: Economic Geology, v. 63, p. 595-611.

Ross, C.L., and Gardner, E.D., 1935, Placer methods of the E.T. Fisher Company, Atlantic City, Wyoming: U.S. Bureau of Mines Information Circular 6846, 11 p.

Smaglik, S.M., 1987, Petrogenesis and tectonic implications for Archean mafic and ultramafic magmas in the Elmers Rock greenstone belt, Laramie Range, Wyoming: M.S. thesis, Colorado School of Mines, Golden, 126 p.

Snyder, G.L, Hausel, W.D., Klein, T.L., Houston, R.S., and Graff, P.J., 1989a, Precambrian rocks and mineralization, Wyoming Province, guide to field trip T-332: 28th International Geological Congress, Washington, D.C., 48 p.

Snyder, G.L., Hughes, D.J., Hall, R.P., and Ludwig, K.R., 1989b, Distribution of Precambrian mafic intrusives penetrating some Archean rocks of western North America: U.S. Geological Survey Open File Report 89-125, 36 p.

Spall, H., 1971, Paleomagnetism and K-Ar age of mafic dikes from the Wind River Range, Wyoming: Geological Society of America Bulletin, v. 82, p. 2457-2472.

Spencer, A.C., 1916, The Atlantic gold district and the north Laramie Mountains: U.S. Geological Survey Bulletin 626, 85 p.

Springer, J.S., 1985, Carbon in Archean rocks of the Abitibi belt (Ontario-Quebec) and its relationship to gold distribution: Canadian Journal of Earth Science, v. 22, p. 1945-1951.

Spry, P.G., and McGowan, K.I., 1989, Origin of Archean lode gold mineralization at Atlantic City-South Pass, Wyoming: fluid inclusion and stable isotope study [abstract]: 28th International Geological Congress, Washington, D.C., p. 3-163.

Steidtmann, J.R., and Middleton, L.T., 1986, Eocene-Pliocene stratigraphy along the southern margin of the Wind River Range, Wyoming: revisions and implications from field and fission-track studies: The Mountain Geologist, v. 23, no. 1, p. 19-25.

Stuckless, J.S., Hedge, C.E., Worl, R.G., Simmons, K.R., Nkomo, I.T., and Wenner, D.B., 1985, Isotopic studies of the late Archean plutonic rocks of the Wind River Range, Wyoming: Geological Society of America Bulletin, v. 96, p. 850-860.

Sun, S.S., 1984, Geochemical characteristics of Archaean ultramafic and mafic volcanic rocks: implications for mantle composition and evolution, *in* Kroner, A., Hanson, G.N., and Goodwin, A.M., editors, Archean geochemistry: Springer-Verlag, New York, p. 25-46.

Sun, S.S., and Nesbitt, R.W., 1978, Petrogenesis of Archean ultrabasic and basic volcanics: evidence from rare-earth elements: Contributions to Mineralogy and Petrology, v. 65, p. 301-325.

Talpey, J.G., 1984, Geochemical and structural evolution of Archean gneisses at South Pass, Wyoming: M.S. thesis, University of Rochester, New York, 102 p.

Trumbull, L.W., 1914, Atlantic City gold mining district, Fremont County: Geological Survey of Wyoming Bulletin 7, 100 p.

Turelle, J.W., 1981, Personal letter to W.D. Hausel about the Duncan mine dated January 21, 1981: Geological Survey of Wyoming files (unpublished), 3 p.

Viljoen, M.J., and Viljoen, R.P., 1969, The geology and geochemistry of the lower ultramafic unit of the Onverwacht Group and a proposed new class of igneous rock: Geological Society of South Africa Special Publication 2, p. 55-86.

Weis, N.D., 1974, Ghost towns of the Northwest: The Caxton Printers, Ltd., Caxton, Idaho, 240 p.

Wildeman, T.R., and Condie, K.C., 1973, Rare earths in Archean greywackes from Wyoming and from the Fig Tree Group, South Africa: Geochimica et Cosmochimica Acta, v. 37, p. 439-453.

Wilson, W.H., 1951, A scheelite deposit near Lewiston, Fremont County, Wyoming: Geological Survey of Wyoming, Mineral Report 51-5 (unpublished), 3 p.

Wilson, W.H., 1953, Notes on the Wyoming Mica and Metals Corporation, Fremont County, Wyoming: Geological Survey of Wyoming Mineral Report 53-1 (unpublished), 2 p.

Worl, R.G., 1963, Superposed deformations in Precambrian rocks near South Pass, Wyoming: Contributions to Geology, v. 2, no. 2, p. 109-116.

Yunker, G.G., 1979, Structural geology and petrology of the South Pass City area, Wyoming: M.A. thesis, University of Missouri-Columbia, 48 p.

Zeller, H.D., and Stephens, E.V., 1969, Geology of the Oregon Buttes area, Sweetwater, Sublette, and Fremont Counties, southwestern Wyoming: U.S. Geological Survey Bulletin 1256, 60 p.

Appendices

A. Chemical analyses of rocks from the South Pass granite-greenstone belt and comparable rocks from elsewhere in the world.

A1. Whole-rock analyses for selected rocks of the gneiss complex.

A2. Whole-rock and trace element analyses of Diamond Springs Formation ultramafic schists and serpentinites.

A3. Major- and trace-element analyses of mafic schists and amphibolites of the Diamond Springs Formation.

A4. Major- and trace-element analyses for selected samples of the Goldman Meadows Formation.

A5. Major- and trace-element analyses of Roundtop Mountain Greenstone rocks.

A6. Major- and trace-element analyses of Miners Delight Formation metasedimentary rocks.

A7. Major- and trace-element analyses of Miners Delight Formation metaigneous rocks.

A8. Chemical analyses of some plutonic and related rocks.

Appendix A1. Whole-rock analyses for selected rocks of the gneiss complex.

	Sample numbers															
	1B	2B	3B	4B	5B	6B	7B	8B	9B	10B	11B	12B	13B	14B	15B	16B
SiO_2(%)[1]	73.70	87.60	72.94	75.40	70.14	66.27	58.90	57.70	55.20	50.18	44.70	39.80	42.30	37.32	49.33	52.80
Al_2O_3	14.50	5.76	13.43	13.60	15.08	14.57	18.70	18.50	15.70	19.65	16.30	27.70	3.98	21.80	23.72	2.08
TiO_2	0.15	0.21	0.24	0.12	0.37	0.50	0.83	0.63	1.15	0.18	1.28	1.08	0.83	1.07	0.70	0.11
Fe_2O_3	1.14	1.79	3.04	1.24	3.63	2.25	5.21	8.63	9.31	5.63	14.80	12.90	18.60	14.34	8.26	41.30
FeO						1.95										
MnO	0.03	0.03	0.03	<0.02	0.05	0.06	0.09	0.06	0.14	0.09	0.22	0.18	0.26	0.27	0.06	0.09
MgO	0.41	1.22	0.45	0.41	1.22	1.76	1.61	5.40	3.92	8.40	7.78	6.50	25.60	14.49	5.26	2.20
CaO	1.57	0.19	1.20	1.43	3.34	3.61	8.96	0.26	8.44	11.34	12.40	0.31	5.04	2.49	0.27	1.75
Na2O	3.70	1.41	3.23	3.98	3.86	3.81	4.11	0.74	3.72	1.94	0.86	0.01	0.32	1.29	4.27	<0.01
K2O	4.47	0.59	4.81	2.96	1.36	2.94	0.72	3.48	0.43	0.88	0.29	5.93	0.08	1.47	3.64	0.16
P_2O_5	0.04	0.03	0.22	0.15	0.23	0.23	0.25	<0.05	0.36	0.13	0.09	0.03	0.02	0.06	0.14	0.04
LOI	0.54	1.16	0.33	0.92	0.58	0.80	0.85	4.55	0.70	1.33	1.08	5.70	1.05	4.30	4.23	<0.61
TOTAL (%)	100.25	99.99	99.92	100.21	99.86	98.75	100.23	99.95	99.07	99.75	99.80	100.14	98.08	98.90	99.88	100.53
Ag[2]		<0.5		<2				<2		0.5	<0.5	<0.5				<0.5
As		2		<10				<10		25	<2	2				3
Au (ppb)		<10	<5	<8	<5			<8		5	<10	<10	75		<5	<10
B		10								21	<10	10				<10
Ba	680	230	400	480	400	1000	280	400	170	484	110	570	64	110	300	140
Be		<10		5				2		0.5	<10	<10				<10
Bi		<0.5		<10				<10		<2	1	<0.5				<0.5
Br		2									2	1				2
Cd		<0.2		<2				<2		<1	<0.2	<0.2				<0.2
Ce		21		41				44		7	19	13				6
Co		11		2				47		35	51	38				4
Cr	10	360	100	4	100	70	50	360	50	157	170	830	3812	684	900	50
Cs		0.9									<0.8	6.8				<0.6
Cu		11		<1				25		50	84	130				9
Eu		0.6		<2				<2			1	0.3				0.3
Ga				15				23		10						
Ge		<10									<10	10				10
Hf		5									1	4				<1
La		11.3		25				58		7	5.3	6.6				3
Li		<10		64				280		<1	<10	<10				<10
Mo		<5		<2				<2		3	<5	<5				<5
Nb	20	20		<4		11	<20	4	30	13	20	20	2			40
Nd		7		17				18			10	5				<5

A1 continued.

	Sample numbers															
	1B	2B	3B	4B	5B	6B	7B	8B	9B	10B	11B	12B	13B	14B	15B	16B
Ni		60		2		19	34	280	47	282	150	210	1690	82		16
Os		0.15									0.44	0.48				0.09
Pb		8		35				5		10	4	4				<2
Pd (ppb)													<2			
Pt (ppb)													<15			
Rb	160	60				115	20		<20	<20	<20	290				<20
Sb		<0.2								<5	<0.2	<0.2				<0.2
Sc		5.1		3				15		5	52.3	39.6				3.1
Se		<.3									<3	<3				<3
Sm		1.3									2.7	0.8				0.6
Sn			5	<10	8			<10		<20						
Sr	190	40		160		270	600	51	400	124	140	<20	62	50		<20
Ta		<1		<40				<40		<10	<1	1				<1
Te										<10						
Th		8		17				14			0.5	3.3				0.8
U		1		<100				<100			<0.5	2.4				1.1
V	30	30		7		53	140	120	190	79	400	330	145	85	152	30
W		<3	3		2					<10	53	<3				<3
Y	<20	<20		9		8	40	9	20	2	2	20	9	<5		<20
Yb		0.9		1				1			2.9	2.8				0.6
Zn		17		26				72		49	100	170				34
Zr	80	20				155	180		190	8	40	130	42	150		<20

[1] Oxides and LOI given in weight percent.
[2] All trace-element analyses are in ppm unless otherwise stated.

Sample lithologies

(1B) leucocratic augen felsic gneiss; **(2B)** fuchsitic gneiss; **(3B)** quartzofeldspathic gneiss; **(4B)** granite gneiss; **(5B)** quartzofeldspathic gneiss; **(6B)** quartzofeldspathic gneiss; **(7B)** gray augen gneiss; **(8B)** gray migmatitic gneiss; **(9B)** amphibolite; **(10B)** metadiabase; **(11B)** amphibolite; **(12B)** lamprophyre(?); **(13B)** ultramafic schist; **(14B)** ultramafic schist; **(15B)** fuchsite-chlorite-schist; **(16B)** banded iron formation.

Appendix A2. Whole-rock and trace-element analyses of Diamond Springs Formation ultramafic schists and serpentinites and comparable rocks from South Africa, Western Australia, Canada, and the Seminoe Mountains, Wyoming.

	Sample numbers														
	1D	2D	3D	4D	5D	6D	7D	8D	9D	10D	11D	12D	13D	14D	15D
SiO_2(%)[1]	42.52	41.90	42.90	48.66	45.20	47.30	45.70	38.90	42.90	39.88	36.38	37.90	39.86	37.50	41.50
Al_2O_3	3.44	5.22	7.46	9.21	7.17	2.70	3.10	0.08	2.84	2.42	2.70	0.65	2.11	3.86	1.19
TiO_2	0.18	0.23	0.36	0.50	0.31	0.13	0.21	<0.01	0.13	0.09	0.10	0.03	0.09	0.20	0.05
Fe_2O_3	4.92	3.62	2.90	12.33	13.00			8.53	2.93	6.79	11.66	9.14	7.67	9.27	6.22
FeO	5.87	5.21	6.50			8.60	8.80	5.62	4.77						
MnO	0.19	0.18	0.22	0.22	0.15	0.12	0.13	0.08	0.17	0.08	0.09	0.09	0.05	0.18	0.12
MgO	30.27	29.86	24.00	18.95	22.10	38.80	40.00	43.50	41.90	38.10	37.61	37.60	36.80	36.70	36.30
CaO	4.96	4.69	7.21	8.83	6.75	1.50	1.50	0.18	3.32	0.10	0.19	0.32	0.08	0.18	0.92
Na_2O	0.41	0.22	0.13	1.24	0.42	0.05	0.05	0.35	0.31	<0.01	0.04	<0.01	0.02	0.01	0.11
K_2O	0.16	0.02	0.06	0.04	<0.01	0.04	0.08	0.01	0.01	0.06	0.06	0.09	0.11	<0.03	<0.03
P_2O_5	0.02	0.02	0.02	0.04	<0.05	0.02	0.02	0.02	0.03	0.01	0.05	0.32	<0.01	0.28	0.31
CO_2															
LOI	7.10	8.39	6.00	4.17	4.62					12.00	11.10	12.40	12.30	11.40	12.10
TOTAL (%)	100.04	99.56	97.76	104.19	99.72	99.26	99.59	97.27	99.31	99.53	99.98	98.55	99.10	99.61	98.85
CaO/Al_2O_3	1.4	0.9	0.97	0.96	0.94	0.56	0.48	2.25	1.17	0.04	0.07	0.49	0.04	0.05	0.77
Ag[2]					0.068							<5		<5	<5
As					18					25		36	12	20	21
Au (ppb)					4					<5		<5	<5	6	7
Ba					44					<100		<100	<100	<100	<100
Be															
Bi															
Cd												<10		<10	<10
Ce	2.1	1.65	1.18							6		<10	<10	<10	62
Co	60	105	110		68					97		120	160	110	97
Cr	2,200	3,000	2,700		3,900	6,900	5,400	2,100		6,650	8,655	5,370	1,700	2,600	3,000
Cs													4	<1	<1
Cu	45	95	89		23					1		6	4	6	5
Eu	0.18	0.22	0.21							0.18		<2		<2	<2
Ga															
Ge															
Hf										<2		<2	<2	<2	<2
La	0.8	0.55	0.45							1.1		<5		<5	<5
Li					7										
Lu	0.1	0.11	0.08							0.05		<100		<100	<100
Mo												<2		<2	<2
Nb															
Nd	1.7	1.53	1.33							<3					
Ni	2,000	1,600	1,300		690	2,500	2,500	10,683		2,570	1,630	2,200	2,180	1,700	1,500
Pb					10										
Pd (ppb)										<2		<2	<2	4	<2
Pt (ppb)										<15		20	<15	20	<15
Rb					9							<10		<10	<10
Sb					0.32					0.5		0.4	6.2	0.9	6.1
Sc										7.1		6.7	8.9	13	5.8
Se												<10		<10	<10
Sm	0.51	0.56	0.45							0.2		<0.5	0.6	<0.6	<0.5
Sn												<200		<200	<200
Sr					26										
Ta												<1		<1	<1
Tb	0.15	0.15	0.09							<0.1		<1		<1	<1
Te												<20		<20	<20
Th												<0.5		<0.5	<0.5
Ti/V	12	12	13							8	26		14		10
U												0.6		1.4	4.1
V	90	120	170							66	23		39		31
W										<2		4	<2	<2	<2
Y	3	6	10												
Yb	0.47	0.63	0.88							0.28		<5		<5	<5
Zn	102	130	90		75					20		15	18	30	28
Zr	34	15	35								61	<500		<500	<500

A2 continued.

	Sample numbers														
	16D	17D	18D	19D	20D	21D	22D	23D	24D	25D	26D	27D	28D	29D	30D
SiO_2(%)[1]	38.80	37.00	39.91	42.42	28.60	43.47	42.37	37.80	41.90	48.16	45.96	48.68	47.50	49.66	47.40
Al_2O_3	2.73	1.44	3.06	3.69	15.00	3.89	5.14	4.18	5.01	4.86	5.19	0.36	5.89	5.25	6.10
TiO_2	0.11	0.10	0.14	0.18	0.81	0.25	0.20	0.40	0.22	0.19	0.29	0.02	0.16	0.25	0.20
Fe_2O_3	9.03	13.30	9.85	8.96	10.20	9.54	10.32	14.60	12.92	10.21	11.93	9.56	11.20	10.45	11.20
FeO															
MnO	0.09	0.17	0.12	0.13	0.28	0.13	0.13	0.17	0.17	0.11	0.14	0.20	0.13	0.11	0.14
MgO	35.20	34.90	33.70	32.68	31.30	31.09	30.67	30.60	28.20	27.21	26.66	26.60	24.80	24.75	24.40
CaO	0.16	0.72	1.19	0.86	0.47	2.86	0.77	2.56	3.49	1.99	4.38	8.10	3.98	1.61	4.08
Na_2O	0.04	<0.01	0.01	0.03	<0.01	0.06	0.02	0.03	0.02	0.03	0.10	0.03	<0.15	0.02	0.12
K_2O	0.04	<0.03	0.03	0.06	0.08	0.10	0.09	<0.03	0.07	0.08	0.07	<0.03	<0.02	0.07	0.05
P_2O_5	<0.01	0.31	0.17	0.05	0.47	0.08	0.06	0.34	0.30	0.04	0.09	0.29	<0.05	0.06	0.04
CO_2													0.01		
LOI	11.15	11.10	10.74	10.00	11.40	9.10	9.80	8.80	6.90	6.80	5.50	5.30	5.13	6.50	4.80
TOTAL (%)	97.36	99.08	98.92	99.06	98.62	100.57	99.57	99.48	99.20	99.68	100.31	99.14	99.02	98.73	98.53
CaO/Al_2O_3	0.06	0.5	0.39	0.23	0.03	0.74	0.15	0.61	0.7	0.41	0.84	22.5	0.68	0.31	0.7
Ag[2]		<5	<0.1		<5			<5	<5			<5	<2		
As	20	11			9		6	2	2	10		43	<10	10	
Au (ppb)	8	7	16		7		<5	6	<5	<5		<5	<5	15	
Ba		67	400	20	<100	220	100	<100	<100	<100		<100	9	<100	
Be													<1		
Bi													<10		
Cd		<10			<10			<10	<10			<10	<2		
Ce		<10			22			<10	<10	<10		<10	<4	<10	
Co	77	130			54		66	120	100	100		86	100	83	
Cr	7,587	3,420	10,100	3,131	2,990	7,906	2,000	2,700	5,040	2,400	3,734	4,000	2,900	2,600	3,627
Cs		<1													
Cu	12	13			6		22	5	2	45		20	28	1	
Eu		<2			<2			<2	<2			<2	<2		
Ga													8		
Ge															
Hf		<2			3		<2	<2	<2	<2		<2		<2	
La		<5			2			<5	<5			<5	<2		
Li													5		
Lu		<100			<100			<100	<100			<100			
Mo		<2			<2			<2	<2			8	<2		
Nb													<4		
Nd													<4		
Ni	1,690	2,110	860	905	1,890	810	1,800	1,200	1,300	1,200	289	1,100	1,000	400	730
Pb													7		
Pd (ppb)	2	4	4		2		<2	6	<2	<2		<2		<2	
Pt (ppb)	<15	<15	<15		<15		<15	20	15	<15		<15		<15	
Rb		<10			<10			<10	<10			<10			
Sb	0.4	3.2			0.4		0.3	0.4	0.5	0.3		0.3		1	
Sc	8.1	6.8			24.5		13	13	19	20		5	26	24	
Se		<10			<10			<10	<10			<10			
Sm		0.4			2.1		0.8	0.7	1.2	0.5		<0.5		0.7	
Sn		<200			<200			<200	<200			<200	<10		
Sr	7			6		45							10		10
Ta		<1			<1			<1	<1			<1	<40		
Tb		<1			<1			<1	<1			<1			
Te		<20			<20			<20	<20			<20			
Th	0.7	0.4			4.2			<0.5	0.6			<0.5	<4		
Ti/V	12		3.8	19			12			9	40		8	14	10
U	0.5	0.5			0.7			<0.5	<0.5			0.6	<100		
V	55		219	57			100			125	43		120	110	108
W		<2			<2		<2	<2	<2	<2		3		<2	
Y	5										70		5		8
Yb		<5			<5			<5	<5			<5	<1		
Zn	14	25			20		40	28	28	31		15	91	15	
Zr	19	<500		62	500	88		<500	<500			<500			20

A2 continued.

	Sample numbers														
	31D	32D	33D	34D	35D	36D	37D	38D	39D	40D	41D	74D	75D	76D	77D
SiO_2(%)	48.00	46.22	46.10	49.50	48.20	50.18	48.60	44.70	50.41	48.53	50.64	40.50	38.50	38.40	40.70
Al_2O_3	5.00	6.56	7.80	5.79	6.99	5.75	5.03	6.72	6.26	4.57	3.76	8.20	9.37	4.65	11.40
TiO_2	0.36	0.24	0.23	0.21	0.28	0.20	0.65	0.71	0.24	0.38	0.33	0.42	0.36	0.44	0.30
Fe_2O_3	12.32	10.71	9.08	11.40	11.30	11.55	12.50	12.60	10.43	12.59	11.09	12.60	11.20	14.50	12.80
FeO															
MnO	0.20	0.16	0.13	0.17	0.20	0.16	0.24	0.16	0.17	0.23	0.22	0.13	0.16	0.21	0.19
MgO	24.30	23.42	23.36	22.60	22.60	21.97	21.27	21.20	21.15	18.70	18.52	23.90	24.50	28.20	22.40
CaO	3.50	6.60	6.56	3.58	7.09	5.37	5.96	7.09	5.72	11.16	10.44	5.35	4.98	2.63	6.26
Na_2O	0.06	0.07	0.07	0.10	0.15	0.10	0.25	0.18	0.15	0.41	0.23	0.14	0.10	0.03	0.21
K_2O	<0.03	0.10	0.07	0.05	0.07	0.11	<0.03	<0.03	0.10	0.09	0.10	0.29	0.31	0.3	0.31
P_2O_5	0.32	0.36	0.04	0.04	0.05	0.09	0.29	0.29	0.12	0.21	0.03	0.54	0.57	0.56	0.60
CO_2															
LOI	5.30	6.00	5.50	4.50	3.45	4.40	4.10	4.70	4.30	2.55	2.30	6.14	7.06	8.52	6.02
TOTAL (%)	99.39	100.44	98.94	97.94	100.38	99.88	98.92	98.38	99.05	99.42	97.66	98.21	97.11	98.44	101.19
CaO/Al_2O_3	0.7	1	0.84	0.6	1.01	0.93	1.18	1.06	0.91	2.4	2.8	0.65	0.53	0.56	0.55
Ag[2]	<5					6	<5	<5							
As	8			4	27	297	<1	3	<3						
Au (ppb)	<5			6	<5	<5	<5	<5	<5	<5					
Ba	<100					<100	130	<100	<100	100		<100	<100	100	<100
Be															
Bi															
Cd	<10					<10	<10	<10							
Ce	<10					<10	15	<10	14						
Co	81			82	62	160	83	98	110						
Cr	3,600	3,432	3,230	3,807	2,979	2,600	1,400	3,100	2,800	3,100	595	9,200	1,200	2,500	1,300
Cs															
Cu	30			80	9	14	30	35	12						
Eu	<2					<2	<2	<2	0.35						
Ga															
Ge															
Hf	<2					<2	2	<2	<2						
La	8					5	12	8							
Li															
Lu	<100					<100	<100	<100	0.12						
Mo	<2					<2	<2	<2							
Nb															
Nd															
Ni	590	320	317	680	570	1,200	950	1,200	760		160				
Pb															
Pd (ppb)	2				2	10	4	2	2						
Pt (ppb)	20				20	25	15	15	<15						
Rb	<10			2	1	<10	<10	<10							
Sb	0.4			0.3	0.5	<0.2	<0.2	0.5	0.4						
Sc	24			21.8	23.9	23	20	22	27						
Se	<10					<10	<10	<10							
Sm	1.1					0.7	2.5	1.9	0.8						
Sn	<200					<200	<200	<200							
Sr		23	13	14	12						9				
Ta	<1					<1	<1	<1							
Tb	<1					<1	<1	<1	<0.1						
Te	<20					<20	<20	<20							
Th	1.3				0.8	0.7	2.6	1.5							
Ti/V		26	28	10	12.6	8.6	35		11		34				
U	<0.5					<0.5	0.9	0.8							
V		55	49	110	118	139	111		129		58				
W	<2				8	<2	<2	<2	<2						
Y				7											
Yb	<5					<5	<5	<5	0.7						
Zn	25			22	25	33	23	20	32						
Zr	<500	66	17	18	27	<500	<500	<500			64				

[1]Oxides and LOI given in weight percent.
[2]All trace element analyses are in ppm unless otherwise noted.

Sample lithologies

(1D) spinifex-textured peridotitic komatiite, Komati Formation, South Africa (Viljoen and Viljoen, 1969); **(2D)** spinifex-textured peridotitic komatiite, Western Australia (Condie, 1981); **(3D)** spinifex-textured peridotitic komatiite, Abitibi belt, Canada (Condie, 1981); **(4D)** spinifex-textured peridotitic komatiite, Marshall Pool, Western Australia (Nesbitt and others, 1979); **(5D)** average of 8 tremolite schist samples, Seminoe Mountains greenstone belt, Wyoming (Klein, 1981); **(6D)** average of 7 serpentinite and talc carbonate hosts to volcanic associated nickel deposits, Eastern Goldfields, Western Australia (Groves and Hudson, 1981); **(7D)** average of 56 ultramafic hosts to volcanic-associated nickel deposits, Eastern Goldfields, Western Australia (Groves and Hudson, 1981); **(8D)** lizardite serpentinite after coarse-grained komatiitic dunite, Honeymoon Well, Western Australia (Donaldson and others, 1986); **(9D)** fine-grained cumulate komatiite, Kambalda, Western Australia (Donaldson and others, 1986) Diamond Springs Formation sample lithologies: **(10D)** massive fine-grained serpentinite, Lewiston district; **(11D)** massive fine-grained serpentinite; **(12D)** Crysotile serpentinite, Atlantic City mine; **(13D)** massive serpentinite, Lewiston district; **(14D)** massive fine-grained serpentinite, Atlantic City mine; **(15D)** serpentinized peridotite, Atlantic City mine area; **(16D)** serpentinite, Lewiston district; **(17D)** cumulate-textured serpentinite, Atlantic City mine area; **(18D)** serpentinized peridotite; **(19D)** tremolite-talc-chlorite schist; **(20D)** spinifex(?) textured tremolite-talc-chlorite schist; **(21D)** serpentine-talc-anthophyllite schist; **(22D)** serpentinite; **(23D)** cumulate textured serpentinite; **(24D)** serpentinite; **(25D)** talc-chlorite schist; **(26D)** talc-chlorite schist; **(27D)** asbestos serpentinite; **(28D)** actinolite-talc-chlorite schist; **(29D)** talc-chlorite schist; **(30D)** talc-chlorite schist; **(31D)** talc-chlorite schist; **(32D)** porphyroblastic talc-chlorite-tremolite schist; **(33D)** porphyroblastic talc-chlorite schist; **(34D)** talc-tremolite-chlorite schist; **(35D)** tremolite-anthyphyllite-talc schist; **(36D)** serpentine-tremolite-talc schist; **(37D)** tremolite-talc schist; **(38D)** actinolite schist; **(39D)** talc schist; **(40D)** amphibolite; **(41D)** amphibolite; **(74D)** serpentinite; **(75D)** serpentinite; **(76D)** cumulate serpentinite; **(77D)** serpentine-prochlorite schist.

Appendix A3. Major-element and trace-element analyses of mafic schists and amphibolites of the Diamond Springs Formation (basaltic komatiites from Canada and average Archean tholeiites added for camparison).

	Sample numbers										
	42D	43D	44D	45D	46D	47D	48D	49D	50D	51D	52D
SiO_2(%)[1]	46.40	32.42	55.33	49.74	52.68	47.80	54.70	46.63	49.10	52.18	54.58
Al_2O_3	14.60	16.39	11.25	14.98	14.27	15.41	11.50	15.08	13.70	14.13	10.52
TiO_2	1.25	1.43	0.92	0.88	0.60	0.83	0.99	1.19	1.53	1.01	1.01
Fe_2O_3	16.10	14.64	11.88	12.16	9.80	13.52	11.70	13.42	14.30	12.99	11.47
FeO											
MnO	0.28	0.32	0.17	0.20	0.14	0.21	0.16	0.21	0.34	0.21	0.16
MgO	9.35	9.34	8.10	8.04	7.88	7.76	7.73	7.32	7.30	6.92	6.72
CaO	10.00	15.53	7.83	11.15	9.39	11.34	7.52	11.15	7.58	10.94	9.24
Na_2O	1.78	1.18	3.30	1.96	3.33	1.38	3.15	1.99	2.84	2.07	2.70
K_2O	0.24	0.90	0.21	0.65	0.49		0.24	0.10	0.34	0.20	0.46
P_2O_5	0.14	0.12	0.13	0.05	0.12	0.39	0.02	0.25	0.32	0.06	0.12
CO_2											
LOI	0.85	1.60	0.80	0.97	1.10	0.50	0.50	0.70	0.80	0.67	1.10
TOTAL (%)	100.99	93.87	99.92	100.78	99.80	99.14	98.21	98.04	98.15	101.38	98.08
CaO/Al_2O_3	0.7	0.95	0.7	0.74	0.66	0.74	0.7	0.74	0.55	0.77	0.9
Ti/V	24	19			13		24	20	17		
Ag[2]								<5	<5		
As		11			7			4	5.1		
Au (ppb)	10	<5			<5			<5	7		
Ba	125	160	50	179	240	90	92	<100	89	90	
Cd								10<	<10		
Ce		<10			<10			<10	22		
Co		81			52			58	54		
Cr	355	290	29		140		343	300	210		55
Cs		2			<1			<1	<1		
Cu		195			153			28	1.15		
Eu								<2	1.57		
Hf		4			2			<2	4		
Ir								<100	<100		
La		6			7			<5	8		
Lu									0.55		
Mo								<2	<2		
Nb											
Nd											
Ni	150	140	26		190		115	140	120		19
Pb											
Pd (ppb)	4										
Pt (ppb)	25										
Rb	5						7	<10	13		
Sb		0.5			0.2			0.8	0.9		
Sc		57.3			44.0			45.0	46.5		
Se								<10	<10		
Sm		3.7			2.6			2.9	4.1		
Sn								<200	<200		
Sr	88	200		85		85	109			85	83
Ta								<1	0.5		
Tb								<1	0.8		
Te								<20	<20		
Th								<0.5	1.2		
U								<0.5	<0.5		
V	306	445			270		246	350	535		
W		30			<2			<2	3		
Y	33		9				31				10
Yb								<5	3.69		
Zn		49			36			18	190		
Zr	133		125	74		74	116	<500	<500	74	125

A3 continued.

	Sample numbers										
	53D	54D	55D	56D	57D	58D	59D	60D	61D	62D	63D
SiO_2(%)[1]	50.77	53.70	56.81	55.46	48.66	49.70	49.49	49.61	53.90	47.17	55.28
Al_2O_3	13.42	14.20	12.73	12.10	13.82	14.17	14.85	15.43	9.03	12.26	10.86
TiO_2	1.02	0.94	0.92	0.91	0.72	1.65	0.86	0.97	0.75	1.33	0.43
Fe_2O_3	13.66	10.30	10.17	13.68	13.98	15.73	12.71	12.96	11.90	12.16	9.52
FeO											
MnO	0.22	0.16	0.15	0.20	0.24	0.24	0.21	0.19	0.22	0.13	0.18
MgO	6.67	6.64	5.70	5.96	8.22	5.83	8.02	7.85	11.50	10.43	11.20
CaO	10.22	8.56	7.26	9.14	11.62	9.51	10.83	9.78	7.58	10.68	7.92
Na_2O	2.12	2.98	3.36	1.94	1.60	2.76	2.04	2.18	2.04	0.92	2.50
K_2O	0.19	0.12	0.60	0.10	0.08	0.22	0.66	0.22	0.15	1.54	0.49
P_2O_5	0.31	0.17	0.17	0.17	0.20	0.22	0.18	0.29	0.20	0.14	0.08
CO_2											
LOI	0.30	0.05	0.80	0.30	0.50	0.22	1.00	0.29	0.60	1.80	1.40
TOTAL (%)	98.90	97.82	98.67	99.96	99.64	100.25	100.85	99.77	97.87	98.56	99.86
CaO/Al_2O_3	0.76	0.60	0.60	0.76	0.84	0.67	0.73	0.63	0.84	0.87	0.73
Ti/V	14	23		23	15	27	22.3	25.6			
Ag[2]				0.3	0.2	<0.1	0.1	<0.1			
As											
Au (ppb)				32	<5	<5	<5	<5	10		
Ba	<100	51	130	<100	<100	<100	100	200	162	100	100
Cd											
Ce											
Co											
Cr	200	57	20	400	400	200	400	400	960	1,139	97
Cs											
Cu	91										
Eu											
Hf											
Ir											
La											
Lu											
Mo											
Nb		1									
Nd											
Ni		77	17	30	35	25	44	50	197	245	30
Pb											
Pd (ppb)									4		
Pt (ppb)									20		
Rb									3		
Sb									0.3		
Sc									28.1		
Se											
Sm											
Sn											
Sr		179	220						127	105	110
Ta											
Tb											
Te											
Th									2.6		
U									0.7		
V	425	246		237	290	366	231	227	190	44	14
W											
Y		28	5						25	12	
Yb											
Zn	10										
Zr		97	120						72	165	88

A3 continued.

	Sample numbers									
	64D	65D	66D	67D	68D	69D	70D	71D	72D	73D
SiO_2(%)[1]	55.53	49.90	43.30	49.80	47.40	51.40	49.00	50.70	50.20	49.50
Al_2O_3	8.08	4.06	13.60	5.09	6.66	12.90	12.50	8.60	15.50	15.20
TiO_2	0.83	0.17	0.49	0.68	0.56	0.80	0.70	0.50	0.94	1.49
Fe_2O_3	11.7	7.86	12.00	12.60	13.30				1.63	2.80
FeO						7.90	10.90	8.60	9.26	9.17
MnO	0.21	0.47	0.17	0.25	0.24				0.22	0.18
MgO	9.16	11.37	14.28	15.30	19.00	11.1	11.90	16.60	7.53	6.82
CaO	8.41	23.50	9.07	13.07	8.19	7.90	6.70	10.20	11.60	8.79
Na_2O	2.95	0.54	1.12	0.54	0.35	3.70	2.70	1.10	2.15	2.70
K_2O	0.24	<0.03	0.16	0.14	0.17	0.10	0.90	0.01	0.22	0.69
P_2O_5	0.14	0.22	0.27	0.29	0.32	0.05	0.05	0.03	0.10	0.17
CO_2						0.20	0.21	0.20		
LOI	1.10	1.30	3.80	1.20	3.30	3.70	4.05	2.70	1.62	2.04
TOTAL (%)	98.35	99.39	98.26	98.96	99.49	99.75	99.61	99.24	100.97	99.55
CaO/Al_2O_3	1.04	5.8	0.67	2.6	1.2	0.61	0.54	1.2	0.75	0.58
Ti/V										
Ag[2]		<5	<5	<5	<5					
As		22	2	<1	2					
Au (ppb)		6	<5	<5	<5					
Ba		<100	<100	<100	<100				80	90
Cd		<10	<10	<10	<10					
Ce		<10	<10	13	12	5.8	9.7	6.4	9.2	30
Co		80	83	83	79				52	55
Cr	103	2,900	330	2,500	1,400				490	250
Cs										
Cu		3	86	7	20				110	100
Eu		<2	<2	0.8	0.99				0.73	1.3
Hf		<2	<2	<2	<2					
Ir		<100	<100	<100	<100					
La		<5	<5	8	13	3	3.4	2.2	3.6	13
Lu				0.14	0.24					
Mo		<2	<2	<2	<2					
Nb										
Nd									6.6	17
Ni	32	570	570	530	980				140	125
Pb										
Pd (ppb)				2	4					
Pt (ppb)				<15	20					
Rb		<10	<10	<10	<10					
Sb		0.9	0.7	0.5	0.2					
Sc		13	25	25	18	41	39	29		
Se		<10	<10	<10	<10					
Sm		0.7	1.1	2.3	3				2	4
Sn		<200	<200	<200	<200					
Sr	130					63	360	34	100	190
Ta		<1	<1	<1	<1					
Tb		<1	<1	0.1	0.4					
Te		<20	<20	<20	<20					
Th		<0.5	<0.5	1.3	6.5					
U		<0.5	<0.5	<0.5	1.3					
V	29								260	365
W		<2	<2	<2	<2					
Y	8					20	22	18	20	30
Yb		<5	<5	1.04	1.61	1.7	2	1.5	1.9	2.2
Zn		210	210	200	27				80	120
Zr	125	<500	<500	<500	<500	47	51	36	53	135

[1]Oxides and LOI given in weight percent.
[2]All trace element analyses are in ppm unless otherwise noted.

Sample lithologies

(42D) metabasalt; **(43D)** metadiabase; **(44D)** metabasalt; **(45D)** amphibolite (Talpey, 1984); **(46D)** metadiabase; **(47D)** amphibolite (Talpey, 1984); **(48D)** amphibolite; **(49D)** amphibolite; **(50D)** amphibolite; **(51D)** amphibolite (Talpey, 1984); **(52D)** amphibolite; **(53D)** metabasalt; **(54D)** amphibolite; **(55D)** metabasalt; **(56D)** metabasalt; **(57D)** metabasalt; **(58D)** fine-grained amphibolite; **(59D)** medium-grained amphibolite; **(60D)** metabasalt; **(61D)** talc schist; **(62D)** metabasalt; **(63D)** metabasalt; **(64D)** metabasalt; **(65D)** serpentinite chlorite schist; **(66D)** serpentinite chlorite schist; **(67D)** chlorite-actinolite schist; **(68D)** chlorite-actinolite schist; **(69)** basaltic komatiite, Destor Township, Quebec (Ludden and Gelinas, 1982); **(70)** basaltic komatiite, Destor Township, Quebec (Ludden and Gelinas, 1982); **(71)** basaltic komatiite, Destor Township, Quebec (Ludden and Gelinas, 1982); **(72)** Average Archean tholeiite TH1 (Condie, 1981); **(73)** Average Archean tholeiite TH2 (Condie, 1981).

Appendix A4. Major and trace-element analyses for selected samples of the Goldman Meadows Formation.

	Sample numbers								
	1G	2G	3G	4G	5G	6G	7G	8G	9G
SiO_2(%)[1]	56.1	58.4	54.8	93.84	50.43	90.41	59.95	52.74	56.23
Al_2O_3	0.23	24	15.7	2.7	16.57	0.23	12.62		0.45
TiO_2	<0.03	0.9	0.61	0.09	0.45	0.06	0.98		0.02
Fe_2O_3	43.4	5.72	9.78	0.34	8.37	8.41	9.07	43.28	34.96
FeO									5.67
MnO	0.19	0.05	0.16	0.01	0.14	0.02	0.17		0.07
MgO	0.76	3.29	7.93	0.01	9.07	0.01	5.25		1.13
CaO	1.5	0.35	9.07	0.21	9.37	0.26	7.5		0.81
Na_2O	<0.20	0.79	1.71	0.01	2.28	0.01	4.09		0.15
K_2O	<0.03	2.77	0.23	0.72	0.99	0.03	0.22		0.12
P_2O_5	0.1	0.4	0.06	0.11	0.15	0.13	0.25		0.05
CO_2	0.02	<0.01	0.02						0.06
LOI	0.27	3.82	0.5	1.4	1.47	0.14	0.09		0.52
TOTAL (%)	102.83	100.49	100.57	99.44	99.29	99.71	100.19	96.02	100.24
CaO/Al_2O_3			0.58		0.57		0.59		
Ti/V			15		14.6		22		
Ag[2]	<2	<2	<2	0.3	<0.1			<0.2	
As	10	40	<10					97	
Au (ppb)	<8	<8	<8	<5	12	<5	<5	<5	
B								69	
Ba	64	520	170	100	100	100	100	74	
Be	<1	2	<1					1.5	
Bi	<10	<10	<10					32	
Cd	<2	<2	<2					<1	
Ce	<4	110	13					12	
Co	9	20	48					<1	
Cr	11	390	140	400	400	100	500	3	
Cu	28	32	190					18	
Eu	<2	<2	<2						
Ga	<4	28	16					<2	
La	<2	58	6					41	
Li	3	290	27					<1	
Mo	<2	<2	<2					<1	
Nb	<4	4	<4					1	
Nd	<4	47	8						
Ni	14	150	130	5	30			76	
Pb	4	11	7					37	
Rb								<20	
S (%)				0.01	<0.01	0.03			
Sb								8	
Sc	<10	28	41					2	
Sn	<10	<10	<10					<20	
Sr	5	81	120					10	
Ta	<40	<40	<40					37	
Te								<10	
Th	5	15	<4						
Tl								<10	
U	<100	<100	<100						
V	16	210	240		185		267	94	
W								<10	
Y	2	7	17					9	
Yb	<1	<1	2						
Zn	58	110	90					85	
Zr								12	

[1]Oxides and LOI given in weight percent.
[2]All trace-element analyses are in ppm unless otherwise stated.

Sample lithologies

(1G) Banded iron formation; (2G) andalusite schist; (3G) coarse grained amphibolite; (4G) fuchsitic quartzite; (5G) amphibolite; (6G) quartzite; (7G) amphibolite; (8G) banded iron formation; (9G) banded iron formation.

Appendix A5. Major and trace-element analyses of metaigneous and metasedimentary rocks of the Roundtop Mountain Greenstone and comparable rocks from the Elmers Rock greenstone belt, Wyoming and average tholeiites.

	Sample numbers											
	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	11R	12R
SiO_2(%)[1]	47.61	57.40	48.50	50.20	46.11	50.40	50.10	46.70	48.30	49.00	46.94	46.50
Al_2O_3	15.52	14.43	14.60	12.80	13.91	16.80	15.70	14.80	15.20	15.00	15.60	15.08
TiO_2	1.05	0.96	0.88	1.96	1.43	1.69	1.92	1.10	1.80	1.86	1.45	1.15
Fe_2O_3	11.92	8.21	9.19	17.10	12.86	13.40	13.70		15.00	14.90	16.26	14.94
FeO								7.53				
MnO	0.15	0.07	0.15	0.26	0.24	0.19	0.21	0.22	0.23	0.30	0.20	0.24
MgO	5.59	5.48	5.29	5.27	3.11	4.83	4.77	4.62	4.97	5.72	6.32	6.03
CaO	6.02	6.89	8.32	9.44	9.41	10.10	9.56	12.83	9.18	9.36	8.80	11.87
Na_2O	3.48	1.15	3.76	2.24	2.96	3.04	3.37	3.47	3.34	3.05	0.51	1.46
K_2O	0.25	0.15	0.04	1.30	0.24	0.54	0.53	0.02	0.54	0.42	<0.03	0.03
P_2O_5	0.24	0.79	0.35	0.28	0.23	0.32	0.42	0.07	0.05	0.37	0.20	0.24
CO_2												
LOI	8.40	2.90	8.10	0.55	9.60	0.25	0.60	9.24	0.20	0.50	3.60	3.20
TOTAL (%)	100.23	98.43	99.18	101.40	100.10	101.56	100.88	100.60	98.81	100.48	99.88	100.74
CaO/Al_2O_3	0.39	0.48	0.57	0.74	0.68	0.6	0.61	0.87	0.6	0.62	0.56	0.79
Ti/V	35	35	23	28	31	31	29	20	28	28	44	22
Ag[2]	<0.1	0.1	<5		<0.1						<0.1	<5
As			10									11
Au (ppb)	8	20	<5		<5						<5	<5
Ba	100	200	170	557	<100	472	407		172	190	<100	<100
Be												
Bi												
Cd			<10									<10
Ce			48									<10
Co			35									45
Cr	400	100	200	52	200	69	71	300	70	66	200	200
Cu			85									93
Eu			1.72									<2
Ga												
Hf			2									2
Ir			<1									<1
La			24									6
Li												
Lu			0.25									
Mo			<2									<2
Nb				3		7	<1	5	<1	3		
Nd												
Ni	87	72	<50	36	75	50	39	118	55	56	86	84
Pb												
Pd (ppb)												
Pt												
Rb			<10	50		16	12	9	12	9		<10
Rd												
Sb			2.0									3.0
Sc			28									47
Se			<10									<10
Sm			5.2									2.9
Sn			<200									<200
Sr				149		186	169	89	194	236		
Ta			<1									<1
Tb			0.4									<1
Te			<20									<20
Th			4.9									0.9
U			1.2									<0.5
V	181	164	225	426	280	323	403	330	379	397	192	315
W			<2									<2
Y				39		30	34	23	30	32		
Yb			1.78									<5
Zn			80									260
Zr			540	110		81	106	78	90	104		<500

A5 continued.

	Sample numbers											
	13R	14R	15R	16R	17R	18R	19R	20R	21R	22R	23R	24R
SiO_2(%)[1]	47.63	48.5	55.8	46.4	46.6	46.15	48.1	47.28	52.79	47.15	48.44	46.4
Al_2O_3	14.21	15.5	13.2	17.2	15	14.97	13.9	14.22	13.77	14.44	14.93	14.9
TiO_2	1.16	1.2	0.68	0.69	1.26	1.01	1.21	1.03	1.01	1.07	1.07	1.23
Fe_2O_3	12.89	13.7	9.46		13.2	13.98	13.2	14.19	12.96	14.09	12.36	13.2
FeO				10.47								
MnO	0.21	0.19	0.18	0.24	0.2	0.2	0.27	0.21	0.2	0.21	0.21	0.2
MgO	5.56	6.38	5.93	8.44	7.41	7.18	7.17	7.7	6.69	7.11	7.23	7.49
CaO	11.93	9.89	8.49	13.39	10.4	10.12	11.4	11.36	10.31	10.52	10.56	10.4
Na_2O	0.67	2.48	3.72	1.06	1.85	1.77	2.37	2.05	1.9	1.48	2	1.85
K_2O	<0.03	0.42	0.61	0.32	0.14	<0.03	0.29	0.26	0.04	0.06	1.02	0.13
P_2O_5	0.29	0.1	0.3	0.11	0.25	0.14	0.22	0.09	0.28	0.2	0.18	0.27
CO_2		0.26										
LOI	7.5	2.18	0.5	1.73	2.7	2.5	0.3	1.7	1.7	2.6	1.42	2.7
TOTAL (%)	102.05	100.8	98.87	100.05	99.01	98.02	98.43	100.09	101.65	98.93	99.42	98.8
CaO/Al_2O_3	0.84	0.64	0.64	0.78	0.69	0.68	0.82	0.8	0.75	0.73	0.7	0.7
Ti/V	22	34	20	15	23	30	22		24	25	15	19
Ag[2]	<5	<2			<5	<0.1			<0.1	<0.1		<5
As	11	<10			6							3
Au (ppb)	<5	<8			<5	<5			<5	<5	<5	6
Ba	<100	82	201		130	<100	221		200	200	200	<100
Be		<1										
Bi		<10										
Cd	<10	<2			<10							<10
Ce	10	10			15							13
Co	39	49			49							49
Cr	400	150	56	254	300	200	154	33	200	200	100	310
Cu	62	110			116							82
Eu	1.06	<2			<2							<2
Ga		20										
Hf	<2				<2							<2
Ir	<1				<1							<1
La	6	3			6							6
Li		17										
Lu	0.37											
Mo	<2	<2			3							<2
Nb		<4	<1	6			<1					
Nd		9										
Ni	120	96	40	125	120	67	92	36	48	72		93
Pb		5										
Pd (ppb)												
Pt (ppb)												
Rb	<10		19	16	<10		8					<10
Rd												
Sb	1.7				6							1.4
Sc	37	39			41							43
Se	<10				<10							<10
Sm	2.8				3.1							3
Sn	<200	<10			<200							<200
Sr		130	87	63			150	86				
Ta	<1	<40			<1							<1
Tb	0.6				<1							<1
Te	<20				<20							<20
Th	0.9	<4			0.6							0.7
U	<0.5	<100			<0.5							<0.5
V	320	210	199	278	325	199	320		244	252	345	310
W	<2				<2							<2
Y		24	20	17			26					
Yb	2.42	3			<5							<5
Zn	220	84			60							58
Zr	<500		64	76	<500		67	93				<500

A5 continued.

	Sample numbers										
	25R	26R	27R	28R	29R	30R	31R	32R	33R	34R	35R
SiO_2(%)[1]	48.7	47.52	49.43	51.87	49.4	50.32	49.3	48.37	50.41	50.36	55.02
Al_2O_3	14.95	13.75	13.7	13.11	15.7	14.95	14	15.04	13.07	15.67	8.49
TiO_2	1.07	0.88	0.92	0.92	0.55	0.72	0.99	0.86	0.73	1.14	0.91
Fe_2O_3	12.14	13.29	12.35	10.78	10.5	11.7	11.7	12.3	12.34	12.21	12.83
FeO											
MnO	0.21	0.19	0.18	0.21	0.18	0.2	0.21	0.2	0.17	0.18	0.25
MgO	7.22	7.85	7.45	6.64	8.05	8.26	8.07	9.1	8.3	7.5	8.92
CaO	11.83	10.93	11.58	8.85	11.3	11.15	11.1	11.21	11.47	11.24	10.6
Na_2O	2.11	1.6	2.14	10.14	2.31	2.38	2.31	2.44	1.75	2.45	1.17
K_2O	0.19	<0.03	0.3	0.25	0.08	0.09	0.25	0.54	0.3	0.05	0.9
P_2O_5	0.26	0.25	0.16		0.25	0.22	0.27	0.12	0.09	0.16	0.11
CO_2											
LOI	0.4	2.3	1.2		0.8	0.7	1.1	1.6	1.9	0.5	0.9
TOTAL (%)	99.08	98.56	99.41	102.77	99.12	100.69	99.3	101.78	100.53	101.46	100.1
CaO/Al_2O_3	0.79	0.79	0.85	0.68	0.72	0.75	0.79	0.75	0.88	0.72	1.25
Ti/V	20	21			14	19	22			27	
Ag[2]		<0.1			<5	<0.1				<0.1	
As					2						
Au (ppb)		<5			<5	<5				6	
Ba		<100			<100	200	184	70	100	<100	150
Be											
Bi											
Cd					<10						
Ce					<10						
Co					52						
Cr	400	400	43		580	400	249	95	60	500	51
Cu	89				40						
Eu					<2						
Ga											
Hf					<2		129	60	58		47
Ir			61		<1						
La					<5						
Li											
Lu											
Mo					<2						
Nb											
Nd											
Ni		88	50		86	23	100	65	36	32	29
Pb											
Pd (ppb)											
Pt (ppb)											
Rb					<10						
Rd							7				
Sb					5.1						
Sc					34						
Se					<10						
Sm					1.9						
Sn					<200						
Sr			80				92	130	120		81
Ta					<1						
Tb					<1						
Te					<20						
Th					1.4						
U					<5						
V	315	250			230	220	267			251	
W					<2						
Y							21	9			11
Yb					<5						
Zn	10				12						
Zr			91		640		46	86	75		115

A5 continued.

	Sample numbers											
	36R	37R	38R	39R	40R	41R	42R	43R	44R	45R	46R	47R
SiO_2(%)[1]	42.4	41.62	45.32	50.2	49.5	49.8	51.1	50.83	52.1	61.6	73.4	54.9
Al_2O_3	7.34	6.89	6.68	15.5	15.2	16	16.1	14.68	12.13	1.18	11.5	13.8
TiO_2	1.92	1.77	1.94	0.94	1.49	1.5	0.83	1.92	0.78	0.05	0.55	0.66
Fe_2O_3	17.9	17.82	17.57	1.63	2.8	2	3	2.52	1.7	23.3	4.47	11
FeO				9.26	9.17	7.5	7.3	10.47	8.94		3.24	8.44
MnO	0.26	0.24	0.24	0.22	0.18	0.17	0.17	0.19	0.18	0.33	0.04	0.22
MgO	16.91	17.91	17.72	7.53	6.82	7.5	5.1	5.64	9.11	8.02	1.92	6.95
CaO	6.43	7.22	5.22	11.6	8.79	11.2	10.8	10.4	10.96	2.99	1.82	7.71
Na_2O	0.56	0.44	0.83	2.15	2.7	2.8	2	2.19	1.47	0.12	2.16	2.71
K_2O	0.04	<0.03	<0.03	0.22	0.69	0.14	0.3	0.19	0.47	0.05	2.15	1.11
P_2O_5	0.36	0.23	0.23	0.1	0.17	0.2	0.15	0.16	0.07	0.19	0.09	0.07
CO_2											<0.01	0.02
LOI	4.4	5.6	4.4	1.62	2.04	1.3	0.5	1.17	1	<0.01	1.66	1.29
TOTAL (%)	98.67	99.74	100.15	100.97	99.55	100.11	97.35	100.36	98.91	97.83	103	108.88
CaO/Al_2O_3	0.88	1.05		0.75	0.58	0.7	0.67	0.71	0.9			
Ti/V		41	51	22	24	30	18	30.9	17.8			
Ag[2]	<5	<0.1	<0.1								<2	<2
As	67										10	<10
Au (ppb)	6	6	25								<8	<8
Ba	<100	<100	<100	80	90	11	60			156	680	420
Be											<1	<1
Bi											<10	<10
Cd	<10										<2	<2
Ce	35			9.2	30	12	7				36	24
Co	87			52	55	32	20	48	50		14	46
Cr	1500	1600	1400	490	250	300	50	94	454	151	74	430
Cu	265			110	100	70	80				17	71
Eu	1.6			0.73	1.3	1.5	0.9				<2	<2
Ga											12	17
Hf	3											
Ir	<1											
La	19			3.6	13	3.5	3.9				21	13
Li											21	12
Lu	0.19											
Mo	<2										<2	<2
Nb								3	3	<1	6	<4
Nd				6.6	17	11	6				16	12
Ni	950	660	527	140	125	100	25			37	47	110
Pb											11	10
Pd (ppb)	2											
Pt (ppb)	<15											
Rb	<10							7	8	1		
Rd												
Sb	0.4											
Sc	27										13	34
Se	<10											
Sm	5.7			2	4	3.9	2.2					
Sn	<200										<10	<10
Sr				100	190	135	225	143	116	10	130	140
Ta	1										<40	<40
Tb	0.3											
Te	<20											
Th	2.1										13	7
U	0.7										<100	<100
V		260	226	260	365	300	270	372	263	<2	77	180
W	<2											
Y				20	30	30	20	22	11	9	16	17
Yb	1.46			1.9	2.2	3	2				2	2
Zn	73			80	120	75	80				33	78
Zr	<500			53	135	100	60	93	45	2		

[1]Oxides and LOI given in weight percent.
[2]All trace-element analyses are in ppm unless 0therwise stated.

Sample lithologies

Major and trace-element analyses of metaigneous and metasedimentary rocks of the Roundtop Mountain Greenstone. **(1R)** chlorite schist; **(2R)** greenschist; **(3R)** greenstone; **(4R)** amphibolite schist; **(5R)** greenstone; **(6R)** amphibolite; **(7R)** amphibolite; **(8R)** metabasalt (Harper, 1985); **(9R)** actinolite schist; **(10R)** amphibolite; **(11R)** greenstone; **(12R)** greenstone; **(13R)** greenstone; **(14R)** metadiabase; **(15R)** metabasalt; **(16R)** metabasalt (Harper, 1985); **(17R)** greenstone; **(18R)** greenstone; **(19R)** amphibolite; **(20R)** metabasalt; **(21R)** greenstone; **(22R)** greenstone; **(23R)** coarse grained amphibolite; **(24R)** greenstone; **(25R)** amphibolite; **(26R)** greenstone; **(27R)** metabasalt; **(28R)** chlorite schist; **(29R)** metabasalt; **(30R)** amphibolite; **(31R)** amphibolite; **(32R)** metabasalt; **(33R)** metadiabase; **(34R)** amphibolite; **(35R)** metadiabase; **(36R)** actinolite schist; **(37R)** chlorite schist; **(38R)** actinolite schist; **(39R)** average Archean tholeiite TH1 (Condie, 1981); **(40R)** average Archean tholeiite TH2 (Condie, 1981); **(41R)** average modern midoceanic ridge basalt (Condie, 1981); **(42R)** average modern arc basalt (Condie, 1981); **(43R)** metatholeiite, Elmers Rock greenstone belt, Wyoming (Smaglik, 1987); **(44R)** metatholeiite, Elmers Rock greenstone belt, Wyoming (Smaglik, 1987); **(45R)** grunerite schist; **(46R)** metachert; **(47R)** chlorite schist.

Appendix A6. Major-element and trace-element analyses of metasedimentary rocks of the Miners Delight Formation and comparable rocks from South Africa and Canada.

	Sample numbers													
	1M	2M	3M	4M	5M	6M	7M	8M	9M	10M	11M	12M	13M	14M
SiO_2(%)[1]	63.70	66.20	64.40	69.20	68.45	71.57	69.26	60.76	63.39	62.37	62.08	62.04	53.95	61.05
Al_2O_3	14.90	10.20	15.50	13.70	15.13	14.30	13.59	16.09	15.28	16.02	16.82	14.96	19.01	17.04
TiO_2	0.57	0.52	0.62	0.53	0.74	0.31	0.56	0.65	0.75	0.67	0.68	0.67	0.82	0.68
Fe_2O_3	1.01	1.63	1.05	1.40	4.83	3.23	5.93	7.39	8.20	9.07	6.61	10.44	8.96	7.30
FeO	4.67	5.38	4.94	3.10										
MnO	0.11	0.10			0.06	0.04	0.05	0.07	0.08	0.11	0.08	0.12	0.13	0.08
MgO	2.99	4.50	3.12	1.60	1.25	0.99	2.37	4.18	3.04	2.89	2.95	3.06	4.56	3.38
CaO	2.63	1.97	2.22	1.80	3.52	1.45	2.70	3.67	2.58	2.89	2.40	2.69	4.17	3.04
Na_2O	3.14	1.80	3.74	3.10	3.60	2.77	3.13	2.69	3.25	3.69	4.73	2.93	3.50	3.67
K_2O	2.30	1.58	2.44	2.00	1.42	3.54	1.77	3.11	2.19	1.98	2.02	2.53	3.18	2.54
P_2O_5	0.14	0.08			0.25	0.21	0.27	0.43	0.30	0.31	0.34	0.32	0.44	0.32
CO_2	1.49	2.59												
LOI	2.17	2.76			0.26	0.96	0.19	0.85	0.73	<0.06	1.10	0.09	0.75	0.85
TOTAL (%)	99.82	99.31	98.03	96.43	99.51	99.37	99.82	99.89	99.79	100	99.81	99.85	99.47	99.95
Na_2O/K_2O	1.4	1.1	1.5		2.5	0.8	1.8	0.9	1.5	1.9	2.3	1.2	1.1	1.4
Al_2O_3/Na_2O	4.8	5.7	4.2		4.2	5.2	4.3	6.0	4.7	4.3	3.6	5.1	5.4	4.6
Ag[2]						<0.20								
As						6.00								
Au (ppb)					<5		<5	<5	<5	<5	<5	9	<5	<5
B						11								
Ba		319		470	400	676	500	1,100	800	700	700	1,000	1,200	800
Be						2								
Bi						7								
Cd						<1								
Ce		46	56	32		27								
Co						13								
Cr					100	13	100	200	200	300	200	200	400	200
Cu						31								
Eu		0.8	1.4	1.1										
Ga						19								
Hf														
Ir														
La		20	29	24		7								
Li						31								
Mo						8								
Nb						15								
Nd														
Ni		290	91	50		21								
Pb						26								
Rb		54	88	75		26								
S (%)					<0.01	<0.01								
Sb						6								
Sc						10								
Se														
Sm		3.2	4.8	4.7										
Sn						<20								
Sr		98	424	190		90								
Ta						<10								
Tb		0.5	0.6	0.6										
Te		1.6	1.5	2.2		<10								
Th														
Tl						<10								
U														
V						37								
W						<10								
Y			16	20		4								
Yb														
Zn						69								
Zr		134	196	370		143								

A6 continued.

	Sample numbers												
	15M	16M	17M	18M	19M	20M	21M	22M	23M	24M	25M	26M	27M
SiO_2(%)[1]	60.20	65.31	62.73	61.80	57.90	63.90	64.40	61.50	63.16	56.21	61.71	65.93	56.50
Al_2O_3	17.23	15.27	15.84	15.98	13.20	14.70	14.30	14.80	14.44	13.94	15.57	13.92	18.90
TiO_2	0.65	0.58	0.73	0.68	0.78	0.60	0.60	0.70	0.50	0.80	0.64	0.55	0.57
Fe_2O_3	8.85	6.72	8.12	8.62	7.54	5.81	5.89	7.92	4.80	1.54	0.95	1.83	5.10
FeO										5.65	4.15	3.20	
MnO	0.09	0.13	0.09	0.10	0.09	0.07	0.09	0.08	0.05	0.11	0.06	0.07	0.09
MgO	3.20	2.33	3.12	2.75	5.73	2.94	3.08	3.45	2.30	6.87	2.92	2.67	2.84
CaO	2.61	2.59	2.56	3.28	4.84	2.85	2.88	2.03	2.98	5.99	2.74	2.02	5.66
Na_2O	4.32	4.09	3.61	3.92	2.78	3.55	3.28	2.99	9.76	3.55	5.00	3.60	2.65
K_2O	2.06	1.94	2.47	1.85	2.29	1.95	2.46	3.30	1.93	2.38	2.73	3.45	4.96
P_2O_5	0.33	0.29	0.35	0.34	0.38	0.25	0.31	0.29		0.24	0.24	0.19	0.30
CO_2													
LOI	0.55	0.51	0.34	0.18	3.20	0.85	0.60	0.55		0.80	0.90	2.00	1.00
TOTAL (%)	100.10	99.76	99.96	99.50	98.73	97.47	97.89	97.61	99.92	98.08	97.61	99.43	98.57
Na_2O/K_2O	2.1	2.1	1.5	2.1	1.2	1.8	1.3	0.9	5.1	1.5	1.8	1.0	0.5
Al_2O_3/Na_2O	4.0	3.7	4.4	4.1	4.7	4.1	4.4	4.9	1.5	3.9	3.1	3.9	7.1
Ag[2]					<0.5								
As					13	22	29	48					
Au (ppb)	<5	<5	<5	<5	21	9	13	9					
B													
Ba	800	700	700	1,000	1,184	1,310	865	896		820	800	1,200	2,200
Be					<10								
Bi					<0.5								
Cd					<0.2								
Ce					92								
Co					22	16	14	13					
Cr	100	100	300	200	507	182	217	187					50
Cu					15	41	48	46					
Eu					2								
Ga													
Hf					4								
Ir													
La					51.9	35	30	11					
Li					<10								
Mo					<5								
Nb					8	3	1	4		12	13	12	<20
Nd					28								
Ni					122	51	43	61		150	61	40	29
Pb					7								
Rb					62	66	86	115		94	55	56	170
S (%)													
Sb					<0.2								
Sc					16	11	11	13					
Se					<3								
Sm					7.5								
Sn													
Sr					606	542	385	443		355	395	280	1,000
Ta					<1								
Tb													
Te													
Th					11	10	8.9	7.8					
Tl													
U					2.8	2.4	1.9	2.1					
V					150								70
W					<3								
Y					26	19	18	15		17	<5	<5	20
Yb					1.9								
Zn					95	76	77	86					
Zr					179	141	145	144		145	135	130	260

A6 continued.

	Sample numbers													
	28M	29M	30M	31M	32M	33M	34M	35M	36M	37M	38M	39M	40M	41M
SiO_2(%)[1]	60.50	49.93	64.35	18.15	61.93	75.16	70.30	62.00	74.04	57.39	61.91	59.9	63.50	51.87
Al_2O_3	14.00	16.15	12.62	3.74	14.94	11.98	15.60	16.30	14.03	15.17	15.50	16.94	16.20	13.11
TiO_2	0.67	0.72	0.42	0.14	0.58	0.22	0.55	0.67	0.27	1.44	0.84	0.64	0.64	0.92
Fe_2O_3	6.66	10.11	4.49	1.70	10.44	3.64	1.57	5.92	2.38	8.18	6.20	7.48	7.27	10.78
FeO														
MnO	0.10	0.17	0.12	0.09	0.14	0.05	0.03	0.09	0.03	0.21	0.09	0.09	0.08	0.21
MgO	4.77	8.61	2.34	0.27	2.97	0.80	1.33	3.29	1.04	3.08	3.10	3.82	3.67	6.64
CaO	10.10	1.11	0.65	42.21	1.75	5.18	1.31	1.95	1.78	7.13	4.98	2.57	1.34	8.85
Na_2O	2.09	8.77	6.73	0.01	3.43	0.40	8.08	4.17	5.03	2.67	2.97	4.19	2.19	10.14
K_2O	0.16	2.32	7.88	0.40	2.24	1.23	0.23	2.93	0.92	2.68	1.49	1.94	2.29	0.25
P_2O_5	0.21			0.2	0.29	0.25	0.12	0.21	0.21	0.62	0.32	0.28	0.18	
CO_2				31.85										
LOI	0.62				0.63	<0.05	0.62	2.39	0.50	2.60	2.90	2.50	3.08	
TOTAL (%)	99.88	97.89	99.6	98.76	99.34	98.91	99.74	99.92	100.23	101.17	100.3	100.35	100.44	102.77
Na_2O/K_2O	13	3.8	0.9											
Al_2O_3/Na_2O	6.7	1.8	1.9											
Ag[2]				0.7			<0.5	<0.5	<0.1	<5	<0.1			
As				<5			5	14		2				
Au (ppb)				<5	<5	<5	<10	<10	<5	<5	<5			
B				66			10	10						
Ba	150			>2,000	900	500	120	1,000	500	1,500	600	1,100	690	
Be				0.7			<10	<10						
Bi				<2			<0.5	<0.5						
Cd				<1			<0.2	<0.2		<10				
Ce				22			43	72		210				
Co				12			5	19		29				
Cr	250			13	300	100	50	160	<100	100	100	158	160	
Cu				16			4	44		44				
Eu							1.6	1.7		2				
Ga				6										
Hf							4	4		8				
Ir										<100				
La				11			16.9	40.4		100				
Li				22			<10	<10						
Mo				<1			<5	<5		<2				
Nb	20			7			<20	<20					30	
Nd							20	28						
Ni	130			32			20	76		<50	64	85	92	
Pb				26			14	18						
Rb	<20			<20			30	100		73			150	
S (%)				0.01					<0.02		<0.02			
Sb				10			<0.2	<0.2		0.8				
Sc				15			9.1	13.5		15				
Se							<3	<3		<10				
Sm							3.6	4.8		15				
Sn				<20						<200				
Sr	510			104			140	510				345	230	
Ta				<10			<1	<1		2				
Tb										1				
Te				<10						<20				
Th							6	7.3		23				
Tl				18										
U							2.2	2.5		4.5				
V	120			31			70	120			109	99	140	
W				<10			<3	<3	2	<2				
Y	<20			7			30	20				<5	20	
Yb							1.7	1.6		<5				
Zn				20			14	87		95				
Zr	140			29			170	180		560		150	150	

[1] Oxides and LOI given in weight percent.
[2] All trace-element analyses are in ppm unless otherwise stated.

Sample lithologies

(1M) Average of 20 Archean greywackes (Henderson, 1972); **(2M)** average of 17 Archean greywackes from the Sheba Formation, South Africa (Condie and others, 1970); **(3M)** composite Archean greywacke (Condie, 1976); **(4M)** average of 23 greywackes from the Miners Delight Formation (Condie, 1981); **(5M-6M)** metagreywacke, Anderson Ridge area; **(7M-23M)** metagreywacke, Lewiston district; **(24M-25M)** metagreywacke, Anderson Ridge area; **(26M)** metagreywacke, Halls Meadow Spring quadrangle; **(27M-28M)** metagreywacke, Anderson Ridge area; **(29M-30M)** metagreywacke, Lewiston district; **(31M)** metacarbonate; **(32M)** chloritic quartzite; **(33M)** cherty metagreywacke; **(34M)** cherty metagreywacke; **(35M)** cherty metagreywacke; **(36M)** cherty metagreywacke; **(37M)** metaconglomerate; **(38M)** tectonic breccia; **(39M)** chloritic quartzite; **(40M)** mica schist; **(41M)** chlorite schist.

Appendix A7. Major-element and trace-element analyses of Miners Delight Formation metaigneous rocks.

	Sample numbers													
	Komatiite suite													
	42M	43M	44M	45M	46M	47M	48M	49M	50M	51M	52M	53M	54M	55M
SiO_2(%)[1]	46.94	42.52	44.18	46.30	41.30	45.90	49.30	50.29	43.91	49.33	48.00	38.28	47.73	45.38
Al_2O_3	7.74	8.22	8.45	10.40	6.66	8.41	8.11	5.98	8.41	6.48	8.87	9.08	7.66	7.87
TiO_2	0.98	0.81	0.79	0.84	0.61	0.71	0.69	0.54	0.78	0.62	0.84	0.78	0.74	0.77
Fe_2O_3	13.16	12.34	10.55	10.80	7.14	10.70	9.80	10.37	10.78	10.51	12.40	11.37	8.29	10.05
FeO														
MnO	0.32	0.25	0.17	0.20	0.19	0.25	0.26	0.21	0.19	0.21	0.15	0.26	0.22	0.15
MgO	14.09	18.31	20.84	15.19	5.44	20.44	16.40	18.54	22.00	16.77	11.22	8.21	17.76	21.60
CaO	9.84	9.22	7.17	11.20	22.40	9.18	10.45	10.68	7.07	11.48	12.10	19.95	11.28	7.99
Na_2O	6.12	6.18	0.66	1.57	1.29	0.21	0.72	0.28	0.13	0.42	2.68	1.51	0.33	0.31
K_2O	0.71	0.19	<0.03	0.28	0.67	0.06	0.66	0.20	<0.03	0.19	0.07	0.99	0.81	0.05
P_2O_5			0.42	0.39	0.29	0.37	0.37	0.23	0.40	0.31	0.31	0.22	0.31	0.33
CO_2					1.25	0.52								
LOI			4.80	1.60	12.20	4.20	1.50	2.30	5.30	2.50	2.20	10.40	4.270	5.22
TOTAL (%)	99.90	98.04	98.03	98.77	99.44	100.95	98.26	99.62	98.97	98.82	98.84	101.05	99.40	99.72
CaO/Al_2O_3	1.3	1.1	0.8	1.1	3.4	1.1	1.3	1.8	0.8	1.8	1.4	2.2	1.5	1.0
Ti/V														
Ag[2]		0.4	<5	<5		<5		<5	<5	<2	<5		0.6	0.2
As			2	2	3.3	66	306	40	141	108	4			
Au (ppb)		13	<5	<5	6	31	22	<5	14	17	<5		11	50
Ba		100	<100	200	490	<100	710	100	<100	60	400	330	100	100
Be														
Bi														
Cd			<10	<10		<10			<10	5	<10			
Ce			31	<10	39	13	13	15	11	<7.3	16			
Co			67	52	42	35	46	57	73	73	84			
Cr		2,100	1,900	1,400	1,300	1,800	1,400	1,500	2,400	1,500	1,700	1,009	1,700	1,900
Cs				2			4.9	1		1.1				
Cu			90	16	33	5	9	4	7	4	22			
Eu			1.33	<2	1	<2		<2	0.87	1	<2			
Ga														
Hf			2	<2	2	<2			<2	<1	<2			
Hg														
Ir			<1	<1		<1		<100	<100	<50	<1			
La			12	7	15	7	6	10	8	7	12			
Li								<2						
Lu			0.23						0.23					
Mo			<2	<2		<2			<2	<1	<2			
Nb														
Nd														
Ni		630	680	410	280	500	430	650	440	800	720	142	620	285
Os														
Pb														
Pd (ppb)		4	<2			2		<2	4	2			4	4
Pt (ppb)		<15	15			20		<15	20	20			<15	<15
Rb			<10	<10	20	<10	20	<10	<10	7	<10			
Rd														
Sb			0.6	0.9	0.3	1	0.7	3.2	31.7	11.4	0.9			
Sc			28	34	21	27	21.4	21	26	20.6	30			
Se			<10	<10		<10		<10	<10	<5	<10			
Sm			4	3.3	4.2	2.8	2.7	2.8	2.8	2.5	3.7			
Sn			<200	<200		<200		<200	<200	<100	<200			
Sr												135		
Ta			<1	<1		<1		<1	<1	<0.5	<1			
Tb			0.5	<1	0.6	<1		<1	0.3	<0.5	<1			
Te			<20	<20		<20		<20	<20	<10	<20			
Th			2.5	1.4	3.1	1.5	1	2.3	1.2	1.5	2.4			
U			0.7	<0.5	0.8	<0.5	0.5	<0.5	0.5	0.5	0.8			
V				245	194			162			220	46		197
W			<2	<2		<2	3	<2	<2	<1				
Y											<2			
Yb			1.61	<5		<5	3	<5	1.52		<5			
Zn			30	18	16	45	140	38	43	110	12			
Zr			<500	<500		<500		<500	<500	<200	<500	86		

A7 continued.

								Tholeiite suite						
	56M	57M	58M	59M	60M	61M	62M	63M	64M	65M	66M	67M	68M	69M
SiO_2(%)[1]	47.90	37.60	43.04	51.80	41.52	40.35	46.08	47.09	44.42	48.20	52.14	48.74	49.44	52.80
Al_2O_3	5.28	5.93	11.71	10.90	10.50	10.90	9.10	13.47	13.62	13.70	13.01	14.22	15.00	15.10
TiO_2	1.28	0.52	0.94	0.80	0.66	0.66	0.86	1.82	1.17	1.28	1.11	1.27	0.83	2.05
Fe_2O_3	14.10	6.08	11.61	8.58	10.58	11.60	11.86	16.73	18.20	15.50	14.19	14.83	1.44	14.10
FeO													9.19	
MnO	0.27	0.32	0.18	0.17	0.19	0.20	0.25	0.25	0.36	0.21	0.20	0.22	0.18	0.32
MgO	17.00	4.79	18.75	11.39	20.49	22.73	11.48	6.16	6.85	5.84	6.46	7.20	7.76	4.18
CaO	9.12	25.3	5.30	10.30	7.74	6.84	17.52	10.02	10.73	10.40	9.07	10.12	10.8	8.26
Na_2O	0.20	1.20	0.76	3.49	0.30	0.24	0.93	1.95	1.53	1.93	2.33	2.53	2.29	2.87
K_2O	0.13	0.40	1.45	0.22	0.17	0.09	0.55	0.43	0.12	0.22	0.18	0.22	0.37	0.64
P_2O_5	0.12	0.28	0.41	0.34	0.20	0.23	0.29	0.33	0.32	0.28	0.22	0.23	0.24	0.30
CO_2							0.50						0.25	
LOI	3.00	16.00	4.80	1.00	4.60	5.90	1.40	0.60	1.20	0.60	0.46	0.58	2.00	0.80
TOTAL (%)	98.40	98.42	98.95	98.99	96.95	99.74	100.82	98.85	98.52	98.16	99.37	100.16	99.79	101.42
CaO/Al_2O_3	1.7	4.3	0.5	0.9	0.7	0.6	1.9	0.7	0.8	0.8	0.7	0.7	0.7	0.5
Ti/V								30	19	20	24	23		28
Ag[2]		<5	<5	<5				<5	<5	<5	<0.1	0.1		
As		7	41	3	80	30	280	45	4	14				
Au (ppb)		<5	6	7	20	20	430	5	<5	<5	<5	<5		
Ba	110	280	400	700				<100	120	100	100	100		148
Be														
Bi														
Cd		<10	<10	<10				<10	<10	<10				
Ce		30	<10	<10				19	15	11				
Co		33	55	44				54	65	53				
Cr	1,500	1,400	1,300	530	2,047	2,095	1,957	300	240	300	300	500		131
Cs			9											
Cu		27	7	9				29	50	140				
Eu		1.25	<2	<2				<2	<2	<2				
Ga														
Hf		<2	<2	<2				4	<2	<2				
Hg														
Ir		<1	<1	<1				<100	<1	<1				
La		15	7	5				9	9	8				
Li														
Lu		0.19												
Mo		<2	<2	<2				<2	<2	<2				
Nb														1
Nd														
Ni	1,100	250	420	120	409	692	492	<50	78	59	20	36		63
Os														
Pb														
Pd (ppb)														
Pt (ppb)														
Rb	<20	<10	54	<10				<10	<10	<10				14
Rd														
Sb		0.2	0.7	0.7				3.1	4.2	2				
Sc		21	35	30				41	54.7	49				
Se		<10	<10	<10				<10	<10	<10				
Sm		3.9	3.3	2.9				3.5	3.6	3.4				
Sn		<200	<200	<200				<200	<200	<200				
Sr					21	50	583							235
Ta		<1	<1	<1				<1	<1	<1				
Tb		0.1	<1	<1				<1	1	<1				
Te		<20	<20	<20				<20	<20	<20				
Th		2.8	1.3	0.9				1.5	2	1.6				
U		0.7	0.5	<0.5				0.5	0.7	<0.5				
V	220			191				365	360	375	272	325		440
W		<2	<2					2						
Y				<2					2	2				33
Yb		1.08	<5	<5				<5	5	<5				
Zn		8	86	200				34	<22	<14				
Zr		<500	<500	<500	67	80	89	<500	<500	<500				107

A7 continued.

	Tholeiite suite												Calc-alkaline suite	
	70M	71M	72M	73M	74M	75M	76M	77M	78M	79M	80M	81M	82M	83M
SiO_2(%)[2]	56.05	42.10	50.90	55.65	51.00	53.90	52.70	60.52	67.12	51.22	49.29	38.40	57.27	50.80
Al_2O_3	13.09	18.90	14.70	14.83	15.10	15.00	17.20	16.63	14.26	18.20	14.60	9.72	13.97	15.60
TiO_2	1.00	0.98	0.91	1.19	0.9	1.24	1.59	1.13	1.05	1.21	1.74	0.78	1.04	1.13
Fe_2O_3	11.19	17.40	12.40	12.17	10.10	11.70	10.20	8.10	6.02	10.62	17.14	9.55	8.88	9.42
FeO														
MnO	0.19	0.24	0.2	0.24	0.3	0.29	0.17	0.13	0.06	0.12	0.24	0.24	0.11	0.21
MgO	4.62	9.11	6.42	3.87	3.57	3.60	30.60	2.37	1.28	3.53	5.41	5.28	4.82	5.00
CaO	11.05	1.46	8.86	10.30	10.03	8.69	4.89	3.84	1.54	7.16	8.38	18.8	5.42	8.23
Na_2O	0.64	3.54	3.18	2.40	2.95	3.14	3.69	4.08	4.46	3.61	2.91	1.70	3.83	2.49
K_2O	0.11	0.13	1.08	0.16	1.50	0.14	3.61	2.05	2.53	1.35	0.31	2.51	0.74	2.01
P_2O_5	0.24	0.11	0.08	0.32	0.55	0.28	0.54	0.44	0.42	0.35	0.18	0.22	0.34	0.61
CO_2										0.20	1.30	11.5		
LOI	0.30	5.85	1.39	1.20	3.20	0.80	1.80	0.83	1.15	1.50	1.30		1.90	3.30
TOTAL (%)	98.48	99.82	100.12	102.33	99.20	98.78	126.99	100.12	99.89	99.07	102.80	98.70	98.32	98.80
CaO/Al_2O_3	0.8	0.08	0.6											
Ti/V	20	35	23											
Ag[2]	<5			<5	<5	<5	<5		<0.1					<5
As	<1			1	<1	16	16			10	30	20		<1
Au (ppb)	<5			<5	<5	6	<5	8	219	20	20	5		7
Ba	<100	140	170	<100	490	300	1500	500	900				110	1100
Be														
Bi														
Cd	<10			<10	<10	<10	<10							<10
Ce	28			39	140	22	120							230
Co	41			41	38	53	32							34
Cr	210	410	250	300	100	240	380	100	100	123	239	390	70	360
Cs					2		15							
Cu	13			59	52	61	67							28
Eu	<2			<2	5	1.29	2.87							<2
Ga														
Hf	3			3	4	3	4							6
Hg														
Ir	<1			<1	<1	<1	<1							<1
La	18			17	75	8	71							110
Li														
Lu						0.37	0.5							
Mo	<2			<2	<2	<2	<2							<2
Nb		20	<20											
Nd														
Ni	71	140	81	70	100	61	89		5	58	75	180	66	<50
Os														
Pb														
Pd (ppb)														
Pt (ppb)														
Rb	<10	<20	50	<10	46	<10	72							54
Rd														
Sb	0.4			0.7	1.3	3	3.1							2.3
Sc	36			32	16	41	25							26
Se	<10			<10	<10	<10	<10							<10
Sm	3.8			4.3	13	3.2	11							19
Sn	<200			<200	<200	<200	<200							<200
Sr		80	150							542	181	250	53	
Ta	<1			<1	<1	<1	<1							<1
Tb	<1			<1	2	0.6	1.2							2
Te	<20			<20	<20	<20	<20							<20
Th	5.1			3.8	13	2.1	14							18
U	1.2			0.9	2.2	0.5	3							3.5
V	305	170	240	255	169	340	235	164	73					225
W	4				<2	<2	<2							2
Y		<20	<20	<2										
Yb	<5			<5	<5	2.54	3.29							<5
Zn	9			30	52	22	260							69
Zr	<500	40	40	<500	570	<500	<500			196	138	40		<500

A7 continued.

	Calc-alkaline suite												
	84M	85M	86M	87M	88M	89M	90M	91M	92M	93M	94M	95M	96M
SiO_2(%)[1]	56.00	55.00	58.30	58.30	62.81	61.20	64.48	51.22	52.72	59.55	57.75	58.16	54.63
Al_2O_3	14.70	17.00	15.79	17.20	14.85	16.30	15.92	14.90	15.40	17.49	19.05	17.44	17.40
TiO_2	0.90	1.06	0.97	1.56	1.20	1.01	0.57	0.75	1.03	1.45	0.96	1.16	1.09
Fe_2O_3	6.65	8.82	1.77	6.03	4.99	4.98	4.56	9.75	10.31	0.75	1.83	1.22	2.70
FeO			4.30							3.61	3.53	4.31	5.72
MnO	0.11	0.12	0.10	0.12	0.12	0.10	0.06	0.18	0.14			0.11	0.13
MgO	5.24	3.59	3.06	2.92	1.94	1.83	2.08	5.89	5.53	2.30	2.26	3.01	3.71
CaO	6.24	7.22	5.60	4.23	5.73	4.22	2.12	9.12	8.49	4.68	6.18	5.81	8.54
Na_2O	2.98	3.78	4.28	4.01	3.53	5.11	6.91	2.77	2.83	4.07	4.37	4.17	3.34
K_2O	3.16	1.79	2.19	2.56	1.67	2.05	2.27	1.20	0.61	2.83	1.38	1.79	0.94
P_2O_5	0.56	0.28	0.35	0.99	0.51	0.46	0.14	0.13	0.24			0.46	0.24
CO_2								0.80				0.40	0.03
LOI	2.40	1.23	1.20	1.70	2.50	1.50	0.70	1.30	1.40			1.59	1.36
TOTAL (%)	98.94	99.89	97.91	99.62	99.85	98.76	99.81	98.01	98.70	96.73	97.31	99.63	99.83
CaO/Al_2O_3													
Ti/V													
Ag[2]	<5				<5	<5	<5						
As	4				98	21	9	70	10				
Au (ppb)	<5				9	<5	<5	70	20				
Ba	640	600	670	1,266	420	520	560						
Be													
Bi													
Cd	<10				<10	<10	<10						
Ce	140				100	62	51						
Co	23				22	16	15						
Cr	220	50		57	560	150	<50	675	287				
Cs	2				1	3	1						
Cu	62				78		14						
Eu	2				<2	<2	<2						
Ga													
Hf	6				4	6							
Hg													
Ir	<1				<1	<1	<100						
La	72				56	33	26						
Li													
Lu													
Mo	<2				<2	<2	<2						
Nb		20		15									
Nd													
Ni	73	55	15	72	120	72	<50	206	41				
Os													
Pb													
Pd (ppb)													
Pt (ppb)													
Rb	99	70	70	68	40	55	49						
Rd													
Sb	3.1				2.8	6.1	1.3						
Sc	17				24	10	8.3						
Se	<10				<10	<10	<10						
Sm	13				10	6.4	4.3						
Sn	<200				<200	<100	<200						
Sr		460		595				356	352				
Ta	<1				<1	1	<1						
Tb	1				<1	<1	<1						
Te	<20				<20	<20	<20						
Th	15				11	11	8.4						
U	3.2				2.3	3.5	1.9						
V	163	160		193	205		6.7						
W	2				<2	<2	<2						
Y		30		37	<2								
Yb	<5				<5	<5	<5						
Zn	72				52	<200	53						
Zr	<500	180		378	<500	640	<500	121	214				

A7 continued.

[1] Oxides and LOI given in weight percent.
[2] All trace-element analyses are in ppm unless otherwise stated.

Sample lithologies

(42M-51M) actinolite schist; **(52M)** chlorite-actinolite schist; **(53M)** chlorite-tremolite-talc-carbonate schist; **(54M-55M)** actinolite schist; **(56M)** amphibolite; **(57M)** chlorite schist; **(58M)** chlorite schist; **(59M)** vesicular metabasalt; **(60M)** tremolite/actinolite schist (Bow, 1986); **(61M)** deformed tremolite schist (Bow, 1986); **(62M)** calc-silicate tremolite schist (Bow, 1986); **(63M)** metagabbro; **(64M)** coarse grained amphibolite; **(65M-66M)** medium grained amphibolite; **(67M)** metagabbro?; **(68M)** metagabbro (Bayley and others, 1973); **(69M)** metabasalt; **(70M)** amphibolite; **(71M)** amphibolite; **(72M)** metadiabase; **(73M)** meta-andesite; **(74M-76M)** metabasalt; **(77M)** metadacite porphyry; **(78M)** metaporphyry; **(79M-80M)** hornblende plagioclase amphibolite (Bow, 1986); **(81M)** carbonate-actinolite-hornblende-plagioclase-quartz-fragmental rock (Bow, 1986); **(82M)** amphibolite; **(83M)** metabasalt; **(84M)** fine grained amphibolite; **(85M-86M)** amphibolite; **(87M)** metatuff; **(88M)** vesicular metavolcanic; **(89M)** metaporphyry; **(90M)** metatuff; **(91M-92M)** hornblende-plagioclase amphibolite (Bow, 1986); **(93M-94M)** meta-andesite porphyry (Bayley and others, 1973); **(95M)** meta-andesite (average of 3 analyses; Bayley and others, 1973); **(96M)** metadacite (Bayley and others, 1973).

Appendix A8. Chemical analyses of some plutonic and related rocks from the South Pass granite-greenstone belt.

	Sample numbers							
	1P	2P	3P	4P	5P	6P	7P	8P
SiO_2(%)	75.40	57.70	75.00	57.50	70.05	50.50	49.52	48.45
Al_2O_3	13.60	18.50	14.20	15.30	15.87	13.40	13.13	13.00
TiO_2	0.12	0.63	0.20	2.34	0.39	1.76	1.85	2.07
Fe_2O_3	1.24	8.63	0.62	13.30	2.47	15.90	16.64	15.09
FeO	0.79		0.28					
MnO	<0.02	0.06	<0.02	0.18	0.03	0.24	0.22	0.28
MgO	0.41	5.40	0.51	1.52	0.88	5.15	4.76	5.63
CaO	1.43	0.26	2.73	5.40	1.75	8.52	9.32	7.30
Na_2O	3.98	0.74	5.29	2.96	5.09	2.82	8.09	9.49
K_2O	2.96	3.48	1.00	1.30	2.00	0.81	1.11	1.06
P_2O_5	0.15	<0.05	<0.05		0.22	0.17		
CO_2	0.08	0.02	<0.01			0.03		
LOI	0.92	4.55	0.42		2.00	1.41		
TOTAL (%)	101.10	100.02	100.31	99.80	100.75	100.71	104.64	102.37
Ag[2]	<2	<2	<2		<0.1	<2		
As	<10	<10	<10			<10		
Au (ppb)	<8	<8	<8		<5	<8		
Ba	480	400	230		800	360		
Be	5	2	<1			<1		
Bi	<10	<10	<10			<10		
Cd	<2	<2	<2			<2		
Ce	41	44	31			36		
Co	2	47	<1			53		
Cr	4	360	2		<100	61		
Cu	<1	25	<1			67		
Eu	<2	<2	<2			<2		
Ga	15	23	15			23		
Hf								
Ir								
La	25	26	20			17		
Li	64	280	<2			20		
Mo	<2	<2	<2			<2		
Nb	<4	4	<4			<4		
Nd	17	18	13			22		
Ni	2	280	<2			55		
Os								
Pb	35	6	16			8		
Sc	3	15	<2			43		
Sm								
Sn	<10	<10	<10		7	<10		
Sr	160	51	400			230		
Ta	<40	<40	<40			<40		
Th	17	14	8			5		
U	<100	<100	<100			<100		
V	7	120	16			210		
W					2			
Y	9	9	5			30		
Yb	1	1	<1			4		
Zn	26	72	5			130		

[1]Oxides and LOI given in weight percent.
[2]All trace-element analyses are in ppm unless otherwise stated.

Sample lithologies

(1P) granite; (2P) quartz diorite; (3P) metatonalite; (4P) basalt; (5P) diabase; (6P) basalt; (7P) basalt; (8P) basalt.

B. Sample descriptions and assay values for samples from the South Pass greenstone belt shown on Plate 2.

Appendix B. Sample descriptions and assay values of rocks from the South Pass greenstone belt (n.d. = not detected).

Map no.	Location	Description	Ag (ppm)	As (ppm)	Au (ppm)	B (ppm)	Bi (ppm)	Co (ppm)	Cr (ppm)	Cu (%)	Fe (%)	Fe^{2+} (%)	Fe^{3+} (%)	Ga (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Sb (ppm)	Sn (ppm)	V (ppm)	W (ppm)	Zn (ppm)
1A	NE/4 sec. 4, T28N, R98W	Cu-stained quartz from dump	5.2		2.8					1.38														
2A	Wolf mine dump	Fe-stained quartz from dump	0.3		23.3																			
3A	NE of Mint mine	Metachert			0.2																			
4A	NE of Mint mine	Metachert			<0.005																			
5A	SE/4 sec. 18, T28N, R98W	Gray quartz from dump	<0.3		<0.3																			
6A	Iron Duke mine	Metagreywacke with boxworks	<0.3		7.2																			
	Iron Duke mine	Sample 6-24-2, 16-in channel of altered greywacke w/quartz	<0.3		1.6																			
	Iron Duke mine	Sample 6-24-3 (continuation of 6-24-2) 18-in channel	<0.3		0.48																			
	Iron Duke mine	Sample 6-24-4 (continuation of 6-24-3) 10-in channel	<0.3		0.41																			
	Iron Duke mine	Silicified chloritized metagreywacke grab	0.3		0.75																			
	Iron Duke mine	6-ft channel across shear zone	0.4		1.24																			
7A	Hidden Hand mine	Grab of quartz w/sheared metagreywacke	<0.3		<0.03																			
	Hidden Hand mine	Grab from dump	0.5		0.11																			
	Hidden Hand mine	Silicified metagreywacke from dump	<0.3		1.7																			
	Hidden Hand mine	Gray translucent quartz in greywacke from dump	<0.3		<0.3																			
	Hidden Hand mine	Silicified metagreywacke from dump	0.3		<0.3																			
	Hidden Hand mine	Ore bin sample			4.2																			
8A	Goodhope mine	2-ft channel across shear	1.2		0.48																			
	Goodhope mine	Limonitic greywacke from dump	<0.3		40.47																			
	Goodhope mine	Metagreywacke from dump	<0.3		<0.3																			
	Goodhope mine	Representative sample of quartz adjacent to trench	<0.3		21.54																			
	Goodhope mine	Sample GH1-86, 2-ft channel across shear	0.5		12.04																			
	Goodhope mine	2-ft channel ~ 10 ft south of GH1-86	0.4		3.68																			
	Goodhope mine	Float quartz, 500 ft NE of shaft	<0.3		0.89																			
9A	Burr mine	Hematitic metagreywacke from Amanda shaft	0.6		0.20																			
	Burr mine	Silicified metagreywacke	0.5		0.07																			
	Burr mine	Dump sample			<0.3																			
	Burr mine	Metagreywacke w/gray quartz	<0.3		<0.3																			
	Burr mine	Translucent gray quartz	<0.3		<0.3																			
	Burr mine	4-ft channel in shear			<0.05																			
10A	Wilson Bar adit	Limonitic stained milky quartz from dump	<0.3		<0.3																			
11A	Sec. 7, T28N, R98W	Translucent quartz from inclined shaft	1.72		<0.3																			
12A	Lone Pine trench	6-ft channel in chlorite schist, west end of trench	2.9		1.6																			
	Lone Pine trench	E to W, channel sample from 0 to 4-ft	2.5		0.47																			
	Lone Pine trench	E to W, channel sample from 4 to 7-ft	1.9		0.69																			
	Lone Pine trench	E to W, channel sample from 7 to 11-ft	4.3		3.5																			

Appendix B continued.

Map no.	Location	Description	Ag (ppm)	As (ppm)	Au (ppm)	B (ppm)	Bi (ppm)	Co (ppm)	Cr (ppm)	Cu (%)	Fe (%)	Fe^{2+} (%)	Fe^{3+} (%)	Ga (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Sb (ppm)	Sn (ppm)	V (ppm)	W (ppm)	Zn (ppm)
13A	Lone Pine adit	Arsenopyrite-bearing quartz from mine rib	20.77		<0.3																			
14A	Bullion mine	Grab-sample from dump			<0.3																			
	Bullion mine	Grab sample from dump	<0.3		<0.3																			
15A	Mint mine	Grab sample from mine dump	<0.3		<0.3																		<100	
	Mint mine	Milky quartz from dump			44.25																			
	Mint mine	Quartz from shear	<0.3		<0.3																			
	Mint mine	30-in composite chip across shear	10.98		104.62																			
16A	SE/4 sec. 9, T28N, R98W	Hanging wall of arsenopyrite quartz vein	130.0		0.85																			
	SE/4 sec. 9, T28N, R98W	Arsenopyrite-bearing quartz	24.0		1.73																			
	SE/4 sec. 9, T28N, R98W	Arsenopyrite-bearing quartz	20.9		<0.3																			
17A	SW/4 sec. 19, T29N, R97W	BIF	<0.3		0.69																			
	SW/4 sec. 19, T29N, R97W	Fuchsitic quartzite	<0.3		1.37																			
	SW/4 sec. 19, T29N, R97W	Fuchsitic quartzite	<0.3		<0.3																			
	SW/4 sec. 19, T29N, R97W	BIF	<0.3		<0.3						22.0													
	SW/4 sec. 19, T29N, R97W	BIF	<0.3		<0.3																			
18A	Sec. 25, T29N, R98W	Hematitic iron formation	1.72		0.69						21.0													
	Sec. 25, T29N, R98W	Copper-stained hematitic iron formation	<0.3		0.69					0.56														
	Sec. 25, T29N, R98W	Quartz with limonitic boxworks	3.43		0.34						10.7													
19A	Sec. 34, T29N, R102W	Panned concentrate from boulder conglomerate			n.d.																			
20A	Sec. 34, T29N, R102W	Panned concentrate from boulder conglomerate			n.d.																			
21A	NE sec. 21, T29N, R101W	Fault breccia			<0.005																			
	NE sec. 21, T29N, R101W	Fault breccia			0.005																			
	NE sec. 21, T29N, R101W	Fault breccia			<0.005																			
	NE sec. 21, T29N, R101W	Fault breccia			<0.005																			
	NE sec. 21, T29N, R101W	Fault breccia			<0.005																			
	NE sec. 21, T29N, R101W	Fault breccia			<0.005																			
	NE sec. 21, T29N, R101W	Fault breccia			0.025																			
	NE sec. 21, T29N, R101W	Fault breccia			0.015																			
	NE sec. 21, T29N, R101W	Fault breccia			0.060																			
	NE sec. 21, T29N, R101W	Fault breccia	<0.2		2.27																			
	NE sec. 21, T29N, R101W	Copper-stained cataclastics	<0.2		0.18					1.86														
	NE sec. 21, T29N, R101W	Fault breccia	<0.3		<0.03																			
	NE sec. 21, T29N, R101W	Representive sample from 2nd trench (50-ft)	<0.3		0.65																			
22A	NE sec. 21, T29N, R101W	Grab-sample from dump, copper-stained	4.4		3.4					1.54														
23A	Burnt Meadow prospect	Copper-stained granodiorite	103.9		4.03					2.75														
24A	NW sec. 9, T29N, R100W	BIF			1.30																			
	NW sec. 9, T29N, R100W	Quartz vein in BIF			0.40																			
25A		Fuchsitic quartzite	0.68		0.43				2,300	0.012	1.17													
	Quartz-rich BIF	2.9		0.10							36.4													
26A	sec. 33, T30N, R100W	Stockwork	3.2		0.16					3.23														5.1
27A		BIF adjacent to serpentinite	n.d.		n.d.				84			11.0	25.0			28								
28A		Sheared amphibolite	1.0		0.05																			
29A		8-ft. channel across Tabor Grand shear	1.7		3.8																			
30A		Composite of 20' wide vein west, Tabor Grand mine	n.d.		0.24																			

Appendix B continued.

Map no.	Location	Description	Ag (ppm)	As (ppm)	Au (ppm)	B (ppm)	Bi (ppm)	Co (ppm)	Cr (ppm)	Cu (%)	Fe (%)	Fe^{2+} (%)	Fe^{3+} (%)	Ga (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Sb (ppm)	Sn (ppm)	V (ppm)	W (ppm)	Zn (ppm)
31A		Metacarbonate south of Mary Ellen mine	2.9		n.d.																			225
32A	Yellow jacket mine	Grab sample from mine dump	0.2		0.02																			
33A	Tornando mine	Sulfide-bearing quartz-calcite vein	10.0		15.33					1.68														
34A	Diamond Dev. adit	Flathead conglomerate			<0.3																			
	Diamond Dev. adit	Flathead conglomerate			<0.3																			
	Diamond Dev. adit	Flathead conglomerate			<0.3																			
	Diamond Dev. adit	Milky quartz with pyrite & chalcopyrite	<1.0		0.14																			
	Diamond Dev. adit	Milky quartz	<1.0		0.06					0.004														
	Diamond Dev. adit	Flathead conglomerate			<0.005																			
35A	Gold dollar shaft	Grab sample of quartz from dump (Prinz, 1974)		60	17.5																			
36A	Gold dollar adit	Quartz from dump			<0.3																			
	Gold dollar adit	Pyritized metagreywacke			<0.3																			
37A	Atlantic City iron mine	BIF w/minor pyrite & chalcopyrite	<0.3		<0.3																			
	Atlantic City iron mine	Limonite-stained BIF	<0.3		<0.3																			
	Atlantic City iron mine	Chlorite schist selvage from BIF	1.37		<0.3																			
	Atlantic City iron mine	Quartz vein w/pyrite & chalcopyrite from BIF	0.69		<0.3					0.026														
	Atlantic City iron mine	BIF w/pyrite-bearing quartz vein	0.69		<0.3																			
	Atlantic City iron mine	Gray quartz w/calcite in chlorite schist selvage	<0.3		<0.3																			
38A	Smith Gulch adit	Sulfide-bearing quartz from south rib	216.4		2.28																			
	Smith Gulch adit	Actinolite schist from north rib	0.4		0.08																			
	Smith Gulch adit	Dump sample	2.1	277	n.d.	>5,000	<2	20	240	0.009				14	8	122	25			>1	<20	102	<10	120
39A	Snowbird mine	Calcite-rich vein (Prinz, 1974)		30	4.5																			
40A	Midas mine	Quartz vein above portal	<0.2		0.24																			
	Midas mine	Graphitic schist from south rib	<0.2		0.10																			
	Midas mine	Graphitic schist adjacent to vein above adit	<0.2		0.24																			
	Midas mine	Graphitic schist	<0.2		0.41																			
	Midas mine	Contact between mafic amphibolite & schist (Prinz, 1974)		1200	2.8					0.01														
41A	Rock Creek adit	Hematite-stained metagreywacke	<0.2		0.03																			
	Rock Creek adit	Grab sample from dump	<0.2		0.04																			
42A	Big Chief mine	Gray quartz w/disseminated arsenopyrite	0.69		<0.3																			
	Big Chief mine	Translucent gray quartz from mine dump	1.4	>2,000	1.25		<2	36	113	0.009				18	9	90	30				<20	129	<10	89
43A	Outpost mine	Composite of vein quartz and limonitic greywacke	<0.2		0.01																			
	Outpost mine	Grab sample from east dump	0.7		<0.005																			
	Outpost mine	Vein w/limonite pseudomorphs after pyrite from back	8.2		0.87																			
	Outpost mine	Hematite fault gouge from west adit back	0.2		1.33																			
44A	Tabor Grand mine	Sample of 2-ft vein about 500-ft north of mine (Prinz, 1974)		30	0.10					0.05														
45A	Exchange prospect	Cupriferous milky quartz	27.0		0.73					18.1														

Map no.	Location	Description	Ag (ppm)	As (ppm)	Au (ppm)	B (ppm)	Bi (ppm)	Co (ppm)	Cr (ppm)	Cu (%)	Fe (%)	Fe^{2+} (%)	Fe^{3+} (%)	Ga (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Sb (ppm)	Sn (ppm)	V (ppm)	W (ppm)	Zn (ppm)
	Exchange prospect	3-ft channel cut across shear, common quartz	1.2		2.1																			
46A	Duncan mine	2-ft chip channel (SW to NE) (0 to 2-ft)	2.2		3.0																			
	Duncan mine	2-ft chip channel across quartz boudin in fold nose (2 to 4-ft)	6.0		33.0																			
	Duncan mine	5-ft chip channel across shear (4 to 9-ft)	1.8		1.8																			
	Duncan mine	10-ft chip channel (9 to 19-ft)	2.7		6.6																			
	Duncan mine	10-ft chip channel (19 to 29-ft)	7.4		0.71																			
	Duncan mine	10-ft chip channel (29 to 39-ft)	1.0		0.53																			
47A	Carrie Shields mine	Quartz from dump			<0.3																			
	Carrie Shields mine	Dump sample	1.37		<0.3																			
	Carrie Shields mine	Grab of quartz from dump	<0.3		<0.3																			
48A	Sec. 31, T30N, R99W	Fe-Cu-stained quartz in greenstones	6.7		4.53					2.65						120								
49A	Sec. 31, T30N, R99W	Limonitic quartz vein material	n.d.		2.4					0.04						36								
50A	Sec. 31, T30N, R99W	Hematitic quartz from mine dump	n.d.		n.d.					0.02						36								
51A	Sec. 31, T30N, R99W	Milky quartz from mine dump			0.05					0.002						17								
52A	E/2 sec. 36, T30N, R100W	Silicified-carbonated breccia in Roundtop Mtn, deformation zone	n.d.		n.d.					0.005						43								
53A	Sec. 24, T30N, R100W	Quartz-rich BIF (no sulfide)	n.d.		n.d.				22	0.003			35.6			20								
54A	Sec. 24, T30N, R100W	BIF (no sulfides)	n.d.		n.d.				<20	0.002			32.1			10								
55A	NE sec. 26, T30N, R100W	Limonite-stained quartz-rich iron formation	n.d.		n.d.				79	0.013			5.26			11								
56A	Sec. 6, T29N, R99W	Milky quartz breccia vein from mine dump	n.d.		0.06					0.004														29
57A	Caribou mine	2-ft channel across shear east of shaft	1.0		n.d.																			
	Caribou mine	6-ft channel across shear west of shaft	1.0		2.0																			
	Caribou mine	Carbonated metagabbro NW of shaft	1.6		0.34																			
	Caribou mine	Grab sample from mine dump			11.3																			
58A	Sec. 2, T29N, R100W	Quartz from mine dump on Cutter Gulch	n.d.		0.08																			
59A	Rose mine	1-ft channel across Rose shear	n.d.		0.35																			
	Rose mine	2-ft channel in footwall of shear	n.d.		0.61																			
	Rose mine	Grab sample of dump material	1.0		0.29																			
	Rose mine	Grab sample of dump material	0.69		0.34																			
60A	Sec 2, T29N, R100W	Grab sample from dump on Rose shear	<0.03		15.4																			
61A	NE sec. 5, T29N, R99W	Graphitic schist from mine dump	3.9		0.23					0.1														
62A	Sec. 4, T29N, R99W	Quartz from mine dump	n.d.		0.07																			
63A	NE sec. 21, T29, R100W	Arsenopyrite-actinolite schist	<0.3		<0.3																			
	Homestake mine	Dump sample	0.34		3.09																			
	Homestake mine	Grab sample from dump (Prinz, 1974)		250	0.2																			
	Homestake mine	Grab sample from dump (Prinz, 1974)		300	10.9																			
	Homestake mine	Arsenopyrite-bearing quartz	2.1	>2,000	1.56	16	8	80	7	0.04				16	7	31	9	2	<15	15	<20	67	<10	32
64A	SW sec. 15, T29N, R100W	Grab samples from mine dump	2.1	>2,000	1.56																			
65A	SE sec. 15, T29N, R100W	Quartz from Kenyon mine dump	n.d.		0.79																			
66A	Groundhog group	2-ft channel, mixed quartz & graphitic schist	1.1		4.6																			

Appendix B continued.

Map no.	Location	Description	Ag (ppm)	As (ppm)	Au (ppm)	B (ppm)	Bi (ppm)	Co (ppm)	Cr (ppm)	Cu (%)	Fe (%)	Fe^{3+} (%)	Fe^{2+} (%)	Ga (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Sb (ppm)	Sn (ppm)	V (ppm)	W (ppm)	Zn (ppm)
	Groundhog group	2-ft channel, mixed quartz & amphibolite (Prinz, 1974)		250	47.3																			
67A	Wareagle mine	Grab sample from mine dump (Prinz, 1974) (Sample 167)		450	0.2																			
	Wareagle mine	Grab sample from dump SW of 167 (Prinz, 1974)		600	0.3																			
68A	Atlantic City mine	Cumulus serpentinite	<1.0		<0.05					<0.001														
69A	S/2 sec. 18, T29N, R100W	Willow Creek (WY Copper) mine 40-ft chip of quartz-limonite	<0.3		<0.03																			
	Willow Creek mine	Selected quartz from dump	1.1		0.005																			
	Willow Creek mine	Chalcopyrite-bearing quartz chip west of shaft	8.4		0.11					2.88														
70A	W/2 sec. 20, T29N, R100W	White River Formation tuffaceous sandstone	5.3		0.13																			
71A	Garfield mine	Quartz w/limonite stains from dump	<0.3		2.4																			
	Garfield mine	Iron-stained greywacke	1.03		<0.3																			
72A	SE sec. 25, T30N, R99W	2-ft shear exposed in road cut	<0.3		<0.03																			
73A	Miners Delight mine	6-ft channel cut across pillar in shear (Bond, 1986)	<0.3		12.38																			
	Miners Delight mine	2-ft channel cut across shear east of shaft	2.6		4.95																			
	Miners Delight mine	2.5-ft vein sample NE of shaft (Prinz, 1974)		450	0.4																			
74A	Dexter tunnel	Grab sample from dump	0.69		0.34																			
	Dexter tunnel	Iron-stained quartz w/arsenopyrite from dump	1.1	29	0.013	39	3	24	62	0.02				.11	8	65	14			7	<20	72	<10	54
75A	Diana mine	Grab sample from dump	<0.3		<0.3																			
	Diana mine	Grab sample from dump (Prinz, 1974)		450	26.0																			
76A	Doc Barr mine	Iron-stained breccia	<0.3		<0.3																			
	Doc Barr mine	Limonite-stained sheared greywacke (Prinz, 1974)		250	32.8																			
	Doc Barr mine	Metagreywacke adjacent to shear (Prinz, 1974)		10	0.1																			
77A	B&H mine	Scorodite-limonite-stained quartz from dump	5.49		<0.3																			
78A	1914 adit	Iron-stained graphitic-schist	1.03		<0.3																			
79A	Franklin mine	Quartz from mine dump			17.2																			
80A	NE sec. 24, T29N R102W	Ultramafic schist			0.08																			
81A	Monte Carlo mine	Grab of sample quartz from dump	0.3		0.03																			
82A	NW sec. 21, T29N, R100W	Grab sample from dump (Prinz, 1974)		100	0.2																			
83A	NW sec. 21, T29N, R100W	Thin quartz stringers (Prinz, 1974)		10	0.4																			
84A	S/2 sec. 15, T29N, R100W	3-ft vein sample (Prinz, 1974)		600	0.9					600														
85A	SE sec. 12, T29N, R100W	1-ft copper-stained quartz vein (Prinz, 1974)		100	2.5					>2.0														
	SE sec. 12, T29N, R100W	Brecciated metagreywacke, 50-ft thick (Prinz, 1974)		40	<0.1																			
86A	Carissa mine	1.5-ft channel across shear in glory hole	0.4		5.2																			
	Carissa mine	30-ft composite chip in wallrock north of main shear			2.4																			
	Carissa mine	Composite, 0 to 10 ft north of main shear			0.4																			

Appendix B continued.

Map no.	Location	Description	Ag (ppm)	As (ppm)	Au (ppm)	B (ppm)	Bi (ppm)	Co (ppm)	Cr (ppm)	Cu (%)	Fe (%)	Fe^{2+} (%)	Fe^{3+} (%)	Ga (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Sb (ppm)	Sn (ppm)	V (ppm)	W (ppm)	Zn (ppm)
	Carissa mine	Composite, 10 to 20 ft north of main shear			1.05																			
	Carissa mine	Composite, 20 to 37 ft north of main shear			2.5																			
	Carissa mine	Composite, 0 to 10 ft south of main shear			0.65																			
	Carissa mine	Composite, 10 to 20 ft south of main shear			0.25																			
	Carissa mine	Composite, 20 to 30 ft south of main shear			0.30																			
	Carissa mine	Composite, 30 to 60 ft south of main shear			0.35																			
87A	Sec 6, T29N, R 99W	Chip of agglomerate	0.1		n.d.																			
88A	Sec 25, T29N, R98W	BIF	n.d.		n.d.																			
89A	Monarch mine	Limonite-stained quartz from mine back	0.2		8.76																			
90A	Midas mine	Quartz boudin in graphitic schist			0.24																			
	Midas mine	Graphitic schist			0.10																			
	Midas mine	Graphitic schist			0.24																			
	Midas mine	Graphitic schist			0.41																			
91A	See Old Hermit mine map																							
92A	Sec. 4, T29N, R100W	Chip samples of discrete quartz veins in greenstones			9.5																			

Alphabetical index of districts, mines, prospects, and other areas of interest

(listing is first page of main reference)

ABBREVIATIONS USED IN THE TEXT

Measurements

oz(s)	ounce(es)	mi	mile(s)	ft or'	foot (feet)	m	meter(s)
lb	pound(s)	yd^3	cubic yard(s)	in or"	inch(es)	km	kilometer(s)

Age

Ma or m.y.	million years (old)	Ga	billion years (old)

Chemical symbols

Symbol	Element	Symbol	Element	Symbol	Element
Al	aluminum	Ge	germanium	Rb	rubidium
Ag	silver	Hf	hafnium	S	sulfur
Ar	argon	Hg	mercury	Sb	antimony
As	arsenic	Ir	iridium	Sc	scandium
Au	gold	K	potassium	Se	selenium
B	boron	La	lanthanum	Si	silicon
Ba	barium	Li	lithium	Sm	samarium
Be	beryllium	Lu	lutetium	Sn	tin
Bi	bismuth	Mg	magnesium	Sr	strontium
Br	bromine	Mn	manganese	Ta	tantalum
C	carbon	Mo	molybdenum	Tb	terbium
Ca	calcium	Na	sodium	Te	tellurium
Cd	cadmium	Nb	niobium	Th	thorium
Ce	cerium	Nd	neodymium	Ti	titanium
Co	cobalt	Ni	nickel	U	uranium
Cr	chromium	O	oxygen	V	vanadium
Cs	cesium	Os	osmium	W	tungsten
Cu	copper	P	phosphorus	Y	yttrium
Eu	europium	Pb	lead	Yb	ytterbium
Fe	iron	Pd	palladium	Zn	zinc
Ga	gallium	Pt	platinum	Zr	zirconium

Miscellaneous

<	less than	ppb	parts per billion
>	greater than	ppm	parts per million
BLM	Bureau of Land Management	REE	rare-earth element(s)
LOI	loss on ignition		

Locations are abbreviated, for example, "W/2 SE sec. 34, T30N, R100W" is west half of the southeast quarter, section 34, Township 34 north, Range 100 west.

Conversion factors

1 ounce (oz)	=	20 pennyweights
1 short ton	=	0.907 metric ton or 2,000 pounds
1 ounce per ton (oz/ton)	=	34.3 parts per million (ppm)
1 part per million (ppm)	=	1,000 parts per billion (ppb)
1 percent	=	10,000 ppm

STATE OF WYOMING

1933

GEOLOGICAL SURVEY

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1933
GEOLOGICAL SURVEY

Geology -- Interpreting the past to provide for the future