GEOLOGY, ORE DEPOSITS,

and

HISTORY

of the

BIG COTTONWOOD MINING DISTRICT

SALT LAKE COUNTY, UTAH

by Laurence P. James

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Frontispiece: Looking southeast across Silver Fork Canyon, near its head. Prince of Wales Hill, atop the Honeycomb Cliffs on the skyline, consists of strongly bleached, recrystallized Cambrian and Mississippian carbonate rocks cut by at least two overthrusts of the Grizzly (Alta) zone. Portal of Alta tunnel at lower left. By F.C. Calkins, ca. 1920; courtesy U.S. Geological Survey.

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Pen and ink drawings by Betsy James.

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ABSTRACT

The Big Cottonwood Mining District is in the central Wasatch Mountains of northern Utah, and centers on a major regional uplift whose axis lies south of Big Cottonwood Canyon.

The oldest rocks are contorted schists and gneisses of Precambrian X (?) age, exposed only in an area near Little Willow (Deaf Smith) Canyon along the western front of the Wasatch range. Unconformably atop these lies a thick sequence of little-deformed later Precambrian quartzites, slates and an unusual tillite. Paleozoic, Triassic and Jurassic marine quartzites, shales, and thick carbonate sequences overlie the Precambrian.

Three large multi-phase mid-Tertiary granodiorite-quartz monzonite bodies, the Clayton Peak, Alta and Little Cottonwood stocks, border the area on the south and east. Near the stocks, and in the north central part of the district, near Mill A Gulch and Little Water Peak, numerous dikes and small plutons occur which are mainly diorites. A single K-Ar date suggests they are Cretaceous (Laramide) in age.

The sedimentary rocks of the district have undergone folding along east and northeast axes and have been piled up by regional imbricate thrust faulting and high angle faulting of Laramide age, followed by mid-Tertiary intrusion, ore deposition, and later high angle faulting.

Three types of mineral deposits occur in the district. Quartz veins with native gold, silver, copper sulfides and tungsten cut older Precambrian amphibolite in the Little Willow area. The veins appear genetically related to the nearby Little Cottonwood stock, but the metals may have come from a quartz-sericite schist unit. Production was a few thousand tons. Skarn deposits, or calc-silicate-magnetite bodies in carbonate rocks at intrusive contacts, show highly variable copper, gold, lead, zinc and tungsten contents and have yielded at most a few thousand tons to date. The third type of deposits, fissure veins in later Precambrian and Paleozoic quartzites and associated bedded replacement bodies in carbonate rocks, contain lead, silver, copper, zinc and gold in sulfide, sulfo-salt and secondary oxide minerals, plus manganese carbonates and oxides. These deposits have yielded by far the largest production in the area.

The majority of the deposits of the second two types are localized in carbonate rocks around the Alta stock. These deposits tend to be richer in copper and gold closer to the stock. The largest deposits are replaced brecciated carbonates at the intersection of the mineralized fissure veins with the Alta overthrust, the lowest of the thrust faults. Of these the Cardiff ore body, largest in the district, has produced about 163,000 dry tons containing about 6900 oz. gold, 2.7 million oz. silver, 3.6 million lbs. copper, and 72 million lbs. lead. Zinc, recovered only from part of the sulfide ore, totalled about 9.2 million lbs.

Analyses for a number of trace metals in ore samples, bulk dump samples and igneous and metamorphic rocks showed anomalous values in molybdenum and tungsten, and generally low concentrations of arsenic, nickel, cobalt and uranium. Testing of many samples with ultraviolet light and a scintillation counter failed to suggest widespread tungsten or uranium anomalies. Gallium was highly anomalous in three zinc ore samples.

Mining in the district began just prior to 1870, and progressed in several stages related to historic events and economics. The mining towns of Silver Springs, Argenta and Gold City flourished briefly. The most intense underground exploration followed the Cardiff discovery in 1914, and was accompanied by many colorful promotions and deep drainage tunnel projects. Long snowy winters, avalanches, primitive transportation, extensive post-mineral faulting, and a lack of full-time geological expertise hindered systematic exploration and the development of ore reserves.

Potential for undiscovered commercial ore exists 1) along thrust faults, near mineralized fissures of intrusive bodies, 2) in skarn along intrusive contacts and 3) at fissure-bed intersections similar to those mined in the nearby Park City district. Probable ore occurs in the downward extension of some old ore bodies and in oxidized zinc deposits. Unmined deposits are likely to be small and rich in silver. Since the area now serves as an important watershed and a recreation complex, mineral exploration will face many restrictions.

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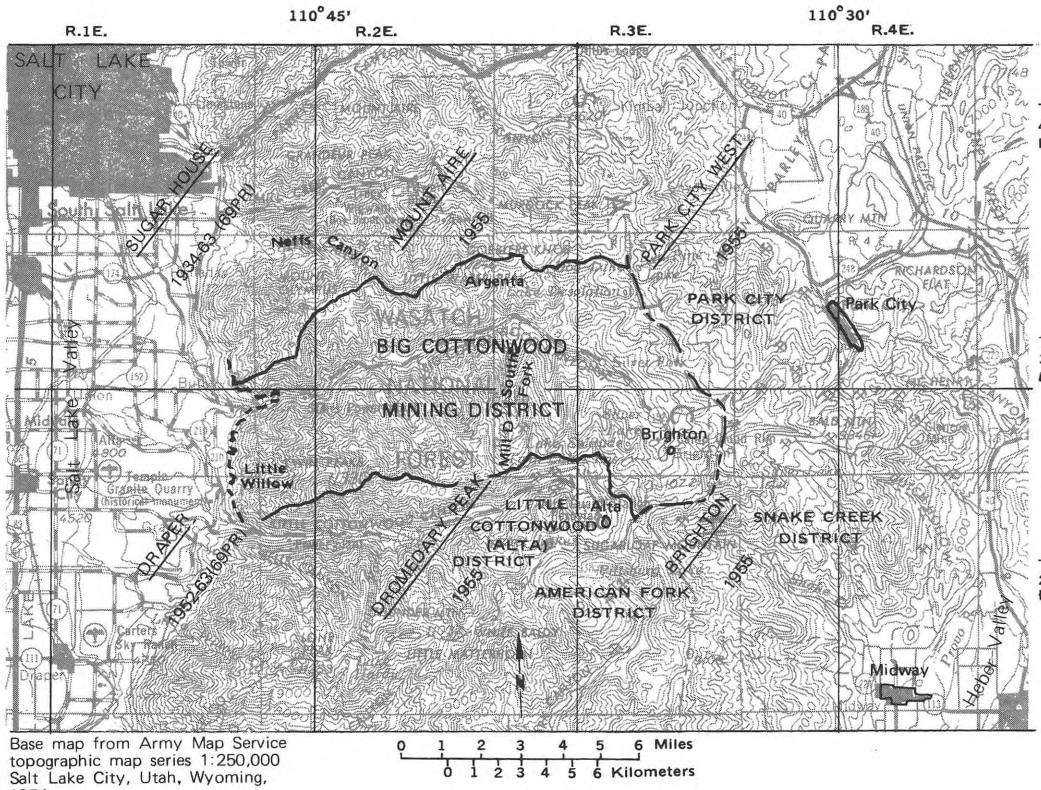
INTRODUCTION

The Big Cottonwood area (figure 1) lies in the highest portion of the Wasatch Mountains southeast of Salt Lake City. It contains exposed geologic features developed during two billion years of earth history. Discoveries of small but rich mineral deposits within the area led to a colorful, moderately productive, century-long period of metal mining.

The district is bounded on the west by the Salt Lake Valley, on the north by Neffs Canyon, on the east by the crest of the range, and on the south by the historic Alta or Little Cottonwood mining district.

While there is no mining activity in the Big Cottonwood mining district today, the area is of considerable interest to students of regional geology and to numerous visitors to the mountain recreational areas. Major thrust faulting is well exposed in outcrops and in mine workings and is of economic importance on a regional scale. The unusual occurrence of the major ore bodies, at the intersections of steep fissure veins with several overthrust planes, similar to that of deposits mined in the adjoining Little Cottonwood (Alta) and American Fork districts to the south, is a classic regional feature. The small deposits in the older Precambrian rocks at the eastern edge of the district present features not seen elsewhere in the state (figure 2). This report



Base map from Army Map Service topographic map series 1:250,000 Salt Lake City, Utah, Wyoming, 1954.

Figure 1. Index map showing approximate boundaries of Big Cottonwood district, adjacent districts, resort areas, and topographic map coverage.

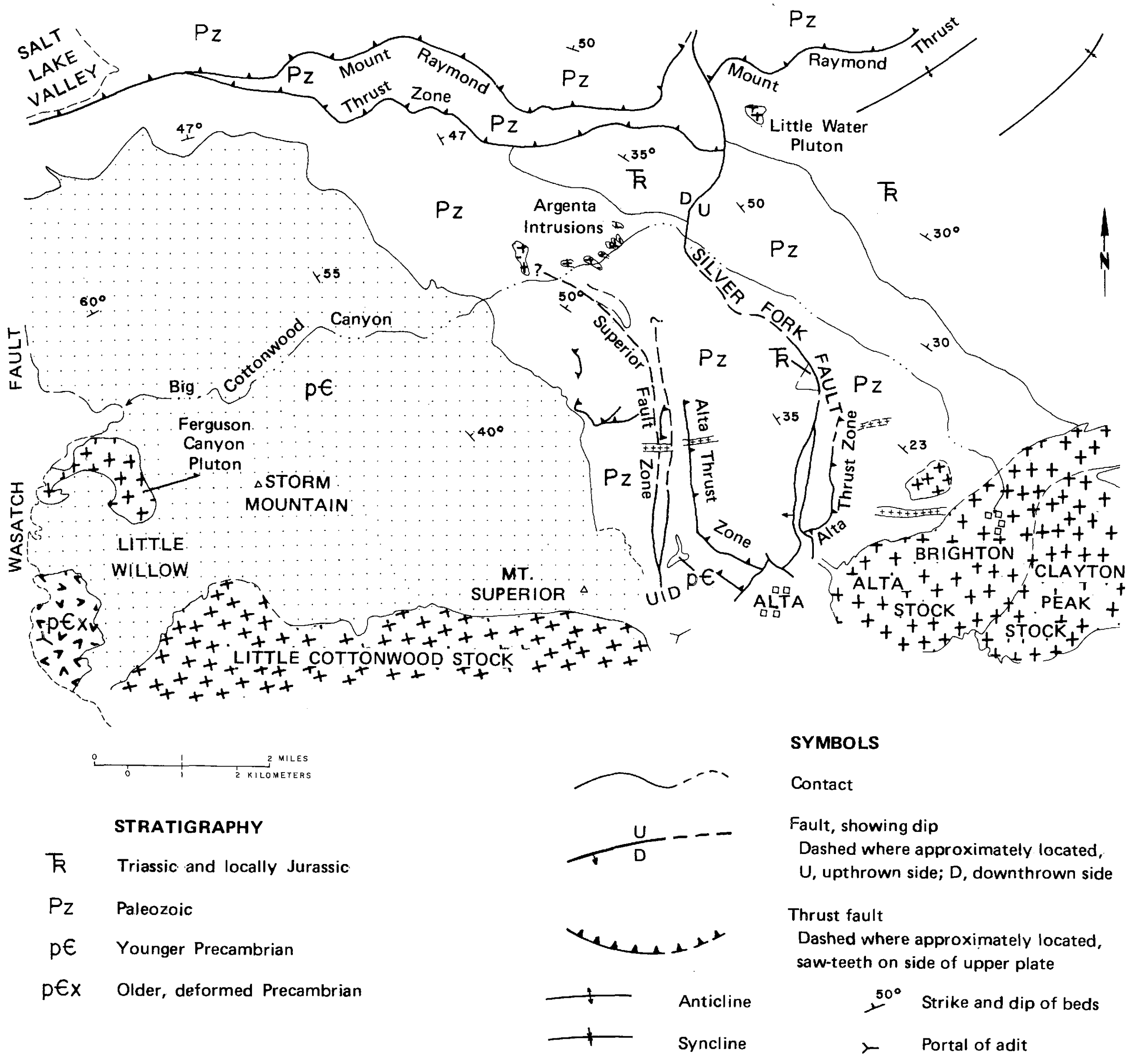


Figure 2. Generalized geologic map of Big Cottonwood mining area showing major features discussed in the text (adapted mainly from Crittenden (1965), Calkins and Sharp (1966) and Baker, Calkins, Crittenden and Bromfield (1965).

presents new detail on these and other aspects of the geology of the district, and records available geology and history of the many formerly-active underground mines. It presents an update on regional geology. It is written for readers of many interests, not merely for economic geologists.

Present Work

The writer became interested in the geology and mining history of the Big Cottonwood district during the 1950s and over a period of years has visited nearly all of the mines and prospects of the district. Contacts with former operators have yielded considerable unpublished information. Field work for the present study was done in the summer of 1976. Important mines were visited and, where possible, mapped. Geochemical samples were taken of mineralized rock to study the elemental composition of the ore of the district, and to seek previously unsuspected areas of economic mineralization.

The older Precambrian rocks near Little Willow (Gold City) and the Argenta intrusions were mapped by the author (see figure 2). In both places mapping was oriented toward understanding the ore deposits. The geologic map (plate 1) accompanying this bulletin is a

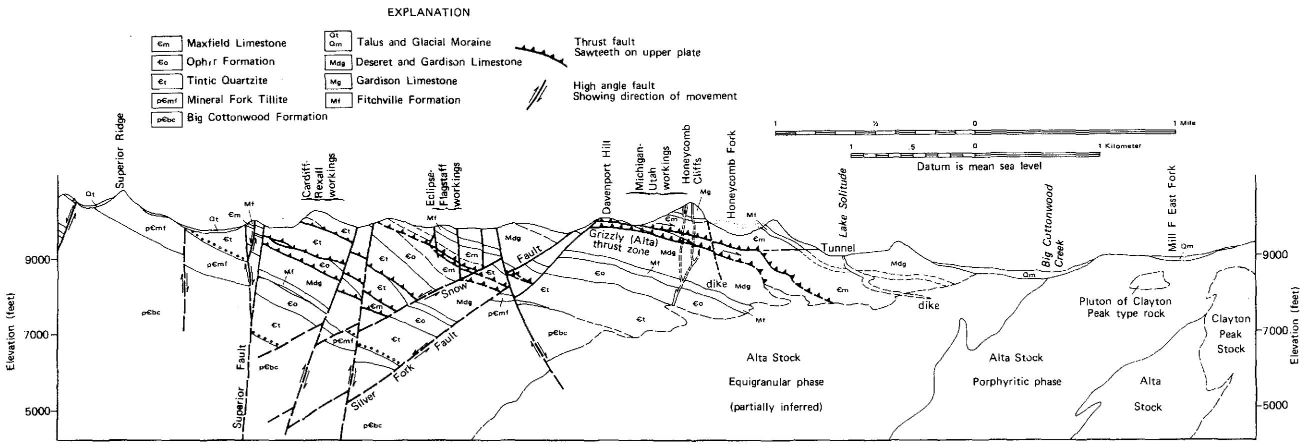


Figure 3. Cross section through Davenport Hill showing fault zones and mines. Rock units and symbols same as on plate 1. After Crittenden (1965) and Baker et al, (1965).

composite of maps made by M.D. Crittenden, Jr., F.C. Calkins, A.A. Baker and others of the U. S. Geological Survey, modified slightly by the author.

Acknowledgments

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Information on mining history came from such a variety of sources that complete acknowledgement is impossible. Special thanks are due Murray C. Godbe, III, who provided stratigraphic and production data, Joseph J. and Desdemona S. Beeson, for unpublished information, and Charles S. and H. Jay Woodward for unpublished maps.

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Previous Work

The histories of the old mining districts of the west abound with fascinating tales about human ventures and struggles, triumphs and losses. Big Cottonwood, close to Salt Lake City, a major center of mine promotion and finance, attracted many colorful individuals. Some are mentioned in this technical study because an understanding of the extensive underground exploratory work would not be complete without them. Much historical information was derived from verbal sources, written reports, and from highly promotional mining newspapers. Assays may have represented carefully picked specimens or may have been outright falsehood, while vein intersections always tended to be wider when the canyons were blocked by heavy snow. Any data reported from the mining journals, especially the local ones, must be viewed with healthy skepticism, even though they are repeated herein for their historical interest.

References to more complete works on the stratigraphy and regional geology are included at the end of this work. A number of general interest works on the area are also cited. The excellent mapping by Max D. Crittenden, Jr., and co-workers of the U.S. Geological Survey, provides a framework for any further study of the region. A geologic cross section, extending east-northeastward through the district, by Crittenden (1965) and Baker and others (1966), is partially reproduced as figure 3. The older works of Calkins and Butler (1943) and Butler and others (1920) provide many details of geology and ore occurrence in the central part of the district not repeated here. The area described in this volume extends several miles east and north of the area covered by previous studies and includes many mines and prospects not described elsewhere.

A list of mines described in this report is given in Appendix I and their locations are shown on Plate 2.

Physiography

The Big Cottonwood area (figure 1) is reached by a highway from the Salt Lake valley to Brighton. A graded dirt road, closed during the winter, extends from near Brighton to Park City, on the eastern slope of the Wasatch Range, and to Midway in Heber Valley east of the Wasatch Range. Rough dirt roads extend into most of the major tributary gulches of Big Cottonwood Canyon. Several of these are now accessible only by four-wheel-drive vehicle or on foot.

Much of the Big Cottonwood area is characterized by rugged, treeless peaks, rising to elevations of eleven thousand feet (3350m) or more. These tower above the bottoms of steep-walled gulches and the main canyon, with a relief of six to eight thousand feet (1800-2400m). The gulches to the south of the main canyon, which contain most of the mines of the district, generally are several miles in length and bounded by steep cliffs. North of the main canyon the gulches are shorter and steeper, and tend to have greater development of soil and vegetation.

The rugged topography in the lower half of Big Cottonwood Canyon has long fascinated geologists and sightseers, In the late 1860s, Clarence King's 40th Parallel survey camped in the canyon, and T. H. O'Sullivan, expedition photographer, tried to capture the character of the Storm Mountain area on half a dozen glass plates. A few years later Dr. Rossiter W. Raymond, a government mining engineer and statistician, described this portion of the Wasatch range:

> The scenery in the Cottonwood canyons is both grand and lovely. The Big Cottonwood Canyon is wild, precipitous, narrow, and tortuous. At twenty different points, as one rides along the bank of the stream, the rock-masses before and behind seem to close up, and leave neither inlet nor outlet for the tumbling waters. But the reckless river, getting used to this sort of thing at last, plunges boldly toward the apparently impenetrable barrier, and lo! a narrow fissure, unseen before, opens around some jutting crag, and the flood surges through, to enter another cul-de-sac and escape again by a hidden outlet...
>
> When it is added that Big Cottonwood canyon is not more than fourteen miles from Salt Lake City, and that even this short distance will soon be traversed by rail, so that the tourist can leave the cars almost at the very mouth of the canyon, it will be evident that this remarkable scenery is destined to become well known and loved by thousands of travelers. (Raymond, 1873, p. 320).

Climate

In Big Cottonwood Canyon the climate changes with altitude, normal annual precipitation ranging from 15 inches in the foothills to 60 inches in the mountains, and normal annual temperatures ranging from 51°F in the valley to 36° at the peaks. The altitudinal variation affects the growing season in a predictable way: Salt Lake Valley averages 160 frost-free days, while Brighton, at 8,700 feet, has a growing season of only 90 days, and snow has fallen as late as the Fourth of July.

Vegetation

According to Claire Gabriel, a student of western plant life, the foothills were once covered with native bunch grasses. Under pressure of overgrazing, however, the grasses gave way to sagebrush *(Artemisia)* from higher elevations (Cottam, 1961). The following description was sent to Brigham Young by three of his scouts on July 22, 1847, two days before he entered the Great Salt Lake Valley for the first time:

> ...sage is as rare as timber, so that if you want to raise sage ... you had better bring the seeds with you from the mountains. In many places the grasses, rushes, etc., are ten feet high but no more. Feed abundant and of the best quality ...

Before the inclusion of most of the canyon land in a forest reserve in 1904, grazing was heavy. Many of the side canyons were denuded each summer by sheep. Herds commonly stopped traffic for hours on the main road, clouding the air with dust, (Allan, 1961). Animals provided transportation for all who earned their livelihood in Big Cottonwood and also carried the valley residents to Brighton for recreation. Although grazing has been nearly eliminated in Big Cottonwood, owing to the importance of the canyon as a watershed for Salt Lake County, sheep can be seen on the north divide from Clayton Peak to Gobbler's Knob. On slopes where the vegetation is cropped to the ground, thunderstorms inevitably carry away topsoil.

Although good quality timber does not extend below the 7,500 foot elevation in Big Cottonwood, the lower streambank is lined with cottonwood trees *(Populus augustifolia)*, from which the canyon took its name. Scrub oak (*Quercus gambelii)* and other shrubs and small trees, such as maple *(Acer grandidentatum)*, chokecherry *(Prunus virginiana)*, and mountain mahogany (*Cercocarpus ledifolius)* dominate the landscape to about 7,500 feet, painting the lower canyon red in autumn. As one ascends the canyon the reds give way to the yellow of the aspen*(Populus tremuloides)* and the dark-green conifers *(Abies concolor* and *Pseudotsuga menziesii)*. Two other species of spruce and fir *(Picea engelmannii* and *Abies lasiocarpa)* appear at higher elevations and up to timberline where they persist as twisted shrubs buffeted by winter winds.

To build and fuel their settlement in the relatively barren Salt Lake valley, the settlers cut timber from the canyons. Big Cottonwood saw the first of 23 sawmills in 1855. According to Bowthorpe (1972) by 1858 three of the mills were supplying over a million board feet of lumber per year. 567,000 shingles of Douglas fir were cut by Nelson Whipple at Mill E, one-fourth mile below Brighton, and at Mill D Fork, to roof the Mormon Tabernacle. The demand for timber ran high among the canyon dwellers as well. So much timber was stripped from the slopes that virtually all the conifers in Big Cottonwood Canyon are second growth (T. Arnow, personal communication, 1977).

Aspen covers 25 percent of the drainage (Allan,

Table 1. Stratigraphy of the Cottonwood Area, Utah (after Crittenden, *et al.*, 1952; Crittenden, 1965; Baker, *et al.*, 1966; Crittenden, *et al.*, 1965, 1966).

System	Stratigraphic Unit	Thickness Feet	Description
CRETACEOUS		absent in map area	
JURASSIC		(largely outside map area)	
	Morrison (?) Formation	100	White algal limestone.
	Preuss Formation	1,000	Pale red shale and sandstone.
	Twin Creek Limestone	2,800	Pale gray, olive-drab-weathering silty limestone.
	Nugget Sandstone	800	Pale orange, strongly cross-bedded sandstone.
TRIASSIC	Ankareh Formation	1,575	Cross-bedded, white to pale purple pebbly quartzite and reddish brown, reddish purple, or bright-red shale, mudstone, and sandstone.
	Thaynes Formation	10,000	Brown-stained limy sandstone, inter-bedded with olive green to dull red shale and gray, fine-grained fossiliferous limestone. Thick "Mid red" shaly beds distinctive in district.
	Woodside Shales	1,000	Dark red shale and siltstone.
PERMIAN	Park City Formation	600-640	Pale gray-weathering fossiliferous and cherty limestone containing a medial phosphatic shale member. Thin interbedded quartzite and pure limestone (including Jenney ore horizon of Park City district) at base.
PENNSYLVANIAN	Weber Quartzite	1,200 to 1,500	Pale gray, tan weathering quartzite and limy sandstone with some interbedded gray to white limestone and dolomite.
	Round Valley Limestone	200 to 300	Pale gray limestone with sparse orange pink chert nodules and silicified fossils. "Morgan Formation" of Park City district.
MISSISSIPPIAN	Doughnut Formation	300	Black shale and a few beds of rusty-weathering sandstone grading into dark gray, fossiliferous silty limestone.
	Humbug Formation	200	Dark to light gray limestone and dolomite interbedded with tan-weathering sandstone.
	Deseret Limestone	800 to 900	Dark to light gray limestone and dolomite with lenses and thin beds of chert and a dark-colored shale at the base.
	Gardison Limestone	450	Fossiliferous, pale-gray to dark-gray limestone and dolomite, with lenses and nodules of chert in upper part. Formerly correlated with Madison Limestone.
	Fitchville Formation	120 to 150	Pale-gray and dark-gray massive dolomite with a 6 inch to 4 foot bed of coarse-grained, locally pebbly sandstone at the base. (Formerly "Jefferson (?)" Dolomite).
		UNCONFORMITY	
CAMBRIAN	Maxfield Limestone	0 to 1,000	Upper member: dark gray, oolitic dolomite. Middle member: mottled magnesian limestone and nodular shale. Lower member: massive, dark gray, mottled dolomite and limestone, oolitic to pisolitic at base, with irregular laminae of fine sand and silt.
	Ophir Formation (shale)	400	Upper member: 70 feet of brown-weathering calcareous shaly sandstone.

Table 1 *(continued)*

CAMBRIAN			Middle member: 80 feet of light gray limestone with wavy or crinkly tan-weathering siliceous laminae Lower member: 250 feet of dull olive green micaceous, worm-tracked shale.
	Tintic Quartzite	800	Coarse-grained, white or pinkish, buff- to rusty-weathered quartzite, with a thin pebble conglomerate at the base and interbedded greenish shale near the top.
		UNCONFORMITY	
PRECAMBRIAN	Mutual Formation	0 to 1,200	Medium- to coarse-grained red purple quartzites and variegated red and green shales.
		UNCONFORMITY	
	Mineral Fork Tillite	0 to 3,000	Black tillite, consisting of boulders, cobbles, and pebbles of quartzite, limestone, schist, and granitic rocks in an abundant black sandy matrix. Interbedded with black shale, dark gray quartzite, and conglomerate.
		UNCONFORMITY	
	Big Cottonwood Formation	16,000	White, green, and gray, rusty-weathering quartzite inter-bedded with grayish red, olive green, brown or greenish gray, and blue gray shales and siltstones. Weakly metamorphosed except near plutons.
	Little Willow Formation		Strongly folded gneissic quartzites, quartz mica schists and stretched-pebble schists of unknown thickness, intruded (?) by basic igneous rocks now altered to amphibolites and chlorite-amphibolite schists.

1961). Although it is of little value as lumber, aspen logs were ground into pulp for paper in the Deseret Mill (a mile below the canyon mouth) from 1882 until 1893, and the wood was put to good use by a cabinet maker, Julius Kuck, in the 1920s.

GEOLOGY

Introduction

In Big Cottonwood Canyon, the exposed sedimentary rocks range from metamorphosed earlier Precambrian rocks in the Little Willow-Gold City area, on the west, to mid Triassic rocks at the head of the canyon on the east (figure 2). Table 1 summarizes the stratigraphic succession. Cretaceous (?) and Tertiary intrusive igneous rocks crop out to the south and at the head of the canyon.

The area has a unique structural setting. It lies at the boundary between a geologically stable platform environment, which stretches eastward into western Colorado and Wyoming, and a much more mobile geosynclinal, or "flysch" environment. Regional thrust faults have tectonically transported rocks, most probably from the west, in great sheets into the area (figure 3). A major east-west trending arch or anticlinal axis has its crest within the area, and brings all of these varied rock types and structures into view.

Stratigraphy

Older Precambrian Rocks

The Little Willow Formation is the oldest Precambrian unit of the Big Cottonwood district (table 1). It crops out along the western front of the Wasatch Range between the mouths of Big and Little Cottonwood canyons (figure 2). The major topographic feature in these rocks is a sizeable west-trending gulch generally known as Little Willow Canyon, but renamed on the latest edition of the U. S. Geological Survey Draper 7½ minute quadrangle as Deaf Smith Canyon. This gulch is referred to as the Little Willow area of the Big Cottonwood mining district. The area to the south of Little Willow Canyon, where two mills and the most extensive underground workings were located, was known as Gold City.

As the rocks in this area have never been described adequately, and the mineral deposits in them have not been mentioned in the literature, an effort was made in this study to map and describe both in some detail. (See section on Little Willow area, in chapter on Mines and Prospects).

Crittenden (1965) redefined the Little Willow Formation to include all of the older (Precambrian X) metamorphic rocks of the Little Willow area. He (written communication, 1976) estimated that a stratigraphic thickness of 3500 to 4000 feet (1060-1200m) of older Precambrian rocks might be present between the Wasatch fault and the overlying Big Cottonwood formation, if minor folds are ignored. About 25 percent of this thickness is occupied by dark amphibolites, derived from one or more types of mafic igneous (?) rocks. The remainder consists of white to tan and green schists, gneisses, metaquartzites and conglomerates, largely recognizeable as former sedimentary rocks. No stratigraphic top or bottom was defined for the Little Willow Formation during this study.

The rocks of the Little Willow area are the most highly metamorphosed and deformed in the Big Cottonwood region. Locally the rocks show pronounced lineations and small isoclinal folds having a period of 10 cm or less, but no features suggesting complete large-scale folds within the area of exposure were noted.

Their relationship to other Precambrian rocks in the state remains uncertain. Schneider (1925) correlated them with the Farmington Canyon metamorphic complex, which lies northeast of Salt Lake City and is now known to be at least 1.6 to 1.8 billion years old (Crittenden, 1977, p. 366). Crittenden notes that the Little Willow rocks more closely resemble the 2.3 billion year old Red Creek Quartzite, described by Hansen (1965) in the nearby Uinta Mountains, except that the Little Willow rocks are lower in metamorphic grade than either the Red Creek or Farmington rocks, and lack the abundant pegmatites of the latter. All three units are classified by the U.S. Geological Survey as of Precambrian X age (Crittenden, 1977).

Later Precambrian Rocks

The Big Cottonwood Formation, consisting of quartzites and shales, overlies the Little Willow Formation within the map area. In the Little Willow-Gold City area the contact, which shows considerable deformation, was mapped by Crittenden (1965) as a depositional unconformity. The formation is approximately 16,000 feet (4880 m) thick and is well exposed in steeply dipping exposures in lower Big Cottonwood Canyon. Unlike the Little Willow rocks, it has generally undergone only a slight dynamothermal metamorphism, in which slates and phyllites were produced. Pyrophyllite is reported in shale from one locality (Ehlmann, 1959).

The Mineral Fork Tillite unconformably overlies the Big Cottonwood Formation. This unusual black sandstone and conglomerate unit has been the subject of considerable debate regarding origin (for example Condie, 1967; Ojakangas and Matsch, 1976; Varney, 1977).

The Mutual Formation, consisting of shale, quartzite and local conglomerate, unconformably overlies the "tillite", and unconformably underlies the lower Cambrian Tintic Quartzite. The regional correlation of these late Precambrian rocks, so well exposed in the Big Cottonwood district, has been variously interpreted (for example Armstrong, 1968; Crittenden and others 1971; Woodward, 1977).

Paleozoic and Mesozoic Rocks

Paleozoic sedimentary units attain an aggregate maximum thickness of about 6600 feet (2010 m) in the Big Cottonwood area (Crittenden and others, 1965, 1966) and are overlain by more than 3500 feet (1070 m) of Triassic rocks. To the north and east of the area, several thousand feet (700 m) of Jurassic rocks are also present (Armstrong, 1968). Brief descriptions of these rocks are given in table 1.

Lower Cambrian rocks, the Tintic Quartzite and Ophir limestone and shale, are similar to equivalent rock units found in much of the eastern Great Basin (for example Lochman-Balk, 1977).

Within the Big and Little Cottonwood mining districts, a number of thin early Paleozoic-age beds closely associated with ore deposition were named by mine operators and early geologists. While these names may have no regional significance, and few of them appear in stratigraphic literature, they were used widely in private reports. A diagram showing this local terminology within the stratigraphic column was courteously provided by M. C. Godbe III (figure 4).

Stratigraphy and favorable ore beds of the upper Mississippian and overlying Pennsylvanian through Triassic rocks have been studied in detail in the adjacent Park City district (Boutwell, 1912; Barnes and Simos, 1968; Garmoe and Erickson, 1968; Erickson, 1968) where they are important ore hosts. It is not known whether the detailed stratigraphy of Park City can be extrapolated westward into the entire Big Cottonwood district.

Jurassic units, which occur largely outside the district, have also been extensively studied (for example Imlay, 1967).

Tertiary Rocks

No Tertiary sediments or volcanics are exposed in the mapped area. Tertiary intrusive are discussed below.

Quaternary Deposits

Extensive areas along Big Cottonwood Canyon are covered by alluvium and glacial moraine. A large terminal moraine lies at the west end of the wide valley in the canyon above Argenta, where Big Cottonwood and Mill D South Fork creeks meet. Large talus slopes and local incipient rock glaciers conceal bedrock at the heads of numerous gulches. Much of the moraine is rich in granitic boulders and grus.

Atwood (1909), Richmond (1964) and Hart (1977) have discussed glaciation and Quaternary features of the area. Small lakes are present in the cirques at the heads of several gulches. Most of the lakes have been considerably enlarged by man-made dams that date back to the early years of this century.

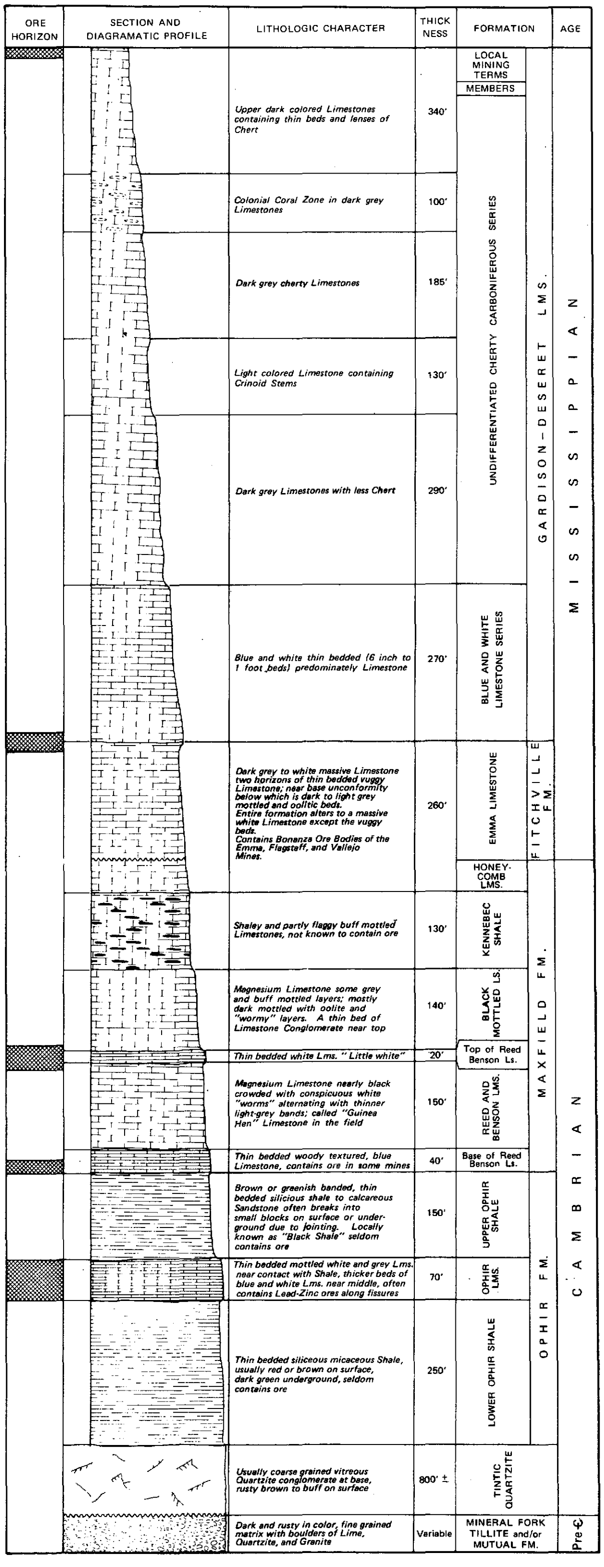


Figure 4. Stratigraphic column showing late Precambrian to mid Paleozoic rocks of the district and local terminology for favorable beds. After M.C. Godbe, III.

During a brief visit to the upper reaches of Big Cottonwood Canyon, Dr. D. R. Currey, University of Utah, suggested to the author that the large, steep moraine adjacent to the highway between Brighton and Solitude Resort is a medial moraine. Glacial debris of more than one generation was found higher on the slopes of Scott Hill by the author, as indicated on plate 1 (see Baker and others 1966).

The author found that the transition from slope-wash to moraine in the canyon appears to be marked by an increase in vertical field magnetic intensity, and can therefore be mapped with a portable magnetometer.

Intrusive Rocks

The plutons in the Big Cottonwood mining district are part of an east-northeasterly trending belt of intrusive rocks (figure 5) and uplifted sediments extending from the Keetley volcanic field east of Park City to the western front of the Wasatch Range. (Stewart and others, 1977). Aeromagnetic data (Mabey and others, 1964) suggests the Bingham district to the west lies on the same belt of intrusions. This structural and intrusive alignment has been called the Uinta or Cortez Uinta axis (Beeson, 1927; Eardley, 1939; Roberts and others (1965) or the Uinta-Gold Hill trend (Erickson, 1975).

On the east the Big Cottonwood district contains major parts of two sizeable Tertiary intrusive bodies, the Alta and Clayton Peak stocks (figure 5) which are described as granodiorite by Baker and others (1966). The Alta stock has a granitic-textured outer phase intruded by a northeast-trending porphyritic inner phase (Wilson 1961, 1962). Zonation in the Clayton Peak stock is described by Palmer (1974). Heavy minerals in the plutons are discussed by Berge (1960).

A variety of lamprophyric, silicic and intermediate dikes flank the Alta stock. A few of these dikes are not clearly related to the stock, for example, the Tar Baby dike described by Calkins and Butler (1943, p. 42-43) as probably extending from near Kessler Peak for at least six miles north-northeastward. The dike is not well exposed on the surface, but is cut by the Tar Baby and Kentucky Utah mine tunnels (on Plate 2).

The larger portion of the Little Cottonwood quartz monzonite stock lies almost entirely to the south of the Big Cottonwood mining district (figure 5). At and near Dromedary Peak, some contacts of the Little Cottonwood stock with overlying younger Precambrian sediments are almost sill-like.

In the central part of the district, the small dioritic intrusions of the Argenta and Little Water Peak areas are strikingly different from the other igneous rocks of the intrusive belt, in that they typically lack quartz, are low in potassium feldspar and are rich in mafic minerals. Detailed mapping in the Argenta area (see section on Argenta area) revealed at least forty separate intrusions with differing textures. Both sills and dikes are present.

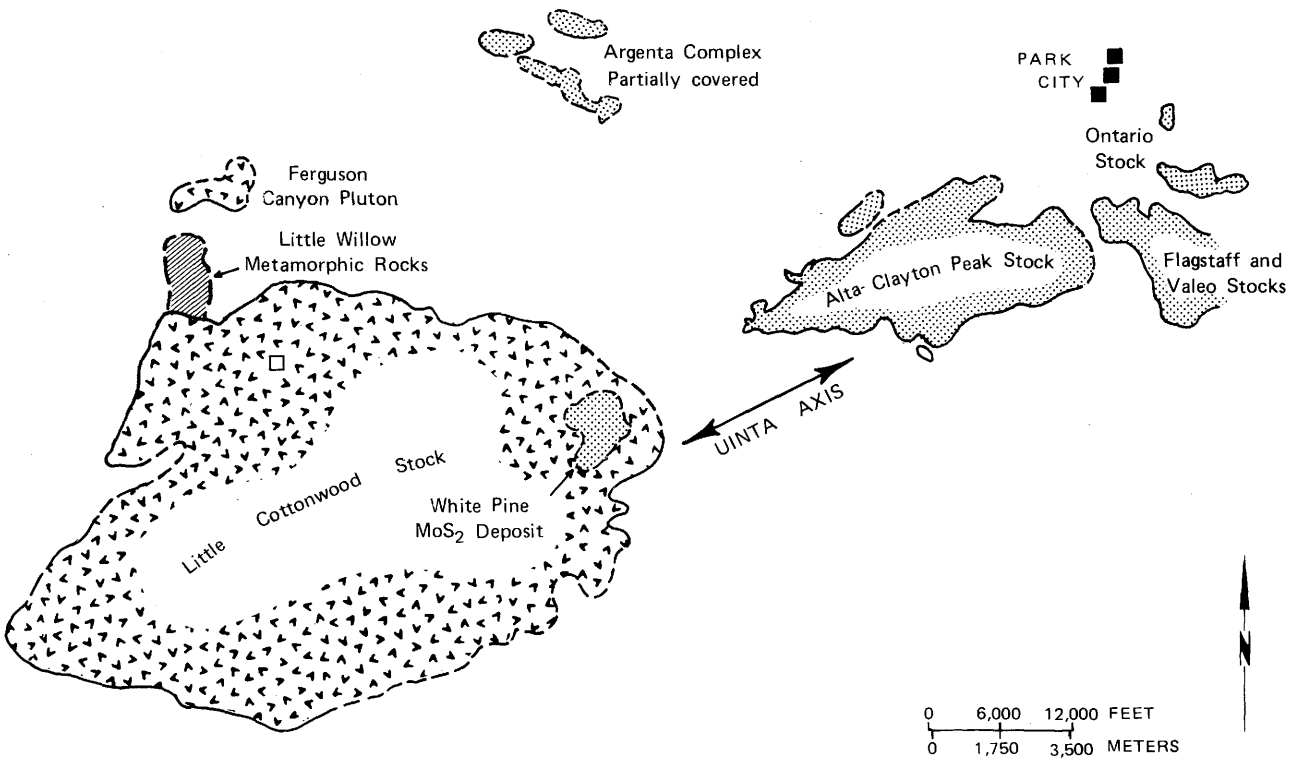


Figure 5. Intrusive rocks of Cottonwood-Park City area

Xenoliths found in the Little Cottonwood stock are of fine-grained gray hornblende diorite (?) typically rounded as if by partial assimilation and are similar to many of the fine-grained dikes and sills of the Argenta complex. Further work is needed to determine their interrelationship.

The pluton near Little Water Peak was not mapped in detail. A few magnetometer traverses west of the pluton suggest that this body continues at depth, beneath bleached sedimentary rocks, to the vicinity of the Silver Fork fault zone.

On the western edge of the district, a small pluton texturally similar to the Little Cottonwood stock, shown on figures 2 and 5 as the Ferguson Cayon pluton, crops out at the mouth of Big Cottonwood and Ferguson canyons.

Age of Intrusions

Crittenden and others (1973) and Bromfield and others(1977) have summarized the age dates obtained on the major intrusive stocks of the central Wasatch Range based on fission track and potassium-argon (K-Ar) dating of zircon, sphene, apatite, muscovite, biotite, and hornblende. They report the Clayton Peak stock was emplaced between 37 and 41 million years ago, the Alta stock between 32 and 33 m. y., and the Little Cottonwood stock, 24 to 31 m. y. Five of the samples on which potassium argon data is given came from within the Big Cottonwood district.

A sample of coarse equigranular hornblende diorite from the largest exposed pluton in the Argenta area (Table 2) was found by E. H. McKee of the U. S. Geological Survey to have a radiometric age of 72.4 m. y. (latest Cretaceous). This makes it the oldest intrusive rock reported in the Wasatch Range.

Potassium -argon (K-Ar) radiometric age dates on biotite and muscovite from schist, and hornblende from

Table 2. Potassium - Argon analysis of diorite, Argenta area. [1]

K_2O, percent	Ar^{40} rad 10^{-11} mole/g	Ar^{40} rad / Ar^{40} total	Apparent age, millions of years
0.671	7.13931	0.35	72.4 ±4

[1] Coarse equigranular hornblende diorite from the largest exposed pluton in the Argenta area, located in the southwest side of a branch of Mill A Gulch, in the SE¼ NE¼ NE¼ of section 14, R. 2 E, T. 2 S, north of Big Cottonwood Creek. Dated by E. H. McKee, U.S. Geological Survey. (U.S.G.S. Lab. No. 71700)

amphibolite from the Little Willow Formation are presented by Whelan (1969). The dates obtained are, respectively, 27.3, 19.1 and 560 million years (m.y.), all clearly much younger than the metamorphic rocks. The two younger ages approximate those obtained from the nearby Little Cottonwood stock (Crittenden and others, 1973) while the older age is thought by Whelan to represent an earlier regional metamorphic event.

No age dates are yet available for the smaller Little Water and Ferguson Canyon intrusive bodies.

Contact Metamorphism and Metasomatism

Contact metamorphic zones containing copper oxides and magnetite were recognized near the divide between Big Cottonwood Canyon (Brighton Bowl area) and Snake Creek prior to 1900. The calc-silicate rocks were examined in 1869 and described by King (1878, p. 47-48) and his assistant, S.F. Emmons, as "a curious garnetiferous schist" which they believed to be related to an "Archean" granitic basement high, now known as the Tertiary Clayton Peak and Alta Stocks. Ferdinand Zirkel, petrographer for the King survey (1876) described zoned garnets and actinolitic alteration from this vicinity. In 1903, after Archibald Geike criticized King's Archean uplift hypothesis, J. M. Boutwell was asked to visit the area. Emmons (1903, p. 141) stated that later forest clearing and prospect holes revealed the assemblages to be contact metamorphic in origin.

Subsequent studies of the mineralogy of the contact metasomatic metal deposits of the area were made by Calkins and Butler (1943). Cranor (1973), Moore and Kerrick (1976) and Smith (1972) studied the zonal nature of isochemical metamorphism around the intrusive bodies, and attemped to characterize the physical-chemical conditions responsible. In dolomites, Moore and Kerrick found mainly talc, tremolite, forsterite, clinohumite, periclase and wollastonite. No one has quantitatively studied the relationship of the much smaller contact metasomatic copper-magnetite deposits to the intrusive/metamorphic system. Palmer (1974, p. 211) notes that limestone contacts characterized by extensive metallic mineralization are limited to the Alta stock, although minor magnetite and copper minerals occur in fracture fillings near the Clayton Peak stock.

Wilson (1961, 1962) presents good evidence relating some contact metasomatic and fissure-filling (Pb-Zn) ores to fluids escaping from the porphyritic phase at the center of the Alta stock. The character of the volatiles associated with metamorphism and metasomatism near the Alta stock can partially be determined from the work of Moore and Kerrick (1976) who found as much as 1.9 and 3.7% fluorine in tremolite and humite (chondrodite) respectively. Ludwigite, vonsenite and magnesioludwigite (magnesium-iron borates) are also present locally, notably near ore deposits.

Peripheral Bleaching and Recrystallization

Bleaching, recrystallization, and the local development of tremolite, serpentine, talc, and other minerals are common in the general vicinity of large igneous bodies, as in Honeycomb and Mill F East forks. These are also common near minor igneous rocks, such as along the Silver Fork fault near Reynolds Gulch (Cottonwood Grand Central project area) and in the Argenta area. Some of the bleaching occurs as distinct thin bands in carbonate rocks, suggesting initial compositional differences are responsible. The white bands from such rock near the Confidence mine (Appendix 2) yielded an X-ray diffraction pattern showing only quartz and calcite, plus traces of poorly crystalline (?) saponite or a similar mineral.

A specimen of dark and light banded shaly Maxfield Limestone, now a hard hornfels, was collected from near the northwest face of the Tom Moore tunnel (which portals at Alta), just within the southern boundary of the district. An X-ray diffraction pattern (whole rock) showed calcite, dolomite, quartz, kaolinite and gypsum. A sample of "zebra" banded shaly limestone from further south in the tunnel contained a muscovitic mica.

Bleaching apparently stems from a variety of low-grade metamorphic effects. Also, much of what miners called the "white limestone" may be white because of diagenetic dolomitization.

Structure

The earlier Precambrian rocks of the Big Cottonwood mining district (figure 2) show complex folding and more than one generation of faulting. Their structure is not well understood. Lithologic units strike in a north-northeasterly direction and in many areas stand almost vertically. No studies have been made of the abundant small scale folding and lineations of these rocks.

The sedimentary rocks (later Precambrian Big Cottonwood and younger formations) which comprise most of the district have a generally simple north-northwesterly strike and a moderate northeasterly dip (Plate 1 and figure 2). Regionally these rocks form the north flank of a broad uplift, or anticlinal arch, discussed by Eardley (1968, 1969), Stewart and others (1977) and others. Short-period folding is evident only in the Park City mining district, where the axes of the folds nearly parallel the Mount Raymond overthrust (figure 2), which bounds the mining district on the north.

Great thrust faults cut the Paleozoic section of the district (Plate 1, figure 2). North of Big Cottonwood Canyon along the northern boundary of the district, the Mount Raymond thrust zone extends east-west across the Wasatch Range dipping to the north. Though of much less economic importance than the north-south striking faults to the east, this stratigraphically higher fault has a much longer outcrop length.

In the most productive portion of the Big Cottonwood mining district low-angle faults strike north-south and dip to the east. They are exposed near Reed and Benson Ridge, and locally to the west on Prince of Wales

Hill. Calkins and Butler, (1943, p. 52) refer to this series of imbricate faults as the "Alta thrust zone". It consists of the main Alta overthrust and overlying lesser faults including the Grizzly, Reed and Benson, and Columbus overthrusts. All are important in localizing ore.

The Grizzly thrusts are cut by the Alta stock (figure 3) (Calkins and Butler, 1943, p. 56) but more specific determination of the age of the Alta thrusts has not yet been made. Crittenden (1977) believes the Mount Raymond thrusts are probably younger.

The thrusts are part of a great regional zone of thrust faults and folds. Armstrong (1968) and others designated the portion of this zone in Utah and eastern Nevada as the Sevier orogenic belt. Roberts and Crittenden (1973), Hose and Danes (1973) and others have discussed its origins and significance. Calkins and Butler (1943, p. 54) concluded that the Alta thrusts moved from west to east, and were later tilted to their present generally easterly dip. Crittenden (1977, p. 376) notes that each successively higher thrust plate contains a thicker section of Cambrian carbonate rocks which, based on the regional dip of the Cambrian-late Devonian unconformity, confirms this direction of transport.

Within the Alta thrust zone, the most conspicuous thrusting in the district places Tintic quartzite atop Deseret limestone. This relationship is exposed in the Cardiff mine (see section on mines). The complexity of the Alta thrust zones further to the north was described by Calkins and Butler (1943, p. 56):

> Near the south end of the lower Tar Baby tunnel the overthrust has the same simple character as in much of the Cardiff and as in the cliff east of Superior Gulch: it is a single fissure, dipping gently eastward, along which the Tintic quartzite rests immediately upon the Deseret limestone. But farther north in the workings, and in the Tar Baby upper tunnel, the fault overlain by quartzite swings abruptly so as to strike nearly due east and dip southward; and the lowest member of the thrust zone in the outer part of the Tar Baby and American Metals workings brings Cambrian rocks upon the Deseret.
>
> The northernmost exposure in the area, near the Carbonate mine, is perhaps even more striking in appearance than that east of Superior Gulch; the structural and stratigraphic relations, however, are strikingly different in the two places. In the northern exposure, as in the other, the thrust is parallel to the bedding of the Tintic quartzite in the upper plate, but the underlying rock is Ophir shale, crumpled but in general almost vertical. Here the overthrusting took place mainly on a single fissure, above which, however, is a minor fault which may be either the Columbus or a part of the Alta thrust zone. The rocks in the outer part of the Tar Baby tunnel are in a much faulted layer that forms part of the Alta thrust zone. This layer thickens eastward, but it pinches out to the south, where the Tintic quartzite immediately overlies the Deseret limestone as it does in most of the Cardiff mine.

Minor (drag) folds are present both above and below the Alta thrust zone. They are well exposed in underlying Ophir shales south of the Carbonate mine (Calkins and Butler, 1943, plate 20) and were mapped in overlying Tintic quartzite in the Wasatch Drain tunnel.

Calkins and Butler (1943, p. 55) envision a sequence of thrusting, with the uppermost fault of the Alta thrust zone (placing Tintic Quartzite on Deseret limestone) being the latest in that zone, and not necessarily the largest in displacement. They believe it beveled the underlying thrusts, giving rise to the complex internal structure described above. Further detail on the Alta Thrust zone may be found in the discussions of the Cardiff, Tar Baby, and Prince of Wales mines.

Two major sets of north-south trending normal faults offset the overthrust faults and divide the central sector of the district into three blocks (figure 2). The Silver Fork fault, the greatest within the mountain range, presently dips 30 to 40 degrees to the west (Crittenden and others, 1952, p. 24). Rocks west of the fault are dropped downward, hence surface exposures here are of younger age. Near the middle of the district the fault parallels the upper reaches of Silver Fork, passing just west of the Alta tunnel. Crittenden and others (1952, p. 24) state that it has a normal displacement of 5000 feet (1525 m) in places within the district and that it apparently terminates at Mill Creek Canyon, in the northern part of the map area, in bedding faults along or in the Park City formation. They also note that the Silver Fork fault cuts the Alta stock to the south. The Snow fault, near the south border of the district, branches from the Silver Fork fault, and may extend westward into the Wasatch Drain tunnel area (Plate 1).

To the west, following the course of Mill D South Fork, is the Superior fault zone. This series of two or more faults, as much as 1000 feet (300 m) apart, dips nearly vertically in several mines and is down dropped on the east, exposing older rocks to the west. The fault extends north up Mill D South Fork, and was identified in the now-caved lower Reeds Peak mine workings. North of here its course is not certain; it is not evident on the north side of Big Cottonwood Canyon. The writer believes much of its displacement is taken up by a fault that trends northwestward, beneath the face of Kessler Peak and into the Argenta area. Here, in the vicinity of the Argenta plutonic complex, it apparently terminates along bedding faults in shattered Deseret and Humbug formations.

These two faults outline a graben block of lower Paleozoic sediments and interlayered thrust faults which has been the most important locale in the district for ore deposits. Additional local detail concerning these and subordinate faults is given by Calkins and Butler (1943, p. 60-64). Movement on the Wasatch fault (figure 2) may have affected the dip of all of these faults.

Steeply dipping small faults and fissure veins are abundant in the southern limits of the district and are closely related to most of the ores mined. Many are occupied by thin dikes, and most have a northeasterly strike. Landwehr (1932) found that the vast majority of veins in the Big and Little Cottonwood districts strike between 29 and 65 degrees to the east. Similar relations hold in the Park City district. Stokes (1968) verifies this fact on a regional basis.

The age of these veins with respect to the north-south faults is not totally clear. Calkins and Butler (1943), p. 61) believe most of them were of:

comparatively early origin... possibl(y) even that they resulted from the strains set up by overthrusting, though the mineral bearing fissures are all, so far as known, later than the thrust faults, which are commonly more or less displaced at their intersection with fissures.

They state that the Silver Fork fault is younger than the mineralized fissures, and is offset by still younger faults. In contrast, J.J. Beeson (personal communication, 1964) noted weak mineralization along the Silver Fork fault in the Little Cottonwood district. Various workings in Mill D South Fork suggest weak mineralization occurred in the Superior fault zone. Possibly the large normal faults and the northeasterly trending fissures, striking at roughly 45 degrees to the the faults, comprise a conjugate set of contemporary structures, but the large faults underwent further later movement.

The relation between intrusions and the major north-south faults is likewise uncertain. The gap between the Little Cottonwood and Alta stocks coincides closely with the southerly extension of the above--described graben block. As discussed in the section on intrusive rocks, the Little Water pluton nearly coincides with the northerly extension of the Silver Fork fault. The Argenta complex of similar dioritic rocks lies along the probable extension of the Superior fault zone.

Most of the mines encountered numerous post-ore faults of uncertain age, both normal and reverse in movements. Some of these must correspond with the Basin and Range period of faulting.

The largest single displacement zone within the district is that of the Wasatch fault, along the western front of the Wasatch Range. Typically this fault brings Recent alluvium against Precambrian rocks, and has been active as late as the last century. In the Little Willow (Gold City) area more than one fault is evident (for example Kaliser, 1973). Crittenden and others (1952, p. 27-30) describe the fault and the physiography of the range front in more detail. They note an older erosion surface, indicated by high level ridge crests and spurs along Big Cottonwood Canyon which project to mid-canyon at an altitude of about 8000 feet (2440 m). Projection of these levels out to the mountain front indicates a displacement on the frontal Wasatch fault of about 3,000 feet (900 m). Much work is now in progress concerning the Wasatch fault and its potential for earthquake hazards.

GEOCHEMICAL STUDIES

Composition of intrusive rocks

Many studies of the post Paleozoic intrusive rocks of Utah and their component minerals have been made in recent decades and a number of possible models proposed for ore genesis. This section discusses recent work relating to the Big Cottonwood mining district; earlier studies of general interest are cited for reference only.

Major Elements

The chemical compositions of samples from the Alta, Clayton Peak and Little Cottonwood stocks were determined by the U.S. Geological Survey (Calkins and Butler, 1943); their analyses are reprinted as samples 1 through 5 in table 3. These rocks range in composition from granodiorite to quartz monzonite according to Crittenden and others (1973) and Baker and others (1966). Calkins and Butler (1943) state that the Argenta (and also the Clayton Peak) intrusions are dioritic in composition, but give no analyses of them.

A single chemical analysis of a sample of the coarse hornblende rich Argenta pluton in the west fork of Mill A Gulch (No. 6, table 3) was made by N. H. Suhr and J. B. Bodkin of the Pennsylvania State University in October 1976, using standardized atomic absorption techniques. The sample analyzed was split from 1 kg (approx. 2.2 lb) of rock chips from an outcrop on the hillside west of the gulch north of the Maxfield mine (Nos. 3,4). Table 3 also compares the normative compositions of the six samples, calculated by W.P. Nash of the University of Utah.

Trace Elements

Several regional studies of trace element distribution and partition have included samples from the major intrusive bodies of the Cottonwood area. Slawson and Nackowski (1959) measured the lead content of feldspar in plutons of the Great Basin. Parry (1961) studied metal content of biotite from the same region.

Wilson (1961) studied the metallic content of separates of eight rock-forming minerals from the Alta intrusive body using emission spectroscopy and presented modal data on various phases of the pluton. He concluded that residual liquids from the central porphyritic phase may have concentrated ore elements (Pb-Zn) and deposited them in the Michigan Utah mine contact metasomatic-fissure vein area. Zartman and others (1968) show that lead becomes more radiogenic with distance from intrusive centers, for example Cardiff versus Maxfield mines in the Big Cottonwood district, and derive a model by which part of the lead in the region was derived from Precambrian basement rocks over a long period of time. The studies generally conclude that at least part of the lead in ores was derived from nearby intrusives.

Studies of trace ore metals in bulk igneous rocks were made by Belt (1969) in search of geochemical anomalies related to disseminated or localized ore deposits. Belt used atomic absorption spectrophotometry to measure copper, zinc and iron distribution in the Alta and Clayton Peak stocks. A summary of his results (table 4) shows considerable variation of copper within the Clayton Peak pluton.

Table 3. Chemical composition of plutonic igneous rocks from the Cottonwood area, Utah and mole percent normative minerals*

	1	2	3	4	5	6
SiO_2	67.02	65.27	63.26	62.16	59.35	49.4
Al_2O_3	15.78	15.75	15.93	17.17	16.36	18.5
Fe_2O_3	1.56	2.31	2.61	2.26	2.90	3.65
FeO	2.80	1.85	2.31	2.78	3.36	5.60
MgO	1.09	1.62	2.27	1.81	3.08	5.95
CaO	3.31	4.09	4.33	4.70	5.03	9.03
Na_2O	3.85	3.92	3.66	3.96	3.73	2.68
K_2O	3.67	3.25	3.49	3.58	3.85	0.98
H_2O	.29	.21	.27	.03	.28	
H_2O+	.63	.53	.74	.60	.64	
TiO_2	.37	.55	.62	.53	.87	1.02
ZrO_2	.04	.02	.03	.01	.03	
P_2O_5	.26	.25	.16	1.7	.44	
S	.03			.04		
MnO	.02	.10	.09	.06	.07	0.16
CO_2		trace	trace		trace	
BaO	.13	.11	.15	.17	.16	0.083
Cl		.01	.05		.05	
FeS_2		.02			.02	.tr
SrO		.05			.05	0.10
Total	100.85	99.91	100.17	100.03	100.29	97.15
Quartz	19.63	18.59	15.95	11.93	8.39	1.02
Zircon	0.04	0.02	0.03	0.01	0.03	
Corundum						
Orthoclase	21.84	19.47	20.91	21.33	22.96	5.98
Albite	34.87	35.62	32.93	35.86	33.42	24.84
Anorthite	15.07	16.05	17.17	18.66	16.89	36.70
H1		0.02	0.08		0.08	
Diopside	0.02	2.57	3.07	3.24	4.67	7.97
(Wollastonite)	0.01	1.29	1.53	1.62	2.33	3.99
(Enstatite)		1.12	1.32	1.15	1.88	3.06
(Ferrosalite)		0.16	0.22	0.47	0.46	0.92
Hypersthene	5.77	3.91	5.87	5.46	8.35	18.09
Olivine						
Magnetite	1.65	2.45	2.77	2.38	3.06	3.94
Ilmenite	0.52	0.78	9.88	0.74	1.22	1.47
Apatite	0.55	0.53	0.34	0.36	0.93	--
Pyrite	0.03			0.04		

1. Quartz monzonite of Little Cottonwood stock, below upper power plant, Little Cottonwood Creek, west of Cottonwood Quadrangle R.C. Wells, analyst. In Butler, B.S., and others, Ore deposits of Utah: U.S. Geological Survey Professional Paper 111, p. 95, 1920.
2. Granodiorite of Alta stock. W.F. Hillebrand, analyst, F.W. Clarke, Analyses of rocks and minerals from the laboratory of the U.S. Geological Survey: U.S. Geological Survey Bulletin 429, p. 95, 1910.
3. Granodiorite, east side of Brighton Gap, Park City quadrangle. Called "quartz diorite" in Professional Paper 77, p. 92. W.F. Hillebrand, analyst.
4. Granodiorite of Alta stock, dump of Steamboat tunnel, Snake Creek, Charles Milton, analyst. R.C. Wells, Analyses of rocks and minerals from the laboratory of the U.S. Geological Survey, 1914-36: U.S. Geological Survey Bulletin 878, p. 41, 1937.
5. Quartz diorite of Clayton Peak stock, three-fourths of a mile northeast of Clayton Peak, Park City quadrangle. W.F. Hillebrand, analyst.
6. Coarse hornblende-rich dioritic intrusive body, southwest slope of west fork, Mill A Gulch, Big Cottonwood Canyon, largest exposed body of Argenta intrusive complex. Split from 2.2 lb (1 kg.) sample, analyzed by atomic absorption methods by N.H. Suhr and J.B. Bodkin, 1976.

Analyses 1-5 are from Calkins and Butler, 1943, p. 40. They state: "Analysis 5 shows 0.01 percent each of CuO and ZnO. Analyses 3 and 5 show faint traces of LiO_2." Base metal content of sample 6 is shown as analysis 55 on table 5. Sample 46 was taken nearby.

* Calculated with a computer program by W.P. Nash, University of Utah.

Table 4. Metal content of Alta and Clayton Peak intrusions (Belt 1969).

Element	Intrusive	No. of Samples	ppm
Cu	Alta	19	27 ± 20 ppm
	Clayton Peak	25	250 ± 250
Zn	Alta	20	53 ± 14 ppm
	Clayton Peak	25	87 ± 14
Fe	Alta	19	3.1 ± 0.4 percent
	Clayton Peak	22	4.8 ± 0.4

Parry and Jacobs (1975) and Jacobs and Parry (1976) discussed chlorine, fluorine, barium and iron content of biotites from the Cottonwood and many other plutons of the Great Basin region.

Kuryvial (1976) studied partitioning of trace elements in alkali feldspar in the Cottonwood plutons.

Ore metal distribution

As part of the present study of ore metal distribution in the district, 55 samples, (typically about 1 kg., or 2.2 lbs., or more of chips and fines) were collected from mine dumps areas of mineralization, and unmineralized rocks. These bulk samples were taken from a variety of igneous, sedimentary-metasedimentary and ore deposit environments in the district.

Analysis, conducted by C.M.S. Laboratories, Salt Lake City, consisted of crushing, splitting out a representative sample, dissolution, and atomic absorption spectrophotometry. Values obtained for Cu, Pb, Zn, Ag, Au, Mo, As, W, U, Co, and Ni are shown in Table 5.

Precambrian Rocks
Little Willow area

Emphasis was placed on the Precambrian rocks of the district and mineralization within them, partially because so little published information is available. These rocks and ores appear in table 5 as samples 1 through 30. Several small dumps and narrow veinlets show high values in trace gold, silver, tungsten and copper. Individual analyses are further discussed in the section on mines. Samples were taken to determine whether any of the pyritic or sericitic beds in the older Precambrian (for example samples 1-6, 10, 23-27) or shaly beds in the younger Precambrian tillite (samples 32,53) or shale (sample 54) were sufficiently metal-rich to have been source rocks from which later vein mineralization was derived. None of the older Precambrian rocks sampled any distance from later vein mineralization shows notable metal content. Pyritic gneiss of the Little Willow formation shows visual traces of chalcopyrite underground, but is not unusually rich in ore metals (samples 26, 27). Only one of the two samples of the black tillite of the Mutual Formation (sample 32) shows a very high zinc content relative to most sediments.

Samples of mineralized rock from the undeformed younger Precambrian and later units included primary sulfides, partially oxidized sulfides, and fully oxidized, possibly secondarily enriched material from dumps and workings.

Argenta area

At the writer's suggestion, James Obulaney collected 14 bulk samples of fresh and altered dioritic dikes from the central (Argenta) area of Big Cottonwood Canyon. Atomic absorption analyses of these samples at the University of Utah showed zinc contents ranging from 65 to 245 ppm, and copper and lead contents well below 100 ppm. Additional samples from this area are discussed in the chapter on mines.

Main Canyon area

Sulfide samples from the Wasatch Gold or Silver King (Sample 33 in table 5), Copper Apex (Sample 38), Cardiff (Sample 56) and Alta tunnel (Sample 59) properties show the typical high lead and silver content of Cottonwood ores. The Cardiff sample, a galena and sphalerite hand specimen from the last operations in the deep levels, shows that the high silver content of the ores of the area was not merely due to supergene enrichment. Arsenic is also abundant (1.8%) in this sample and in several oxidized samples. Enargite and tetrahedrite series minerals, visible in some ores, presumably are the source of silver. Moderate gold content was obtained mainly from samples containing high silver, generally from in or near the younger Precambrian rocks.

Two oxidized samples from goethite veins cropping out above the major Cardiff ore body show highly "anomalous" silver, copper, lead and zinc values. Sample 36 is from a shear zone near the Cardiff fissure, and 37 is from the dump of a small (Cardiff?) shaft.

Unmineralized intrusive rock

The trace ore metal content of unmineralized intrusive rock from some of the smaller igneous bodies of the district is given by samples 39, 40, 46, 55 and 57,

Table 6. Trace element content of sphalerite, Big Cottonwood district (parts per million) (Burnham 1959).

Ag	As	Bi	Cd	Ga	Ge	In	Mn	Ni	Sb	Sn
50	1,000	3	6,000	> 700	40	10	4,000	6	60	3

Table 5. Trace element analyses of samples from Big Cottonwood mining district, (see plate 2 for sample locations). All values are in parts per million (ppm). Blank spaces indicate analyses were not performed.

Sample No.	Type	Ag	Au	Cu	Mo	Pb	Zn	As	W	U_3O_8	Co	Ni
1[1]	RC	0.66	<.03	35.								
2	RC	44.5	0.56	25.	3.	25.	80.		<2.		18	30
3	RC	2.9	<.03	15.								
4	RC	2.9	0.033	30.								
5	RC	1.32	<.03	12.								
6	RC	0.66	<.03	15.								
7	D	.7	.02	25.	1.	12.	35.		<2.		18	35
8	D	1.0	.02	210.	1.	15.	35.		5.			
9	D	1.5	23.26	230.			15.		2.		25	40
10	RC	1.5	.07	1200.	1.	50.	30.		<2.		30	55
12	QV	.7	.37				15.		<2.			
13	D	1.0	.02				25.		<2.			
14	D	2.2	.14	1280.	3.	25.	10.	<1.	<2.		20	35
15	D	.7	.04	25.			15.		<2.			
16	QVD	.7	.02	20.			20.		<2.			
17	D	8.8	.24	9800.	5.	12.	45.	<1.	<2.		20	18
18	QV	6.1	.34	1580.			15.		<2.			
19	D	1.4	.04	300.	35.	15.	35.	315.	2250.		30	35
20	QV	2.5	.21	230.	1.	60.	160.		<2.			
21	QV	2.2	.77	750.	<1.	45.	45.		<2.		20	30
22	QV	6.5	5.40	4500.					<2.			
23	RC	.7	.06						<2.			
26	RC	1.4	.02	85.	<1.	25.	55.		<2.		14	18
27	RC	1.2	.05	30.	<1	40.	30.					
28	D	.7	.03	25.	<1.	25.	15.				7.	13
29	D	2.4	.14	2100.[2]	9.	40.	160.				40.	40
30	D	1.0	.07	50.	3.	70.	90.					
31	D	3.7	.07	50.	4.	60.	80.					
31A	D	3.4		50.	35.[3]	125.	545.					
32	RC			45.	2.	170.	500.					
33	D	333.2		1450.[4]	3.	8100.[4]	4250.[4]	1275.			35	265
34	D	81.6		2750.[4]	5.	37000.[4]	97000.[4]	2415.			35	35
35	D	574.6	1.12	1250.[4]	2.	110000.[4]	145000.[4]	150.			17	14
36	RC	9.2		500.	2.	1600.[4]	980.	6.			7	19
37	D	367.2	.58	5500.[4]	5.	27500.[4]	4300.[4]	2575.			35	35
38	D			2650.[4]	2–	100000.[4]	87500.[4]	140.	50.		55	25
39	IR-D			95.	1.	325.	350.				11	20
40	IRC			50.	2.	100.	180.				20.	30
43	RCV	129.2		390.	2.	275.	205000.[4]	80.			14	55
44	RCV	5.1		320.	3.	200.	2000.[4]				10	70
45	D	66.6		135000.[4]	2.	45500.[4]	130000.[4]				30	40
46	IR			50.	<1.	15.	100.				40	50
47	D	1.87	.062	30.	18.	10.	30.				35	25
48	RC			35.	<1.	20.	75.					
49	D	66.25	0.28	3200.	40.	680.	150.		<2.		30	19
50	mte	7.78	.031	2250.	2.	15.	250.				65	70
51	phl			480.	<1.	10.	130.		<2.	1.5	25	40
52.	D	37.4		195.	30.	1250.[4]	23500.[4]				25	75
53	RC-D	1.7		35.	1.	15.	65.			<1.0	16	30
54	RC	1.7		30.	1.	30.	125.			1.0	7	20.
55	IRC			140.	<1.	30.	220.			<1.0	30.	35.
56	ore	3230.0	0.34	188000.[4]		92500.[4]	78500.[4]	18250.			6	20
57	IRC			40.	<1.	60.	200.			2.0	<5	35
58	ore	1275.0	<.01	<1200.	<1.	60500.	505000.				<5	35
59	D	1443.5	.04	2030.	<1	35000.	385.				7.	50.

[1] Samples 1-28 are from the Little Willow (Gold City) area; others from the main Big Cottonwood district.
[2] Other analyses, when noted, are reported separately.
[3] Analysis rechecked.
[4] These analyses were assays.

one percent = 10,000 parts per million; ppm ÷ 34.3 = troy ounces per ton.

Analyses in this table by R.L. Broadhead, C.M.S., Inc., Salt Lake City.

Sample Types:
RC, Rock chips broken from outcrop;
D, dump - not necessarily representative;
QV, quartz vein, possibly including some wall rock;
V, chip sample of vein matter;
IR, intrusive rock, lacking veining or gossan;
mte, massive magnetite;
phl. massive phlogopite;
ore, hand specimens of sulfides;

(table 5). The metal contents are generally low. The highest copper lead and zinc contents are found in a porphyritic dike (sample 39), from the Scottish Chief mine, closely associated with fissure-bedded replacement ores on Scott Hill. The number of samples is small, however, and some environments (for example Clayton Peak Stock, table 4) were not sampled in this study.

Less Common Trace Elements

Only a few other, less common trace metals were sought in geochemical studies of the district. Burnham (1959) reported a spectrographic analysis of sphalerite from an unidentified mine in Big Cottonwood Canyon (table 6).

The high gallium content is the most striking feature of this analysis. Gallium and germanium are known to occur in other districts in unusual concentrations in oxidized zinc ores. Splits from two zinc-rich oxide samples from the Carbonate mine were sent to the research laboratory of a major mining company for atomic absorption analysis as shown on table 7.

Sample 34 has a higher Ga content than most ores from which Ga is a byproduct or coproduct (Chin, 1975). The sample was broken from about 20 pieces of goethite on the dump, and may possibly be representative of a few hundred tons of material.

With a few exceptions, molybdenum content of mineralized rocks is low. Wulfenite is locally abundant in mines near the Alta Stock, for example, the Michigan Utah group. A sulfide vein from within the Alta Stock, southwest of Mt. Millicent (sample 49, table 5) contained 40 ppm of molybdenum. Several samples of oxidized mineralization from the vicinity of dioritic rocks in the Argenta (central Big Cottonwood) area (samples 31, 47, 52) showed similar high trace molybdenum values.

Cobalt shows low concentrations and small variance in the 34 samples (table 5) analyzed for this element.

Nickel was noticeably "anomalous" only in one sample (sample 33, 265 ppm) from the dump of the Wasatch Gold (Mountain Mines, Silver King fissure) adit. Several samples from the vicinity of diorite bodies in the southern Argenta area (sample 43, 44, 52, table 5) contain twice the nickel of samples from elsewhere in the district, and may be slightly "anomalous" in cobalt also. The data presented are insufficient for rigorous determination of variations of these elements within the district.

Samples were analyzed for tungsten only where its presence was suspected. A strong trace is indicated in a calc-silicate ore sample from the Copper Apex-Crystal Elgin vein (sample 38, table 5) from near the Alta stock. Black light examination of many samples of recrystallized limestone showed no scheelite.

Uranium was similarly measured only in a few samples, and was found to occur at very low levels when compared to uranium-bearing rocks of other regions. Examination of many samples with a scintillation counter failed to show anomalous radioactivity.

GEOPHYSICAL STUDIES

The Big Cottonwood area was included in a regional gravity survey by Cook and Berg (1961). Very few of the stations measured lie within the area under discussion.

A regional magnetic map including the Big Cottonwood area was published by Mabey and others (1964), and presented at a reduced scale, after computerized removal of the main geomagnetic field and reduction to a common datum, by Shuey and Zietz (1976). The survey was flown at 12,000 feet (3,658 m) barometric altitude, with a spacing of two miles (3,200 m) between lines.

Electrical methods used to search for metallic deposits apparently have not been tried in most areas of the district. The writer and D. Pridmore ran two lines of two-frequency horizontal loop electromagnetic (HLEM) survey at right angles to the Baby McKee fissure of the Howell mine. One hundred and two hundred foot coil separations were used. The survey found no indication of the pyrite-bearing fissure.

The writer also conducted a detailed ground magnetic survey in the Argenta area, in the central part of Big Cottonwood Canyon, in 1976. This survey is discussed in detail in the section on the Argenta area.

MINERAL DEPOSITS

The Big Cottonwood district contains a diverse

Table 7. Germanium and gallium analyses of oxide ore from Carbonate mine (anonymous source).

Sample No.	Locality	Mineralogy (visual)	%Ga	%Ge
34	Little Giant tunnel dump	Goethite, traces smithsonite, galena	.019 .020	<.001
45	Homeward Bound tunnel dump	Goethite, brown oxide zinc, aurichalcite, cuprite, malachite, azurite	.0069 .0064	(no trace)

variety of ore deposit types. Overthrust-controlled silver-rich lead-zinc deposits have been the most productive. Low grade contact metasomatic deposits probably contain the greatest tonnages of base and ferrous metals, though mining to date has proven uneconomic. Fissure vein deposits have been developed in later Precambrian, Paleozoic and Tertiary intrusive rocks and much smaller precious metal deposits have been worked in earlier Precambrian rocks.

The major ore deposits of the entire Cottonwood - American Fork region are localized along an irregular, north-trending sigmoidal belt parallel to the Silver Fork and Superior fault zones and their probable extensions. The best ore deposits are in the vicinity of the intersection of this belt with the east-west belt of major intrusions. Favorable carbonate rocks, breccia created by thrusting, and wide, strongly-mineralized fissures extending upward into such lithologies tend to yield ore when close to the major north and east trends.

Deposits in Precambrian Rocks

Little Willow Area

Three types of metalliferous deposits were noted in the Little Willow earlier Precambrian rocks: 1) possible low-grade syngenetic or stratabound concentrations of gold and copper in the schistose, felsic rocks, 2) steeply dipping bull quartz veins of later age, containing and associated with disseminations of chalcopyrite, pyrite and gold and 3) quartz veins containing pyrite, heubnerite, scheelite, albite and green amphibole with only traces of copper and precious metals. Each is discussed in terms of individual occurrences in the section on mines. With the exception of a silver occurrence in the Wasatch Utah glory hole and an oxidized gold-pyrite deposit of uncertain character on the Jefferson Extension (?) prospect (Shaffer claim), type 1 deposits are limited to stains and very minor trace metal anomalies, associated with rock units questionably of volcanic origin within the schists. Type 2 deposits have produced most of the values from the Gold City area. Type 3 deposits have no recorded production, though a few tons of possibly ore-grade tungsten mineralization have been developed underground.

Most of the quartz veins in the older Precambrian rocks are rimmed by local alteration haloes and post-date metamorphism and deformation. They are spatially related to the nearby Little Cottonwood quartz monzonite pluton. However, most of the area prospected for gold is in the vicinity of some thin sericite-chlorite-quartz schist units, and the Wasatch Utah glory hole produced some thousands of tons of rock, milled on the property, from such a unit. In the glory hole and locally elsewhere, the unit contains irregular, deformed clasts. Possibly it is of volcanic origin.

Elsewhere in the world, notably in the Canadian Shield and in later greenstone belts, precious metals are localized in zones of sericite schist of pyroclastic origin. Recent studies have ascribed such deposits to volcanic exhalations on or near an ancient sea floor. The tiny occurrences discussed here have features in common with such deposits, but strong evidence for or against a volcanic origin here must await further study. No major rock units were positively identified as Precambrian volcanics. No evidence of massive bedded sulfides was found. The limited extent of the Little Willow rocks and their closeness to residential areas leaves little potential for major economic occurrences in such rock.

Later Precambrian Rocks

Extensive prospecting during the early mining periods failed to reveal economic metal deposits in the thick shale-quartzite sequence of the Big Cottonwood Series, which comprises a large part of the district.

Deposits Localized Along Thrust Faults

Within the main Big Cottonwood Mining District several bedded replacement ore bodies of silver, lead, and zinc plus subordinate copper were localized at the intersection of mineralized fissures with thrust fault zones in favorable Paleozoic carbonate rock units. The Cardiff mine which produced 162,652 tons of ore to 1968 is the best example. Silver, lead and zinc were the major metals. The Columbus Rexall mine, developed along parallel structures immediately south of the Cardiff, was similar except that its ores were rich in tetrahedrite, and hence noted more for their copper content. Both mines were localized along the upper contact of the Alta thrust zone, where Cambrian quartzite overlies Mississippian carbonates. The best ore of the Michigan Utah and Prince of Wales mines also coincides with projected thrust fault zones. Another overthrust zone, less obvious because it places carbonate rocks against carbonate rocks, is believed to have localized ore in the Reed and Benson (Kennebec) and Eclipse mines. Both lie on extensions of well mineralized zones developed on Emma Hill in the Little Cottonwood (Alta) district to the south.

No exposures of sulfide ores localized along overthrust faults were accessible during the study. In 1964-1966 the writer briefly examined ore in Deseret Limestone exposed in the deepest Cardiff-Kennebec workings, off the Wasatch drain tunnel. This ore replaced and surrounded clasts in brecciated, soft, bleached carbonate rock. Galena, sphalerite and tetrahedrite were abundant. Quartz, calcite, some crystalline dolomite, talc (?) and traces of an unidentified soft pink mineral constituted the gangue. Some vugs were evident in the ore. Calkins and Butler (1943, p. 95) conclude:

> The thrust faulting preceded the formation of the ore-bearing fissures, and the zones of crushing along the thrust faults have been replaced by solutions from the fissures . . . . The ore shoots of these deposits follow the intersections of the breccia zones with the fissures. A thrust fault may cut across the limestone beds, usually at low angles, and the fissure, when followed either lengthwise or vertically, may cut several different beds. These beds are likely to be replaced to different degrees . . . . The ore shoots therefore pinch and swell as they pass from bed to bed.

The best deposits found along thrust-fissure intersections apparently require a combination of several ore controls. Typically, the fissures are sufficiently mineralized to be recognizable above the thrust fault. Most, as at the Cardiff mine, were minable themselves on a small scale. A favorable, brecciated host rock, i. e. a carbonate unit, is required in the thrust zone. A general proximity to intrusive stocks also appears necessary. Much prospecting of carbonate rocks in the general vicinity of tiny fissures along the Alta thrust zone north of the intrusive area, as in the Tar Baby mine, has failed to find large ore bodies.

Bedded Replacement Deposits

The thrust deposits are a special class of bedded replacement deposits. The earlier discoveries of the district (for example, the Reed and Benson and Prince of Wales mines) have been ascribed to simple bedded replacement, though thrust faults appear to localize them. Highly oxidized bedded replacement deposits examined at the Maxfield mine occur at the intersections of distinct beds of Mississippian Limestone with fissures. Hoskins (1927) stated that four horizons were mineralized. There, local bedding slip may be an important ore control. Crystalline quartz is the most evident gangue mineral in the mine. The same ore controls cited above seem to be necessary to form minable deposits.

Favorable Beds

As stated in the section on stratigraphy and illustrated in figure 4, several carbonate beds have long been recognized as favorable for ore deposition. Within the Big Cottonwood district the very lowest Cambrian limestone beds have not yielded large ore bodies. This is in contrast with much of the Great Basin region, where the lowest carbonate horizons have long been recognized as the best ore hosts.

Veins passing from quartzite to carbonate rocks can only be observed in a few instances (as in the bottom of the Cardiff mine), generally with complicating circumstances. The small ore body of the Silver Mountain mine was localized immediately below the basal carbonates (which are now eroded there), and apparently narrowed with depth. Small dolomite crystals were noted in the wall rock quartzite.

Calkins and Butler (1943, p. 94), who had the opportunity to see many of the mines in operation, describe several of the favorable horizons. The dark, "wormy" and mottled dolomites immediately above and below the prominent white dolomite beds in the Cambrian Maxfield Limestone were important ore hosts at and in the vicinity of the Reed and Benson, Carbonate, and Solitude Tunnel - Michigan Utah deposits. A bed of pale gray fine-grained dolomite about 150 feet (46 m) above the top of the Cambrian was the host in some of the deposits mined long ago, notably the Eclipse and its southerly extension, the Flagstaff, and also the Prince of Wales and Michigan Utah mines, (Calkins and Butler, 1943, p. 94). These authors also describe a higher Mississippian horizon "near the base of the chert series marked by a very thin bed of very dark carbonaceous shale, which is regarded as the basal bed of the Humbug Formation" which has yielded ore in the Alta tunnel and Michigan Utah mines.

In the Maxfield mine the Gardison Limestone contains extensive, very thin bedded replacement deposits. Replacement also has been noted in other, unidentified beds in the lower Paleozoic carbonates in other mines. Replacement by magnetite-calc silicate ores has been widespread in the Deseret Limestone in the vicinity of Brighton.

The upper Mississippian, Pennsylvanian, and overlying rocks of the district host major replacement ore bodies in the mines of the adjacent Park City district (for example Garmoe and Erickson, 1968; Barnes and Simos, 1968; Boutwell, 1912). The remarkable control of large, nearly massive lenticular sulfide ore bodies by a few thin calcareous horizons lying adjacent to sandstone or quartzite units in the Park City district warrants careful study by the exploration geologist. Two major horizons, the 2002 and 1809 in the lower Humbug Formation, and several in the Upper Humbug limestones have been producers in recent years (Erickson, 1968; personal communication 1974). The most famous ore horizons of the Park City Formation are known as the Jenney, (100 feet above the base of the formation), the 1253-1254, the 920 series, and the Elephant. The same host rock units are present in the Big Cottonwood district (plate 1). Replacement deposits in Pennsylvanian-Permian rocks (as at the American and Iowa Copper Mines of the Silver King group) have not yet proven to be extensive. However, favorable beds in these rocks are poorly exposed and little explored in the district, and even their stratigraphic continuity remains unproven.

Fissure Vein Deposits

Quartz bearing fissure veins in Tintic and underlying Precambrian rocks have yielded some production, notably at the Howell (Baby McKee), Silver King (Regulator Johnson) and Branborg mines. Where the Cardiff fissure had quartzite walls, some replacement was noted by Calkins and Butler (1943) and J. J. Beeson (personal communication, 1965). More typically the contacts are sharp and the fissure narrow. Gangue minerals include sericite and abundant pyrite. The best ore shoots in several veins appear to have been localized where small east-west or north-south structures cut across the typically northeast-trending fissures.

Mineralized fissures tend to persist to great depths. The Cardiff fissure, followed down and into quartzite northeast of large stopes in limestone, contained good values. The Silver King (Regulator Johnson) fissure yielded good assays nearly two thousand feet (600 m) below its outcrop, on the Wasatch Gold tunnel level, though it was too narrow to be mined. Most ore production from fissure veins in quartzite has come from partially oxidized, and hence probably enriched, deposits near the surface.

Ore has been produced from fissures in carbonate rocks at many of the smaller mines and prospects of the district. This ore was oxidized. None was studied in detail. Mineralized fissures containing quartz veins are present in the Alta and Ferguson Canyon plutons and cut adjacent metamorphosed sediments.

Contact Metasomatic Deposits

Contact metasomatic deposits, consisting of magnetite, copper and other sulfide minerals, and hydrous silicates, are localized near the contact of the Alta stock with carbonate units. These ores are most extensive near Dog Lake (Mountain Lake-Great Western mines group) and in the Michigan Utah mine area, largely in the Little Cottonwood district. Similar ore has also been found on Scott Hill and Mount Evergreen (plate 2). The main metallic mineral is magnetite, though specular hematite was noted in the latter two localities. Chalcopyrite, bornite and chalcocite are present. Massive magnetite locally replaces quartz monzonite on the Michigan Utah group, immediately south of the district. Metal content of massive magnetite and massive phlogopite rock (sample 50) from the Mountain Lake mine are shown in table 5.

Small deposits of tungsten (scheelite) ores are reported at the Mountain Lake and Michigan-Utah mines. The scheelite is generally disseminated through bands of garnet rock.

In the Argenta area small deposits of oxidized zinc ores are closely associated with calc-silicate assemblages near dioritic plutons. These deposits lack magnetite. They can tentatively be classified as contact metasomatic.

In several areas, minor lead-silver-zinc production has come from bedded replacement-fissure vein deposits spatially related to contact zones containing calc-silicate minerals. Such relations are visible in open stopes at the Copper Apex group on Scott Hill, and are indicated by historical data on the Maxfield and nearby mines at Argenta and the Woodlawn-Kentucky Utah mines. These associations, plus the general spatial relationship between ore and intrusive bodies, suggest that the igneous bodies were essential in the genesis of the ores of the main district. No radiometric age dates have yet been obtained from the ore deposits described.

Mineralogy

As far as could be observed, the sulfide ores of the district contain no unusual minerals in abundance. Pyrite, often the earliest and most abundant sulfide, is accompanied by galena, sphalerite, chalcopyrite, tetrahedrite, argentite, and enargite. Calkins and Butler (1943) report minor chalcocite, bornite and covellite and probable jamesonite and argentite. Some reported tetrahedrite may be tennantite. Siderite, calcite, quartz, and rhodochrosite were noted in gangue. Fluorite and barite are rare (Brobst, 1964). Manganese oxides are locally abundant, as in the Michigan Utah group. The very rare sulfide tungstenite found in abundance below the water table in the Emma mine at Alta, might be anticipated in sulfide ores from the Michigan Utah group of mines, where tungsten and molybdenum are abundant in oxide ores. Scheelite and heubnerite were both noted in the Little Willow (Gold City) area, and scheelite occurs in the aureole of the Alta stock (Crawford and Buranek, 1944). Though native gold is known to be present at Gold City, examination of many quartz-sulfide samples failed to show it.

The usual suite of oxide and carbonate lead, zinc and copper minerals are present in the oxidized zones of the deposits. The silicate calamine (hemimorphite) was noted in at least one instance, and the mineralogy of a brown fine-grained dense rock very rich in zinc was not determined. Ledoux (1917) described the occurrence of aurichalcite, the zinc-copper carbonate at the Carbonate mine. Wulfenite is abundant in the Michigan Utah and adjacent workings. Calkins and Butler (1943, p. 97) state that stolzite, argentojarosite and plumbojarosite may be present.

Small openings were noted locally in samples of ore from the deepest workings in fissure veins. Some open vugs were evident in sulfide ores of the Kennebec property on the Wasatch Drain tunnel level.

Zoning

Some zoning of metals is evident among different ore deposit types of the district. The contact metasomatic deposits tend to be dominated by copper and gold; tungsten deposits have not been found far from igneous contacts. But metal zoning is either not well developed, or is hard to define, among most of the deposits. There may be a decrease in copper content as one proceeds northward from the Columbus Rexall and Cardiff mines toward the Carbonate and Maxfield mines. But all have produced notable copper. Mines in or close to intrusive contact zones (the Woodlawn Mountain Lake and Scott Hill mines) have produced both lead-silver and copper-gold ores from structures containing calc-silicate alteration.

While production records show typical grades for ores of the larger mines of the district, few records are available to show distribution of values within individual deposits.

Where the Silver King vein was cut by the deep Wasatch Gold tunnel, records and dump rock indicate it was dominantly pyrite and quartz, and was closely associated with a narrow dike. The area beneath the old Regulator Johnson workings locally contained about 0.4 oz gold per ton and about 2 oz silver per ton some 2,000 feet (600 m) below the discovery point. A definite zonation is present (samples 6 through 15-a). As the fissure was followed to the southwest, silver, lead and zinc tended to increase while gold decreased. To the northeast, where the same fissure was explored in Mill D South Fork at similar elevation, the gold values were virtually absent. Possibly the carbonaceous host rock "tillite" is somehow responsible for the greater gold content on the Mineral Fork end of the vein system.

Some other mines in the district encountered dikes at depth in ore-bearing fissures. The Prince of Wales fissure may pass into an intermediate, altered dike at depth (Calkins and Butler, 1943, p. 116), and dikes followed fissures in the Michigan Utah group. In the Maxfield mine ore and igneous activity are clearly related, and the ores become more zinc rich near dikes. But the igneous rocks trend east-west and northwest, sometimes following bedding, while the mineralized fissures trend northeast.

Genesis of the Ores

The major deposits of lead, silver, zinc and copper in the district are younger than their Paleozoic sedimentary host rocks and show a close spacial relationship to intrusive igneous rocks. With the exception of minor veins on Mt. Millicent (plate 1) and the White Pine Canyon molybdenite prospect in the Little Cottonwood intrusive body south of the area described (figure 5), the metal content within the intrusive rocks of the district is very low. Geochemical studies have not been able to demonstrate that the ore metals are derived from either the intrusions or from the intruded sedimentary rocks.

METAL PRODUCTION

The Big and Little Cottonwood districts together rank sixth in the State of Utah in production, through 1961, of lead, zinc, or silver, and eighth in gold (Stowe, 1975, p. 44-45). Minor output since then probably also makes them sixth in copper production. The Big Cottonwood district has probably been the fifth largest source of zinc-rich oxide ores in the state (Heyl, 1963, p. B-45).

Mardirosian (1966) calculated that, using 1965 metal prices, the Big and Little Cottonwood districts had produced $68,515,129 from a total of 651,374 tons of ore. It is impossible to isolate accurately the metal production of the Big Cottonwood district, because ores from the district have been developed through adits from both sides of the Alta-Big Cottonwood drainage divide and because government records have frequently lumped the districts together. Prior to 1915 a substantially greater share of the production came from the Little Cottonwood district. Since then, owing largely to the Cardiff and Columbus Rexall mines, the Big Cottonwood district has been the greater ore producer during most years. Silver and lead have yielded the greatest dollar values from most of the ores, although small tonnages of high grade copper and gold ores have been produced.

Table 8a, reproduced from Calkins and Butler (1943, p. 81) shows production of nonferrous metals from Big and Little Cottonwood districts between 1867 and 1940. Production credited to the Big Cottonwood district, 1941 through 1954, taken from *Minerals Yearbook,* is shown in table 8b. After 1954 production is either not given or is lumped with production from other districts to avoid disclosure of figures from individual mines.

A set of assay data from (about 1942 to 1952) on veins extending beneath the ridge separating Mineral and Mill D South forks, from the files of the old Mountain Mines (Wasatch Gold) and American Metal mining companies, is presented as table 9a. No information was obtained on the size of samples taken, nor on the degree of selectivity ("high grading") employed. Samples 1 through 15a were taken to determine the possible grade of narrow veins. For samples 6 through 15a, 3 to 36 samples from narrow areas of the Silver King vein were averaged to obtain the reported values, with any unusually high grade sub-samples omitted as indicated. (Locations of most of the samples are shown on figure 19). These samples represent unoxidized ores. The mine samples in table 9b (Nos. 42-50) are smelter records for small shipments of oxidized ore from the higher levels of the same vein. Higher grades were obviously present there.

Stowe (1975) presents total production figures for Big and Little Cottonwood through 1967. As discussed in the section on the Cardiff mine under "Mines and Prospects", production from the Cardiff mine between 1960 and 1967 was substantial. The writer estimates that of production listed from 1962 to 1967 at least 90 percent came from the Cardiff operations, Big Cottonwood district, and the remainder from Little Cottonwood district.

INDUSTRIAL MINERALS

In addition to gravel and silica, which are discussed briefly in the section on mines, other possible industrial mineral commodities may include poor quality marble from thick meta-limestones, and phosphate rock from the Deseret, Humbug and Park City Formations. While these formations contain phosphatic units elsewhere, (Schell and Moore, 1970) no data was obtained on their phosphate content within the district. Environmental and logistical problems may well prevent any type of quarrying within the district.

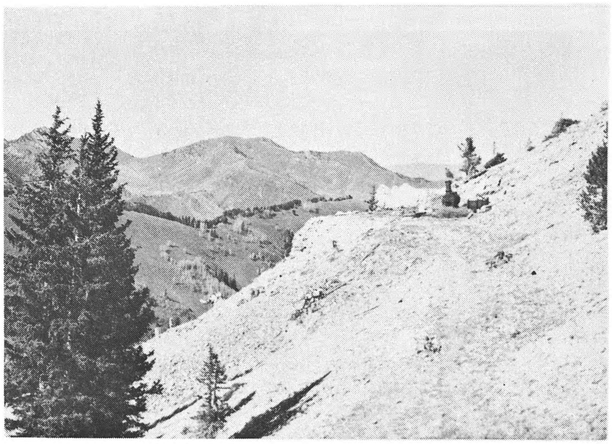
WATER

Water is probably the single most valuable resource of the district, a fact that may prevent the exploitation of other resources there. Some of the larger, low-elevation mine workings of the district might eventually be utilized as small-capacity evaporation-free water reservoirs. As an example, the Wasatch Gold lower adit in Mineral Fork has a total length of workings slightly in excess of 3500 feet. If these workings are assumed to average 6 by 7 feet in cross section, a gate at the tunnel mouth could impound 147,000 cu. feet (3.38 acre feet) of water.

MINING HISTORY

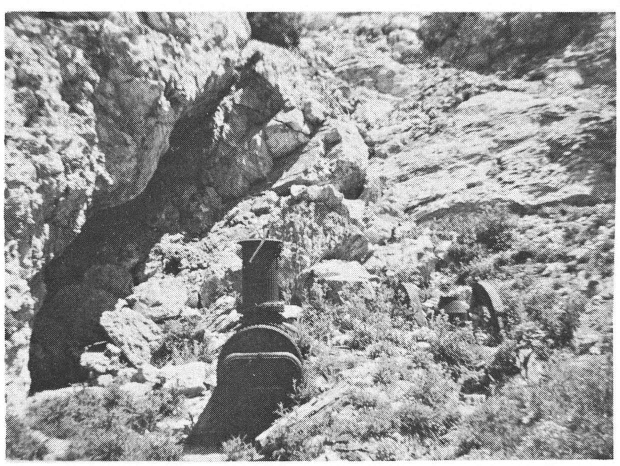
Introduction

Big Cottonwood Canyon, to the north of Alta, had been known to Mormon settlers for a decade or more before ore was discovered. Even then the canyon was recognized as a superb recreation area. At the canyon's

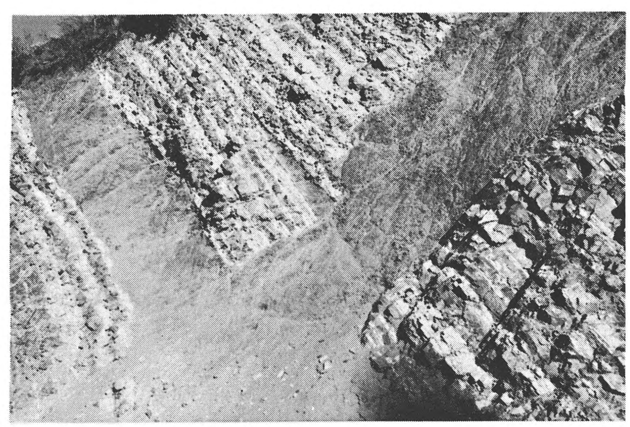


P-2 Prince of Wales shaft and steam hoist, looking northwestward into Silver Fork. Distant mountain is crest north of Big Cottonwood Creek.

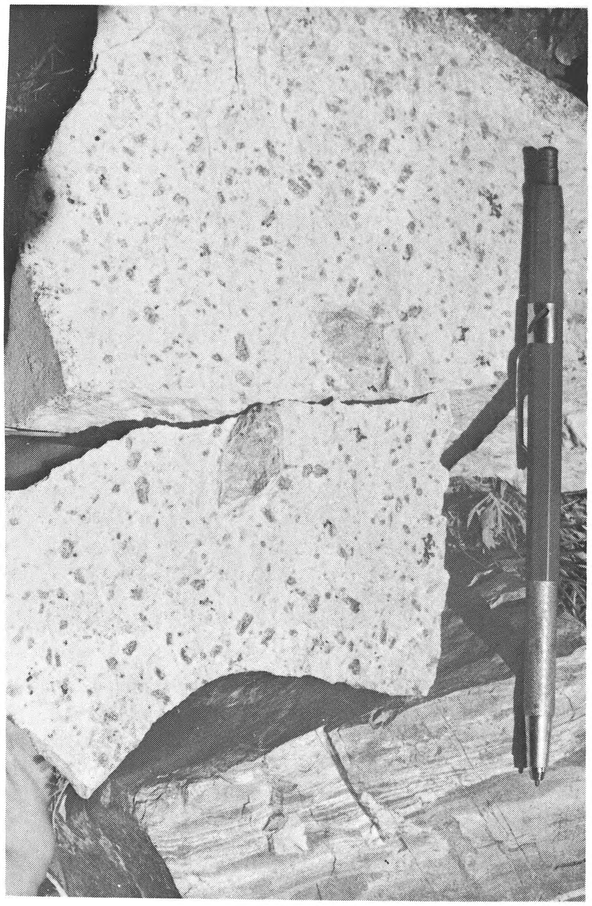
P-4 The Wasatch-Utah glory hole stope near Gold City, Utah (1962) which produced low-grade gold ores ca. 1910-1916. The stope follows the foliation of the Precambrian host rock, and once connected with the New State main tunnel level. The samples discussed in the text are mainly from the upper right hand portion of the hole.



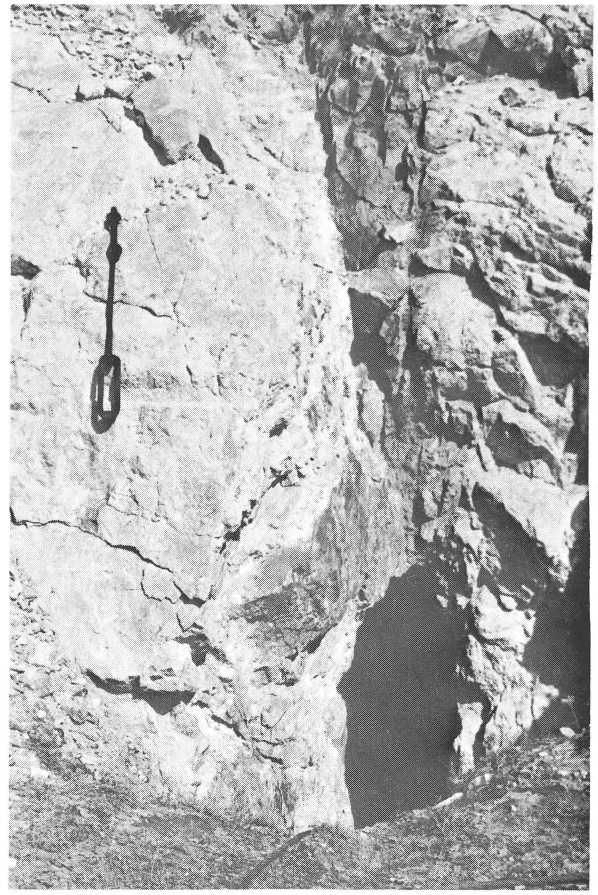
P-3 Open stope in metamorphosed dolomitic limestones, mined in the Highland Chief- Wellington workings, Prince of Wales Hill, in the 1870s. Machinery is steam powered compressor, probably the first in Utah.



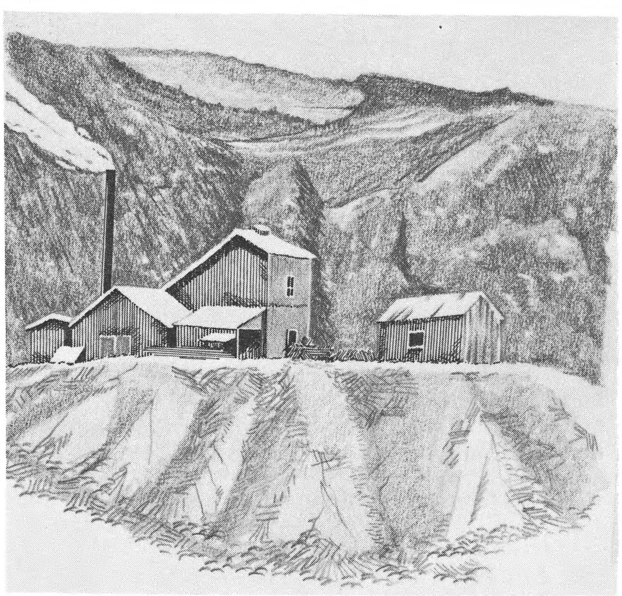
P-5 Dark dioritic sills and dike intruding bleached Doughnut (?) Formation northwest of Confidence Mine, Argenta area, Big Cottonwood Canyon. Note that thin sill, extending upward from center of photograph, lenses out in bedding.



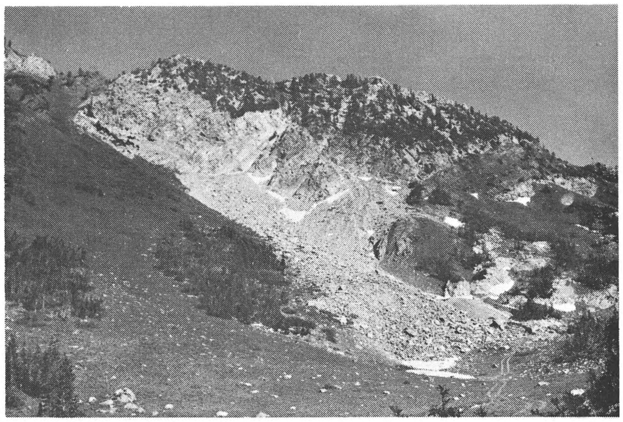
P-6 White altered porphyry and metamorphosed shale (hornfels) at Scottish Chief Mine, Scott Hill.



P-7 Nearly vertical fissure vein immediately south of Prince of Wales fissure and shaft, mined from Crooked incline. Fissure cuts bleached, recrystalline Maxfield limestone, and contains oxidized silver-lead ore minerals. Width varies from 6 inches (15 cm) or less to several feet (1m) in the stoped out area. Bedding differences appear to control width.

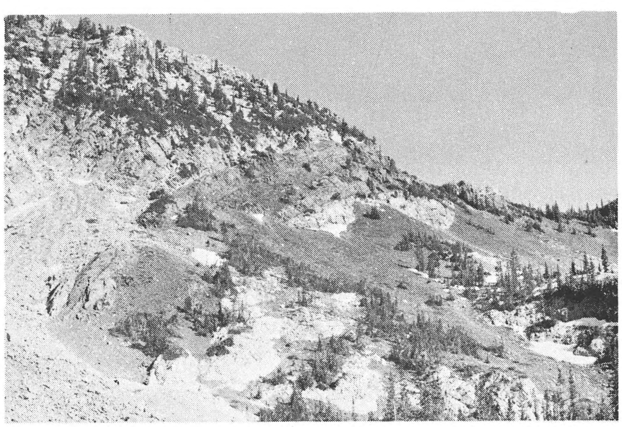


P-8 Shaft house and steam plant of the Consolidated Jefferson Mining Company, at the mouth of Poulson Canyon, Little Willow-Gold City area. Looking southeast. Drawing by G. McLaughlin, based on photograph in *Salt Lake Mining Review,* December 15, 1904.



P-9 Thrust fault above Rexall tunnel, head of Mill D South Fork. Dark unit above mine dump (lower right center) is Precambrian Mineral Fork Tillite, normally overlain by Cambrian Tintic Quartzite and (in saddle at upper left) Ophir Shale. Thrust fault below dark Mineral Fork Tillite places tillite atop another band of Tintic Quartzite.

P-11 View southeasterly from Montreal Hill, Mill D South Fork, showing portals of the Kennebec Tunnel (center) and Cardiff 600 level (main tunnel), 1962. Reed and Benson Ridge lies in background.



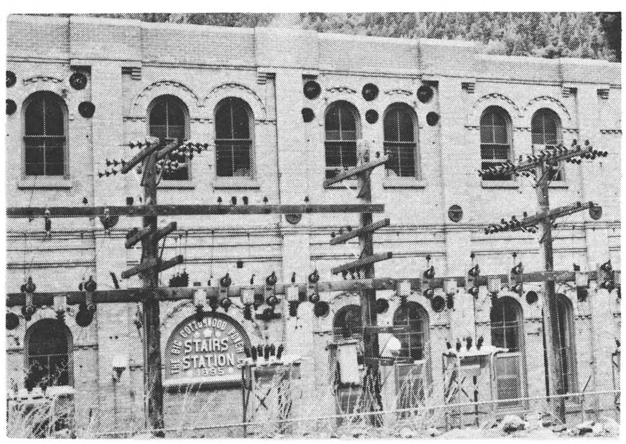
P-10 Closer photograph of same area. Thrust plane is at center of photograph. The Alta overthrust zone, which contained the largest ore bodies of the district, lies beneath the quartzite to the right.

P-12 Tar Baby Mine, lower (main) adit, Mill D South Fork, 1962. Exploration along the Alta Thrust zone in the American Metals and Howell properties was also conducted from this tunnel.

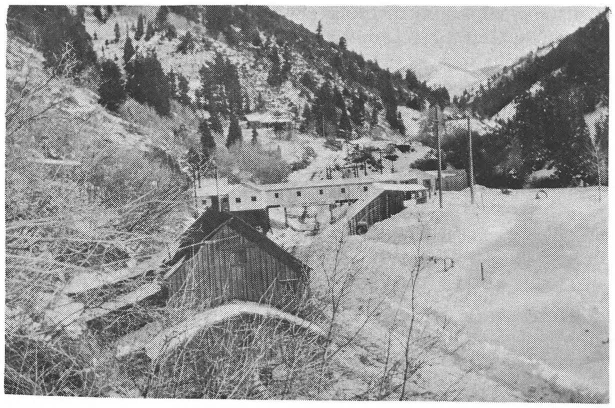
P-13 The Argenta area, Big Cottonwood Canyon, looking west-northwest, ca. 1920. The Argenta townsite and the Maxfield mine (James drain tunnel level) are at lower left. Mill A. Gulch (upper right) exposes northeast-dipping Gardison, Deseret, and Round Valley limestones, bleached in proximity to sills and dikes of dioritic intrusive complex. Photo by B. S. Butler, courtesy U.S. Geological Survey.

P14 Dr. Gerald F. Loughlin, U.S. Geological Survey, the first to describe the overthrust faulting of the Cottonwood region, at work in 1916. (Near Magdalena, N.M., courtesy U.S. Geological Survey).

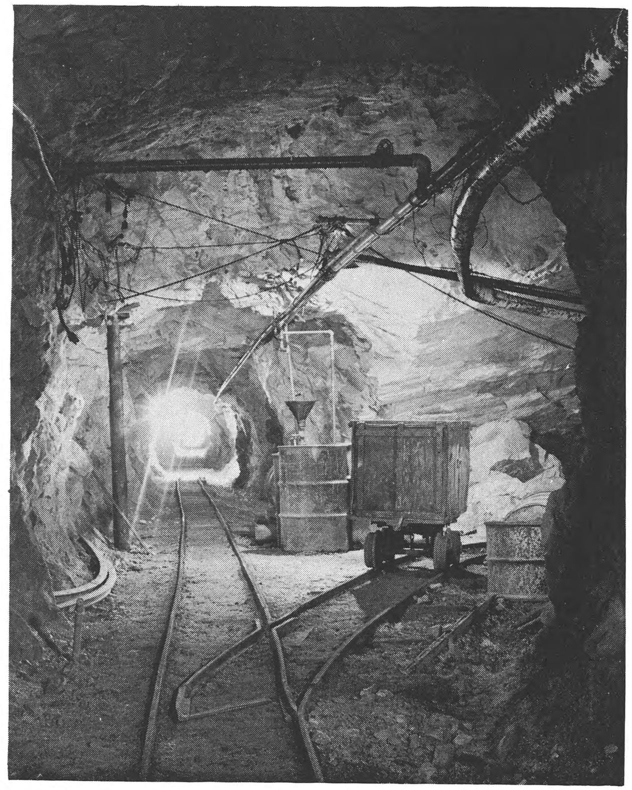
P-15 Portal of the Wasatch Drain tunnel, from which the most recent mining and development along the Alta overthrust zone was conducted, August, 1963. Snowbird resort now occupies this site.



P-16 Upper hydroelectric plant of the Utah Power and Light Company, lower Big Cottonwood Canyon, 1972.



P-17 The Maxfield mine, below Argenta, in the winter of 1930-31. View is easterly, up Big Cottonwood Canyon, with Mill A Gulch to the left. Power plant and boarding house in foreground, ore bin and trestle across canyon highway in center.



P-18 Typical methods used for tunneling in the Big Cottonwood district. View south is main drift, Lost Emma tunnel, 1975. One ton ore car, electric and compressed air lines. Courtesy C. H. Malmborg.

P-19 Wreckage at portal of Wasatch Drain tunnel (deepest entrance to Cardiff mine) below Alta, following avalanche, 1921. Miner Johnnie Hacker, foreground, is searching for personal belongings. Photograph by Robert F. Marvin. According to Marvin (personal communication, 1965) the camp cook and his wife were fatally buried in this slide.

Table 8-a. Gold, silver, copper, lead and zinc produced in Big and Little Cottonwood mining districts, 1867-1976, in terms of recovered metals. (Compiled by V.C. Heikes, revised and brought to date by C.N. Gerry, U.S. Bureau of Mines. Additions since 1927 from U.S. Bureau of Mines, Mineral Resources and Mineral Yearbook, chapters by C.N. Gerry, Paul Luff, and T.H. Miller).

Period	Number of mines	Ore Mined (short tons)	Gold Fine ounces	Silver Fine ounces	Copper Pounds	Lead Pounds	Zinc Pounds	Total value
1867-70		5,573	59.99	703,138		6,444,800		$1,321,955
1871-80		133,796	3,585.02	6,259,000		95,201,998		13,401,108
1881-90		22,515	5,426.90	883,034		14,784,900		1,703,068
1891-1900		13,885	7,581.38	707,731		8,457,869		1,005,819
1867-1900		175,769	16,653.29	8,552,903		124,889,567		17,431,950
1901	3	935	161.19	37,532		300,298		38,764
1902	4	850	146.53	34,120	58,490	272,999		39,442
1903	5	1,977	85.24	69,336	102,260	552,483		76,417
1904	6	4,878	306.36	106,249	235,832	1,190,005		148,703
1905	6	26,003	949.99	371,683	811,639	1,702,258		450,756
1906	10	20,801	762.05	345,102	1,193,743	1,922,276		586,933
1907	11	19,896	976.93	399,417	1,074,238	2,337,924		622,568
1908	21	5,866	321.35	63,246	269,212	603,840		101,061
1909	15	13,208	335.72	158,867	1,842,711	332,475		343,400
1910	17	14,203	381.87	202,010	804,018	1,102,907		267,617
1901-10		108,617	4,427.23	1,787,562	6,392,143	10,317,465		2,675,661
1911	12	6,040	139.17	158,448	407,719	1,043,608		184,783
1912	15	6,566	142.46	186,183	386,963	1,135,191		232,381
1913	12	5,167	112.09	93,821	136,901	1,091,617		128,235
1914	25	12,583	372.25	242,825	214,971	2,887,109	8,804	283,615
1915	18	24,590	430.39	445,111	334,944	12,263,403	229,663	898,041
1916	31	41,960	1,035.90	755,980	819,192	15,061,273	60,746	1,767,738
1917	32	48,203	900.31	917,512	1,163,084	11,927,552	21,721	2,120,149
1918	23	35,269	583.69	482,136	1,715,969	6,007,253	1,121	1,344,663
1919	19	21,766	384.44	321,426	916,049	4,857,211		795,761
1920	15	18,299	329.24	413,863	566,003	5,499,436		1,002,015
1911-20		220,443	4,429.94	4,017,305	6,661,795	61,773,653	322,055	8,757,381
1921	16	14,303	241.92	310,708	296,296	4,459,201		554,595
1922	14	17,459	279.07	294,477	755,995	5,508,133		705,253
1923	14	18,674	206.75	364,355	344,553	7,662,932		890,100
1924	11	16,628	244.68	423,176	246,300	6,256,829		821,397
1925	16	13,565	279.66	254,753	212,221	4,748,256		625,813
1926	15	10,907	246.52	206,498	449,069	3,194,890	360,270	479,433
1927	11	5,181	245.99	148,115	249,337	2,017,283	1,666	248,925
1928	9	1,518	137.34	30,846	139,489	292,975		57,963
1929	7	1,814	33.23	30,212	57,989	346,381	87,213	54.574
1930	7	1,491	61.15	15,779	25,646	250,180		23,182
1921-30		101,540	1,976.31	2,078,919	2,776,895	34,737,060	449,149	4,461,235
1931	10	657	153.70	20,317	10,306	234,943	13,017	19,194
1932	10	488	46.58	9,337	4,710	217,924	1,446	10,474
1933	9	1,434	98.88	11,041	8,852	430,651	354,456	37,778
1934	9	1,881	168.24	36,356	34,612	595,162	184,000	62,085
1935	10	1,979	160.20	38,969	40,723	542,775	100,091	63,111
1936	12	2,890	286.80	50,532	45,598	713,848	29,480	87,681
1937	9	7,858	363.00	132,499	249,000	2,175,000	115,600	281,161
1938	9	3,066	282.00	39,122	89,949	580,348	64,542	73,770
1939	10	2,653	248.00	36,954	69,125	366,319	86,789	62,683
1940	10	2,634	210.00	33,293	81,000	231,800	39,603	54,263
1931-1940		25,540	2,017.40	408,420	633,875	6,088,770	989,024	752,200

(continued)

Table 8-a (continued)

Year	Tons	Gold/Ozs.	Silver/Ozs.	Copper/Pounds	Lead/Pounds	Zinc/Pounds	Total Value
1941	1,463	197.00	25,830	64,000	262,000	57,000	$52,024
1942	1,077	106.00	15,878	44,000	108,700	90,900	36,062
1943	794	46.00	7,709	9,900	167,600	128,000	34,773
1944	329	27.00	8,408	10,400	50,800	43,500	17,351
1945	856	29.00	14,760	69,400	77,000	-	27,502
1946	838	78.00	12,130	45,000	98,400	1,500	30,685
1947	951	30.00	17,926	67,000	233,500	7,800	65,911
1948	2,489	33.00	20,758	66,600	746,700	482,100	232,172
1949	4,796	98.00	35,229	56,000	1,284,000	851,800	354,841
1950	4,027	50.00	23,423	54,000	741,800	866,900	257,424
1941-1950	17,620	694.00	182,051	486,300	3,770,500	2,529,500	$1,108,745
1951	931	10.00	5,941	11,000	117,100	246,100	$246,100
1952	387	15.00	6,107	4,700	89,606	22,200	24,301
1953	40	1.00	97	3,900	100	-	1,255
1954	487	21.00	5,656	13,100	29,800	23,000	16,281
1955	49,108	21.00	14,505	23,000	1,419,500	6,370,000	1,017,458
1956	48,541	9.00	6,879	23,900	940,100	7,147,200	1,143,460
1957-1959				no production			
1960	?	81.00	56,559	125,900	2,045,400	1,692,900	560,117
1951-1960	?	158.00	95,744	205,500	4,641,606	15,501,400	$3,008,972
1961	?	97.00	162,430	364,500	2,568,500	2,175,900	$804,199
1962	?	20.00	31,498	71,400	683,200	536,500	184,197
1963	?	26.00	30,024	64,600	547,700	378,500	157,528
1964	?	27.00	32,250	68,100	459,300	211,900	149,923
1965	?	48.00	44,951	294,800	352,500	146,400	229,070
1966	?	30.00	39,815	80,200	536,800	737,400	272,413
1967	?	6.00	12,371	10,200	444,900	509,700	153,301
1968-1970				no production			
1961-1970	?	254.00	353,339	953,800	5,592,900	4,696,300	$1,950,631
1971-1976				no production			
GRAND TOTALS							
1867-1976	830,023[1]	251,811,521	24,487,428	18,050,899	30,610.17	17,476,243	$40,146,775

[1] Recorded tonnages plus estimates for 1960-1967

Estimated lead value: $15,668,526
Estimated zinc value: 3,062,158

Source of information for 1960-1967: Stowe (1975, p. 50-54)

Table 8b. Production from Big Cottonwood district, 1941-1954, (does not include ore mined in Big Cottonwood district and shipped from Little Cottonwood district).

Ore Mined (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper pounds	Lead pounds	Zinc pounds	Total Value
12,752	283	99,375	223,960	2,780,700	2,614,200	$870,859

(Source: *Minerals Yearbook,* 1941-1954)

Table 9-a. Assays reported from selected vein samples, Upper Mineral and Mill D South Forks (to accompany figure 19). From records of Mountain Mines and American Metal Mining Companies. Assayer, Sampler unknown. Probably taken 1942-1952.

Sample No.	Location	Sample width	No samples	Gold oz/ton	Silver oz/ton	Lead %	Zinc %	Copper %
1	Surface cut	"spots"	1	tr	68.8	74.6	3.7	
1A				tr	49.2	36.0	none	
2	Branborg Tunnel crosscut on Silver King fissure	8"	1	tr	19.6	16.2	15.5	2.2
2A	"	12"	1	0.01	12.7	8.3	3.9	
2B	"	6"	1	none	19.6	16.2	15.5	
2C	"	(not recorded)	1	tr	40.8	51.6	12.1	
2D	"	"	1	0.01	11.4	12.1	2.5	
2E	"	"	1	0.02	74.2	22.0	6.6	5.9
2F	"	"	1	0.01	68.4	51.8	4.6	3.19
2G	"	"	1	0.01	48.2	68.6	3.7	
3	Branborg Tunnel Garfield fissure	8"	1	none	20.6	28.8	14.3	0.4
3A	"	(not recorded)	1	tr	22.0	34.8	4.9	0.3
3B	"	"	1	tr	18.4	33.4	25.8	0.4
3C	"	"	1	0.02	16.4	21.5	15.4	0.09
3D	"	"	1	0.02	14.2	18.6	27.0	0.2
3E	"	"	1	tr	28.1	37.0	11.5	
3F	"	"	1	0.02	20.0	21.0	1.3	
3G	"	"	1	0.01	3.7	5.1	15.1	
3E	"	"	1	0.01	5.36	7.5	9.2	
3F	"	"	1	0.01	8.26	14.0	33.2	
3G	"	"	1	0.005	12.4	19.1	24.4	
3H	"	"	1	0.005	4.4	4.7	3.0	
3I	"	"	1	0.01	26.0	25.2	20.9	7.4
3J	"	"	1	0.01	24.4	39.8	6.6	2.0
	Branborg Tunnel -No location							
A	"	6"	1	0.01	0.8	none	1.0	
B	"	10"	1	tr	0.3	none	3.7	
C	"	24"	1	0.01	0.2	none	1.0	
D	"	18"	1	tr	1.2	1.8	10.0	
E	"	6"	1	0.01	13.8	20.2	15.0	
F	"	4"	1	tr	47.3	64.8	11.1	
4	Malmborg Tunnel	10"	1	0.02	20.0	21.0	1.9	
5	(Tar Baby Tunnel-American Metals Dr.)	6"	1	tr	0.2	5.1	12.3	
5A	"	45 ft *		tr	0.4	none	0.2	
6	Silver King Fissure	12"-36"	3	0.163	1.33	0.3		0.07
	Wasatch Tunnel NE end							
7	" to SW	18"-48"	3	0.44	1.92	0.26		0.07
8	" SW of 7	48"60"	4	0.27	2.35			0.65
8A	" SW of 8	12"-30"	6	0.165	1,77	0.4		
9	" SW of 8	6"-24"	9	0.3	2.4	0.9	1.9	0.1
9A	" SW of 9	6"	5	0.26	11.28	0.42	0.65	
10	" SW of 9A	108"	4	0.385	0.63	0.05		
11	" SW of 10[1]	12"-30"	32	0.16	5.78	0.92	0.22	0.5
12	" SW of 11[2]	24"-36"	5	0.112	5.4	0.43		0.47
12A	" SW of 12	48"	7	0.09	17.6	5.7	2.8	0.25
12B	" SW of 12A	6"-48"	11	0.12	5.6	3.9	2.8	0.05
13	" SW of 12A	72"	17	0.08	3.1	1.7	0.1	0.05
13A	" SW of 13	12"-36"	14	0.08	6.0	1.8	1.2	
14	" SW of 13A	30"-60"	14	0.08	8.3	4.4	2.9	0.09
14A	" SW of 14	24"-60"	10	0.08	8.1	2.5	2.3	0.06
15	" SW of 14A	48"-72"	15	0.064	7.2	1.6	0.9	0.1
15A	" SW of 15[3]	36"	36	0.065	10.3	1.6	3.2	0.12

* 28.0% Iron"

[1] 255 oz Ag omitted)

[2] 14.6% Pb omitted)

[3] (Omitted: 237 oz. Ag; 215 oz. Ag; 17.0% Pb; 17.5% Cu)

*Simple means were calculated from assay data, with extremely high grade samples omitted where noted.

Table 9-b Shipments to Garfield smelter, from Upper Silver King workings, 1941

Sample No.	Location	Sample Width	Shipment Weight	Gold oz/ton	Silver %	Lead %	Zinc %	Copper %
42*	Old upper working Silver King vein	?	18,220 lb.	0.27	11.70	2.25	2.40	0.12
43	"	?	46,230 lb.	0.28	7.97	2.3	-	0.25
44	"	?	20,006 lb.	0.51	18.52	1.50	-	0.22
45	"	?	65,438 lb.	0.19	13.52	1.50	-	0.27
46	"	?	57,388 lb.	0.29	29.10	5.35	-	0.22
47	"	?	52,562 lb.	0.24	22.95	2.8	-	0.4
48	"	?	19,672 lb.	0.34	8.3	4.05	-	0.11
49	"	?	61,614 lb.	0.17	17.25	2.15	-	0.22
50	"	?	54,644 lb.	0.33	43.85	6.70	-	0.37

*No. 42 contained 12.80% "Fe"

headwaters a family named Brighton had settled and built a small resort hotel. On July 24, 1857, Mormon leader Brigham Young held a mass "pic-nic party at the headwaters of Big Cottonwood Kanyon" in celebration of ten successful years of colonization in Utah. Even then there was fear of environmental complications; admission was by invitation only, and all had to pass the first sawmill by 2 p.m. the previous day. Fires were prohibited except on the camp ground. 2857 persons, including three brass bands, 465 carriages and wagons, 1028 horses and mules, and 322 oxen were recorded in attendance (Carter, 1957, p. 30).

Lumber was the most important resource of the area in early decades. Loggers had begun to install water and steam-powered sawmills along the creek and had named the major ones Mill A, Mill B, and Mills C, D, E and F, (figure 2). Adjacent gulches were named after the mills (Bowthorpe, 1972).

In the last half of the nineteenth century, mining booms and mining districts suddenly became an important part of the American west. New mining camps appeared overnight when ore was discovered. Some disappeared almost as rapidly, while others became thriving permanent towns. Utah territory lagged behind neighboring states in such activities. However, a number of prosperous and lively mining camps in Utah were receiving international attention by the early 1870s, most notably the Little Cottonwood and Alta mining districts (figure 1). The early history of Utah mining has been well described by Arrington (1963).

After, or perhaps even before the discovery of the famous Emma mine at Alta, prospectors spread northward across the rugged divide and made discoveries in the Big Cottonwood mining district. The area was originally part of the Mountain Lake mining district, which embraced most of the Wasatch range (Calkins and Butler, 1943, p. 72). On March 17, 1870 the Big Cottonwood drainage basin was declared a separate district (Murphy, 1872, p. 28). At a miners meeting held shortly thereafter to develop laws for the new district, the district was said to extend about 16 miles east-west and 6 miles north-south (Calkins and Butler, 1943, p. 72). As far as the writer was able to determine, the boundaries have never been defined more exactly. Local customs and recording schemes include claims as far west as the Wasatch foothills and as far north as parts of the Mill Creek and Neffs Canyon drainages in the Big Cottonwood district. (Plate 2).

The second miners meeting of the district, held on July 1, 1872, established rules for governing mining locations and annual assessment work. The district mining recorder's duties included the inspection of all annual assessment work (Fee: $5), and the choosing of five disinterested persons to examine any supposedly abandoned claim before it could be relocated. A Miners League "for the protection and security of the miners' interests in this district, including timber," was also organized. (Utah Mining Journal, July 8, 1872).

The Early Boom Era 1871-1885

The best early mines were high in Honeycomb, Silver, and Mill D South forks, practically on the back side of Emma Hill and Flagstaff Mountain (figure 1). Many a miner crossed the high divides to spend his paycheck at Alta.

By 1872 there were 400 to 500 inhabitants in the district, and several properties were paying well (Wheeler, 1874). Raymond (1873) noted that there were about 650 claims by that year, many of them very recent, "of unknown merit". Murphy (1872) described the earliest towns of the district, Homansville and Belleville. Both, now vanished, were connected with Salt Lake City by a tri-weekly stagecoach service. Homansville was apparently located a short distance above the mouth of Silver Fork.

On the flat near the Dolly Varden mine in central Big Cottonwood canyon the little mining town of Argenta developed, with "one good hotel" and tri-weekly stagecoach service to the Salt Lake Valley; soon it also had the only post office in the canyon. One old-time promoter recalled that it once had two hundred inhabitants (Calkins and Butler, 1943; interview with B. A. M. Froiseth, 1921). In 1874 the claimholders and residents of Argenta voted to split off from the rest of the Big Cottonwood district, thus forming the Argenta Mining District. The district extended from the crest of Reed and Benson Ridge to the Salt Lake Valley. William

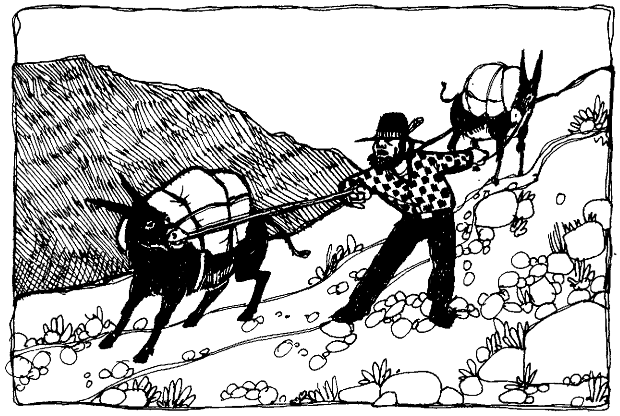
Dix of the Dolly Varden mine served as its first recorder (*Utah Mining Gazette,* March 21, 1874). This separation of districts apparently continued until late in the 19th century. The northernmost end of the area, extending into Porter Fork of Mill Creek Canyon, was once the New Eldorado Mining District.

The town of Emmaville, a real estate promotion enroute to the mines of Alta, flourished briefly in the early 1870s. It was located on Willow Creek, not far from the later site of Gold City (see below).

The greatest early producer of Big Cottonwood was the Reed and Benson mine in Mill D South Fork, now called Cardiff Fork by the Forest Service. Discovered in the spring of 1870, the mine was high on the sheer limestone cliffs between Mill D and Days Forks. Men roped their way down the cliffs carrying single jacks, drill steel and dynamite to cut a trail to the outcrop. Narrow mine buildings were erected on a ledge cut into the rock, and a twenty thousand-dollar rail tramway, 1,582 feet in length, connected the tunnel in the cliff face with the wagon road in the gulch. A nine foot brake drum at the top controlled its motion. It was "the costliest and most perfect tramway ever built in the U.S." according to the *Utah Mining Gazette* (November 15 and December 13, 1873). The mine was also equipped with an assay office, a boarding house for 100 men and storage space for 20,000 sacks of ore at the base of the tram. Another major early producer was the Prince of Wales mine, lying between the Honeycomb Cliffs and the steep cirque at the head of Silver Fork. The Walker brothers of Salt Lake City purchased the Prince not long after its discovery in 1870 and began mining the rich vein through an inclined shaft. Two steam hoists (a large one at the surface and a small 10 h.p. unit underground) raised the ore to the ridgetop, where a covered rail tramway led over to the wagon road down to Alta (Huntley, 1885, p. 140-8). It is said that saloons were built down at the junction of Silver and Honeycomb forks to serve the miners from the Prince (L. W. Hoskins, personal communication 1963).

The Highland Chief company of Boston sank a shaft on the Prince fissure farther down the hill. Lawsuits over claims soon began between the Highland Chief and Walker interests (Copp, 1882). The Walkers eventually acquired the entire hillside, and worked it profitably until the 1880s. Thereafter they directed most of their mining efforts toward central Montana, where their former Alta employee Marcus Daly had developed some fine ore deposits at Walkerville.

By the late 1870s, Argenta remained the major mining town in the canyon (Huntley, 1885). At Silver Springs (or Silver Fork) there were two stores, one saloon, three blacksmith shops, one livery stable, three sawmills and a hotel (*Utah Mining Gazette,* June 10 1874). At Silver Lake or Brighton, at the head of the canyon, a seven-bedroom two-story hotel apparently accomodated mainly tourists. Between Argenta and the canyon mouth the Maxfield Lodge, just above the rugged gorge at Storm Mountain, also became an overnight



stopping point. Despite closeness to Salt Lake City, the rugged terrain kept most of the mines isolated from civilization and from each other. Huntley (1885) noted that food and fuel supplies typically were laid in during October to last until the following June.

Early Geological Efforts

Many of the early miners and prospectors were veterans of Nevada, California and Colorado, and thus had some ability to recognize mineralization, though the ores characteristic of carbonate rocks were doubtless new to most of them. The only formal geologic studies in the area during the 1865-1880 era were those of Clarence King's 40th parallel survey (1878), and its work in the district was rather minimal. The geologic atlas published along with the seven volumes shows the area at a scale of four miles to the inch. R.W. Raymond, during his visits to the district, also made geological observations. Clayton Peak was named after Professor J. E. Clayton, a noted geologist.

Mining engineering clearly was not neglected, as the workings and mechanical apparatus at the various mines demonstrate. The long Kennebec or Goodspeed tunnel, driven beneath the old Reed and Benson mine, passed directly beneath the bottom of the deepest stope from the old workings, accessible only via thousands of feet of winding trails and underground passages. In order to overcome the problem of powder fumes, this tunnel was equipped with a steam-driven fan.

Near an intrusive contact south of Brighton, probably in the Snake Creek drainage, an "electric magnetic rock" obtained from the tunnel of the Addie silver-lead prospect aroused scientific curiosity in the early 1880s. "Rub it with a piece of wood and it emits a bright light which gives no heat whatsoever. There is no phosphorous in it"(*Western Mining Gazetteer,* October 1882, article on Snake Creek). The identity of this material remains uncertain.

The Hard Times Era, 1885-1898

The early bonanza days lasted less than a full decade, and by 1885 even desultory cleanup operations by leasers were becoming rare. In 1880 D. B. Huntley, an experienced mine operator employed by Clarence King to make a special study of Utah mining, concluded that:

> . . . The former great ore producing districts of West Mountain and Big and Little Cottonwoods were comparatively idle. In some instances mines which formerly employed a hundred men were not even being prospected, but were abandoned to three or four men, who were engaged in picking over the dumps and searching the workings for ore that had escaped extraction. Practical and energetic labor is confined to a few large mines, the output of which presents a strikingly noticeable falling off. . . (Huntley 1885).

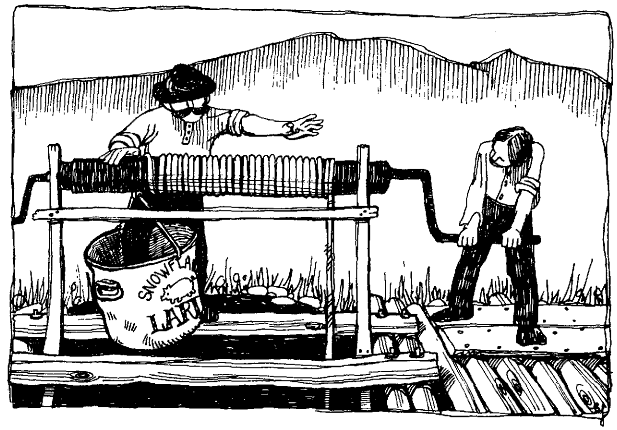
Still harder times followed. The richest ores had been exhausted; the most enthusiastic bonanza seekers had moved on to new boom areas. The towns of Argenta (Carr, 1972) and Silver Springs were both damaged or destroyed by fires. Silver prices had tended to decline, while the mines had reached depths at which operation was difficult. The Reed and Benson group, for example, was developed by four irregular inclines below the adit level, and the Maxfield mine had similar crooked workings. The Prince of Wales main incline had reached 930 feet below its mountain-top hoist. Some of the mines had encountered sulfides and zinc minerals at the water table, and these lower grade so-called "base" ores were difficult to treat in the primitive smelters of Utah of that time.

By the 1890s only a few determined individuals and companies were working in the district. One successful operator was John S. "Regulator" Johnson. He had arrived at Alta in the early 1870s and had sold the rich little Regulator claim, near the divide. For many years he worked the Silver King and Gypsy Blair claim groups in Big Cottonwood. Shipments from the former required a five mile pack trip with a string of mules, but still provided ample capital for further prospecting ventures. "Old Regulator" lost an eye and four fingers in a blast, but still kept working his mines, often alone, and always extolling the future of Big Cottonwood ore deposits.

The Gold City Mining Boom, 1894-1901

The Precambrian rocks south of the mouth of the canyon had not escaped attention during the early boom. Claims were located there as early as 1870, and farmers are said to have found nuggets in streams. Mormon church authorities discouraged such prospecting, however (Bowthorpe, 1972), and it was not until the 1890s that renewed interest in gold brought prospectors to the area. The bull quartz veins near Poulson Canyon, south of Little Willow Canyon (renamed Deaf Smith Canyon on U.S. Geological Survey maps) were found to contain gold. A rush ensued and the town of Gold City appeared for a brief time near the mouth of Poulson Canyon (Salt Lake Mining Review, December 15, 1904, p. 15-17), on the present site of Golden Hills subdivision. The earliest claim identified during this study was located in January , 1894.

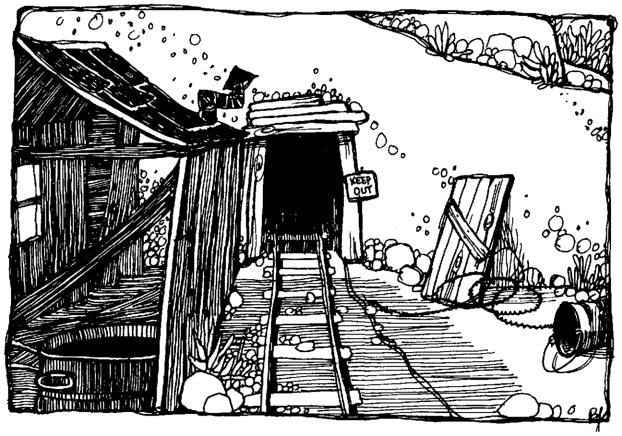
The New State vein, discovered by Daniel and William Wolstenholme, locally assayed several to hundreds of ounces of gold per ton at the surface. The mine



was soon equipped with a steam hoist and a 10 horsepower "dynamo" for lighting purposes. Intermittent discovery of high grade in this mine, as well as in the Dipper and Alix claims to the south and elsewhere, kept the area in the news into 1901, but thousands of feet of tunnels and shafts failed to find major ore bodies. By 1903 only two major claimholders remained in the area. One, an old hermit named Clayton, had a cabin on the Blue Jay claim. Until he finally vanished, he spent evenings strumming a guitar to "My Darling Clementine" and other tunes. The other, Nicholas R. Schmittroth, kept his wife and seven children busy on his Jefferson and Josephine claims.

Schmittroth, a Bavarian-born baker turned prospector, had worked in the district for a decade sinking and tunneling on promising veins in amphibolite, financed partially by the sale of a bakery in Salt Lake City. Finally in about 1903 he had the opportunity to purchase the New State property for $20,000 but had no resources to do so. He formed the Consolidated Jefferson Gold and Copper Mining Company and took a job on a cattle train going to Chicago. In Chicago and Omaha he sold $35,000 in stock. He returned on a first class train, purchased a new home and automobile, and put a crew to work deepening the New State shaft. A five stamp mill was erected. The Jefferson Mercantile Company, below the mine at the site of Gold City, supplied the various needs of the miners. Schmittroth was a good salesman, and many bought shares in his project. While taking his daughter to Munich to study voice and elocution, he met a New York crockery merchant named Getz, who soon invested heavily in the mine (N. M. Schmittroth, personal communication, July 26, 1964).

The Jefferson company was often in debt. When Schmittroth asked his stockholders to approve a $250,000 loan for "further development," they refused. A. W. Nieman, a Chicago grocer, was elected company president. Schmittroth, removed from the directorate, left to open a bakery in Ely, Nevada. He also organized the Jefferson Extension and Diana Gold and Copper companies in the Gold City area. Nieman sent his son to Colorado to study mining, and in 1908 reorganized the property as the Wasatch Utah Mining Company. Two mills were built, one using amalgamation (Salt Lake Mining Review, May 15, July 15, 1913) and cyanidation,



the second using a pressurized cyanide "Koering metal recovery drum". Further lavish expenditures (*Salt Lake Mining Review,* May 13, 1913, October 15, 1915, January 15, 1917) including an office in New York City, followed. Apparently neither mill was successful. Much of the rock treated was clearly very low in grade (Nieman and Wigton, 1913; N. M. Schmittroth, personal communication). Little further work was done in other mines, following the failure of the Wasatch Utah company.

Schmittroth re-purchased the properties a decade later, and organized the Golden Porphyry Mines Company. A drain tunnel beneath the New State workings, intended to extend all the way to the Park City district, was begun from the foot of the Wasatch range, in gravels west of the Wasatch fault. (Schmittroth, 1937). Work ceased when Schmittroth died in 1937. The increase in the gold price stimulated minor production from leases in the area in the 1930s. The last recorded shipment was made in 1946 from the Dipper (Clementine) mine. The old mill area at the mouth of Poulson canyon is now the Golden Hills housing development.

Deep Development, 1898-1913

The twentieth century brought a sudden revival of western mining activity. A number of new companies organized to develop prospects in Big Cottonwood and most other western silver-lead-zinc districts. Prices had risen, and interest in potential copper deposits was suddenly very intense. Big new smelters, capable of handling complex ores at a profit, were being erected in the Salt Lake valley.

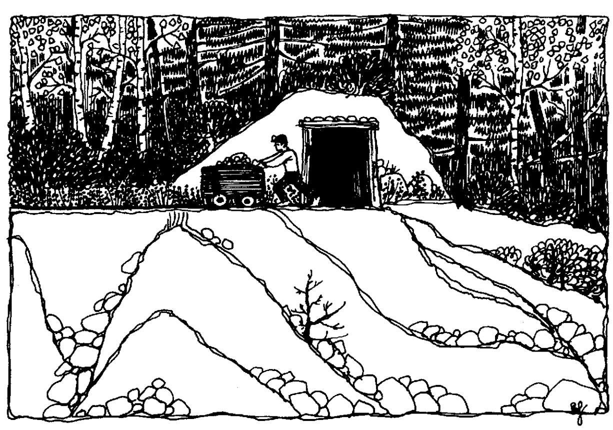
Improved mining equipment, including electric and compressed air-powered rock drills, made long development tunnels more feasible. Capital was becoming available locally and from the Midwest. It was no longer as necessary to depend on eastern United States and British financing for mine development.

Henry W. Lawrence, a noted Utah mining figure of the 1870s, and his sons George and William, actively financed new developments in the Woodlawn, New Sensation, Scottish Chief, and other prospects. F. W. Price and others organized the Cardiff Mining and Milling Company and interested Salt Lake City Mayor Ezra Thompson in financing a deep adit to explore a mineralized fissure zone at depth. Frederick V. Bodfish, mining promotor and self-trained engineer, arrived from Cripple Creek with both personal wealth and financial backing. He was impressed by a lead-silver prospect in Silver Fork held by Fred L. Schrott, locally known as "The Lucky Dutchman". In 1911 he organized the Alta Tunnel and Transportation Company to purchase this ground and to drive a deep tunnel from Silver Fork beneath the Prince of Wales and Michigan Utah mine areas. Several other tunnel schemes were also underway. Miners again populated the canyon in abundance.

The Second Cottonwood Boom, 1914-1926

The long (600 level) adit of the Cardiff mine was driven with great persistence toward the Cardiff fissure, which was yielding small tonnages of high grade ore nearer to the surface. Mssrs. Thompson, Murdock and Price were very persistent. The company levied many stock assessments and many stockholders let their shares lapse in discouragement. After years of work, all by hand, the tunnel entered the Alta overthrust zone, which was followed for more than 700 feet (210 m). While F. F. Hintze clearly had discussed this fault with superintendent Henry Barney, it is not clear how important the thrust was believed to be by the company. In October, 1914, the Cardiff fissure was reached almost 2,500 feet from the portal. The limestone below the thrust contained the largest ore body yet found in the Cottonwood region. A new mining boom suddenly began in the western Wasatch, and stock prices of all companies with prospects in the vicinity of Big Cottonwood soared.

Dozens of new ventures were organized to drive adits beneath old mines, often without any geological guidance. Any limestone-quartzite sequence, including those in the Pennsylvanian rocks higher in the section, was thought to be the "Cardiff contact", and any stock issue containing the name Cottonwood aroused interest. New electric power lines led to widespread installation of air compressors to speed the driving of tunnels. The difficulty of transporting ore out of the district led to a number of schemes for long adits to the valley. None of these materialized, however.



By the mid 1920s exploration drifts had been extended along several lengths of the Alta overthrust zone without discovering ore. Large custom smelting companies in the Salt Lake Valley, foreseeing the need for future ore supplies, sent geologists to map many of the mines. No district-wide private studies of economic potential in the district are known to have been made since.

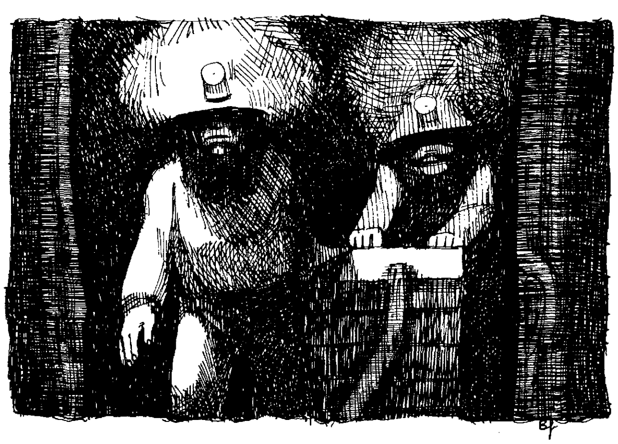
Production from Big and Little Cottonwood districts during this thirteen year period averaged more than 22 thousand tons of ore per year, and reached a maximum of 48,203 tons in 1917 (Calkins and Butler, 1943). A slightly larger share of this production probably came from the Big Cottonwood district.

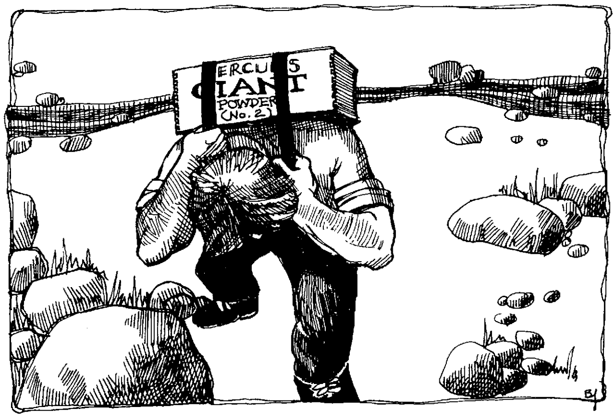
Depression and Stock Promotion 1926-1940

A general decline in exploration activity in the silver-lead-zinc districts of Utah was evident by the mid 1920s. By late in that decade most of the Big Cottonwood production was by leasers, and the drop in metal prices accompanying the great depression of the 1930s made many leases unprofitable. Only properties that were already well equipped and had ore blocked out in old stope areas remained in operation. The steady and rising price of gold caused some renewed interest in veins near Gold City (Little Willow area) and in Mineral Fork.

A number of Big Cottonwood properties remained on the Salt Lake Stock Exchange, and decreased mining activity did not stop speculation in shares. Promotor S. A. Parry hung a huge red wooden bell above the Big Cottonwood road to advertise his Red Bell and Union Associated properties. C. S. Woodward spearheaded the driving of several deep tunnels into fissures in quartzite. Stock promotors touted these as gold mines during the 1930s and as lead-zinc mines during the 1940s. Ore production was small.

Lumbering in the canyon also ceased. The last sawmill, at the mouth of Beartrap Fork, closed in 1928 (Allan, 1961). It was said that, during the prohibition era, a few old mines harbored small "moonshine" stills. Summer homes were becoming numerous in the canyon by the 1920s.





Early 20th Century Geological Studies

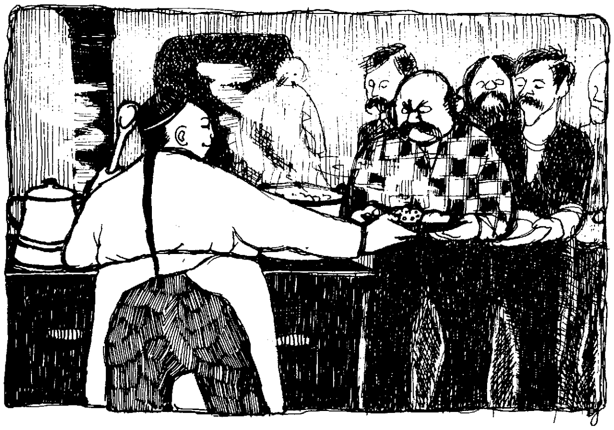
Interest in the geology of the Wasatch Range began to develop during the early years of this century. G. F. Loughlin of the U. S. Geological Survey and F. F. Hintze, a local resident doing doctoral studies at Columbia University under Dr. A. W. Grabau, both conducted mapping in the Mill D South Fork area. Both recognized the Alta overthrust zone. Hintze, who had been staying at various mine boarding houses and examining underground geology with local mine superintendents, commented on the newly-discovered thrust fault:

> ...The understanding of this relationship is clearly of the utmost importance to the mining people of South Fork, who have never suspected the presence of a limestone series below the quartzites...(Hintze, 1913, p. 138).

B. S. Butler, F. F. Hintze and F. C. Calkins began more detailed mapping and mine studies in 1916-1917, work that was continued by the U. S. Geological Survey until the 1950s. J. J. Beeson, a private consultant, began studies of the mines in the area in 1916, which resulted in the discovery of several ore bodies. R. T. Walker and C.T. Van Winkle, employed by large companies, also contributed extensively to structural studies and the work of the U.S. Geological Survey.

A 1:25,000 scale topographic map of the central part of the area, prepared by the U.S. Geological Survey, was first issued in 1907 as the Cottonwood Special Map. It was revised and reissued in 1939. More modern photogrammetric 1:24,000 topographic maps were issued in the 1950's.

In the early 1930s Carl W. Chilson, inventor of the "Chilson Radio Method" of electromagnetic prospecting, tested his apparatus at the Mineral Park property at the mouth of Mill D South Fork. A fixed radio frequency transmitter with a power of five thousand watts and a large vertical antenna was used, energized from a 500 hertz inverter connected to a nearby power line. A cumbersome battery powered vacuum tube receiver apparently was used, with a small tripod-mounted antenna that could be oriented to measure "the strike



and dip of the wave fronts" of the "secondary field". Several frequencies were routinely used. The apparatus was thought capable of locating any large sulfide bodies within 1,000 to 2,000 feet (300-600 m) of the surface. Although Chilson reported indications of "lead carbonate ore", none was found and this survey is considered to be mainly a historical curiosity.

Persistence and Decay 1941-1961

Conditions during this era were similar to 1927-1940, though production was briefly spurred by the high metal demands of the World War II era. A brief, largely unsuccessful search for tungsten followed development of the ultraviolet lamp.

The last great exploration venture of the district was begun from the Wasatch Drain Tunnel, on the Little Cottonwood side of the divide, in 1955. The Columbus (north) lateral of the tunnel was extended north into Big Cottonwood, beneath the Columbus Rexall and Cardiff mines. Connection was made to the flooded Cardiff workings and a winze beneath them produced some ore from below the drain tunnel level. Thousands of tons of high grade ore were produced, though typically not at a profit. This work was financed by Denver oil interests, Charles A. Steen, and Mr.. Kaufman, the late retired Danish ambassador to the United States. Much of the engineering and geology was carried out by Joseph J. and Desdemona S. Beeson, longtime experts on the district.

The present era

The mine plant was removed from the portal of the Wasatch Drain Tunnel in 1967-68. All other producing properties of the district had ceased activity years to decades prior to this time. Vandals, salvage operations, and heavy snows removed most indications of mining activity. As this is written only two or three small prospecting operations, conducted by experienced former miners, are intermittently active in the district. Large areas of patented mining claims have taken on new value as summer home sites, and many claims have been purchased by the U. S. Forest Service. The area is now valued principally for recreation and watershed.

Skiing facilities were first erected in the 1940s, and now number more than seven lifts plus several lodges and overnight accomodations. The first chair lift was erected at Mt. Millicent, near Brighton. The Solitude area, based on old patented ground financed by money derived from uranium mining in southern Utah, opened in 1958. This resort has operated intermittently. Many summer homes and some year-round residences are now maintained in the canyon. Lack of a sewer line or sewage treatment facility has inhibited commercial development of the area in recent years.

Mining Methods

The mines of Big Cottonwood were noted for being cold and wet. In the deeper adits fissures spout water and recent operators routinely used rubber work-suits. Most bedrock proved solid, and tended to remain open indefinitely. Ground support techniques such as roof bolting and grouting have not been utilized. In 1961, two thirds of the stopes being mined in the Cardiff property were stulled, while the remaining one third utilized square sets for ground support. Calkins and Butler (1943) state that the larger ore bodies were mined either by shrinkage stoping or by top slicing. In a shrinkage stope the miners work on top of broken ore, which is drawn off through short raises as it is accumulated. Top slicing, apparently more common in the district, utilizes raises extended through the ore body to the hanging wall. These are widened at the top, and ore is blasted, caved or shoveled into the raises and loaded into cars.

Most ore was trammed, or moved to the surface, by horses, mules, or men and one-ton ore cars. The last operations in the Cardiff mine utilized three ton cars and battery locomotives. As the topography allowed deep access by tunnels, surface shafts were rare after the early days. Steam hoists were used at the Prince of Wales, Black Bess, New State, Baby McKee and Eclipse shafts. Smaller developments used the horse whim, a hoist powered by a horse walking in a circle. A later generation of prospects used ponderous one-cylinder gasoline hoists, while still later shafts at the Cardiff,Iowa Copper, Maxfield and Monte Cristo mines used air and electric hoists.

Many of the early tunnels were driven by hand, using light drill steel and a hammer (single jack) operated by one man, or a heavier steel and sledge (double jack) and two men. E. W. Newman (personal communication, 1976) states that in Cottonwood rocks, typically 1500 hammer blows were required to advance a hole one inch (2.5 cm) with a single jack. Eight to twelve holes, long enough to contain one or more sticks of dynamite, were required to advance the working face. The human effort represented by long tunnels such as the Kennebec, driven in this manner, is immense.

A world record in single jacking may have been set by the late J. L. (Roy) Newman in the Argenta area. Totally blinded by a dynamite explosion there in 1929, Mr. Newman drove almost 2000 feet (600 m) of workings single handedly prior to his death in 1974. He advanced the main Newman tunnel (figure 15) more than 1000 feet (300 m) straight into the mountain, utilizing a large steel blasting sheet to keep the tunnel on course.

The development of compressed air-powered drills and hoists made mining much easier. Steam-powered equipment was installed at a tunnel near the Wellington (Prince) mine property as early as 1872 (*Utah Mining Journal, October 27, 1872)* and a decade thereafter at the Eclipse shaft.

Labor

In earlier days each sizeable operation had its own boarding house, often with an Oriental cook. The smaller mines attracted fiercely independent individuals, who often worked alone into the winter as long as supplies lasted, then skied or snowshoed to the Salt Lake Valley. Union organizers were rare in the district, and only the Cardiff mine is recorded to have had formal strikes.

The late James W. Wade (personal communication, 1963) stated that this tough breed of miners made many small operations possible. His lease at the Carbonate mine required workers capable of doing a variety of jobs skilfully, including mining, trail maintenance, timber framing, blacksmithing, and repair of the mine's crude tramway. Accomodations for the two to four employees were cramped and exposed to the elements. Other than hunting an occasional deer, recreation was limited mainly to playing cards and watching the trolley cars of Salt Lake City through binoculars.

Financing

Mining development was financed mainly by small stock companies. The *Mines Handbook* (1916-1931) indicates that several dozen small companies were incorporated to work Big Cottonwood properties during the present century. After funds from original stock sales were exhausted, stock assessments were levied. One Big Cottonwood operation levied more than seventy of these, and still failed to find ore in its long tunnels. Since the big Cardiff discovery had been financed by this method, many small stockholders kept paying because they knew what a rich strike could do to stock prices. Individuals without financial backing worked mainly as leasers.

Human ambition and avarice kept some operations going. James W. Wade and Joseph M. Howell, young engineering graduates of Utah and Columbia, respectively, learned their lesson from a lease at the Maxfield mine in 1908. They had believed that with "modern" technology, they could find and mine ore missed by former operators:

We found we were slowly losing our shirts on the lease. One winter day in Salt Lake City Joe and I received notice from our superintendent, W. L. Harwood, that he had struck a huge ore body! I hurried over to the offices of Pete Buller, a brewer who had been backing us, and bought his share of the lease without saying anything. Then I hurried up the canyon in a blinding snowstorm. As I went I figured mentally that we could mine $750 a day from it. Then I figured $1500 per 24 hours, split between the two of us. . .

When I arrived I wanted to go underground immediately. But Mrs. Harwood was a bit smarter than I, and she insisted that I sit down and warm up and eat dinner first. After dinner I hurried underground, and found - as Mrs. Harwood had probably guessed - that the big new strike was just a light sprinkling of galena in limestone. Next spring Joe and I put in a little jigging plant and milled some of that rock. When we quit the lease, we split the profits. Each of us received eleven dollars. (James W. Wade, personal communication, 1963).

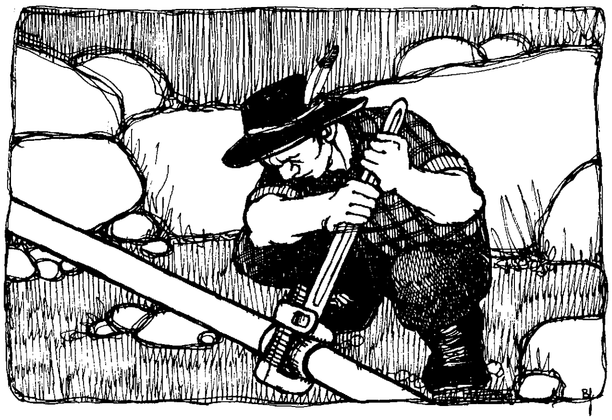
Milling and Smelting

Most Big Cottonwood ores were oxidized or highly siliceous, and were shipped directly to smelters. Small gravity concentrators, utilizing mainly jigs, were erected to treat low grade. The more extensive installations, as at the Alta Tunnel and Maxfield mines, also used vibrating tables. The latter plant, operated for a short time in the 1930s, was located entirely underground. Small shipments of sulfide ore in recent years were treated at custom flotation mills in the Salt Lake City area. Small amalgamation and cyanide mills operated at Little Willow (Gold City) as discussed previously.

Prior to 1880, small simple lead smelters were abundant along Big and Little Cottonwood Creeks in the Salt Lake Valley, but only one plant was ever erected in Big Cottonwood Canyon. This was located near Silver Fork, across the creek from the town of Silver Springs, near the Kentucky Utah tunnel portal (Calkins and Butler, 1943, p. 74). Wheeler (1874) refers to it as the Hawk-Eye smelter, and Murphy (1872) referred to it as the Homansville smelter, "a first class set of works". It consisted of a cupola furnace, granite slag pots and a water-powered blower. Apparently it was unsuccessful, as it was idle by 1872. After 1900 the proximity of the Big Cottonwood mines to large custom smelters at Murray, Midvale, Garfield and Tooele increased the chances that an ore could be mined at a profit.

Electric Power

The canyon is served by lines of the Utah Power and Light Company. One line runs through the main canyon, with branches extending over Cardiff pass and Twin Lakes pass to Alta. Two old public utility hydroelectric plants are still in operation in the canyon. The



Stairs Station, below Storm Mountain, was erected in 1895 by the Big Cottonwood Power Company. It now uses one Morgan-Smith Company Francis-type turbine to run a generator. The lower power station, erected in 1896 by the Utah Power Company, uses two nearly identical Pelton impact water wheels to turn generators, operating under about 180 psi. Each plant generates about 25,000 kw under heavy load conditions.

Prior to 1900 the Maxfield Mining Company built a hydroelectric plant in the basement of its boarding house below Argenta. This consisted of a Victor 15 inch turbine wheel, fed by 730 feet (223 m) of 42 inch (107 cm) pipe, giving a 60 foot (18 m) head (Smith, private report, 1920). The turbine was belted to a 24 ampere 1675 rpm 250 volt "dynamo", and to two single-stage air compressors (Smith 1920). The plant was utilized until 1934 and then scrapped.

Future of Metal Mining in the District

Prior to 1972-73, when Utah's last custom lead-zinc mill and smelter closed, Utah occupied a prominent position in the production of silver, lead and zinc in North America (James, 1973). Production from the Big Cottonwood district had virtually ceased several years prior to 1972 for several reasons. Economically-minable ore in known deposits was virtually exhausted. Also, development of recreation complexes, notably at the portal of the deepest and best-equipped development adit (the Wasatch Drain Tunnel) was not considered compatible with mining.

History of previous exploration and development do not encourage the entry of large mining companies with experienced staffs to enter the region. The ore deposits discovered in the past had generally not proved to be as large or continuous as those in other districts. However, the area cannot be said to have been fully tested or to be completely "worked out". The statement of Calkins and Butler (1943, p. 101) still applies:

> Little ore is in sight in the area at present, but this has nearly always been true . . . . Much ground, however, is still unprospected and there is reason to expect that deposits will continue to be found . . . as they have been in the past.

Since the time of Calkins and Butler's paper, many changes have affected the domestic underground mining industry. Between 1871 and 1927, when the mines of the Big Cottonwood district achieved their major production, the operators faced many problems, including inadequate energy for the moving of rock and removal of water, inadequate materials for the support of heavy ground, primitive methods of transportation, lack of facilities for recovering zinc, isolation, and considerable danger from bad weather and avalanches. A lack of geological guidance and fragmented property ownership prevented systematic development. Environmental problems were created by the widespread use of horses on the Salt Lake City watershed. But in spite of such obstacles, rich ores were developed and mined.

Today there are no operating mines within the area. Processing plants are scarce, distant, and often unwilling to accept small lots of ore, especially oxidized ore. Labor costs are high and skilled labor may be unavailable. Mechanization, or the use of trackless mining equipment, may not be suitable for the small ore bodies characteristic of the area. Financing methods of the past, notably the sale and assessment of "penny" mining stocks, are discouraged by government regulations. If only small ore bodies are anticipated the needed improvements may make a return on investment impossible.

Surface exploration methods such as diamond drilling and electrical geophysics have so far not proven highly effective in the search for small ore bodies beneath steep terrain. However, these techniques are improving, as are geochemical methods and geologic models.

Big Cottonwood ores of the past were high in grade, far exceeding the average value of Utah ores produced in 1960-1969 (James, 1973, p. 4). But the economics and technology of modern underground mining and exploration must change considerably before exploration for Big Cottonwood-type ore bodies will again be economically attractive.

The environment-conscious public must also be willing to accept mining activities within the Wasatch watershed and recreation area. However, the minimal

environmental damage done by underground mining in the area and in the nearby Park City district, where work continues, suggests that environmental considerations and problems are not as severe as with some other types of mining.

MINES AND PROSPECTS OF THE BIG COTTONWOOD MINING DISTRICT

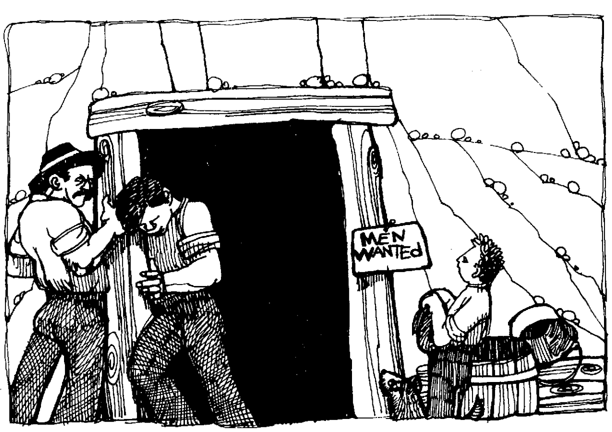
The locations of the major mines in the Big Cottonwood Mining District are shown on figure 6, and many of the mine workings are shown on Plate 2; an alphabetical list of mine names and a key to plate 2 appears in Appendix A-1 and A-2.

There are three general areas of mineralization in the district (Plates 1 and 2). These are the Little Willow area along the Wasatch Front, the Argenta area near the midpoint of Big Cottonwood Canyon, and the main Big Cottonwood mining area, which extends eastward toward the Park City and southward towards the Little Cottonwood (Alta) mining districts. Each of these areas is discussed separately here.

Because the ore deposits and host rocks of the Little Willow area are rather different from those in the rest of the Big Cottonwood district, a discussion of the geology of the host rocks is included here. Prospects near the mouth of Big Cottonwood Canyon and along southwestern slopes of Mt. Olympus are included in the description of the Little Willow area.

The location of the surveyed and potential claims in the main (eastern) part of the district are shown on plate 3, and those in the Little Willow area on figure 7.

Much of the information contained in this section is from single-paragraph descriptions of development at prospects, found in the *Salt Lake Mining Review* and its successors (1899-1965), and other mining journals. Some date and page references for such citations, which typically contain no additional information, are omitted here. Oral information on many of the mines and prospects was obtained from former operators and investors, who are cited in the Acknowledgements.



LITTLE WILLOW (GOLD CITY, DEAF SMITH CANYON) AREA

Geology

As noted in the section on general geology, the mines of this area of the district are in contorted metamorphic rocks of earlier Precambrian age. A description of the rocks in the vicinity of the mines is given below and a provisional geologic map (figure 8 and table 10) are presented here to aid in understanding these small ore deposits. The map is based on two weeks field work by the author and studies by Crittenden (1965).

The oldest and most abundant rock unit is a light feldspathic gneiss or schist, hard, light gray to off white, with ten to twenty percent sheet silicates and amphiboles. The major constituent is feldspar with highly varied subordinate quantities of quartz. White mica, albite, chlorite or green amphibole may be present. Locally the rock is a banded gneiss; elsewhere it grades into aplite-like quartz-feldspar rock. Segregation banding (i. e. anatexis) is not strongly evident. Most of the unit probably was of sedimentary origin. Locally textures suggest intermediate to felsic ash flows and pyroclastic tuffs.

In the underground workings of the New State mine (figures 9 and 10) this rock type shows many copper stains and a few disseminated sulfide grains. Early lens-like quartz bodies are present; some are rimmed by biotite. On the surface and in the few other accessible mine workings the rock tends to be barren of disseminated sulfides.

Thin units of mafic schist (five to twenty feet (1.5 to 6 m) between contacts) occur within the above-described gneissic schist. Typically these consist of felted masses of actinolite, are dark green or brown in color, and dense. Composition is probably quite variable. Outcrops of such units were found extending up the north side of the first major gulch south of Deaf Smith Canyon. (This gulch was referred to as Poulson or Paulsen's Canyon by old mine operators). The mafic schist was also mapped underground on the main New State tunnel level (figure 10).

Thin units of finely-laminated, sometimes malleable sericite schist, consisting mainly of white mica and subordinate quartz or chlorite crop out in several areas. In one bed rounded quartz lenses (probably former cobbles) were noted. Crittenden (1965) traced this latter unit over some distances. He noted (personal communication, 1976) that the cobbles were isolated; they are not in contact with each other. The cobbles range up to 3 inches (7.5cm) in length and have been tectonically stretched and flattened. In many locales the sericite schist unit tends to have minor associated gold and copper showings. The sericite-rich areas may have formed from volcanic ash beds, but most of the unit is probably of sedimentary origin. On the basis of limited petrographic work Crittenden (written communication, 1976)

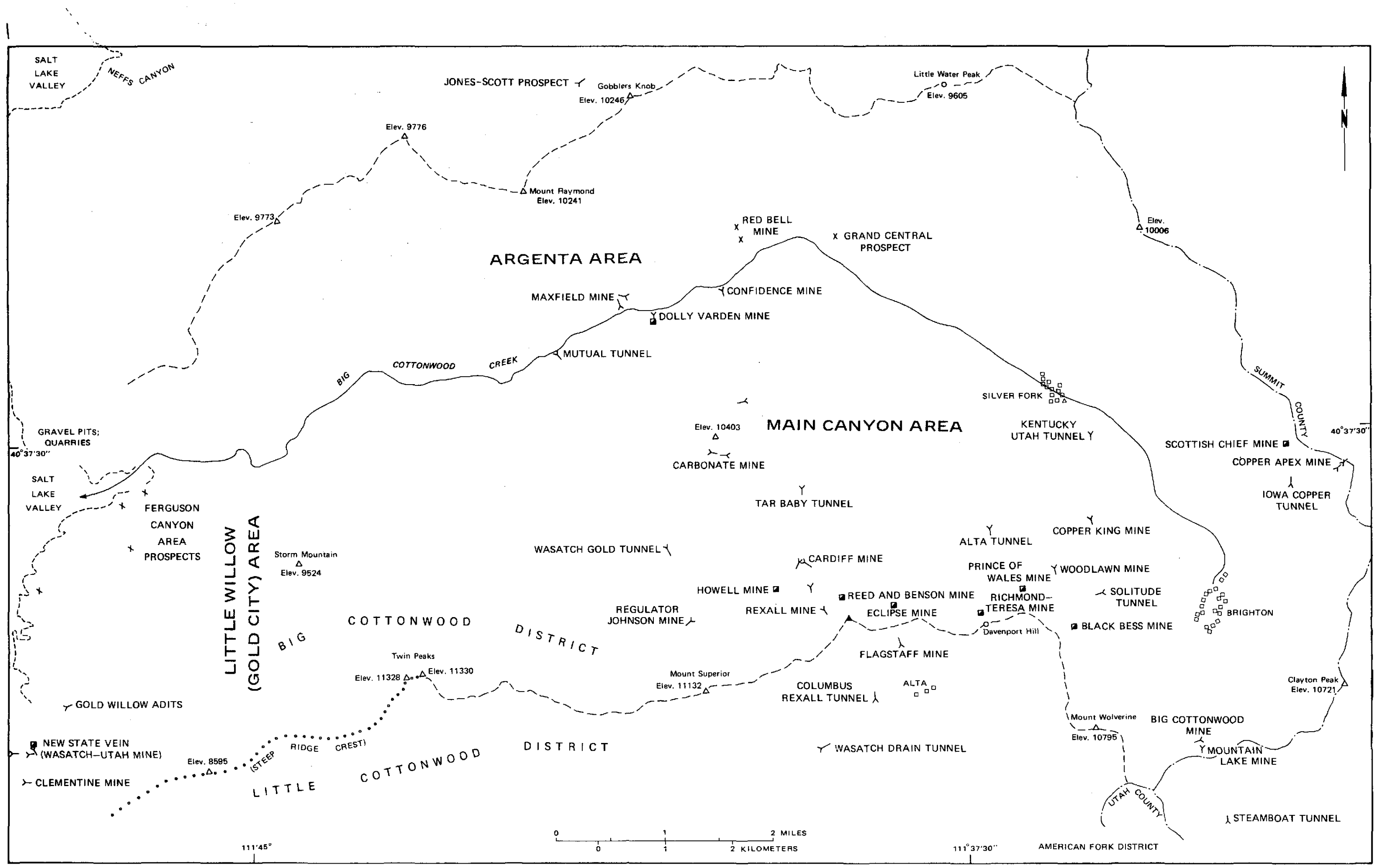


Figure 6. Major mines of the Big Cottonwood district, discussed in the text.

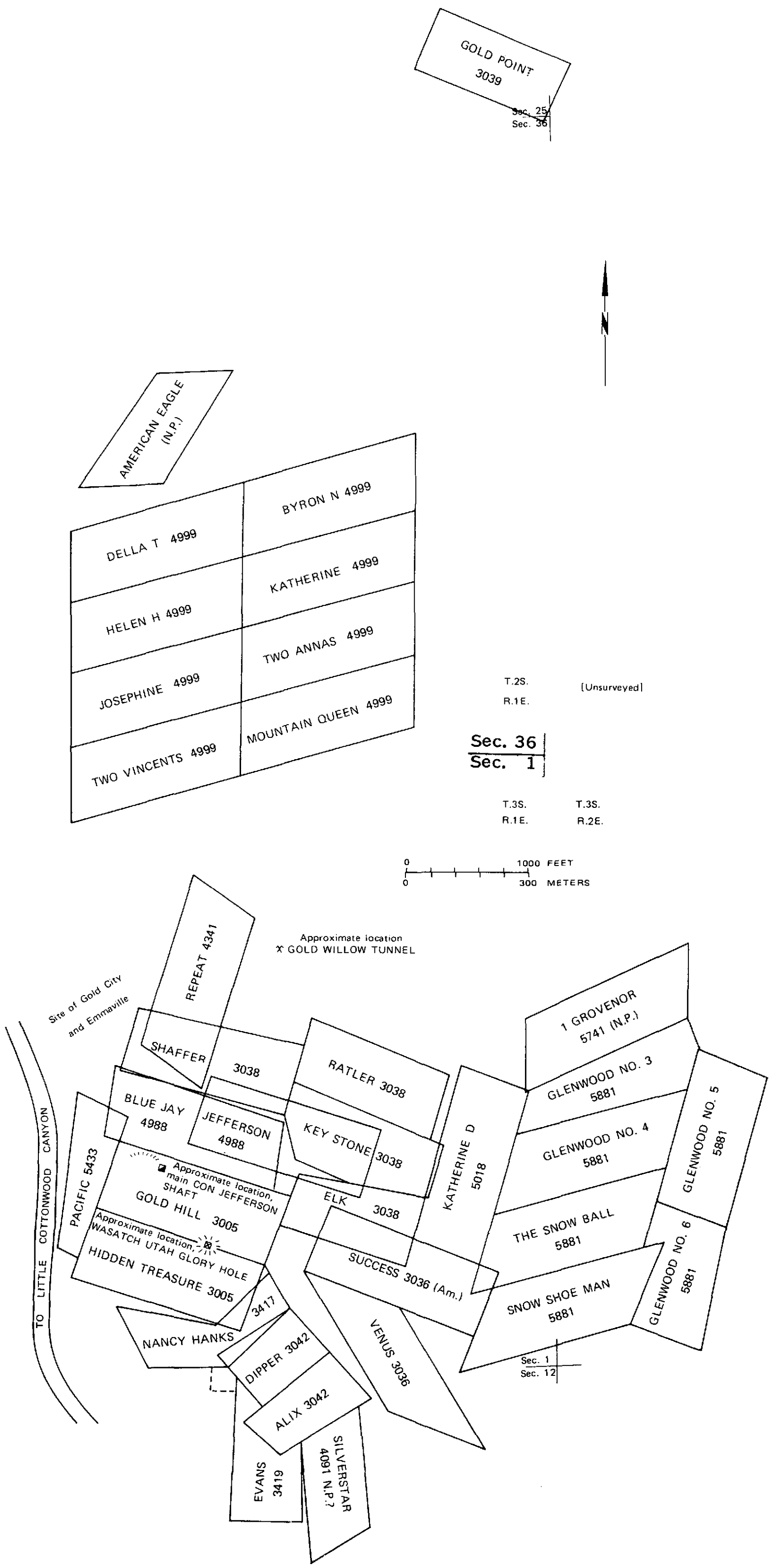


Figure 7. Map of surveyed and patented mining claims in the Little Willow (Gold City) area, Big Cottonwood District. Taken from plats, Salt Lake County Recorder's office.

Table 10. Explanation for preliminary geologic map of Little Willow Area. (figure 8).

Older Precambrian Rocks of the Little Willow Formation (in approximate stratigraphic order).	
Qal, Qm	Alluvium and glacial moraine.
qv	Bull quartz veins, Tertiary (?) age.
ip	Small pyroxenite ? body of Poulson Canyon. Dark green, very heavy rock comprised mainly of elongate crystals. Not strongly foliated; may be intrusive.
am	Amphibolite bodies, lens-like or conformable with bedding. Dark green actinolite and chlorite with light aggregates of quartz and feldspar. Largely the same as mapped by Crittenden (1965).
cg	Traceable bed or beds of sericite schist containing stretched quartz cobbles. Partly after Crittenden (1965).
cb	Thin beds of elongated clasts of biotite schist enclosed in less mafic schist. Noted mainly in float near "am" contacts and in a thin zone in the Wasatch Utah glory hole.
ag	Light gneiss and schist. Typically consists of plagioclase (?) feldspar and subordinate chlorite or sericite and quartz. A hard rock, often poorly foliated or bedded; locally some looks like aplite. Locally has textures suggesting possible origin as a felsic lava.
sqs	Sericite-quartz schist. Includes silvery beds of malleable sericite rock with minimal quartz. In places is interbedded with purer quartzite. Locally contains stretched quartz cobbles.
qzt	Bedded quartzite, contains minor mica or chlorite in most areas.
ims	Quartz-chlorite-biotite-sericite schists, varied composition. From light gray-green to dark green.
ms	Mafic schist. Dark green, dense rock, largely amphibole, chlorite, possibly pyroxene, with evident foliation. Interbedded with unit ag in places.

found the characteristic mineral assemblages of the schists and gneisses to be: 1. quartz-muscovite, 2. quartz-albite-muscovite, 3. quartz-albite-chlorite, 4. quartz-biotite-chlorite, and 5. hornblende-biotite-chlorite.

Irregular, somewhat lenticular units of distinctive hard dark green amphibolite crop out in several areas of the Little Willow formation. The rock consists of dark green fine-grained amphibole, chlorite, and very fine-grained white aggregates of granular quartz, with local feldspar. Grain size varies from very fine (typically near contacts) to fine. Compositional zoning (bedding) is not evident. In some areas the rock is difficult to distinguish from the mafic schist described above. Schistosity is poorly developed, but strong jointing is evident. Contacts with enclosing light schist/gneiss are locally very sharp. Underground, only minor undulations (1 cm high) in unsheared contacts were noted.

Float at the northerly and southerly contacts of the largest amphibolite body (at the mouth of Poulson canyon, containing the New State mine workings) lo-

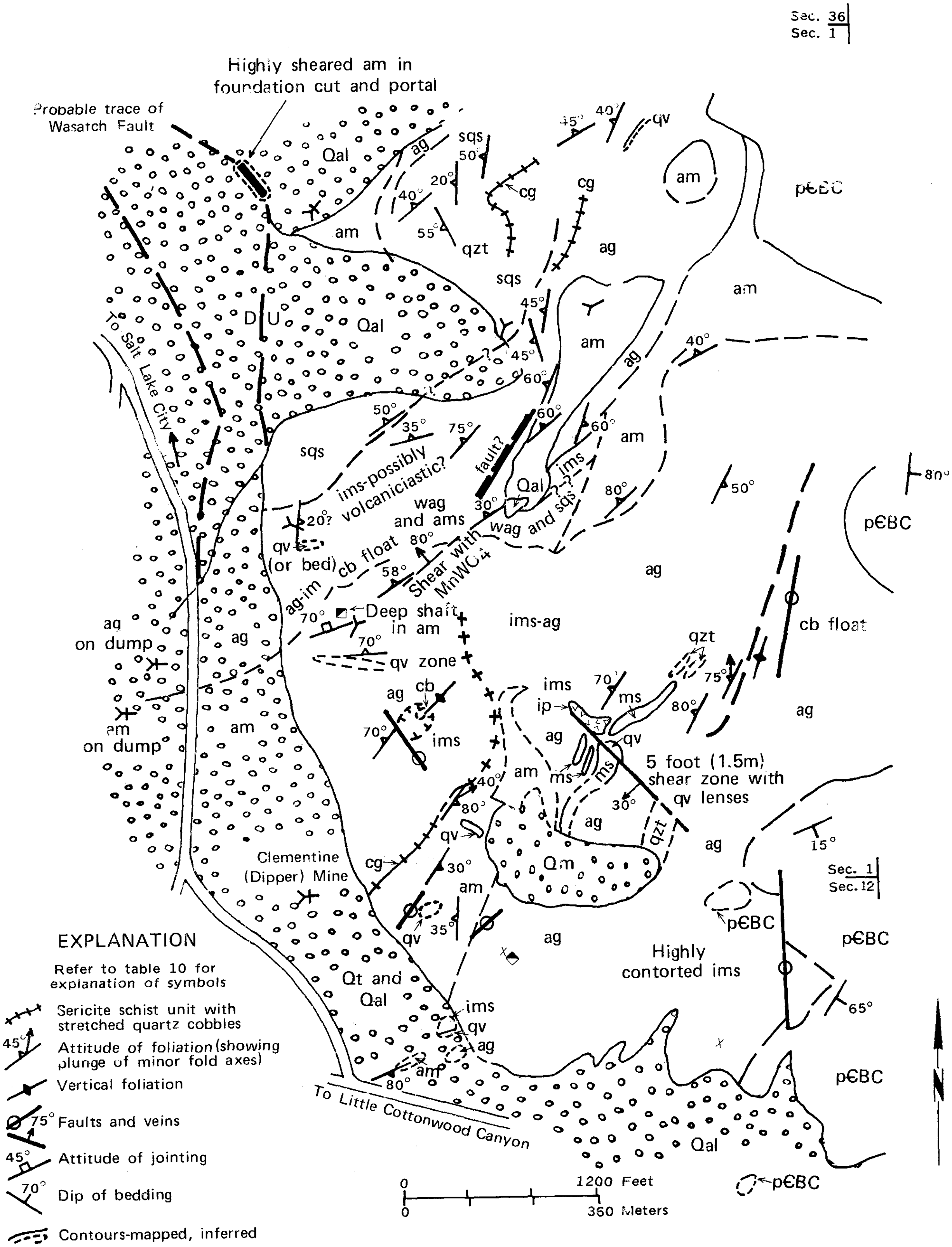


Figure 8. Geologic map of the Little Willow (Gold City) area showing general structure and stratigraphy of older Precambrian rocks (same area as figure 7; see Table 10 for explanation)

cally shows rounded, stretched clasts of mafic schist enclosed in felsic to intermediate micaceous schists. The textures suggest either a conglomerate or a pyroclastic flow top. This amphibolite body extends continuously from the Wasatch fault (at the range front) to the unconformity at the east edge of the map area. But east of the Wasatch Utah glory hole it appears to cut across the cobble-bearing schist.

Crittenden (1965) interpreted the amphibolite as former sills, because of its discordance with beddings of enclosing rock types (figure 8). Geometrically the amphibolite bodies are not simple sedimentary beds. Further work on these distinctive rocks is needed.

Crittenden (written communication, 1976) described the coarsest amphibolites as consisting of large grains of olive-green hornblende as much as 5mm across, set in matrix of fine-grained blue-green amphibole. The large darker grains contain abundant plates of magnetite, oriented along the (110) cleavage planes. Optical properties of amphibole and accompanying plagioclase vary with rock texture, the feldspar ranging from andesine in the darkest rocks to albite in the paler amphibolites.

Because it hosted the gold-copper bearing quartz veins of the New State mine the amphibolite was the most intensely prospected unit of the Little Willow formation.

A small, apparently discordant body of very dense, hard mafic rock amphibolite crops out just above the floor of Poulson Canyon on its south side, about 2000 feet from its mouth. The rock is blackish green, and occurs only beneath a low-angle shear zone several feet thick, which cuts off the schists apparently intruded by the dark rock (figure 8). The rock consists of dark greenish elongate actinolite with minor epidote and talc. Its composition is not typical of any igneous rock. It is not foliated, and appears to be more dense than the mafic schists which occur nearby on the north side of the canyon.

Mines

Figure 9 shows the locations of the mines and prospects in the Little Willow area and the western end of the canyon. The numeral after the name of the mine refers to its location number on Plate 2.

New State Mine (129)
Wasatch Utah (130)

The New State vein system, immediately east of the Wasatch fault zone on a low ridge at the western front of the Wasatch range (Plate 1), yielded the largest production of any property in the older Precambrian rocks of the Big Cottonwood district. As discussed under history, most of the activity in this area was promotional, and the ores mined probably never yielded a profit.

The New State mine, later known as the Wasatch Utah, was first developed by a series of tunnels, extending easterly into a nearly vertical zone of quartz veining. The main crosscut tunnel was driven south from Poulson Canyon, and its dump now fills the mouth of that gulch. The vein was explored below the tunnel level by winzes, some of which are shown on figure 10 (*Salt Lake Mining Review,* December 15, 1904). 80 feet northwest of the tunnel portal was the collar of the main shaft, sunk by the New State and Consolidated Jefferson companies. The shaft (now filled) was yielding two second feet of water at a depth of 320 feet, when high costs forced its abandonment (Schmittroth, 1937). Levels were driven south from the shaft, presumably to the New State vein.

Near-surface production from the New State workings yielded spectacular metal values. In 1900, specimens from a six inch (15 cm) streak reportedly assayed $4,516 per ton in gold, 46 ounces silver and 4 percent copper, while 10 to 12 inch (25-30 cm) widths averaged $250 to $350 per ton in gold (*Salt Lake Mining Review,* 1900). Mapping of the underground workings (figure 10) suggested that such vein widths were typical, but grab samples of vein matter (samples 20, 21, 26 and 27 on table 5 and Plate 2) showed only fraction of an ounce of precious metal values. Mine operator N.M.Schmittroth estimated total production from the property at $160,000 (*Salt Lake Mining Review,* December 27, 1932), presumably including production obtained from the Wasatch Utah operations.

Last operations in the mine were conducted by leasers in a winze below the New State level in the 1930s. An assay from the E.B. Ring lease showed 62 oz. gold per ton in one vein (*Salt Lake Mining Review,* June 15, 1931). Total production to this time was said to have averaged $100 per ton in gold and $4-5 per ton in silver (at 1915 prices) (*The Mining Journal,* February 28, 1927 p. 44; December 30, 1932, p. 23). Such figures at least suggest the relative proportions of gold and silver. Nieman and Wigton (1913) state the gold recovered by amalgamation was alloyed with at least 50 percent silver.

The Wasatch Utah Mining Company extended the New State main tunnel level northeastward, and drove a nearly vertical raise up beneath a showing of low grade gold ore on the surface, some 30 feet (10 m) above. Nieman and Wigton, (1913) described the surface exposure as light brown limonite stained schist containing pyrite and "bunches" of quartz. Gold values tended to be in the schist. Anhedral pyrite and chalcopyrite were reported at depth. The deposit was said to be approximately 400 feet (122m) in diameter. A large trench sample, coned and quartered to 50 lbs (22.7 kg) had an average assay value of $2.00 per ton (Nieman and Wigton, 1913). A two ton mill test sample averaged 0.12 oz. gold per ton. Low grade material from this showing was dropped from a glory hole to the tunnel level, and trammed to one of the two mills built on the property.

It was claimed that the last mill obtained 90 percent recovery, but the operation was not a success. Some copper-rich Wasatch Utah ore was shipped directly to the smelter according to Calkins and Butler (1943, p. 82). The raise was bulldozed shut in the early 1960s.

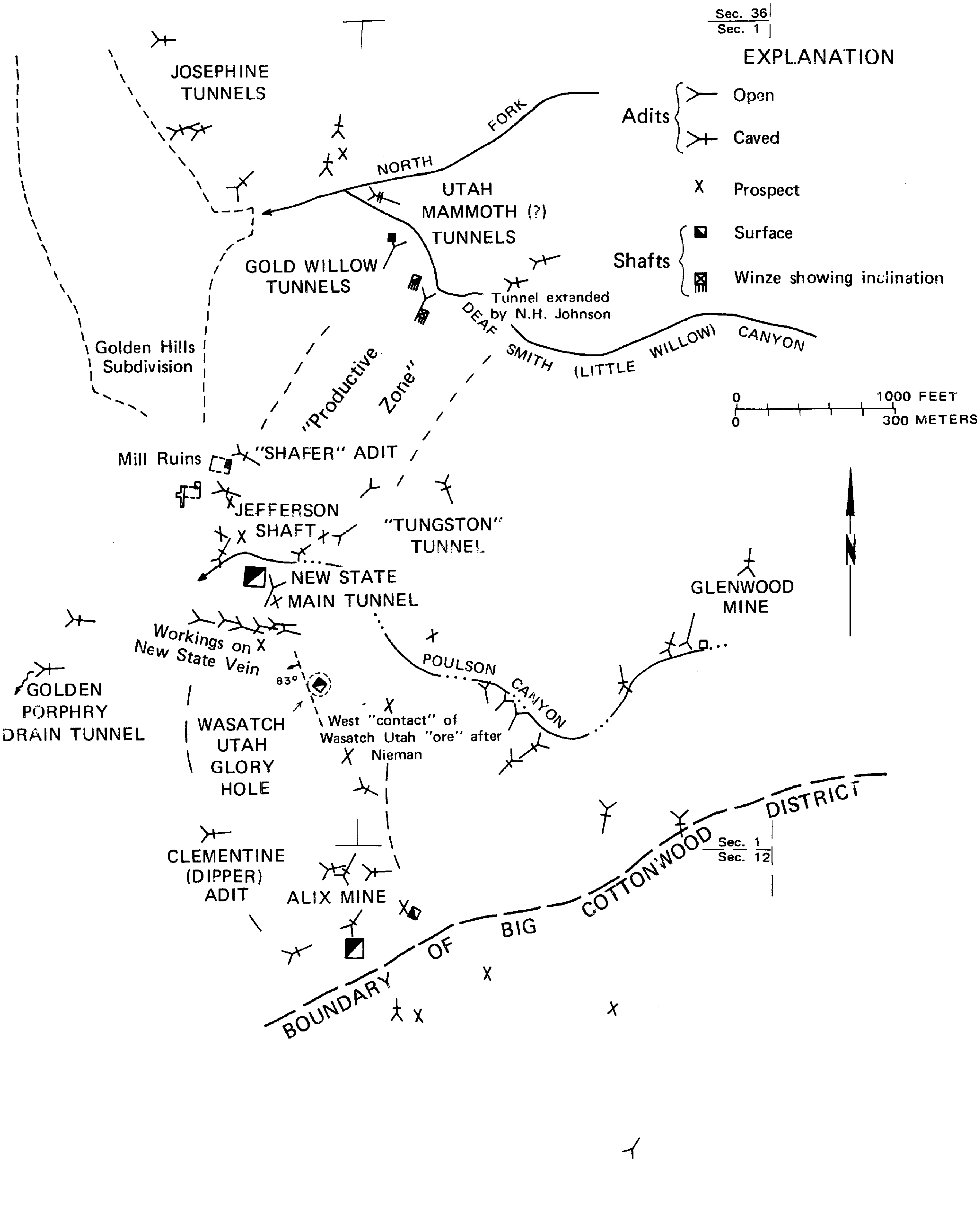


Figure 9. Map showing mines and prospects in the Little Willow (Gold City) area (same area as figure 8).

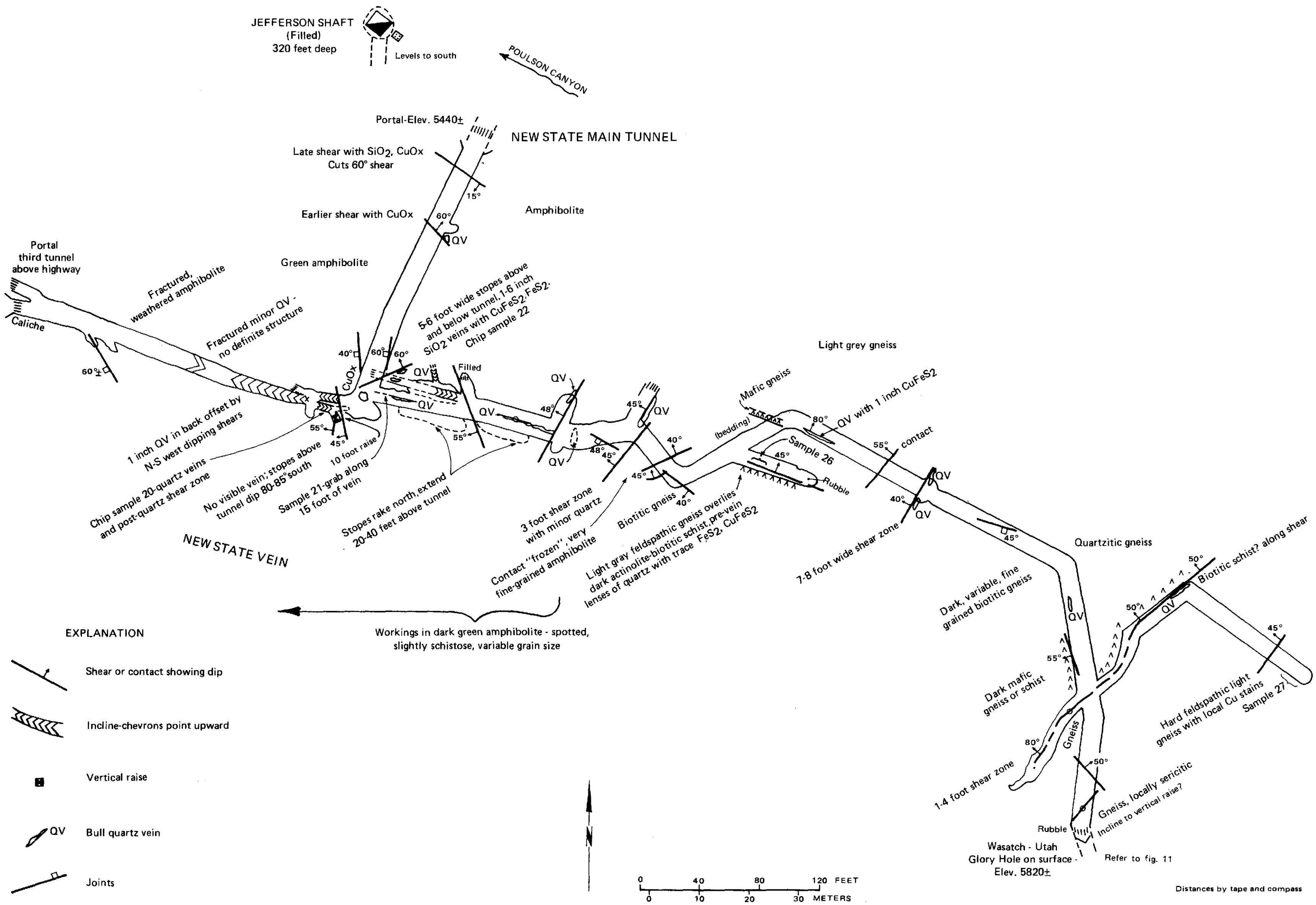


Figure 10. Geologic map of New State lower tunnel.

Mapping of the glory hole (figure 11) showed the main rock type to be light feldspathic to aplite-like gneiss with thinner bands of dark, vertically-foliated biotitic gneiss. A 15-20 inch (0.4-0.5m) wide horizon in the center of the north end of the glory hole consisted of elongate, rounded clast-like inclusions (0.5-2 in or 1 to 5 cm diameter) of chloritic schist in a band of light feldspathic gneiss. A few quartz stringers were present locally; notable crosscutting quartz veins and evidence of sulfides were lacking. The chlorite in the inclusions had a bluish color, not noted elsewhere. Toward the southeast wall of the glory hole, a band of massive dark mica schist occurred adjacent to an aplite-like band of light gneiss (?) with perthitic feldspar-quartz intergrowths, suggestive of local anatexis.

Seven chip samples were taken by the author across 2.5 to six foot widths at right angles to the strike of foliation in the glory hole (Samples 1-6 and 23 on figure 11). Only one (sample 2, across a band of chloritic schist clasts in felsic gneiss) showed significant mineralization. Sample 23, across fairly similar rock on the northerly projection of the sample 2 area, failed to show significant values. No indications of plunging lineation structures were noted in the exposed parts of the glory hole. It is concluded that the mineralized area mined in the glory hole was local and probably of low average grade.

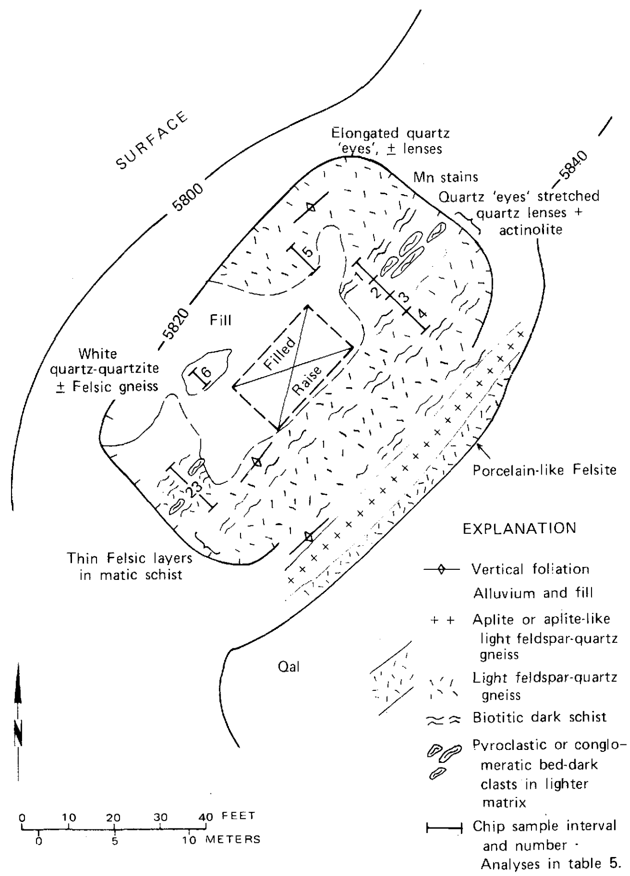


Figure 11. Simplified map of Wasatch Utah glory hole, Gold City area.

Blue Jay (near 129)

The Blue Jay claim lies immediately north of the New State vein system, near the center of section 1, T.3 S., R.1 E. Four men were working on the property in June 1901 (*Salt Lake Mining Review,* June 15, 1901). Later work was carried on by the Consolidated Jefferson Company.

The main development appears to have been done through a tunnel, now caved, extending northeasterly from the bottom of the gulch, near the faulted western contact of the largest amphibolite body of the district. The dump lies at the foot of the large dump of the Jefferson shaft and New State main tunnel (129). It contains quartz veins similar to those of adjacent workings. No record of production from the property was found.

Glenwood (133)

The Glenwood property is high in Poulson canyon, about 4000 feet east of the Wasatch front. Prospect tunnels in the NE¼ of the SE¼ of section 1 extend northerly, following shears in quartzitic biotite-chlorite gneiss. Some pieces of quartz veins from the dump of the highest tunnel were analyzed (table 5, sample 28) and showed only traces of base and precious metals. Veins and shears followed by the 700 foot main tunnel (figure 12) appeared to be small and poorly mineralized.

The property was operated in the early 1900s by Glenwood, Colorado investors. In 1935 the Pelican Mines Company of Florida leased the workings and conducted further development. Small amounts of gold-silver ore reportedly were mined (*Mining and Contracting Monthly Review*, June, 1935). A steep access road to the workings was constructed in the late 1950s.

Tungsten Tunnel (132)

A northeast-trending adit several hundred feet (100 m) above the bottom of the gulch (Poulson Canyon) extending eastward from the Jefferson shaft was mapped during this study (figure 13). This adit, probably driven as part of the Jefferson or Blue Jay operations, follows a shear zone along and near the steeply-dipping northwest contact of an amphibolite body. Vein quartz from this zone has a different appearance than that from the known gold properties, and locally contains crystalline feldspar (identified optically as plagioclase) and actinolite. Open vugs appear to have been present during mineralization. Small crystals of scheelite were identified visually in this rock, and subsequent examination with an ultraviolet lamp revealed small amounts of this mineral in the small stoped area of the adit. Its fluorescence suggested presence of some powellite. An adamantine translucent brown mineral, present in several specimens from the dump was identified as heubnerite by X-ray diffraction. This otherwise unidentified adit is here called the "tungsten" tunnel.

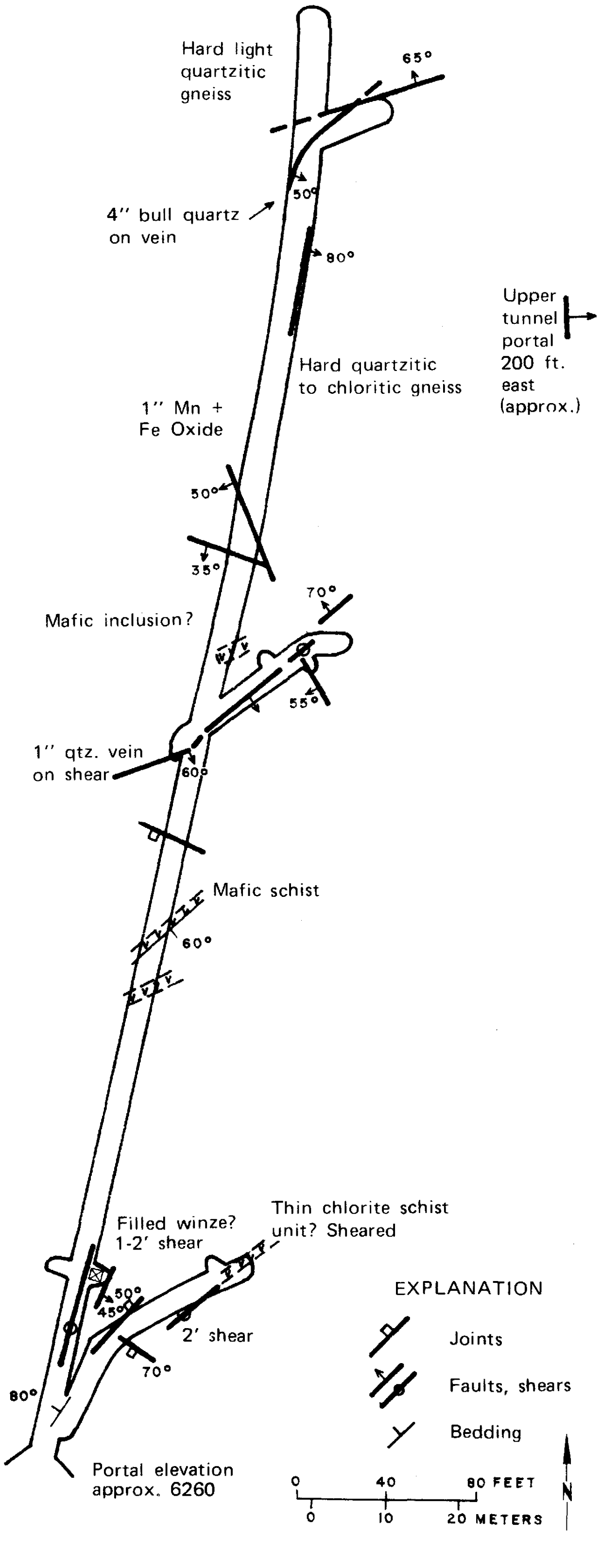


Figure 12. Intermediate tunnel of Glenwood mine, Gold City area.

Mapping indicates the vein here to be narrow, and the tungsten minerals are not highly abundant. A bulk sample of heubnerite–bearing rock and fines from the dump (sample 19, table 5) shows only traces of gold and silver, and 0.23% tungsten. The vein system is believed to be younger than those of the gold mines. The nearby Little Cottonwood stock locally contains scheelite bearing stockworks (Erickson and Sharp, 1954) and is a logical source for the tungsten described here.

Tungsten content of other mineralized areas within the schist and gneiss is typically less than 2 ppm (samples 2, 7-18 and 20-26, table 5).

Dipper (Clementine) (127)

The Dipper claim lies about two thousand feet south of the main New State-Jefferson workings, near the line between sections 1 and 12. The deepest tunnel, now caved, extends from a point just above the highway eastward along this line. Apparently the tunnel follows the contact between sericitic schist and amphibolite. Both rock types plus quartz veins are present on the dump. Sample 7 (table 5) is a composite of light schist, including some possible flattened clasts of intermediate schist.

Operations were conducted in the early 1900s and in the 1930s by the Clementine Mining Company. *The Mines Handbook* (1926, p. 1478) states that an 800 foot (240 m) adit and 100 foot (30 m) shaft revealed a 14 foot quartz vein. Butler and others (1921, p. 261) list the mine as a producer of siliceous ores in 1903 or The last recorded shipment from the property was one ton of "high grade gold ore" produced in 1946 (*Minerals Yearbook*, 1946, p. 1543). One lot shipped in 1928 assayed more than 10 oz/ton in gold, and several lots shipped in 1931 averaged more than 1 oz/ton (*Minerals Yearbook,* 1928, 1931). Total production apparently was not large.

Alix (Utah Philadelphia?) (126)

The Alix claim, operated in the early 1900s, lies south of the Dipper. It is developed by tunnels and shallow prospects, all in amphibolite. No production is recorded, though it may have been included with the Dipper claim. Sample 8 (table 5) consists of quartz-epidote vein material with local iron carbonates, similar to that seen at the "Tungsten" tunnel, from the dump of the lowest tunnel. Sample 9 consists of picked vein quartz rich in cubic pyrite, from a small pile of rock at the second lowest adit. The sample assayed 0.73 oz/ton gold, but is not considered representative of any large quantity of material on the dump. These dumps may actually lie on the adjacent Dipper claim.

Galloway (142)

G. C. Galloway prospected claims just north of the mouth of Little Cottonwood Canyon, and reported finding gold values. His workings probably include the shallow shaft southeast of the Alix mine. In August 1964 he apparently fell down the steep slope; his body was found eight months later (*Salt Lake Tribune,* April 11, 1965). The vein exposed at the shaft shows no sulfides, and does not appear worthy of further exploration.

Josephine Tunnel (136)

The Josephine tunnel apparently was located just north of the mouth of Little Willow (now shown as Deaf Smith on U.S.G.S. maps) canyon, in the NW¼ of section 1. The *Salt Lake Mining Review* (December 15, 1904, p. 16) stated that the main tunnel was 400 feet in length, and that it extended through some low grade oxidized ore assaying $1.60 per ton in gold. "Cross fissures" containing silver values had also been cut. A photograph of the "discovery" cut shows a steeply dipping zone several feet in width. Country rock on the property was quartzitic gneiss or schist (Nieman and Wigton, 1913).

Four caved tunnels were identified along the range front in this immediate area. Two of them, on residential property 100 feet (30 m) north of the corner of Kings Hill road and Golden Hills avenue, apparently follow the contact of amphibolite with feldspathic gneiss. Amphibolite at the mouth of the lower tunnel is intensely sheared, and lies along a strand of the Wasatch Fault zone as mapped by Crittenden (1965). Kaliser (1973) gives some detail on this locality.

Utah Mammoth (Utah Copper Queen) Tunnels (135)

A caved tunnel with a dump suggesting 600 to 1000 feet (180-300 m) of workings extends southeastward from just above the main fork in Deaf Smith canyon, in sericite schist of the Little Willow formation in the north side of the canyon. Higher on the slope, two caved tunnels extend northward along bull quartz veins in quartzite and sericite schist.

Records of mining locations for Salt Lake County describe the Utah Mammoth claims, located in 1922, in this general vicinity. The *Mines Handbook* for 1931 describes the Utah Mammoth Mining Company, owner of these claims, as having an 18 inch (0.5 m) vein carrying $8.00 values at the surface. The mine was equipped with a three drill compressor and a 40 ton concentrator was planned. The claims were deeded to the Utah Copper Queen Mining Company, which was under development in 1928 (*Minerals Year book,* 1928). No production is recorded.

Gold Willow Property (134)

Several adits and shallow shafts near the mouth of the South Fork of Deaf Smith canyon were operated by Nels H. Johnson.

Two caved adits on the north side of the canyon extend N75E in amphibolite. The dump of the upper adit has rusty vein quartz (sample 13 in table 5). The lower adit has minor amounts of pyritic vein quartz on the dump (sample 14, table 5). N. H. Johnson (personal communication, 1976) states that the lower adit extends 1500 feet into the hillside. He claims to have shipped 9

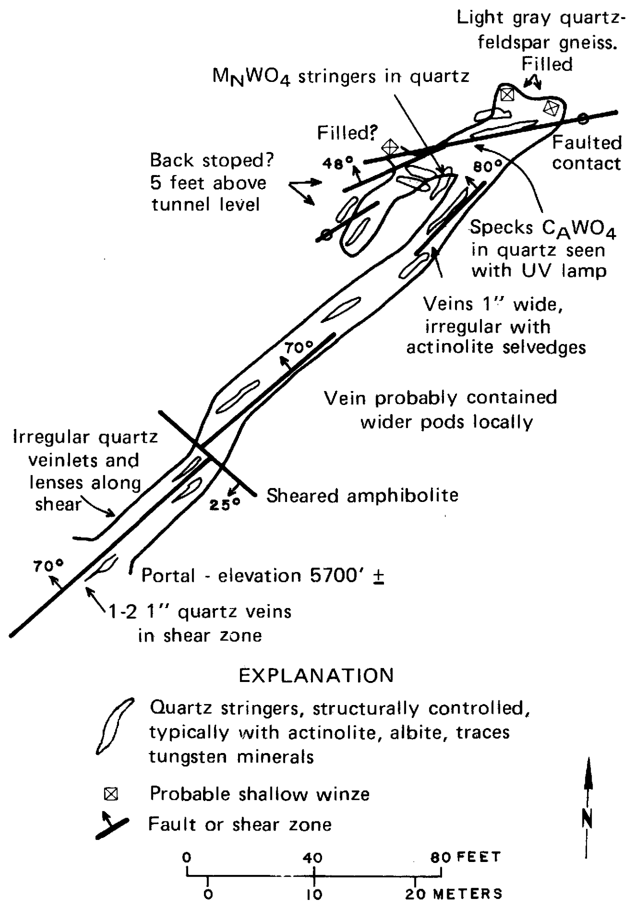


Figure 13. Map of "Tungsten" tunnel, Jefferson claim, Gold City area.

tons of $65.00 per ton gold-silver ore from a one-foot quartz vein, which he followed upward 60 feet with a raise. The vein was very irregular.

A short tunnel on the south side of the canyon, south-southeast of the long tunnel, ends at a 25 foot incline shaft. Johnson stated that he shipped gold ore valued at $8,000 from this shaft, hand cobbed from a small streak. Sample 15 (table 5) is picked vein quartz from the dump of this adit.

In 1976 Mssrs. Francis Coupens and Charles W. Whited were extending a lower tunnel on the south side of Deaf Smith Canyon, just above the forks, to the southwest. A 1 kg (2 lb) sample of quartz from the fresh part of the dump was analyzed (sample 16, Table 5). The workings penetrated quartz sericite schist, with minor quartz veins.

Laura May

The Laura May property, mentioned in 1900-era newspapers, was not identified in this study. In 1903 it had a 470 foot tunnel, exposing a 19 inch (7.4 cm) fissure 180 feet (55m) from the portal. The fissure reportedly assayed $7.50 in gold and copper (*Salt Lake Mineral Review,* July 15, 1903).

CANYON MOUTH AREA

Mines and prospects

Several small, caved prospect workings are located on the south side of Big Cottonwood canyon in Ferguson canyon near the mouth of Big Cottonwood canyon and about 1 mile south along the range front. They are spatially associated with an irregular mass of porphyritic quartz monzonite, probably an offshoot of the Little Cottonwood stock in Ferguson canyon.

Brewer Claims

Two carloads of gold-silver-copper ore reportedly were shipped from a vein "beneath a towering cliff" at the mouth of the canyon in 1909 (*Salt Lake Mining Review*, June 30, 1909). Numerous aplitic dikes and quartz veins occur on the south side of the canyon in this area.

Murray Copper (138)

The Murray Copper group of eight claims, on the south side of the canyon, 3/4 mile (1.3 km) above the hydroelectric plant, was developed by a 467 foot tunnel in 1912. The tunnel reportedly cut three fissures near the intrusive contact, with values in copper, gold and lead. (*Salt Lake Mining Review*, April 15, 1912). A caved tunnel in the NE¼ of the NW¼ of section 30 in this area has minor quartz veins on its dump, with negligible mineralization.

Victor (138)

The *Salt Lake Mining Review*, April 15, 1912 describes "a 65 foot tunnel driven to crosscut a large quartz vein" on this property, located west of the Murray, Copper Group. A caved tunnel in the SW¼ of the NW¼ of section 30 shows malachite-stained schist cut by quartz veins on its dump. Analysis of 1 kg (2 lb) collection of picked samples of this material (sample 29) appears in table 5.

Big Mitt and Blue Point (137)

Various writers mention the Big Mitt gold property, which yielded several small shipments prior to 1913. The mine dump was located 'in a lucerne field,' between Big and Little Cottonwood canyons, and the workings reached a depth of 200 feet.

The Blue Point property, described as a gold mine and copper producer (Butler and others, 1921, p. 82) is also described as being near the mouth of Big Cottonwood Canyon. A company was incorporated to work this property in 1904. By 1907 the property was developed by six surface drifts, from 65 to 230 feet in length (*Mineral Resources of U.S.*, 1907). These possibly are on the Gold Point claim (survey no. 3039, figure 6). Neither property could be identified with certainty.

In the NW¼ of section 36, south of the mouth of Ferguson Canyon, several prospects plus at least three tunnels extend easterly into the contact zone between metamorphosed shale of the Big Cottonwood Formation and porphyritic quartz monzonite. These may be the Big Mitt or Blue Point workings. Monzonite from the dump of one of these tunnels shows argillized plagioclase and quartz phenocrysts up to 1 cm in diameter. Some quartz veining and traces of pyrite are present; a 1 kg (2 lb) sample of the most altered, veined dump rock was analyzed for trace metals (Sample 30 table 5).

Cottonwood Gold Eagle (139)

The Cottonwood Gold Eagle claims were situated in Ferguson Canyon, south of Big Cottonwood Canyon. The *Salt Lake Mining Review* (May 30, 1923) reported that an adit on the property extended 100 feet, with the last 15 feet (4.5 m) "rich in iron." A small lot of ore carrying silver was shipped from the property in 1925 (*Mineral Resources of the U.S.*, 1925). The claims were maintained for 15 years thereafter, but no further production is reported.

The U.S. Geological Survey geologic quadrangle map (Crittenden, 1965) shows an adit high on the northeast side of the canyon, penetrating quartz monzonite near a small dike of intermediate composition, which may be the Gold Eagle. The property was not visited.

Quarries Near the Canyon Mouth

Gravel has been produced for many years from pits in Lake Bonneville sediments immediately north of the mouth of Big Cottonwood Canyon. Intermittent to steady production is currently achieved by at least four operators. An asphalt (mulch) plant is also in operation.

Near the center of section 36, a large cut has been excavated in a somewhat rusty quartzitic unit. Immediately north of the mouth of Big Cottonwood Canyon, near the southeast corner of section 24, a similar cut and a filled shaft was present in sheared, silicified quartzite. These appear to have been silica quarries, and are said by local residents to have shipped material to local refractory manufacturers.

Several miles eastward in the canyon, above the mouth of Mineral Fork, Tintic quartzite exposures show evidence of quarrying. This was said to be the Meridian stone quarry; nothing was found concerning its history.

WEST SLOPE OF MT. OLYMPUS

Mines and prospects

Jones Gold Mine (142)

A tunnel several hundred feet (100 m) in length is driven in orange brown Tintic (?) quartzite just above the highest Lake Bonneville bench, about 0.6 miles (1 km) north of Tolcate Canyon. It is locally known as the Jones Gold Mine. A brief underground visit some years ago showed an adit with two parallel east-trending branches. A thin band of disseminated pyrite was visible at one point in the side of the northern branch. The southern branch contains more extensive workings, and one area of possible minor stoping.

St. Patrick (141)

The St. Patrick Mining Company's property (141) was located in Heughes Canyon, and was reached by ¾ mile (1.2 km) of wagon road from the main canyon. In 1906 the upper tunnel, 70 feet (21 m) long, reportedly revealed values in copper, lead, iron, silver, and from 50 cents to $1.50 in gold. Antimony was also reported on one side of the vein, which was traceable in an east-west direction for 200 to 500 feet on the surface. An incline followed mineralization downward. The "vein" occured between a quartzite hanging wall and a black slate footwall. "Talc" and "porphyry" reportedly occured in the "vein". A lower tunnel, 200 feet in length, also reached the "vein". (*Salt Lake Mining Review,* April 15, 1906, p. 2; May 15, 1906). In 1909 a cave-in entombed two miners for fifty hours, and hundreds of local residents came to battle the running ground. No ore production is recorded.

Silver Cliff

The Silver Cliff property in Heughes Canyon was reported to have both galena and free milling gold ore within a block of ten claims (*Salt Lake Mineral Review,* March 15, 1908).

A visit to the probable location of these properties some years ago showed no significant mineralization on the dumps of caved adits.

LOWER BIG COTTONWOOD CANYON AREA

Mines and prospects

Between the Ferguson Canyon pluton and the outcrops of Mutual Formation at the mouth of Mineral Fork, the rocks exposed along Big Cottonwood Canyon are the monotonous quartzites and shales of the Precambrian Big Cottonwood formation. Prospecting for more than a century in this area has failed to find significant metallic mineralization. Workings visited were typically small and caved. A tunnel extends southwestward from about 1 km (3,000 feet) above the mouth of Stairs Gulch. Its dump shows only metamorphosed shale and siltstone of the Big Cottonwood Formation. Dumps of prospects in Precambrian slate were noted in Mule Hollow. No mineralization was noted.

MILL B NORTH AND SOUTH FORKS AREA

Mines and prospects

Mill B North and South Forks

A tunnel extends approximately 35 feet (10 m) northeasterly from near Hidden Falls, at the mouth of the fork in Big Cottonwood Formation. A deep drainage tunnel for the Maxfield mine was once reportedly started in this vicinity but extended only a few feet. The Squirrel prospect, operated at the turn of the century by Sam McNutt, a local hermit, was nearby. No ore minerals were noted in this vicinity

A caved adit extends westward in shale half way up Mill B South Fork. No mineralization was reported.

ARGENTA AREA (LITTLE WATER PEAK AREA)

Geology

The Argenta area centers on Mill A Gulch, in central Big Cottonwood Canyon. As suggested in the section on general geology, it appears to lie on the northern extension of the Superior fault zone, and may be related to the mineralization further southeast in Mill D South Fork and in the Alta district. However, the Argenta area has always been geographically separated from the other mines of Big Cottonwood.

The dioritic intrusions of the Argenta and Little Water Peak areas are strikingly different from the other igneous rocks of the district. Detailed mapping in the Argenta area revealed at least forty separate intrusions. Both sills and dikes are present and in exposures in recent highway cuts, they cross cut each other.

The intrusions typically lack quartz, are low in potassium feldspar and are rich in mafic minerals. The composition of a bulk sample from the largest body, located in the west fork of Mill A Gulch, is given in table 4, and indicates a true diorite.

Since much of the Argenta area is covered with talus, alluvium and moraine, exposures of these unusual intrusive rocks are confined almost solely to the bottoms of canyons. In underground mines and highway cuts, tabular bodies are found to terminate upwards, typically with knife-edged or wedge shaped outlines.

Because some of the diorite proved to be highly magnetic, the writer conducted a detailed ground magnetic survey in the Argenta area to seek concealed extensions of the dioritic rocks beneath cover. A vertical field fluxgate (Scintrex MF-2) instrument with external batteries was used. Frequent daily reference was made to a base station. A few traverses were also made in the vicinity of the Little Water Peak intrusive body; these are discussed in the section describing the Cottonwood Grand Central prospect.

The survey of the Argenta area revealed strong local highs and lows associated with the larger exposed dioritic bodies, and their local extensions under the alluvium. Some small altered dikes and sills exposed at the surface yielded no significant change in response from that obtained over nearby sedimentary rocks. This amount of diorite present thus remains problematical, but weak magnetic variations suggest additional diorite is concealed beneath recent sediments and glacial till.

Aureoles of calc-silicate minerals adjacent to the small plutons of the Argenta complex were found to extend outward for as much as 2-3 feet (1 meter) into dolomite or limestone. Thin sills show bleaching in places and no more than 0.2 inches (1 cm) of diopsidic pyroxene. X-ray diffraction patterns of bleached carbonate units indicate they consist mainly of calcite and quartz. Idocrase (?) and a silvery phlogopitic mica are also abundant. A specimen from adjacent to an argillized dike in Mill A Gulch contained abundant black euhedral spinel (James D. Stephens, personal communication, 1977).

A greenish-black micaceous material occurring in pods adjacent to a dioritic dike in the upper Maxfield tunnel was identified by x-ray diffraction as an iron - magnesium chlorite, with strong 14Å reflections and weak 7.1Å reflections. Adjacent greenish calc-silicate minerals included actionolite-tremolite, diopsidic pyroxene and montmorillonoid clay.

Mines and prospects

Maxfield Mine (3,4)

The Maxfield mine is located on the north side of Big Cottonwood Canyon at the mouth of Mill A Gulch. The portal of the lower (James Drain) tunnel is situated in the NW¼ NE¼ NE¼ SE¼ of section 14, T. 2 S. R. 2 E. at an elevation of approximately 6,965 feet (2120 m) above sea level.

Access to the workings is by two adits, both caved at the portal, and a shorter upper adit. The workings are extensive, consisting of raises, winzes, drifts, crosscuts, and large stopes totalling more than 15,000 feet (4,500 m). The lower workings are flooded.

History. The mine was discovered in about 1871 by the Maxfield brothers, who found a sulfide-bearing outcrop on the west side of Mill A Gulch. The earliest workings followed one or more thin, bedded replacement horizons westward and downward. The Maxfield Mining Company was incorporated in March, 1897. Huntley reported that total development consisted of 75 feet (23 m) of vertical shafts, 212 feet (65 m) of adits, and 800 feet (243 m) of total workings (Huntley, 1885, p. 427). Access was via a tunnel portaled in Mill A Gulch. Ore was mined above and below this level in steeply inclined stopes over a strike length of 100 feet (300 m).

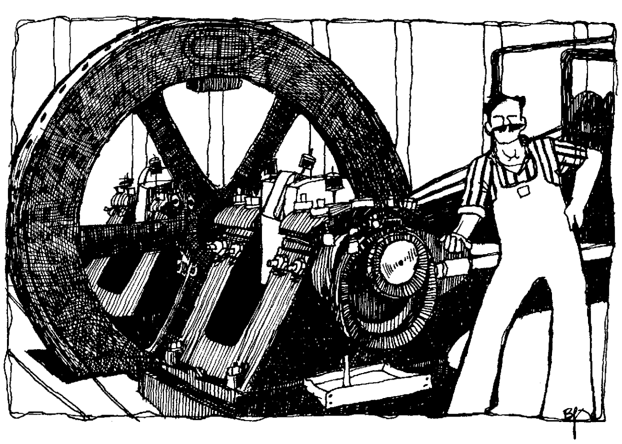
Production continued with some regularity during the 1880's and 1890's. An 1891 report described the operations:

> The Maxfield is the leading mine of the district. (In May) 1888 the ore was cut off by a fault, and it took two years to find it again and to make the necessary connections to resume the extraction of ore . . . They found the new ore body 175 feet southwest and 250 feet above the old workings. Since connections were completed they have taken out 1,100 tons of $70 ore. The ore shoot is about 100 feet long and 2.5 to 3 feet wide, and besides this there are a large number of small ore pipes that will pay for stoping. On seven of these pipes they are raising at a profit, and with the hope of having them open out into large chambers of ore. There is about 1,200 feet of stoping on the big ore shoot from where ore is now being extracted up to the surface, on the dip. Vertically the present stope is about 1,050 feet below the surface. . . (*Union Pacific Railroad,* 1891, p. 60).

The "old ore body" ended against a porphyry dike. In the 17 months of following the losing of the ore, the mine produced $9,732 from the old stopes. From October 1, 1889, when the "new ore body" was found, to April 1, 1891, 1,463 tons were shipped, valued at $100,020.81 *(Engineering and Mining Journal,* May 23, 1891). The nine dividends of the Maxfield Company to April 1892 totaled $118,000 *(Salt Lake Mining Review,* March 15, 1902). Production to the end of 1890 totaled 22,000 tons (Calkins and Butler, p. 103).

The lower, main adit was driven from Big Cottonwood Canyon during the mid 1890s. A drift was extended westward for 1,100 feet (330m) from the main tunnel along the main ore horizon. Winzes followed ore below the tunnel level in at least four places along this drift. The ore apparently did not extend above the tunnel level over much of this length. The last, and most extensive prospecting along and below this level was conducted by the Boston Development, which operated the mine from 1914 to 1918.

Prior to 1907 operations from the drain tunnel were conducted by W. F. James of Boston and A. L. Thomas, Jr., son of a Utah territorial governor and a



noted promoter. Control assays on a car of ore from 1200 feet (365 m) in on the tunnel level reportedly were 25.5% Pb, 73.8 oz/ton Ag, 2.9% Cu, $51.12 Au and 14.9% Fe. A second shipment, from below the tunnel in the Alligator Extension winze, assayed 26.6% Pb, 53.8 oz/ton Ag, 21.7% Cu, $3.50 Au and 14.7% Fe (*Salt Lake Mining Review* September 30, 1904). The workings below the tunnel encountered a water-course near a large dioritic dike, and were flooded beyond the capacity of pumping equipment. Production to 1906 had a total value of $1,053,000. (Calkins and Butler, 1943). J.W. Wade and J.M. Howell again pumped the workings dry in 1909 but found no minable ore. They produced minor sulfide concentrates with a small jigging plant, treating bedded replacement ore from above the tunnel level. (J.W. Wade, personal communication, 1963).

The Boston Development Company was organized by F. H. Vahrenkamp, a flamboyant Nevada mining promoter. He re-equipped the mine and power plant, and connected new pumps with the Utah Power and Light Company line to aid in controlling the troublesome flow of water into the lower workings. By the summer of 1915 the property was second largest in monthly production in the district (*Salt Lake Mining Review* v. 17, no. 12, p. 13-16), and employed fifty men. Some ore, probably the highest grade, averaged $80 per ton. Several thousand gallons of water per minute were being pumped at that time. Effort was concentrated on workings off the main inclined shaft, at the west end of the workings, where winzes reached a depth of 100 feet (30 m) or more below the "1700" level, or about 300 feet (90 m) vertically below the tunnel level. Long crosscuts were extended northerly from the face of the main tunnel and the west drift without finding more ore. (*Salt Lake Mining Review,* various issues, 1914-1917). Bankruptcy and litigation apparently closed the operation in 1917 (Blake vs Boston Development Co., *Utah Reporter,* September 10, 1917).

In 1926 L. W. Hoskins leased the mine. Prospecting below the water level in the 1200 winze (350 level) yielded some ore. Water influx was reportedly 300 gpm. A crosscut through the largest dike cut old workings, and flooded the winze. Hoskins and the Bullion Chief Mining Company conducted limited exploration in the old upper workings, and drove three raises to pass oxidized ore down to the tunnel level. A small gravity concentrator was erected underground, at the entrance to the main west drift, to treat this ore. (Hoskins, 1927; *Salt Lake Mining Review,* December 15, 1930, p. 7-8; November 1, 1932, p. 9).

Production. Underground operations at the mine ceased in 1936; an additional three tons was produced in 1940. U. S. Bureau of Mines records indicate that from 1902 to 1940 a total of 5368 tons of ore were produced, with an average recovered grade of 0.165 oz/ton gold, 51.8 oz/ton silver, and gross metal contents of 1.4% copper and 19.7% lead. About 71% of the copper and 94% of the lead were recovered. The largest production was attained in 1916, when the mine produced 1968 tons of ore averaging 0.154 oz/ton gold, 45 oz/ton silver, 1.3% copper and 16.9% lead. No recovery of zinc was reported, but sphalerite was abundant in samples from the dump.

Geology and ore deposits. The stopes of the Maxfield Mine follow the bedding in the Gardison Limestone, with the larger deposits occurring "in a bed of banded blue and white limestone near the base of the (Gardison) limestone" (Calkins and Butler, 1943, p. 103). In the older workings, stopes can be followed as much as 100 feet (30 m) on both dip and strike. Remnants of the ore consist of brown, copper-stained oxide minerals, often with coarse translucent crystalline quartz, typically 1 foot (0.3 m) in thickness. Four different beds within the limestone reportedly have yielded ore (Hoskins, 1927). The area explored and stoped plunges northwesterly, and lies beneath the water table in the main west drift of the mine. Sulfide-oxide ores there reportedly were accompanied by far less silicification and quartz. Ore apparently occurs adjacent to a series of steeply-dipping fissures, many of which strike to the northeast. (Calkins and Butler, 1943).

Several thin dioritic dikes occur in the workings between Mill A Gulch and the main tunnel (Plate 4). Adjacent carbonate rocks are converted to green diopside epidote, phlogopitic mica and wollastonite for 1 foot (0.3 m) or more from the intrusions; bleaching is common. The inclined 1,200 winze follows a dike below the tunnel level to the "350 level" (*Western Mining Survey,* May 8, 1931). Similar dikes are abundant in the canyon bottom further to the east. They lens out both laterally and vertically, and rarely are found in outcrop very far above the canyon bottom. Thus the Maxfield mine occurs near the top or apex of a small dike and sill swarm.

Sulfide ore minerals from the mine include abundant pyrite and galena, with lesser tetrahedrite and sphalerite. Gangue includes calcite, quartz, sepiolite, and calc-silicates. The mineralogy of the sepiolite was discussed by Ehlmann, and others (1962). Decreased silver and lead content and (in sulfide ores) increased zinc content made mining near the dikes unprofitable. (Calkins and Butler, 1943: L. W. Hoskins, personal communicaton).

Adelaide and others Miscellaneous Prospects

Several small adits and shafts prospected ground near dioritic dikes in Mill A Gulch. The Adelaide property, immediately north of the Maxfield, had 250 feet of tunnels and shafts by 1873, and a lower tunnel was in progress to cut four veins at greater depth. Assays reportedly ran 50 to 150 oz. silver per ton, 30% iron and 25% lead (*Utah Mining Gazette,* February 7, 1874). Plate 4 shows the workings. Production apparently was negligible.

Baker Claims (5, 6)

The Baker claims, along the eastern contact of the largest diorite body in Mill A Gulch, were developed by two tunnels and several shallow shafts. Shallow surface workings near the crest of the hill separating the two forks of the gulch followed pyrite - goethite gossan down the bedding planes in the Humbug Formation. The number two, or upper tunnel was driven about 2000 feet (600 m) beneath this occurrence (plate 4) without discovering significant ore. The lower tunnel, of unknown length, also prospected mainly bleached, metamorphosed sediments near dikes. Calkins and Butler (1943, p. 104) report minor lead was present. An analysis of the gossan material is presented in table 5 (sample 47).

Gold Coin (15)

The Gold Coin claim group lies southeast of USLM 4 on the south side of Big Cottonwood Canyon, near the site of Argenta (Calkins and Butler, 1943, plage 30). It includes the old Defiance Westerly claim, prospected by James Monk between 1883 and 1898. A tunnel portaled in moraine, intended to seek a possible extension of the Dolly Varden ores, never reached bedrock (L.W. Hoskins, personal communication). The tunnel is now caved and the blacksmith shop at its portal burned in 1974.

Dolly Varden Mine (13, 14)

The Dolly Varden mine (figure 14) is located just over one quarter of a mile (0.4 km) east of the Maxfield mine on the southern side of Big Cottonwood Canyon. The mine is located in the SE¼ NW¼ SW¼ of section 13, T. 2 S. R. 2 E. at an elevation of 7,085 feet (2,160 m) above sea level.

The mine was discovered in about 1871, surveyed for patent in 1874, and worked until approximately 1885. The total value of production to 1880 was estimated to be $25,000, primarily in lead-silver ore (Huntley, 1885, p. 430). Production since was probably minimal. Some tunneling was conducted by James Monk in 1896.

Access to the workings is by three adits and a shaft, all now caved. The workings total approximately 1,500 feet (470 m) in length. In 1874 the workings consisted of "an incline shaft, 70 feet, a level 40 feet, all situated more than 600 feet (180 m) south of Big Cottonwood Creek (U. S. Surveyor General's Patent Records, Book 28 p. 7028). Raymond (1873) stated "The mine shows a large deposit of low grade ore; several hundred tons assaying $25 have been sold . . .". The *Utah Mining Gazette* (March 21, 1874) noted, "It is situated 240 feet above the creek level, and is worked to a vertical depth of 150 feet. The vein carries 50 percent magnetic hematite, 5 to 1000 oz. silver, and is highly prized as a flux at smelters. The deposit is ten feet wide at a depth of 100 feet..." The *Utah Mining Gazette* (August 1874) described "A new strike at a depth of 270 feet shows a large body of ore. An assay showed $979 silver and $12 gold".

The workings of the mine are in the upper member of the Ophir Shale and lower part of Maxfield Limestone. Ore was found along an irregular "pipe" with some replacement of limestone (Calkins and Butler, 1943). Thin altered dioritic dikes are present.

Ore minerals included galena, cerussite, and smithsonite (?) in a gangue of calcite. The ore potential of this mine is unknown but probably small.

Newman and Afton groups (9, 10, 8)

The Newman (Big Cottonwood Monarch, Sunken City) group of patented claims lies immediately south of Cottonwood Creek, 2,000 feet (900 m) east of Mill A Gulch. Its owners also hold the patented Afton group, north of the creek (Plate 3).

History. This ground was prospected in the 1870s, and some oxide ore was reportedly shipped from the old Magnolia (?) incline shaft high on the hillside (figure 15). This incline, said to be 300 feet deep, is now caved; an analysis of goethite-rich material from its dump(sample) appears in Table 5. An upper adit, at elevation 7640 feet (2330 m) encountered minor mineralization associated with dikes. Several lower adits were begun from just above the creek bed; one was equipped with a Karns automatic tunnel boring machine and projected to extend to the southeast beneath Alta, but the project was soon abandoned.

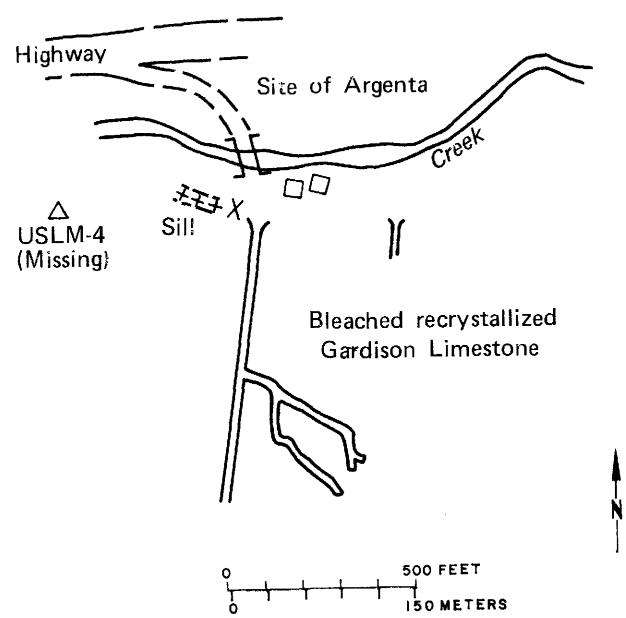


Figure 14. Plan of Dolly Varden lower tunnel.

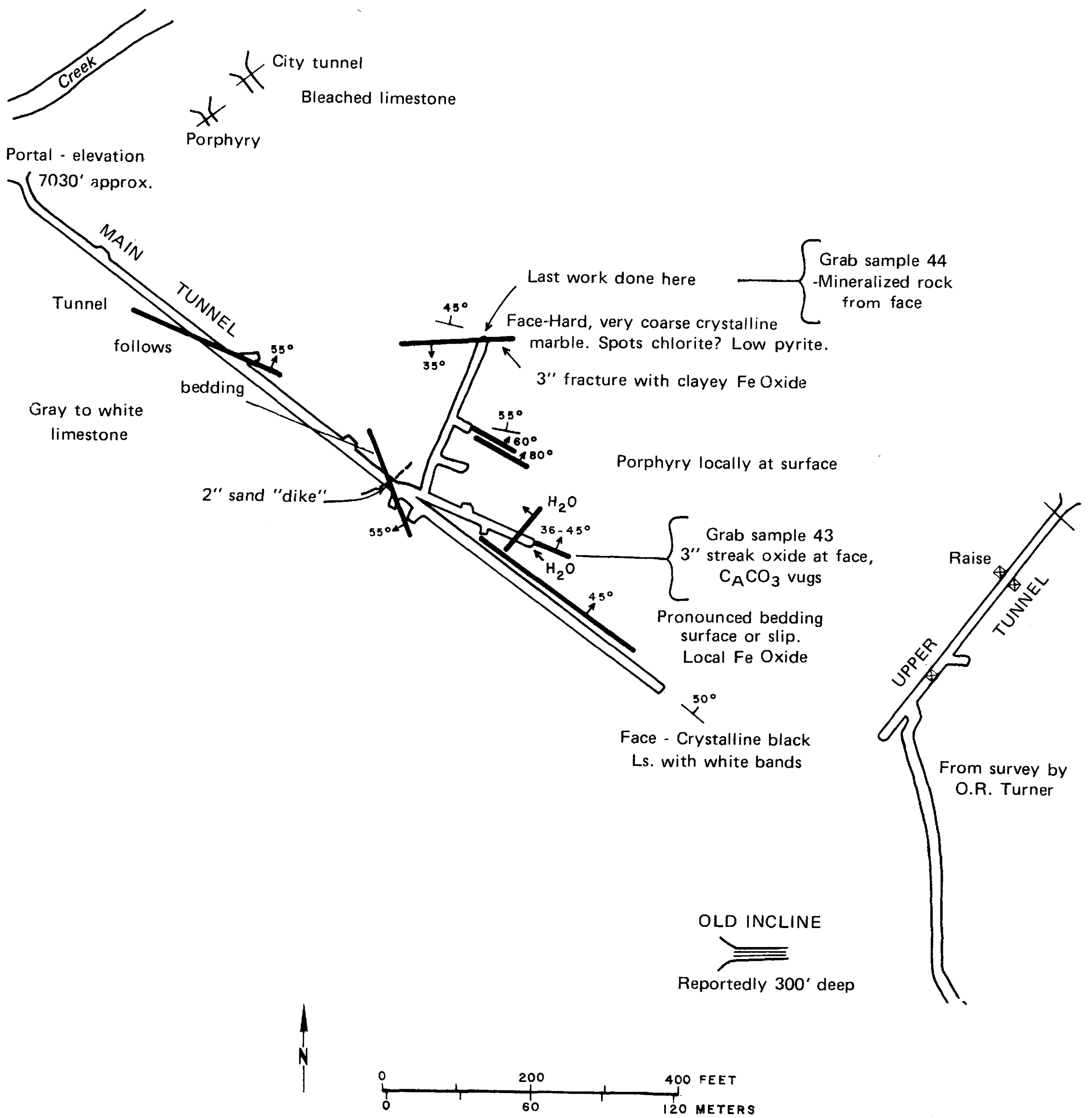


Figure 15. Geologic map of Newman workings, by L.P. James and E.W. Newman.

The Newman family acquired the ground in the 1920s. J. L. (Roy) Newman spent the succeeding 45 years driving the main, lower adit (portal elevation approximately 7020 feet or 2140 m) some 1500 feet (460 m) southward and eastward, using hand steel (figure 15). He and A. Allesini (locally known as Joe Ferry) drove the Afton tunnel into the north side of Big Cottonwood Canyon, immediately north of the main Newman portal. One or two small shipments of zinc-rich ore were made from the Afton property, from limestone adjacent to dioritic dikes.

Geology. Both the Newman and Afton groups (figure 16) are cut by a number of dioritic sills and dikes. Texture and mineralogy of the dikes is highly variable. Carbonate rocks adjacent to the dikes have been altered to diopside, phlogopite, idocrase, garnet and serpentine. Small patches of goethite after sulfides are locally evident. The most extensive igneous body seen on the group is near the portal of the upper Newman tunnel.

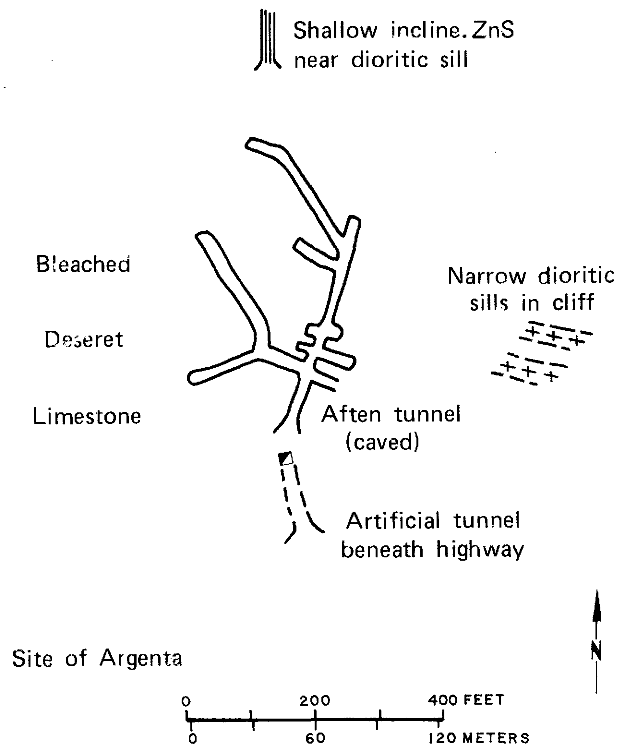


Figure 16. Workings of Afton prospect, Ca. 1950

Gossans from the general vicinity of dioritic rocks on this group have been noted to contain minor nickel and cobalt. In 1928, selected samples taken by the U.S. Forest Service personnel on the Sunken City No. 1 claim assayed 1.89% nickel and 1.35% cobalt. Other assays by the International Smelting and Refining Company confirmed these minor showings. (Unpublished data, U. S. General Land Office, protest of patent application, April 12, 1929; also E. W. Newman, personal communication, 1976). The writer noted one apple green stain possibly indicative of nickel, and obtained traces of Ni and Co from a grab sample of gossan from the old Monarch shaft (sample 52, table 5). These occurrences are not believed to have any economic potential.

No major igneous bodies were seen underground in the main tunnel (figure 15), and the only notable structural features were gouge and slippage along bedding. A few 2-3 cm wide dike-like bodies of sand-like material extend across the main drift, crosscutting bedding. The face of the longest easterly drift is in coarse marble, suggesting proximity to the sills exposed on the surface. Two samples of seams of goethite and quartz (samples 43 and 44, table 5) showed the presence of lead, zinc and silver.

Newport (7)

The Newport patented claim lies on the north slope of Big Cottonwood Canyon, east of Mill A. Gulch. The dump of the long-abandoned inclined shaft shows some quartz and oxidized lead-bearing goethite. The workings were not extensive.

Sunnyside (17)

Calkins and Butler (1943, p. 104) state that the Sunnyside tunnel, "about midway between the Maxfield mine and the mouth of Mill D South Fork" explored the contact between Carboniferous limestone and a porphyry dike. Garnet and other contact minerals occurred in the limestone near the dike, and a little zinc ore was said to have been found. This adit was covered by the present highway. Sizable masses of rusty dioritic rock are evident on the surface in this area. The property was last operated by the Union Associated company. It was previously known as the old Congor or Congo property, mentioned as a minor ore producer prior to 1900. The *Mines Handbook* (1924) states that the Sunnyside had 2400 feet of workings, mainly along the Congor fissure.

Red Bell and Cottonwood King Mines (19,18)

The Red Bell workings are situated in Butler Fork, about 2000 feet (600 m) north of Big Cottonwood Canyon. The main workings are a caved tunnel extending westerly from the west side of the fork, apparently near the base of the Park City formation. The dump shows bleached sedimentary rocks and some altered dioritic dike rock. The *Mines Handbook* (1918) states that the tunnel was at that time 675 feet in length. The property reportedly made a small shipment in 1918 and was sinking "on a seven foot vein" (*Salt Lake Mining Review*, March 15, 1918).

The Cottonwood King tunnel, now exposed in the face of a road cut about 1,000 feet (300 m) west of the mouth of Butler Fork, was driven by the Twin Peaks, Peaks, Cottonwood King and Union Associated Mining Companies to crosscut bedding and develop Red Bell ground. The Cottonwood King is listed as an ore producer in 1922 (*Minerals Yearbook* 1922), but the company of that name also conducted operations in the Giles (Little Dollie) group, so the source of ore is unknown. R. E. Marsell (personal communication, 1964) stated that a few very thin seams of ore minerals were evident in the tunnel in the 1930s. In the summer of 1931 the lower tunnel was 750 feet in length and being driven forward seeking a fissure zone. Work ceased with the death of promotor S. A. Parry in 1935.

Confidence (21)

The Confidence or Bachelor claims, (figure 17), part of the Union Associated group, are on the south side of Big Cottonwood Canyon, adjacent to the creek, about 2000 feet (600 m) southwest of the mouth of Butler Fork. Thin dioritic sills cut the limestone country rock here. At least two adits and a shallow winze explored the contact zones. Leasers mined a little ore in 1931 (*Western Mineral Survey*, January 1, 1932).

According to the *Salt Lake Mining Review* a small lot of ore awaiting shipment from the mine early in 1932 assayed $30-$40 per ton in gold, 100-150 oz. silver per ton, 30% lead and 7% copper. Reports of this nature and all work ceased with the death of S. A. Parry.

Cardiff Extension (Cottonwood Exchequer) (22)

The Cardiff Extension group of unpatented claims was located north of the Reeds Peak property, and later became part of the Confidence group. According to the *Salt Lake Mining Review* an adit was driven 500 feet during 1915, developing a fissure showing lead and silver values at 300 feet from the portal. An old adit extending south 28.5 degrees west lies about 800 feet east of the SE corner of the Gustave claim, just south of the creek flowing from Mill D South Fork, just northwest of the center of section 18; a 1930 map shows it to be about 165 feet long. The Cardiff Extension was a short-lived promotion, and little information is available concerning it.

Mutual Tunnel (1)

The Mutual tunnel extends southeastward from immediately east of Mineral Fork, just above Big Cottonwood Creek. It was begun by the Bankers Mines company during the 1916 boom period. The Greater Consolidated Mining Company obtained the property and conducted a somewhat scandalous promotion of it *(Mines Handbook,* 1920). In 1921 the Mutual Metal Mines Company took over the property. The deep adit was driven to a length of 7200 feet, and was projected to go much further, as a deep drainage tunnel for the entire region *(Mines Handbook,* 1931). Traces of mineralization were occasionally reported; none were observed on the dump.

The adit has been reported to contain poisonous gases, reportedly issuing from the Precambrian Mutual formation. In June 1928, after a vacation shutdown, three men and a mule entered the tunnel. 4200 feet (1400 m) from the portal miner H. Richards saw B.D. Field, the manager and miner A. Haggin, who were ahead of him, fall to the ground. Richards, and later the mule, escaped safely to the portal. A mine rescue team from Bingham found the two men asphyxiated. L.W. Hoskins, who participated in the rescue, reported that a vacuum bottle sample from the tunnel face showed 9.5% oxygen. A heavy flow of water was entering the tunnel at the face (L.W. Hoskins, personal communication, June 1964). The Bureau of Mines analyses of 8 samples taken by vacuum or water displacement showed a marked increase in nitrogen content, suggesting an influx of this gas "from a crevice" or fissure. Oxygen deficiency at 4000 feet from the portal was sufficient to extinguish a flame safety lamp. Apparently little work has since been done in the adit although the company levied several stock assessments during the 1930's. The Sprague mining company conducted minor exploration at a point 600 feet (180 m) from the portal. There is also a short cross cut at 6500 feet from the portal.

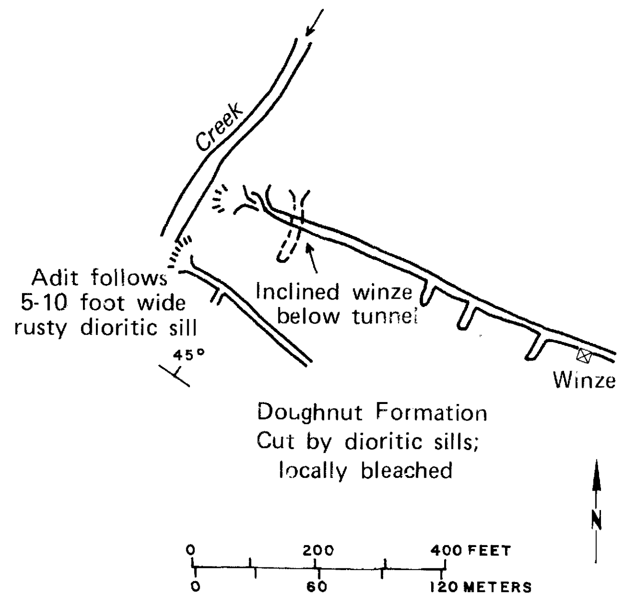


Figure 17. Workings of Confidence mine.

The adit extends about S34°E, and rock on its dump suggests it lies entirely within the conglomerates and "tillites" of the Mutual Formation. An analysis (sample 53, table 5) indicates that the black sandy organic rich unit of the tillite on the dump is relatively poor in trace metals.

Logger Mine (2)

The old Logger unpatented claims are on the south side of the Big Cottonwood Canyon about 2000 feet (600 m) west of the Maxfield mine. Two adits were driven in Tintic quartzite and a soft biotite lamprophyre dike, six to twenty feet (2-6 m) in width. F. F. Hintze reported that in 1916 the upper adit, about 300 feet above the creek bed, had been driven for 300 feet (90 m) along the nearly vertical dike, striking N30°E. Iron, lead and copper sulfides were found in the west wall of the dike. (Calkins and Butler, 1943, p. 104). In 1915 ore exposed on the property was said to assay $70 to $90 per ton. In February 1916 a winze below the upper tunnel was following an 18 inch wide vein, which yielded one carload shipment assaying "as high as 21% (Cu, $40 Au, and 15 oz/ton Ag" according to the *Salt Lake Mining Review* (July 15, 1916). A lower adit, about 100 feet (30 m) deeper, was 475 feet long by the 1920s. Other workings included "A winze sunk on the vein from the 200 foot point and crosscut at 350 feet (105 m) from the protal, exposing ore but not in large amounts." *(Mines Handbook,* 1931). Quartz, green sericite and cubic pyrite were noted on the dump. Apparently very little further work was done. The workings were partially flooded in 1977. A prospect adit higher on the hillside shows the lamprophyre dike to be 18 feet (6m) wide.

MOUNT RAYMOND-PORTER FORK AREA

Mines and Prospects

A few prospects and mineral showings extend north from Big Cottonwood Canyon into Neffs Canyon and Porter Fork, a branch of Mill Creek Canyon. County records show claims in this section as being in the "Big Cottonwood mining district," although it was organized as the New Eldorado district (*Salt Lake Herald,* January 31, 1871). By 1874, fifty claims had been located, but little work was ever done. The Mary Stillman claim reportedly exposed a 12 inch (0.3 m) galena vein assaying 0.6 oz/ton silver. The Keystone claim reportedly yielded shipments of fire clay (*Utah Mining Gazette,* February 27 1874). These prospects were not identified.

In the summer of 1896 placer gold was reported in Mill Creek Canyon, apparently below the mouth of Porter Fork. Although an "average sample of gravel" was said to assay $1 per ton plus traces of silver (*Intermountain Mineral Review,* July, 1896) no further mention of this occurrence was found in the literature. The report may have been a hoax.

Hayes (Baker) Mine

On the northwest slope of Gobblers Knob, three adits penetrate slightly brecciated Humbug Formation near the upper strand of the Mt. Raymond thrust. Only minor iron oxide occurrences were noted on the dumps. The "Baker mine" identified on Geological Survey maps is apparently the old Hayes mine. Huntley (1885) described the Hayes as having 400 feet of workings, but no ore production. It reportedly yielded "some rich gold ore containing copper, in 1904" according to Calkins and Butler, (1943, p. 77), who also list the Hayes as a lead producer.

Scott Prospect

The Scott prospect, on the ridge between Porter Fork and Big Cottonwood Canyon near Mill B North Fork, was not identified during this study. The upper workings showed "carbonate" and galena; a pan concentrate of the latter reportedly assayed 45% lead and 82 oz silver/ton (Malmborg, 1977, p. 50). A lower adit extended six hundred feet without finding ore. A number of claims were located in this general vicinity, 1 to 1.5 miles (1.6-2 km) west northwest of Gobbler's Knob by David A. Jones during the past decade, and some excavation was done. This, and other prospects on the southeast side of Gobbler's Knob, north of Butler Fork, were not examined.

MAIN CANYON AREA

This section discusses mines in the upper portion of Big Cottonwood Canyon and its tributary gulches. The gulches extend southward from Big Cottonwood Canyon and into the upper reaches of the main canyon. This area of the district has yielded the largest production, and is contiguous with the Alta or Little Cottonwood district to the south.

Mineral Fork

Regulator Johnson (Silver King or Wasatch Gold) Mine (119, 118, 117)

This mine is south of Big Cottonwood Canyon near the head of Mineral Fork. The portals of the upper adits are approximately 1 mile (1.6 km) east-southeast of Lake Blanche, in the unsurveyed SE¼ SE¼ NW¼ of section 36, T. 2 S., R. 2 E. The most recent adit is at an elevation of 10,230 feet (3,118 m) above sea level. A jeep trail up Mineral Fork leads to most of the workings.

History J. "Regulator" Johnson conducted early operations on the Silver King claims in the 1870s. Ore from shallow workings was shipped in sacks on muleback down a trail to Big Cottonwood canyon. Early production of high grade ore came from a stope on the Silver King No. 3 claim (G.E. Coxe, private report to Wasatch Gold Mines Company, 1936). Johnson, the Big Cottonwood Silver King Co., and others operated the mine intermittently until about 1924. (*Salt Lake Mining Review,* various issues; N.H. Johnson, personal communication). It is claimed that $280,000 worth of ore was shipped prior to 1914 (G.E. Coxe, ibid) although this figure appears questionable. Ore totalling 186.3 short tons, shipped to the old Germania smelter from the Silver King Extension claim between 1899 and 1901, ranged in metal content as follows:

Au 0.3-1.0 oz/ton	Ag 28-139 oz/ton
Iron 19 to 32%	Pb 1.5%-13.5%

(H. D. Heist, private report to Wasatch Gold Mines Co., 1936). The main upper level, toward the east edge of the cirque at the head of Mineral Fork, encounters the Silver King fissures at a depth of about 500 feet (150 m). An 80 foot (24 m) winze below this level yielded three small shipments prior to 1930 which yielded smelter returns of $28.40 per ton. Minor production was attained in the late 1920s (*Minerals Yearbook and Mineral Resources* of the U.S., 1927-1934).

The Wasatch Gold Mines Company optioned the property, and began shipments from the upper workings in August 1937. Small shipments to the Garfield smelter during 1940-41 totaled 255 tons, for which payment was made for gold, silver, lead and minor copper. One lot was penalized for minor arsenic and antimony. (Table 9B).

A lower tunnel (the "Wasatch Mine" on U.S. Geological Survey maps) was driven southward at elevation 8,680 feet (2646 m) from the valley of Mineral Fork. In 1941 it intersected a pyritic fissure identified as the Silver King at 3,174 feet (967 m) from the portal (figure 11-18). At this point the fissure reportedly contained six inches to six feet (15-180 cm) of mineralization, not of ore grade. 2.22 short tons mined from this locality assayed 0.25 oz /ton gold, 3.32 oz/ton silver, 1.95% lead and 0.25% copper (Records of Mountain Mines Co.). Several hundred feet of drifting along the vein on this level and subsequent minor additional work by the New Park Mining Company failed to reveal commercial ore. A geologist employed by a local smelting company described the vein on this level as mainly a gouge zone, with local showings of sulfides. The Mountain Mines Company, which succeeded Wasatch Gold in 1942, ceased operations in the late 1940s. Company production totaled 72 small shipments, totaling probably $50,000 in value. Values obtained from some shipments are given in table 9. Minor lease production from the upper workings was obtained as late as 1952 by G.A. Rich. (C.S. Woodward, personal communication, 1965). Maps of the workings appear in figures 18 and 19. Total workings in the property probably exceed five thousand feet (1500 m).

Geology. The host rocks are the Pre-Cambrian Mineral Fork Tillite, not far beneath the Cambrian Tintic Quartzite. The Silver King mineralized fissure extends northeastward N42-47° E in the workings across the head of Mineral Fork, and shows a mappable displacement in Mill B South Fork (Crittenden, 1965). The same structure apparently was prospected in the American Consolidated-Brandborg (94) (Meadow tunnel) and South Price tunnel (99) workings in Mill D South Fork. In Mineral Fork the fissure contains a narrow silicic dike in the hanging wall of the mineralized zone. Similar dike rock was encountered on the Wasatch tunnel level, 1400 feet (426 m) below (R.E. Marsell, report to Mountain Mines Company, October 27, 1941). In the latter locality a dark, very fine grained, brassy sulfide occurs in abundance. P.B. Klinger of the Kennecott Copper Corp. Research Center found only normal pyrite in a polished section from this locality. The narrow Waterfall fissure encountered nearer to the portal of the Wasatch tunnel reportedly contained weak mineralization. (Coxe, ibid; *Western Mineral Survey*, April 17, 1939). Prospecting via drifts and short raises failed to discover commercial ore in either the Waterfall or the Silver King veins.

Ore on the upper levels of the Silver King vein was partially oxidized. It tended to be considerably higher in grade than mineralization on the Wasatch level and contained minor dolomite gangue. The best ore shoots reportedly occurred where the fissure was cut by north-trending "breaks" or cross faults of very small displacement. (Heist, ibid.) Some rock on the dump of the main upper tunnel shows minor dissemination of galena and pyrite in porous bleached Mineral Fork "tillite" adjacent to vein matter. Chloritized, sericitized and pyritized dike rock was also noted.

If the "vein" is continuously mineralized between the two levels, several tens of thousands of tons of low gold and silver bearing sulfide ore might be mined from the property under very favorable eco-

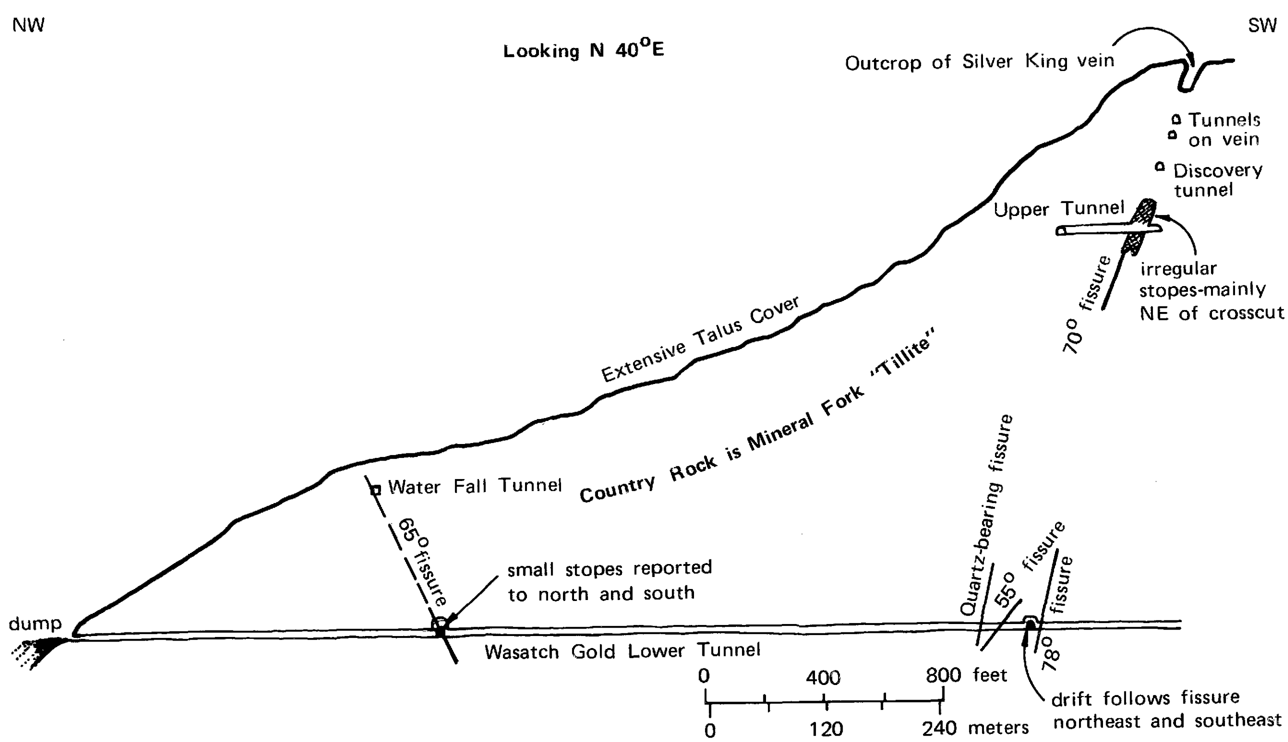


Figure 18. Cross section through Wasatch Gold tunnel and Regulator Johnson (Silver King) workings.

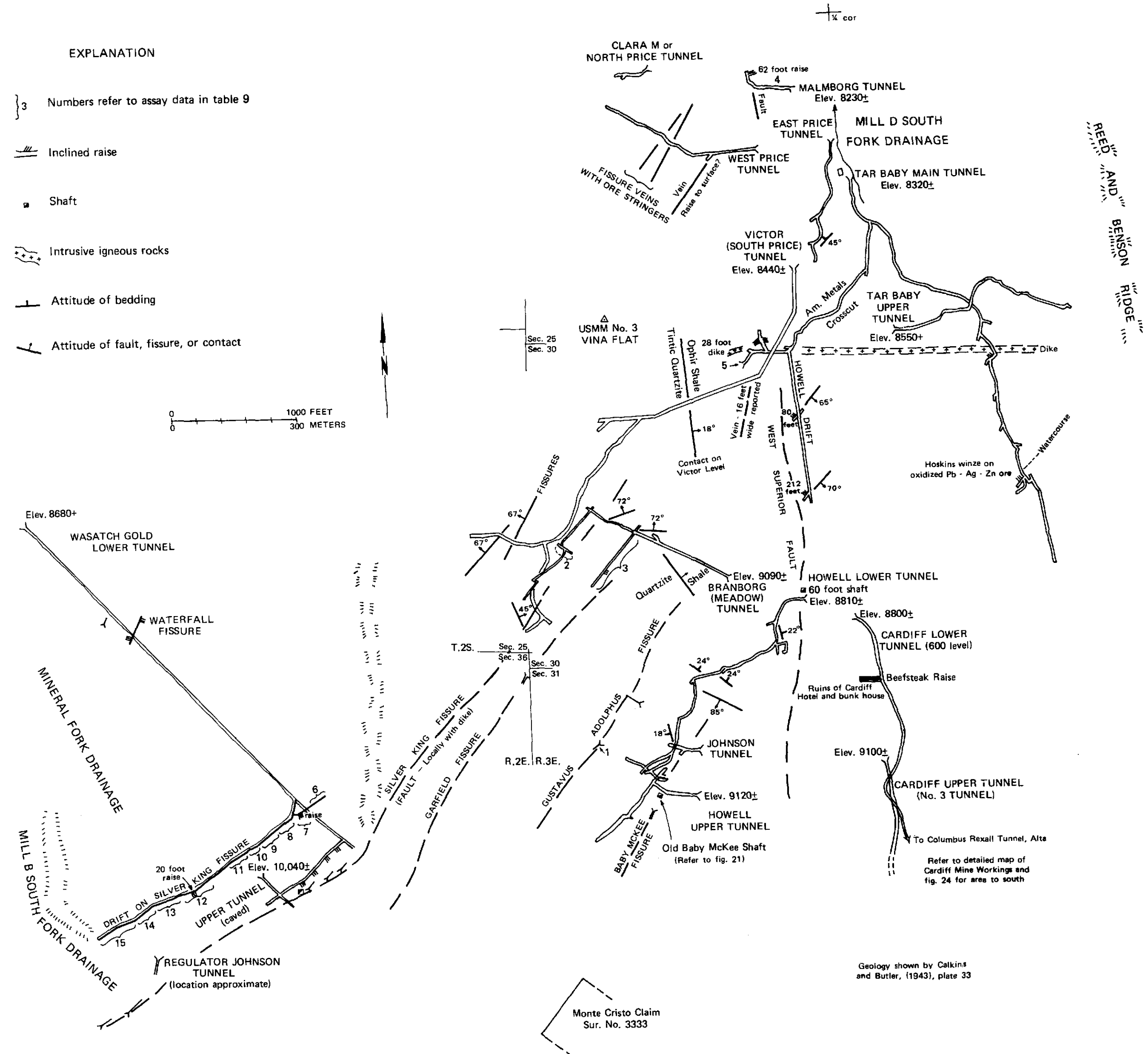


Figure 19. Major Underground Workings in Mineral Fork and upper Mill D South (Cardiff) Fork, ca, 1952.

nomic conditions, although the narrowness of the "vein" would make mining difficult.

Silver Mountain Mine (115, 116)

The Silver Mountain mine is located south of Big Cottonwood Canyon in a gulch on the southwest slope of Kessler Peak, between Mineral Fork and Mill D South Fork. The portal is located in the SE¼ SE¼ SW¼ of section 24, T. 2 S., R. 2 E. at an elevation of 9,000 feet (2,740 m) above sea level. The only access was via a steep, narrow mule trail.

The mine was only a small producer of ore, worked intermittently between about 1880 to 1918. Production records from this property were not obtained. The mine apparently was discovered in the late 1870s. In 1881 workings consisted of a 138 foot (42 m) incline, a tunnel and a 40 foot (12 m) winze. (Western Mining Gazetteer, 1881). 170 tons shipped in 1884 had a value of $36.00 a ton. The total output to 1884 was 1,170 tons of ore (Calkins and Butler, 1943, p 105). The reports of the Director of the Mint (op cit, p. 22) noted a production of "about 300 tons" valued at $40,000 in 1886, and some production in 1887 (ibid. p. 240). Subsequent reports do not mention the mine, but reports for these years tend to be very incomplete. Butler and others, (1920) mention minor production during this century. Workings now consist of an irregular incline, a tunnel, and stopes below the tunnel totalling perhaps 1000 feet (300 m).

Host rock in the mine is the topmost 200 feet (60 m) of the Tintic Quartzite, which is cut by a narrow N60° E striking fissure containing partially oxidized lead silver ore. Ore minerals noted include galena, sphalerite, pyrite and probably cerussite, and smithsonite accompanied by quartz and minor dolomite and calcite. "First class" ore in 1881 reportedly assayed 65% Pb and 80 oz/ton Ag. (*Western Mining Gazetteer* 1881). Table 5 gives an analysis (sample 35) of a picked bulk sample of sulfide ore from the dump of the main adit.

Mill D South Fork

Reeds Peak Consolidated (Big Cottonwood Consolidated) (105)

The Reeds Peak Consolidated group, which includes the former Big Cottonwood Consolidated property, lies along the west slope of Mill D South Fork, on the east slope of Kessler Peak. An adit high on this slope was driven in the 1870s by the Elgin Mining Company of Elgin, Illinois, to develop the Chieftain claim. (*Utah Mining Gazette*, September 6, 1873). In 1907 the Reeds Peak Mining Company was incorporated to work in this vicinity. A deep adit was begun at an elevation of about 7810 feet (2382 m) immediately west of Donut Falls, just below the South Fork road, to test at depth beneath the fissure vein showing in the upper adit. By 1916, the adit had been driven 800 feet (240 m) using hand steel. Following installation of compressed air equipment the adit was rapidly extended to 1700 feet, (Calkins and Butler, 1943, p. 14). The extent of further work is not known and the adit has been caved for many years.

The Big Cottonwood Consolidated group is developed by 3 adits. The lowest and longest is above the road about 800 feet (240 m) to the south of the Reeds Peak. It was in part intended to seek an easterly extension of the Carbonate property along the "limestone-quartzite contact", thought then to be the same as the Alta overthrust. The adit was 740 feet long when compressed air equipment was installed (*Mining World,* October 21, 1916). No ore was developed; the workings are now caved.

Geology. In the upper Reeds Peak adit, a narrow vertical fissure in Deseret and Gardison limestone contains some galena and iron oxides. The shipments of lead ore reported by Calkins and Butler (1943, p. 82) probably came from here. The dumps of both lower adits show no significant mineralization. At the lower Reeds Peak dump, considerable shale and quartzite suggest that the lower Ophir formation was penetrated. Calkins and Butler state that the adit crossed the West Superior fault and entered Ophir shale 900 feet from the portal, as shown on a map by C.T. Van Winkle, mining geologist. This confirms the projection of this fault into this area by Crittenden (1965). High on the ridge a dioritic intrusive body discussed under Igneous Rocks follows this fault zone. No intrusive rocks were found on the dumps.

East Carbonate (103, 104)

The East Carbonate Mining Company of Park City prospected an area on the west slope of Reed and Benson ridge, near the middle of Mill D South Fork. In 1909 it was developed by two adits, the upper 250 feet (75 m) and the lower 90 feet (27 m) in length. Apparently both were on the Snowflake claim (Plate 3). A small quantity of lead-silver ore was reportedly sacked for shipment from both of them. A lower adit was 375 feet long in 1950. Little is known about a third short adit near the canyon botton.

All three adits penetrated Deseret Limestone where it shows local minor recrystallization and bleaching. Mineralization was noted only on the dump of the upper adit. In the portal a narrow (3 cm) east-striking nearly vertical fissure contains local iron oxide concentrations. The limestone shows little bleaching or alteration. The other adits are caved.

To the south, on the Homestead claim, a 350 foot adit reportedly cut a north-south fissure and followed it 30 feet. An assay showed 0.7 oz/ton silver and 0.4% zinc (Unpublished report, Anaconda Company).

West Slope of Mill D South Fork

Several prospect adits south of the Big Cottonwood Consolidated tunnel found only minor mineralization. These included the Keystone-Cottonwood, the South Fork Mining Company, and the Malmborg, all driven in the 1920-1935 era. The latter adit, just north of the Price tunnel, reportedly encountered 16 inches (40 cm) of bedded mineralization in 1931.

Mineral Park: Branborg (94), Contention, Wheeler and Wilson (?), Newton (108)

The Mineral Park group lies on the east side of Mill D South Fork, about 1 mile (1.6 km) by road south of the Big Cottonwood highway. At least five short adits, a longer adit south of the others and a shallow shaft penetrate barren-looking Round Valley Limestone and Doughnut Formation. In 1976 only one crosscut, 80 feet (24 m) in length, was open. The few northeast-trending fractures cut by it were devoid of mineralization. No ore production is known from any of the workings. Exploratory work on the Mineral Park group was conducted under the direction of G. Alexander during the 1920-1935 era, and included a primitive electromagnetic survey by C.W. Chilson, geophysical prospector (discussed previously). The long, southerly adit was last prospected in the 1950s. Very narrow stringers of silver bearing rock were reported.

American Metals-South Price Group (98,99)
Thor, Bright Point, Venus (96)

An elongate claim block covering part of the Alta Overthrust-Superior Fault zone in Mill D South Fork has been prospected by a series of long adits. The main workings are shown on figure 19. Workings on or related to this property, all presently inaccessible extend from the American Metals branch of Tar Baby tunnel (elevation 8330 feet approximately, or 2540 m) to the Branborg or Meadow tunnel (94), south of Montreal Hill, elevation 9120 feet or 2782 m. Further to the west are the old shallow workings of Thor, Bright Point, and Venus mines.

History. The American Consolidated Copper Company was incorporated in 1907. By 1918 the main adit on the property (the "Meadow" tunnel) was 2200 feet long, and minor shipments were reported from fissure vein deposits in quartzite. Later, a branch of the Tar Baby Tunnel, beginning about 400 feet (122 m) from the portal, was extended southwestard into limestone on American Metals ground. At a higher level the Victor or South Price tunnel, portaled near Montreal Spring, was begun to drain and explore beneath Montreal Hill. Beginning in the late 1930s, the Index Daley Mines Co. extended it several thousand feet (more than 1000 m) southward beneath the Meadow workings. Many of these workings encountered mineralization, as is indicated by the assays from Table 9, but no major ore bodies were encountered. The last work was performed in the early 1950s.

Geology The ground lies mainly in Tintic and older quartzites, west of the West Superior fault. A series of parallel northeast fissures, some of which extend southwestward onto the Regulator Johnson (Silver King) claims, have been the main targets for underground work. The Meadow tunnel cut the Silver King fissure 1200 feet (360 m) from the portal, revealing vein quartz and a little sulfide (Calkins and Butler, 1943, p. 106). The Garfield and Gustavus Adolphus fissures were similar narrow, strongly to moderately mineralized structures. The South Price tunnel cut extensive conglomeratic sandstone of the Mutual Formation. Minor sphalerite-galena-pyrite mineralization was noted on the dump.

On the Tar Baby level, the workings are partially in Paleozoic carbonate rocks. The lower portions of the Alta Overthrust zone have been cut, but not widely explored. Calkins and Butler, (1943, p. 107) state that good ore is said to have been taken from several places in these workings, but from fissures rather than bedded replacement deposits.

A granodiorite dike 30 feet (9 m) wide extends persistently through several mine workings. Geology on the Tar Baby level is shown by Calkins and Butler (1943, plate 33), and discussed in this report under structure.

Tar Baby (97, 98)

The Tar Baby Mining Company was incorporated in 1911, at the time when fissure ore production from the Cardiff was arousing new interest in Mill D South Fork. An upper adit portaled in a narrow portion of the gulch bottom, northeast of Montreal Hill, penetrated talus and Tintic Quartzite, and then followed the Alta Overthrust without finding ore. The Cardiff discovery prompted extensive exploration from a lower tunnel (elevation 8330 feet or 2540 m), which continued until the late 1930s or thereafter. In 1913 an air shaft was sunk to connect with the tunnel at 800 feet from the portal. Thousands of feet of drifting southward along the Alta overthrust zone found only a few hundred tons of high grade lead-silver ore. L.W. Hoskins, one of the last lessees, reported that one or more narrow ore-bearing fissures continued below the tunnel level (*Mining and Contractors Review,* October 13, 1936, p. 36). Heavy flows of water prevented their exploration at greater depth.

The Tar Baby lower tunnel provided a good exposure of the geologic complexity along the Alta overthrust zone. Calkins and Butler (plate 33 and p. 106-107) describe this structure, explored on three levels in the southern part of the workings:

Here the hanging wall of the overthrust is Tintic quartzite and the footwall Deseret Limestone, as in a large part of the Cardiff mine. In the drift to the north along the overthrust the hanging wall is still Tintic quartzite but the limestone footwall appears to be older than Deseret. It is uncertain where these older rocks come in because the bedding of the limestone converges northward with the fault or because branch overthrusts diverge northward from it; the latter hypothesis appears most probable . . . At any rate the overthrust apparently bends eastward, on a very short curve, near the middle of the workings, and in the drift that follows it eastward its footwall consists of Ophir shale. The Tar Baby dike here follows the contact for a short distance . . .

In the northern part of the lower workings there are a few reverse faults of low or moderate eastward dip whose hanging walls are of Ophir Shale or Maxfield Limestone. These faults are presumably lower branches of the overthrust, corresponding to those exposed in the cliff above the Frederick Tunnel (Little Cottonwood District). One reverse fault near the entrance to the American Metal branch (of the tunnel) dips westward and possibly represents the west limb of an arch in the thrust surface . . . (or) . . . a different, west-dipping overthrust, one or two of which have been found in other workings.

In the southern part of the Tar Baby workings, the Alta overthrust brings Tintic Quartzite over Deseret Limestone, and northeast-striking mineralized fissures cut the contact. The situation is very similar to that at the site of the Cardiff ore body, and may account for the persistence of the Tar Baby operators in driving tunnels. As Calkins and Butler state:

Several carloads of ore are said to have been taken from one of the fissures, but unfortunately the mineralization does not, to any great extent, either penetrate the quartzite or bed out along the contact. Years ago some ore consisting partly of

galena was taken from a raise where the overthrust bends eastward and is cut by the dike, but the precise relations and amount of this ore were not determined. All the ore taken from the Tar Baby property appears to have been taken from places near the main, or upper, Alta overthrust.

In comparing this property with the Cardiff (85, 86, 87) one can only note that it is farther from the Alta stock intrusive system, and that the mineralized fissures were considerably less productive above the thrust than was the Cardiff fissure. As most of the surface on the Tar Baby group is covered by alluvium the search for other mineralized fissures is difficult.

Price (Clara M) Group (100)

The Price group lies on the west side of Mill D South Fork, mainly north of Montreal Hill. Prospects on the Clara M claim of the group reportedly encountered weak mineralization in Tintic quartzite prior to 1900. In 1915 F. W. Price sold most of his holdings in the Cardiff property and organized a new company to seek a Cardiff-type ore deposit in this area. An upper adit had reached a length of 350 feet by 1916; a lower adit, from near the creek bed in Mill D South Fork, extended for more than 1000 feet without encountering significant ore. Some of the workings are shown on figure 19. By 1932 the property reportedly had a 2400 foot adit with a 300 foot raise. The last work on the property was done by Index Daley Mines, Inc., in the South Price adit.

The main rock type on the property is Tintic Quartzite, which is cut by the Alta overthrust fault south of the Carbonate mine (112, 113, 114). This fault here brings lower Tintic Quartzite over the upper part of the same unit and the lower and middle members of the Ophir shale. The 600 feet of the lower adit completed by 1919 were in quartzite below the thrust. (Calkins and Butler, 1943, p. 109).

Last Chance (95), Vina

The Last Chance and Vina claims are on Montreal Hill, and were located in the early days of the district. Calkins and Butler (1943, p. 109) state that ore is said to have been taken from replacement deposits in limestone near the top of the hill. In 1916 a tunnel was being driven south into the hill from above Vina flat. 150 feet (45 m) from the portal, a 4 inch (10 cm) streak of high grade was reported in 1918, but no large ore body was found.

Carbonate (112, 113, 114)

The Carbonate mine is on the rugged divide between Mineral Fork and Mill "D" South Forks. It is in the unsurveyed SW¼ SE¼ SE¼ of section 24, T. 2 S., R 2 E. with the main portal at an elevation of 9,960 feet (3,030 m) above sea level. The workings lie just south of Carbonate peak, which in turn lies south of Kessler peak.

Access to the workings was by means of several adits and shallow shafts (figure 20). The two main levels, the upper Carbonate tunnel level and the lower Homeward Bound tunnel level, are approximately 110 feet (34 m) apart. Several raises connect the two levels. Total length of workings is approximately 1,800 feet (549 m). The workings are now inaccessible.

History and Production. Production of lead-silver ore was considerable in the early years of the district. Ore shipped during 1878 had a grade of 55 to 65 percent lead and 50 to 60 ounces of silver to the ton. Later shipments were of considerably lower grade of lead and silver, but zinc was an important constituent (Calkins and Butler, 1943, p. 105).

The earliest discovery was on the Provo claim, located in November, 1870, reportedly on a "24 foot vein". By 1872, 200 tons of oxidized ore had been extracted from a 120 foot (37 m) incline (Murphy, 1872) by a New York company. The adjacent Sailor Jack and Homeward Bound claims to the north were being worked by the Deseret Silver Mining Company of Michigan. (*Utah Mining Gazette* March 21, 1874). A few years later leasers, hand picking the Provo dump, discovered the main ore body. Major production was achieved in 1877-78, and much of the ore was shipped to the Carbonate company's charcoal-fired smelter near Hilliard, Wyoming. Calkins and Butler cite figures from the *Salt Lake Tribune* regarding the metal content of shipments to the smelter: in 1877 (4 months), 932 oz Au, 168,813 oz Ag and 2,590,263 lbs Pb were received and in 1878, 513 oz Au, 164,848 oz Ag and 1,698,670 lbs Pb.

According to the *Engineering and Mining Journal* (January 11, 1879, p. 30-31) the main Carbonate stope of the mine was 60 ft. x 20 ft. x 26 ft. high and had yielded 4,208 tons of ore and no waste to date. That ore was worth $61 per ton, average, and assayed 55-65% Pb and 50-60 oz Ag per ton. Stopes on the Sailor Jack fissures, being worked from the Baker tunnel, had yielded an additional $100,000. The Cave stope, connected by drift with the Carbonate stope, measured 30 x 10 x 9 feet high and had yielded 400 tons. The discovery glory hole, on the west side of the ridge, 250 feet below

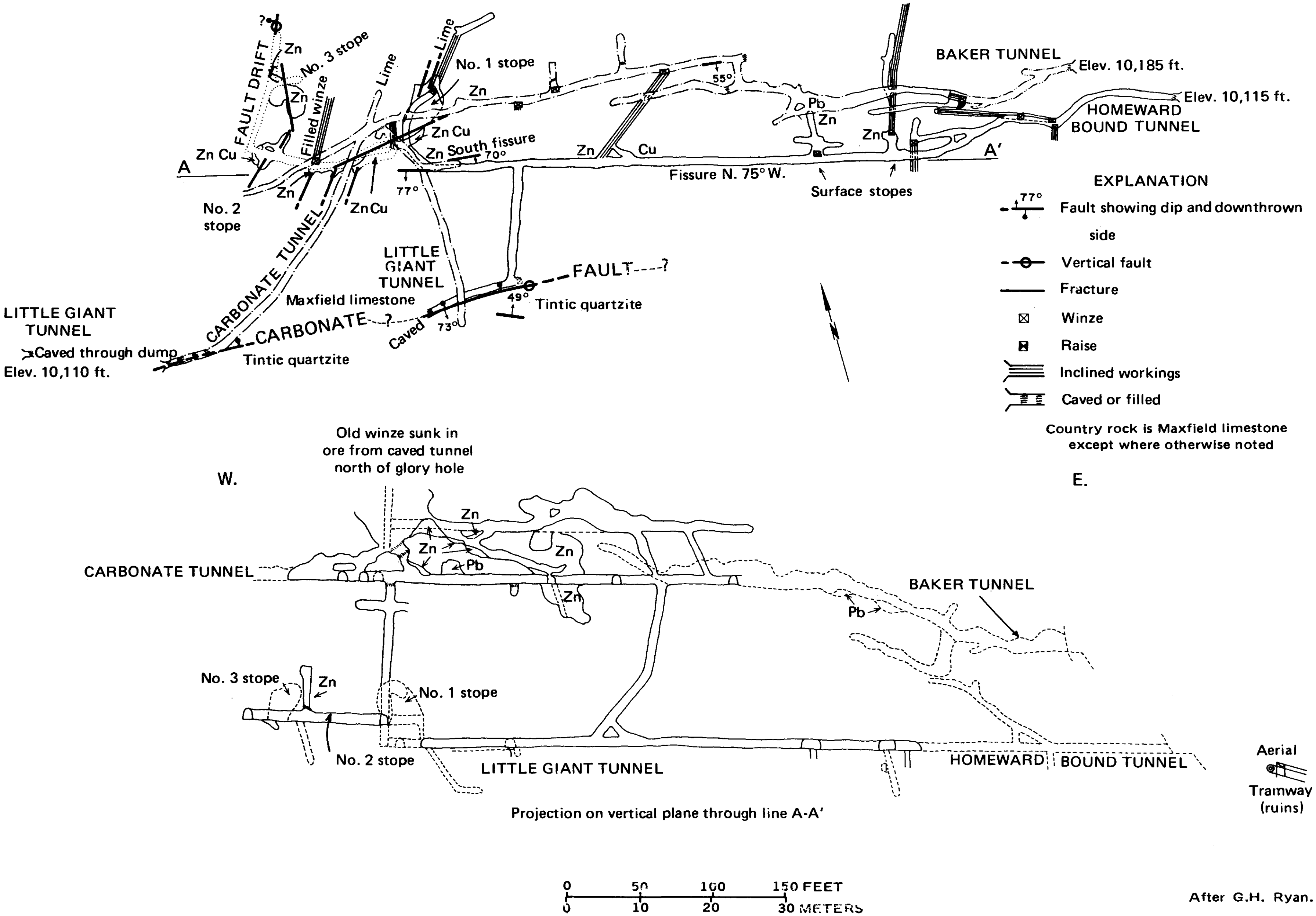


Figure 20. Plan and Sections of Carbonate mine.

the crest, revealed an ore body 28 feet (9 m) wide. The Kessler Mining and Smelting Company of New York purchased the mine, planning to mine further ores from these excavations. Huntley (1880, p. 430) noted that the largest body was lenticular in shape, had dimensions of 200 x 100 x 50 feet and it was timbered by 365 square sets. Leasers were operating the mine by 1884 (Director of the Mint, report for 1884, p. 422). Minor work was under way in the early 1900s, and during 1910 some ore apparently was produced by E. R. Woolley and associates (*Salt Lake Mining Review*, July 15, 1910 and other issues). Woolley, noted as a flamboyant promoter, was apparently the source for the total production figure of $1,250,000 quoted by Calkins and Butler.

Transportation to and from the mine was at first via two trails, one from Argenta extending up the north and northwestern slope of Kessler Peak, and the other from Mill D South Fork. Shipments were sent down these trails on cowhides, apparently often atop a coating of ice. Forty to sixty tons per day were shipped during the winter of 1878 until snow closed the roads (*Engineering and Mining Journal* v. 25, p. 201, March 23, 1878). In about 1911, Robert Stevens erected a "jig-back" aerial tramway, utilizing a continuous cable passing over a wooden drum at the mine, and two counter-balancing buckets. The last operations at the mine, conducted by James W. Wade, George H. Ryan, Ben F. Tibby and D. Fenkell, used this tramway to transport ore and supplies to and from a flat near the Price tunnel, Mill D South Fork (J.W. Wade, personal communication 1963). Production between 1913 and 1916 totaled 658 tons, most of it averaging 23.6% recoverable zinc. This was the last ore mined from the Carbonate group.

Geology. The Carbonate mine is localized in a block of spotted, mottled lower Cambrian ("Reed and Benson" member of Ophir Shale) limestone, flanked by Tintic quartzite on the south, east and west. A branch of the Alta Overthrust crops out south of the deposit. Heyl (1963, p B-45, B-46) describes the geology and potential reserves of the mine:

> At the Carbonate mine the ore bodies are mostly along several subsidiary fissures that strike N. 75°W., and dip steeply southward parallel to the Carbonate reverse fault, which is 100 feet to the south. Other mineralized fissures in the western part of the mine strike northward, and some of the largest ore bodies are at the intersections of these two fissure systems. During oxidation the zinc and some of the copper migrated outward and downward from the primary ore bodies and replaced certain beds of mottled Maxfield limestone adjacent to the fissures (Calkins and Butler, 1943, pl. 32, section B-B').
>
> East of the glory hole in the main lead ore body, the northward--striking cross fissures are weak and most of the oxidized lead and zinc ore bodies are in pod-shaped shoots or pipes that pitch 10 or 20° E. along the eastward-striking fissures. Several of these pipes, which are elongate oxidized lead ore bodies having zinc carbonate shells, occur one above the other in the fissures; they apparently join westward into one large pod, which rises gently upward into the eastern base of the glory-hole ore body.
>
> East of the base of the glory hole, beneath the lead stopes, is a large podlike ore body of rich zinc carbonate that has filled and replaced the fissure walls to a width of 2 to 6 feet. This zinc ore body curves shaply downward to the east and grades into leaner zinc carbonate ore with depth. It is still present in the Homeward Bound tunnel below. G. H. Ryan, who operated this mine for the oxidized zinc ores, states that in the deepest part of this main zinc stope the high-grade band of ore in the center was still 2 feet wide and had a marginal shell of low-grade zinc carbonate and copper-zinc carbonate (aurichalcite) material, the latter being outermost (oral communication, 1953). The overall grade of the ore that was shipped from the bottom of this stope was 26 percent zinc. The Carbonate mine is unusual because aurichalcite has been produced as a principal ore.

Minerals noted at the mine include galena, cuprite, azurite, malachite, aurichalcite, smithsonite, cerussite, and brown limonite rich in zinc. Iron oxides are abundant, but quartz was apparently not common in the ore. A possible small resource of gallium is indicated (table 8) by grab samples from boulders of goethite and oxidized lead and zinc minerals from the dumps of the Little Giant and Carbonate adits, on the west side of Carbonate Peak.

Howell Mine (88, 89) Baby McKee (90)

The Howell group lies south of Big Cottonwood Canyon on the eastern side of Mill D South Fork. The portal of the lower adit of the mine is approximately 2,600 feet (800 m) southeast of Montreal Hill, just west of the Cardiff main adit. It is located in the SW¼ NW¼ NW¼ of section 21 T. 2 S., R. 3 E. at an elevation of 9,200 feet (2,800 m) above sea level.

Ore discovery at the Baby McKee mine was made in the early 1890s. The report of the Director of the Mint for 1892 indicates 70 tons of ore were produced that year. Development, financed by Capt. A. H. Mayne and Judge W. J. Herrick of Chicago, was through an inclined shaft equipped with a steam hoist. In 1907 the Park City Mining and Power Company installed a water powered compressor and drove the upper adit beneath the old shaft (*Salt Lake Mining Review*, September 15, September 30, 1904, April 30, 1907, August 15, 1908, et seq.). This adit exposed galena and carbonate ore 135 feet below the old shaft. In 1910 Congressman Joseph Howell and his son obtained the property (*Salt Lake Mining Review*, July 30, 1911, April 15, 1916). The 2,500 foot (760 m) lower adit was begun to follow the fissure at greater depths (Calkins and Butler, 1943, plate 34). In the 1930s, work was begun in Howell ground from the face of the American Metals branch of the Tar Baby tunnel, at still greater depth (Mining and Contracting Review, May 1, 1934). Small raises and extensive tunneling in this area found only a few tons of ore.

During these prospecting operations, intermittent production was achieved by leasers and the company from raises and winzes following steeply dipping ore shoots in the upper tunnel level. Most of the workings on the property, all presently inaccessible, are on the Baby McKee fissure (figure 21). Prospecting was attempted on the Alta overthrust on the lower levels. Other mineralized fissures were prospected on the lower tunnel level (Calkins and Butler, 1943, p. 109). Production from the mine clearly has not been large.

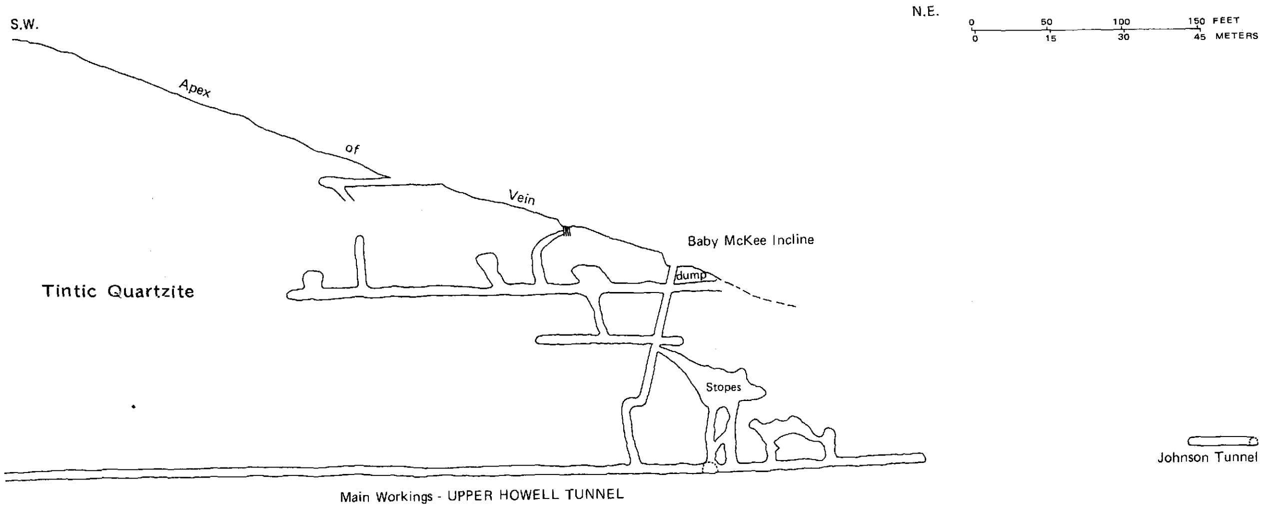


Figure 21. Section through upper (Baby McKee) workings, Howell Mine.

The main and upper tunnels are largely in Tintic quartzite, and follow a zone of sericitization, pyritization and crystalline quartz associated with the fissures. In outcrop, the Baby McKee fissure is 15 to 80 cm. in width, and contains crystalline quartz and some pyrite and sericite. The main (lower) tunnel passed through the Tintic quartzite and into the underlying tillite and conglomerate of the Mutual formation (Calkins and Butler, 1943, p. 109), which now comprise much of the dump of this adit. The northernmost part of the property, prospected from the American Metals level, lies partially east of the West Superior fault and hence in Paleozoic carbonate rocks.

Minerals noted on the dump include coarse galena, pyrite, sphalerite, chalcopyrite, and secondary carbonates and oxides of lead and copper. Ore potential in areas thus far explored appears to be small.

Cardiff Mine (85, 86, 87)

The Cardiff mine is located on the south side of Mill D South Fork and west of Reed and Benson Ridge. The main (600 level) adit is located in SW¼ SE¼ SW¼ of section 30, T. 2 S., R. 3 E, at an elevation of approximately 9,080 feet (2,768 m) above sea level, near the creek bottom.

History. Mineralization was prospected near the head of Mill D South Fork prior to 1900 by the South Fork Consolidated and Jones mining companies. Thomas B. Jones, a persistent prospector, began work there in the 1880s. When Jones' principal backer finally died in 1902, control of the property fell to Fred W. Price, a native of Cardiff, Wales, who organized the Mountain Chief Mining Company. A shaft was sunk on a persistent mineralized fissure near its junction with the large East Superior fault zone, in a small cirque at the southeast end of the fork. In January 1906 a snowslide smashed the shafthouse and ended operations (*Salt Lake Tribune* January 25, 1906).

The new Cardiff Mining and Milling Company was formed to finance a deeper adit, the No. 3 or 300 level, from a safer location. The tunnel, begun in the summer of 1907, encountered a 15 inch (60 cm) wide zone of high grade copper-silver ore in Tintic quartzite at about 1,400 feet (427 m) from the portal. Exploration showed that this zone, known as the Cardiff fissure, strikes N 50-60° E and dips about 70 degrees north. Small scale production was begun, reaching 150 tons per month in 1911 (*Mining World, February 1911).*

A lower (600 level) adit was driven toward the same zone, as discussed in the section on history. The Alta overthrust zone was encountered by the adit, but was barren. The tunnel was continued ahead along the thrust (figures 22, 23) under the burden of dozens of stock assessments. Production continued on a small scale from several 140 foot (42 m) raises and shallow winzes, one 85 feet (26 m) below the upper tunnel. The mine was the major producer of the district. In September 1913, minor streaks of ore were reported at 1,350 feet (411 m) from the portal (*Mining World,* September 30, 1913). Work continued through the winter. In the fall of 1914, reportedly on October 15, at 2,400 feet from the portal, the adit entered a large ore body in crushed limestone at the intersection of the Cardiff fissure and the Alta overthrust fault. A raise above the 600 level also followed very high grade silver lead ore (*Salt Lake Mining Review,* June 15, 1915, November 30, 1914, p. 15). The ore body soon proved to be the largest yet discovered in the district, averaging ten feet (3 m) thick and following the plunging intersection of the thrust and the fissure for more than 300 feet (90 m) in horizontal plan.

Stoping was conducted to below the 1,500 level (504 feet, or 154 meters, below the 600 level portal) along the intersection of the Cardiff fissure and the overthrust, in several Paleozoic carbonate lithologies. A vertical shaft and an 1,180 foot (360 m) 25 degree incline serviced these levels. (E.W. Newman, personal communication, 1976). Other ore bodies were later found on the thrust contact at its intersection with other fissures; one of these bodies, the No. 1 vein, 800 feet (244 m) south of the main incline, was 5 feet thick and 9 feet wide (1.5 x 2.7 m) and was continuous for a horizontal distance of over 200 feet (61 m) along the strike of the fissure (Calkins and Butler, 1943, p. 110).

By the late 1920s, known economic ores were exhausted. Stopes below the 1,500 level ended in a narrow fissure zone (E.W. Newman, personal communication, 1977). Geologic work by R.T. Walker led to discovery of one small faulted ore body on the intermediate levels. In 1935-1937 the company and leasers dewatered the lower workings and shipped as much as 20,000 tons from the Greek (Kolovos) Winze and old stopes. The Cardiff Deep Mines Company attempted to again dewater these workings in 1950, without success. Average grade of the bulk of the Cardiff production appears in table 11-a.

Commencing in the summer of 1955, W.H.H. Cranmer and others promoted the one mile extension of the Wasatch Drain Tunnel (portaled on the Snow Bird claim at the mouth of Peruvian Gulch, Little Cottonwood District) beneath the Cardiff stopes. The drain tunnel at that time extended for more than a mile to connect with the bottom of the old Columbus Consolidated mine of the Little Cottonwood district (figure 22) (Calkins and Butler, 1943). A new plant was erected at the tunnel portal. Leases were obtained on adjoining properties. Extension of the north lateral followed the overthrust zone. A small ore body was first encountered on the Hillside claim, apparently at the intersection of the main fissure zone of the Columbus Consolidated mine with the overthrust (figure 24). Other small ore bodies and finally the Cardiff fissure were encountered, yielding only a few thousand tons of ore. Development and equipment costs to June 30, 1959 were reported as $843,867. Drilling failed to encounter the bottom of the flooded Cardiff stopes above. J.J. Beeson (personal communication, 1964) was finally employed to map the mine, and connection with the old workings was made via a series of raises. Leasers extracted ore from above the drain tunnel until 1967. Apparently the best ores came from several small "blind" ore bodies along the overthrust zone in the general vicinity of fissures that had produced on higher levels. As suggested by table 11-b, ore from the drain tunnel level was of similar grade to that mined from the old Cardiff workings. In the down-dip extension of the Cardiff body, the best assay from one face ran 37.8 oz/ton silver, 26.6% lead, 5.02% copper and 35.6% zinc (*Salt Lake Tribune,* October 6, 1960). One 66.59 ton shipment the following summer yielded a net return of $84.45 per ton, and assayed 0.014 oz gold per ton, 32.1 oz silver per ton, 4.13% copper, 21.3% lead, 16.1% zinc and 0.95% arsenic. (*Salt Lake Tribune,* April 5, 1961, July 28, 1961).

The following autumn, an inclined winze was sunk about 170 feet (52 m) on the Cardiff fissure at its intersection with the hanging wall of the overthrust. Samples from two railroad cars of ore from the winze assayed 0.20 oz per ton gold, 27.9 oz per ton silver, 18.9% lead, 3.45% copper and 7.6% lead. According to C.A. Steen, who financed the work, the ore body reached a thickness of 9 feet (3 m) and a width of 12 to 14 feet (3.6-4.3 m) at a depth of 27 feet (9 m) below the drain tunnel (*Engineering and Mining Journal,* September, 1961). The fissure varied considerably in width below the drain tunnel, and ore was largely confined to quartzite. Very little bedded replacement was observed here, and ore terminated against a fault. A total production of between $500,000 and $600,000 was achieved from the Cardiff operations through the drain tunnel (J.J. Beeson, personal communication). Total production by the Cardiff company totals nearly 170,000 tons of ore (Table 11-a).

In September 1966, during the writer's last visit to the mine, exploration was being conducted near fissures crossing the thrust zone a few hundred feet (50 m) north-northeast of the Cardiff, on the drain tunnel level. The working face exposed a narrow fissure containing lead, zinc and copper mineralization, while a 25 foot (8 m) raise and short drift about 50 feet (16 m) to the southwest had yielded small tonnages of ore. The lease allowing access through the drain tunnel was terminated during the smelter strike of 1967. Equipment was removed from the mine, and no work has been done since.

Production. A summary of production from the Cardiff mine appears in table 11-a. Records to 1926, covering the bulk of production are believed to be complete. Operations from the drain tunnel-level after 1959 yielded ore from several properties, and the bulk of this production came from ground beneath or on strike with the old Cardiff ore body. From 1959 to 1962 Utah smelter records indicate 5,546 tons milling ore and

Table 11a. Production from the Cardiff Mine, Big Cottonwood district, 1910-1967: Recovered metals. (From: U.S. Bureau of Mines, unpublished data and unpublished report).

Period	Dry short tons	Gold (oz)	Silver (oz)	Copper (lbs)	Lead (lbs)	Zinc (lbs)
1910-1950	139,125	6,612.4	2,347,372	2,706,401	65,199,030	3,567,542
1951-1957*	689	3.0	3,555	2,347	73,013	212,800
1958-1967	22,838	237.0	344,762	856,474	6,091,350	5,700,562

*No production 1952-1955.

Table 11b. Average grade of partial production from the Cardiff Mine, Big Cottonwood district, 1910-1961.

Period	Dry short tons	Gold (oz/ton)	Silver (oz/ton)	Copper %	Lead %	Zinc %	Iron %	S%
1910-1926[1]	108,443.	–	17.73	0.83	8.26	26.74	9.51	
1927[2]	1,138.	0.01	21.3	2.3	19.7	16.3		
1959[3,4]	8,534.46	0.009	1.87	0.37	6.57	8.95		
1960[4]	9,726.36	0.008	3.10	0.46	7.35	9.09		
1960[5]	830.17	0.011	20.99	2.79			2.97	11.54
1961[4]	2,703.46	0.009	4.88	1.00	10.34	14.18		
1961[5]	6,136.39	0.013	23.25	2.99	15.92	14.79	3.34	6.95
1962[6]	2,203.							

[1] Compiled by R.T. Walker from Cardiff company records. Net smelter return $3,560,115.52.
[2] Shipped to U.S. Smelting and Refining Co. custom mill. Midvale, Utah. Total production was 3,099 tons.
[3] Unpublished U.S. Bureau of Mines and *Mineral Yearbook* figures for 1927-1956 total 27,318 tons.
[4] Milling ore (same as 2) produced from drain tunnel level - some years probably include ore from Columbus Rexall fissure area.
[5] Direct smelting ore shipped to Tooele plant. May include minor ores from Columbus Rexall stope area as in (4).
[6] Milling and direct smelting ore, as above, from Cardiff, Kennebec, Hirschman properties.

4,300 tons direct smelting ore, some of which is included in table 11-a, from the Cardiff property alone. The Hirschman (old Eclipse) claims contributed an additional 3,655 tons of milling ore from Cardiff drain tunnel level operations during this time, while the adjacent Kennebec contributed 7,666 tons of mill and direct smelting ore. At least some ore from this period was shipped to Tacoma smelter.

The mine had paid $1,025,000 in dividends by 1925, and a total of $1,082,500 in dividends to 1958 (*Denver Mining Record*, November 13, 1958),

The Cardiff mine reached maximum production (18,781 tons) in 1916 and produced as much as 150 tons per day during the summer season in the 1917-1924 era. The mine operated year round, obtaining supplies and mail in winter either via the connecting Columbus Consolidated tunnel from Alta or occasionally by parachute. The Beefsteak Raise was driven from the main tunnel to the two company boarding houses on the flat above the portal, to provide winter access to the workings.

Geology. Surface rocks on the productive portion of the Cardiff ground, east of the East Superior fault, are Tintic Quartzite and Ophir shale. To the west, in the upthrown block between the Superior faults, the limestone of the lower plate of the thrust is exposed. (Calkins and Butler, 1943, p. 110). The 600 level exposes Deseret Limestone and older formations beneath the thrust. The greatest ore production reportedly came from Deseret Limestone, but deeper units have been productive. Calkins and Butler (1943, plate 35) provide some more detail regarding ore control. Ore from above the lower (600 level) tunnel apparently occurred as lenses partially replacing beds in quartzite, and as filling in the adjacent Cardiff fissure. The ore deposit was thus an irregular replacement body in limestone sandwiched between overlying and underlying Tintic Quartzite which contained fissure ores.

Major sulfide minerals in the ore were galena, pyrite, sphalerite, enargite, and tetrahedrite in varying proportions. (Calkins and Butler, 1943, p. 110). The last ores mined from the drain tunnel level contained these minerals and yielded nearly equal dollar returns in lead, silver, copper and zinc (J.J. Beeson, personal communication, 1966). Oxide ores were increasingly abundant above the 1,500 level and occurred locally even below the drain tunnel level. Most of the ore contained copper carbonates; lead oxide was said to be present locally. The most oxidized ores from the main workings consisted of cerussite and "limonite", plus plumbojarosite and residual galena (Calkins and Butler, 1943, p. 110).

Gangue minerals on the drain tunnel level included pyritohedral pyrite, acicular quartz, crystalline dolomite, and a soft adamantine talc-like material. Ore along the overthrust zone here filled narrow fractures in altered carbonate rocks.

Potential remains for further ore in the mine, notably in the overthrust zone on and below the Wasatch Drain Tunnel Level (J.J. Beeson, personal communication, 1968). According to Heyl, "Oxidized zinc ore is abundant in the upper levels of the Cardiff mine, especially in the western part near the edges of the deposit. This is mostly smithsonite that contains manganese, iron, and copper in such quantities that it has been difficult to fume economically using present (1952) methods" (1963, p. B-46). Oxide ore production ceased in 1951, when smelters refused to purchase such ores (*Minerals Yearbook*, 1952). A small tonnage of sulfide zinc ore is believed to have been left unmined in the lower workings.

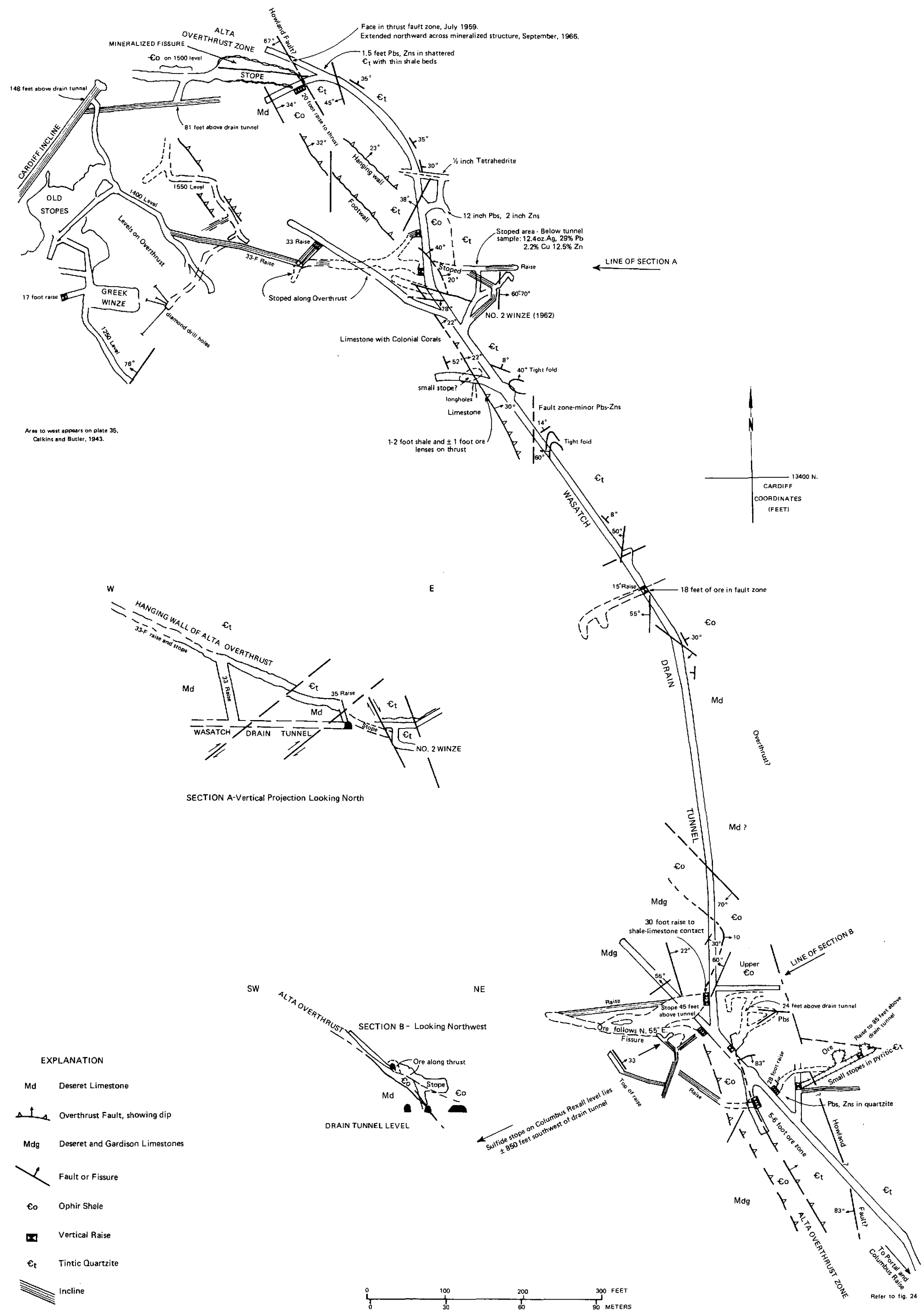


Figure 22. Geologic map of Main Stopes, Cardiff and Columbus Rexall mines.

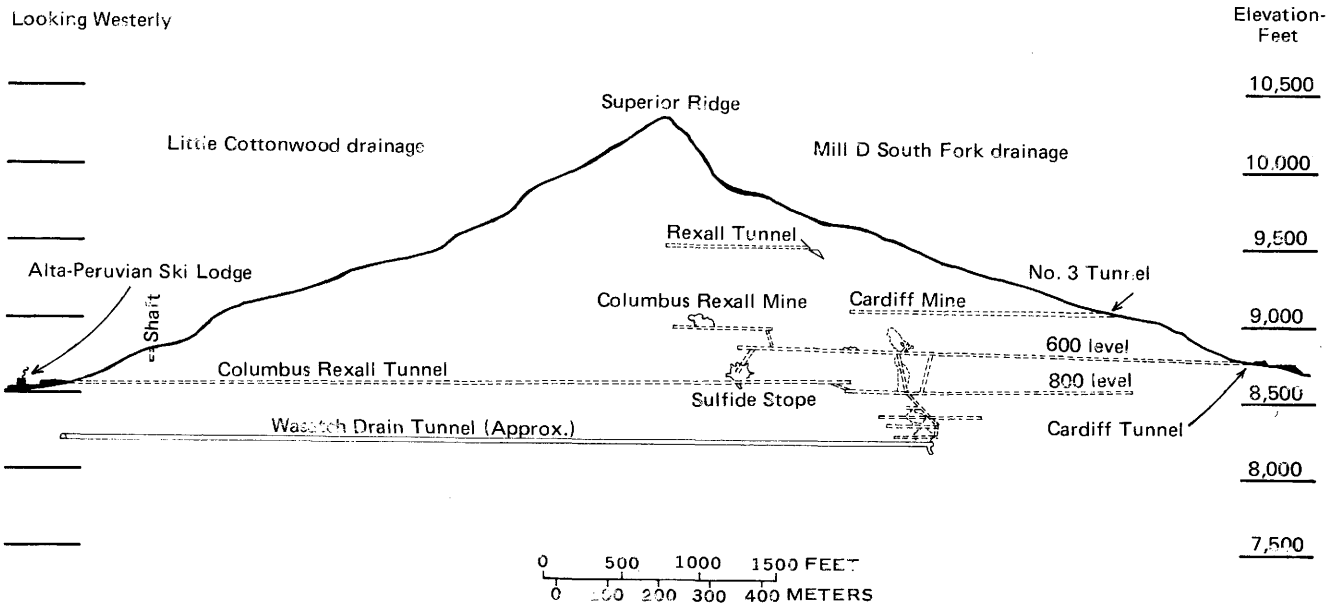


Figure 23. Cross section through Cardiff and Columbus Rexall mines.

Columbus Rexall (120)

The main ore bodies (no. 10 ore zone) of the Columbus Rexall mine are located beneath the northwest flank of Flagstaff Mountain and the basin at the head of the eastern branch of Mill D South Fork. Like the Cardiff, the Columbus Rexall ores occurred at the intersections of fissure with the Alta thrust zone. Since they were discovered and mined through adits from Alta, and since they lie nearly beneath the divide between Big and Little Cottonwood districts, production from them has generally been credited to the latter district. The portal of the main access adit is located just above the Alta highway, north of the Alta Peruvian Lodge, in the NW corner of unsurveyed section 5, T. 3 S., R. 3 E.

History The Rexall mining company was organized early in the twentieth century to prospect an unusual mineralized structure at the head of Mill D South Fork. One thousand feet of tunnel, portaled in what is now recognized as the Columbus thrust fault, failed to find commercial ore. On the Alta side of the divide, meanwhile, the Columbus Extension mining company was driving a long adit northward from a branch of the Howland tunnel of the Columbus Consolidated mine, seeking the Toledo fissure. Only minor production was attained.

In 1915, following the Cardiff discovery, the two groups combined as the Columbus Rexall Consolidated Mines Co., and drove the Columbus Extension adit northward into the Big Cottonwood district. Morris R. Evans, a veteran operator of the region, directed the work. In July 1917 a rich ore deposit was found in the Rexall ground. The discovery was hailed as a major find (*Salt Lake Mining Review*, January 15, 1918, p. 50). It was localized in Deseret Limestone beneath the Alta overthrust zone, and thus similar to the Cardiff. A raise was put up along the thrust zone toward the old Rexall workings to the west, and sublevels were driven in search of more ore. (Calkins and Butler, 1943, plate 35). About 160 feet above the level (400 feet on the incline), a second ore body was found beneath the old Rexall tunnel, in a similar geologic setting (*Salt Lake Mining Review*, June 15, 1920, p. 27-29). To the north, some ore was mined from the "south stope" along a steep fissure beneath the overthrust. The zone containing all of these ore bodies was known as the No. 10 ore shoot.

The workings were connected with the Cardiff mine some 70 feet (21 m) below early in 1920, and some ore was mined from the connecting winze. Production from August 1917 to March 26, 1920 totaled $276,215, with much of the second ore body remaining unmined. (*Salt Lake Mining Review,* June 15 1920, p. 29). Net smelter returns from 1917 to 1926 totaled $837,118.40 (Private report by R.T. Walker) and dividends to the end of 1933 totaled $79,196.88 (*Mining and Contracting Review,* September 25, 1934). Incomplete data from *Minerals Yearbook* indicate a small, intermittent production from the mine until the 1950s. Table 12 summarizes available production data.

Potential remains in a few areas for discovery of small high grade ore bodies. An unpublished report by R.T. Walker based on work during 1924-1925 predicted that as much as 46,000 tons of "potential" ore might be developed beneath the drain tunnel along three fissures in Columbus Rexall ground, partially in the Little Cottonwood district. Exploration and mining conducted in this general area from the drain tunnel, between 1958 and 1965, yielded nothing approaching these tonnages.

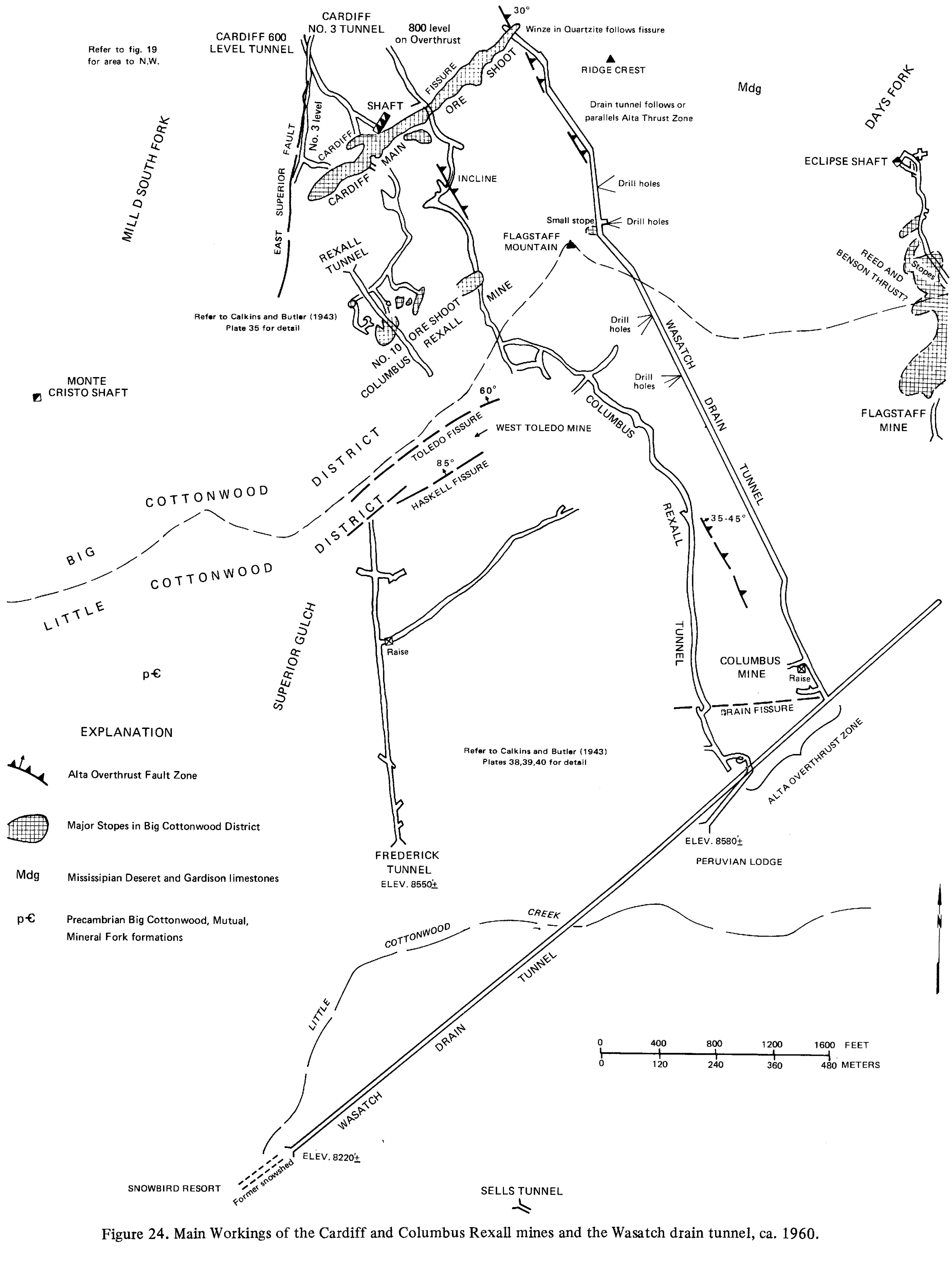


Figure 24. Main Workings of the Cardiff and Columbus Rexall mines and the Wasatch drain tunnel, ca. 1960.

Geology The ore deposits of the Columbus Rexall mine occur in the same structural setting as the Cardiff mine, at the intersection of steep fissures with limestones in the Alta thrust zone. This is illustrated on figure 24, which shows stopes on the Wasatch Drain tunnel level. The larger stopes above, on the Columbus Rexall tunnel level, lie just beneath the Tintic quartzite at the top of the thrust zone which, according to Calkins and Butler:

> is here a simple fracture bringing the quartzite directly upon the (Gardison) limestone. So far as developed, the largest ore body extends up the contact in a direction a little north of west, apparently along a fissure that does not correspond to the prevailing strike of the ore fissures of the district. There are several northeast fissures in this area, but none of them have thus far been shown to be closely connected with valuable ore bodies (1943, p 118).

The metal content of the ore from the Columbus Rexall mine is strikingly different from that of most other mines of the district. The ore was most valuable for copper and had also a high gold content, as shown in table 12. Pyrite was abundant, and considerable tonnages were encountered that contained insufficient metal credits to constitute ore (Calkins and Butler, 1943, p. 118). The lining of one ore body, the "Jewel stope", was a mass of glittering crystalline pyrite. Other ore minerals were tetrahedrite, enargite, bornite, galena, and chalcopyrite with a little quartz and siderite gangue. Most of the ores were not oxidized.

Monte Cristo (91)

The Monte Cristo and Horseshoe claims are located in the broad cirque at the west side of the head of Mill D South Fork. A small shaft, at one time equipped with an electric hoist, is the major opening on the property. The shaft is collared in talus.

The fissure developed by the shaft may extend north-south (*Salt Lake Mining Review,* August 15, 1907). The shaft cannot be more than 200 feet (60 m) deep. Tetrahedrite or a similar mineral was found on the dump, which consists mainly of Tintic Quartzite. No production is recorded.

Neva (92)

The Neva Mining Company held five claims between the Monte Cristo and Cardiff, which were under development in 1915-1925 era by a shallow incline and a short adit. The company won title to the eastern portion of its property in a lawsuit with the Cardiff Mining and Milling Company, but never found ore on its property.

Reed and Benson (Kennebec) Mine (82)

The old Reed and Benson mine is high on the west side of Mill D South Fork (Cardiff Fork), just north of Flagstaff Mountain. It was later known as the Kennebec Consolidated group, and was explored through deeper adits, including the Kennebec, Cardiff, and Wasatch Drain tunnels. The largest production came from an adit and shafts in the NW¼ SE¼ NE¼ of section 31, T. 2S., R. 3 E. high on Reed and Benson Ridge at an elevation of about 10,070 feet (3, 070 m) above sea level.

History and Production. The mine was discovered in August 1870. In the summer of 1973 it was producing 10 tons per day (*Utah Mining Gazette,* July-September 1973). By the fall of 1873 the mine was producing 15 tons per day of "gray carbonate" and galena ore from an adit, which reached the vein at 400 feet (122 m). A 400 lb. specimen of the ore, put on display in Major H.C. Goodspeed's office in Salt Lake City was known as the "Uncle George." It reportedly assayed about 70% lead and 500 oz. silver per ton. (*Utah Mining Gazette*, October 11, 1873; December 6, 1873; Raymond, report for 1873) A series of four irregular inclines followed the ore downward, and had reached a depth of 600 feet by 1874. The ore was then described as being very ferruginous, containing about 25% lead and over 50 oz silver per ton. (Raymond, 1874).

By 1880 the mine was opened 1,100 feet (336 m) down the 35° dip by a series of irregular inclines, following the ore chimmey. Near the surface the ore extended 100 feet (33 m) in a horizontal direction, but its dimensions decreased with depth. (Huntley, 1884). The difficulties associated with hoisting ore up four in-

Table 12. Partial production from the Columbus Rexall mine.

Source of Production	Date	Weight-dry short tons	Gold oz/ton	Silver oz/ton	Copper%	Lead%	Zinc%	Iron%
Sulfide Stope	1917-1918[1]	1,900	0.286	32.9	13.9	(?)	3.8	
Total	1917-1926[2]	29,847	0.020	16.03	3.41	18.46	*	30.8
All or largely from Wasatch Drain Tunnel	1959-1962[3]	8,223						

[1] Calkins and Butler, 1943, p. 117-118; other tonnage figures also given.
[2] R. T. Walker, private report, 1927.
[3] Shipped to Midvale mill, U.S. Smelting, Refining & Mining Co.
* Not tabulated, but present in varying amounts. 1926 production averaged 8.1% Zinc.

clines with windlasses, and then up a final shaft with an underground (horse-powered) whim hoist, soon led to plans for a deeper adit.

In 1875 Major H. C. Goodspeed, president and manager, began a long tunnel at an elevation of about 9,170 feet (2,795 m) to pass beneath the old workings. (Huntley, 1884). Substantial buildings and the latest steam-driven ventilating fan were installed at the portal. Electrically-driven rock drills were said to have been used (*Salt Lake Mining Review,* July 31, 1899, p. 5, August 15, 1902, p. 15). The tunnel was driven more than three thousand feet (920 m) southeasterly (figure 24), but failed to find a downward continuation of the ore. Work reportedly ceased in the 1880s when Goodspeed died and his Boston backers lost interest.

W.J. Craig, a prominent Bingham mine and smelter operator, reincorporated the mine as the Kennebec Consolidated company in 1901. An intermediate level, the Craig tunnel, was driven just beneath the old incline; it, too, failed to find ore (*Mining World,* May 30, 1915). Craig conducted the last work in this tunnel in the 1920s single-handedly, hoping to connect with the old workings above. Thousands of feet of workings were driven along the Alta overthrust fault from the 800 level of the Cardiff mine in 1919-1923, in Kennebec ground (Calkins and Butler, 1943, p. 109, plate 35). Still deeper exploration from the Wasatch Drain Tunnel Cardiff drift led to the mining of small quantities of high grade lead - zinc-silver sulfide ore (J. J. Beeson, personal communication, 1965). Production and exploration ceased here in the late 1960s.

Several smaller oxidized base metal deposits were explored on or adjacent to the Kennebec property. The Ophir, a parallel claim to the southwest, was operated steadily from 1870 to 1880. Huntley (1884, p. 429) described it:

> The ore is found in three bodies in a 30 foot stratum of compact dark-blue limestone . . . The outcrop was a pipe 2.5 feet in diameter . . . The shape of the bodies is that of a flattened or elongated ball, the largest being 15 by 20 feet. They are 4 and 10 feet apart . . . Total cuttings did not exceed 700 feet. During the census year 173 tons of ore, similar to that of the Reed and Benson, except that it was of lower grade, assaying only about 45 percent lead, 42 ounces silver, with 3 percent of moisture, were sold for $8,581. The previous product was estimated at $22,000.

The Excelsior claim, also adjacent to the Reed and Benson, was worked in the early years of the district. The adjacent Sampson claim (79), high on the ridge, was developed by a shaft following a zone of iron oxides, and had about 500 feet (150 m) of workings and one chimney of low grade ore. The St. Louis Tunnel, 700 feet (210 m) long in 1880, was intended to develop this mine at depth (Huntley, 1884).

On the east side of Reed and Benson Ridge, the Sunny Side claim, developed by an incline 108 feet (33 m) deep connecting to a level and a drift, exposed two galena-bearing veins in 1873. The veins reportedly assayed 40 oz silver per ton and 55% lead. Similar ores were being developed at the Independence and Pacific claims nearby. (*Utah Mining Gazette,* March 28, 1874).

Huntley, 1885, p. 429) states that the total production from the Reed and Benson mine was claimed to have averaged 120 ounces silver per ton and 35 percent lead. A total value of $300,000 to $500,000 for these ores is cited in various old mining publications (e.g. *Union Pacific R.R.,* 1891, p. 60). Only minor production has been achieved since, largely by lessees. Production from the Wasatch Drain Tunnel is discussed in the section on the Cardiff mine. The Alta St. Louis company, apparently operating the St. Louis Tunnel (73) in Days Fork, reportedly shipped some sacked copper-silver ore from a limestone-shale horizon in 1905 (*Salt Lake Mining Review,* July 15, 1905).

Geology. Cambrian Tintic Quartzite, Ophir shale, Maxfield Limestone and the overlying Mississippian carbonate rocks crop out on the property. Some of the lower carbonate units have been repeated by the Reed and Benson thrust zone. As far as could be determined, the ore deposits high on the ridge occur in spotted, mottled beds of the Maxfield Limestone known locally as the Reed and Benson limes, in areas where northeasterly fissures intersect the beds. (Calkins and Butler, 1943, p. 108). The largest bodies apparently occur along the thrust plane (figure 25). Henry Sewell, writing to the *London Mining Journal,* described the early ore bodies: "The Reed and Benson is a fissure vein, cutting strata and joined at a depth of 60 feet by two strata veins where the large chamber of ore was discovered . . . To a depth of 150 feet, the maximum width of ore and vein matter was 15 feet, while an average width of 260 feet was attained at a depth of 600 feet. . . "(*Utah Mining Gazette,* December 13, 1873).

Ore minerals seen at the mine included abundant goethite, cerussite, and some hemimorphite at the upper workings, and galena, chalcopyrite, tetrahedrite and sphalerite from the Wasatch Drain Tunnel. Gangue minerals here included crystalline quartz, pyritohedral pyrite, and small amounts of an unidentified very soft pink mineral.

Reynolds Gulch - Days Fork

Cottonwood Grand Central (20)

The Cottonwood Grand Central ground, surveyed but not patented, is on the east slope of Reynolds Gulch, north of Big Cottonwood Creek. In 1924 the main tunnel, elevation 7,440 feet (2,270 m) was 840 feet in length, while the lower tunnel, situated above the present highway, was 250 feet in length (*Mines Handbook,* 1924). In February 1919 a 50 foot raise along a fissure above the main tunnel yielded assays of 7% lead and 1.6 oz silver per ton according to the *Salt Lake Mining Review.* There is no record of production from the property. Its operators, experienced miners, always found "enough encouragement to keep everyone excited" (R. S. Gray, personal communication, 1961).

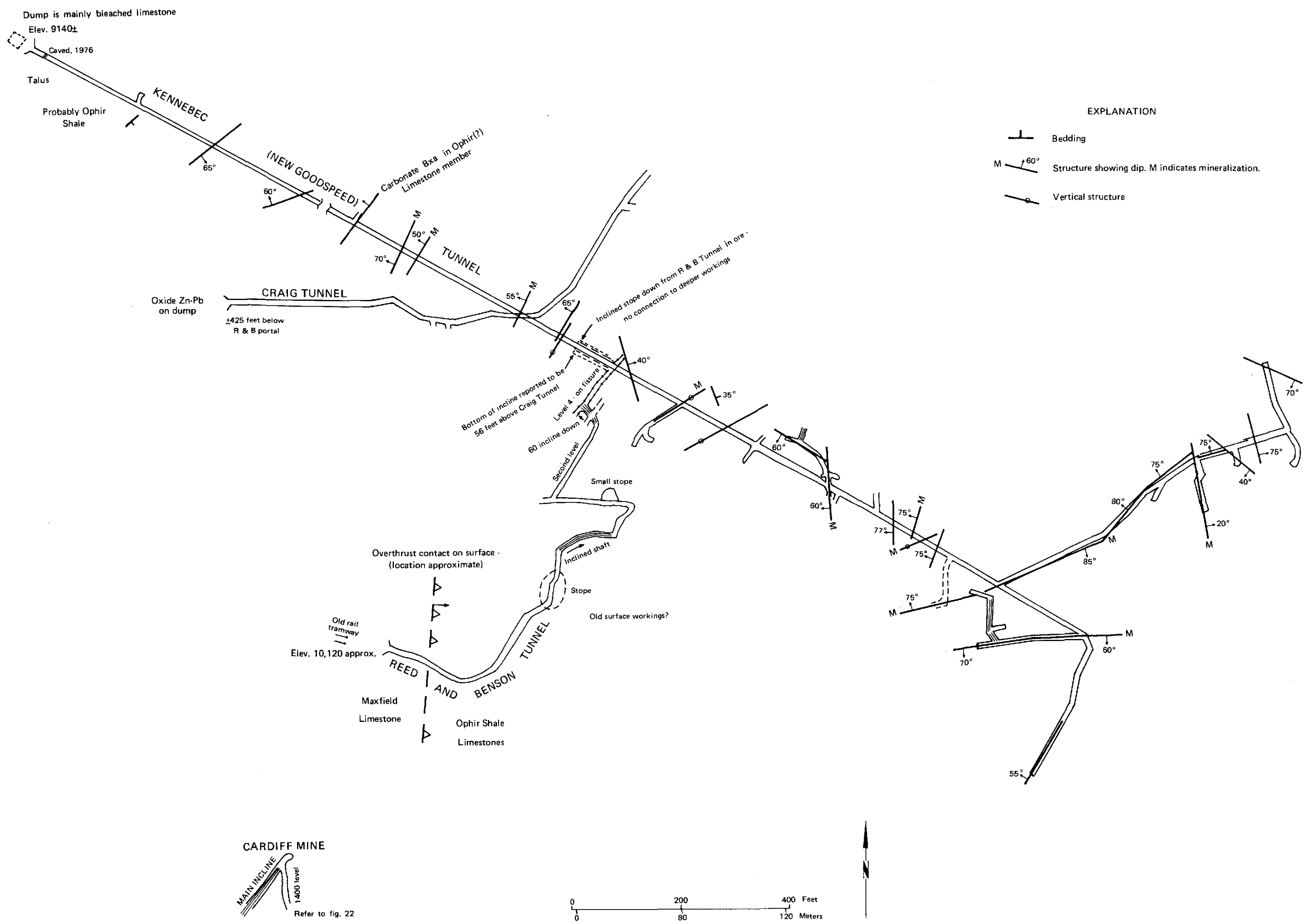


Figure 25. Plan Map of the Kennebec (Reed and Benson) mine.

Geology. The Silver Fork Fault passes west of the tunnel portals, and the carbonate rocks east of it show locally intense bleaching. A 2 foot (0.6 m) dioritic dike crops out in the gulch above the adit. A hand sample of gossan from the prospect workings above the tunnel showed an anomalous trace of molybdenum (sample 31-a, table 5). This prospect is near, and may be related to, the mines of the Argenta area.

The nearby dioritic dike shows no local magnetic anomaly, but magnetometer traverses across the Silver Fork Fault show weak local highs. To the north near Dog Lake, where the Silver Fork fault passes west of the Little Water pluton, anomalies plus bleaching suggest the fault localized minor igneous activity related to the Little Water pluton.

Belden (25)

The Belden tunnel, on the north slope of Big Cottonwood Canyon between Reynolds and Mill D North Forks, penetrates bleached limestone. The workings were driven prior to 1900. No mineralization was noted on the dump. The 1907 map of the area suggests there were two adits both driven toward a prospect high on the ridge.

Cottonwood Metals (24)

The Cottonwood Metals adit extends southward from the Spruces Campground area, just east of the mouth of Days Fork. By 1924 the tunnel was 2,100 feet (640 m) in length, and drifting was in progress on the "best looking fissure" encountered (*Mines Handbook,* 1924). A drift extends easterly on the contact between the limestone and shale members of the Ophir Shale. A major gouge zone in the tunnel caused ground problems. No ore was reported.

Calkins and Butler (1943, p. 104) describe the geology. Mineralized fissures were encountered in the Ophir Formation. Southward the tunnel crosses faulting, and enters Mississippian limestones.

Big Cottonwood Bonanza (23)

The Bonanza group is on the west side of Days Fork, near its mouth. An upper and lower tunnel were driven southwestward. At 775 feet (236 m) from the portal the lower tunnel reportedly encountered 2.5 feet 0.76 m) of ore containing silver, lead and gold values, in a fissure. Mineralization was followed upward by a raise; drifts were extended along a "limestone quartzite contact," presumably a bedding feature within the Doughnut Formation. A west drift in limestone was begun 300 feet (90 m) from the portal. No ore production is recorded.

Silver Moon (74)

The Silver Moon shafts and adit are near a small fork, halfway between the mouth and the headwaters of Days Fork. In 1915 a tunnel was being driven from the canyon bottom on a fissure, toward a shallow shaft with two feet of silver-lead ore at its bottom (*Mining World,* August, 1915). The work evidently was unsuccessful. The country rock is unaltered Deseret and Gardison Limestones.

Victory Lode (75)

The Victory Lode group extends up the west side of Days Fork onto Reed and Benson Ridge, about halfway between the mouth and the headwaters of the fork. A tunnel near the southwest corner of section 20 was driven southeastward, using hand steel, to prospect the ground. According to E.W. Newman, who contracted in the tunnel, it had reached 700 feet (214 m) by 1918 without encountering significant mineralization. The Humbug, Deseret and Gardison Formations are the principal rock units on the ground.

Gypsy Blair (76)

The Gypsy Blair group of four claims lies on the west side of Days Fork, a short distance below the cirque at its head. A nearly-vertical northeast-striking shear zone was prospected by shallow workings, a shaft and a tunnel, cut in the Deseret and Humbug Formations. Calkins and Butler (1943, p. 104) state that the adit was 700 feet (214 m) long in 1916, and had encountered no ore. In the early 1900s at least one small shipment of copper-lead ore was made from the property. (Calkins and Butler, 1943, p. 84). Little mineralization was evident at dumps and outcrops on the property.

Days Fork Mining Co. (Alice Group) (77)

The Days Fork Mining Company, incorporated in 1911, drove two adits southeastward into the east side of Days Fork, east of the Gypsy Blair workings approximately on the line between sections 29 and 32. By 1915, the upper adit was 130 feet long, and 600 feet of work had been completed in the lower adit (*Salt Lake Mining Review,* March 15, 1915, p. 13; September 30, 1915, p. 14), as well as some shallow prospect shafts. By 1920 a total of one thousand feet (330 m) of underground work were reported (*Mines Handbook,* 1920). Apparently no ore was discovered. The Silver Side Mining Company also conducted prospecting in this vicinity at that time.

Eclipse shaft and Hirschman Group (78)

The Eclipse Mine is east-northeast of Flagstaff Mountain near the head of Days Fork. It is approximately 2,500 feet (760 m) east southeast of the Reed and Benson mine, in the NW¼ SE¼ NE¼ of section 32, T. 2 S.,R. 3 E. at an elevation of 9,630 feet (2,935 m) above sea level.

Little is known of the production from this mine. The ore bodies are an extension of the Flagstaff-Emma zone in Little Cottonwood, held under separate ownership. Work was first conducted through the Flagstaff shaft. Apparently ore was discovered in about 1880. In 1881 the main shaft was being sunk in Days Fork (Director of the Mint, report for 1882, page 261) utilizing steam hoisting works and a Rand steam air compressor. Production and operation apparently ceased prior to about 1893, when the hoisting works burned. (*Salt Lake Mining Review,* August 15, 1902, p. 15). The total amount or value of ore produced is unknown. Later development related to other fissures on the Eclipse Extension claim was carried out from the Wasatch Drain tunnel level in 1959-1964.

The workings consist mainly of a vertical shaft, now caved, with at least 4 levels extending southeasterly. Total length of workings is probably less than 3,000 feet (915 m) including connections to the Flagstaff incline, Alta. A very general map of the workings appears in Calkins and Butler (1943, plate 41) and a section (figure 26) is presented here.

Ore apparently occurred in the Gardison and Fitchville Formations, as replacement of certain beds at intersection with mineralized fissures. Overthrusts lying above the Alta zone probably controlled ore here, as at the Flagstaff mine. Ore minerals noted on the dump include galena, cerussite, anglesite, goethite and minor copper carbonates. The potential for additional ore is unknown.

Silver Fork-Honeycomb Fork

Lost Emma (26)

The Lost Emma tunnel site lies just above Big Cottonwood Creek, east of the community of Silver Fork and north of Mats Basin, at an elevation of 7,600 feet (2,318 m). Beginning in 1951, C.H. Malmborg and sons have been driving this adit southwesterly, reportedly toward a small showing of galena found in a basin above.

The extent of the workings late in the summer of 1976 is shown in figure 27. The adit cuts across bedding in the Deseret (?) Limestone, and reveals both dark, cherty, locally coralline limestone and lighter dolomite and dolomitic limestone. No major faults, and no ore minerals were seen during the brief visit to the property. An analysis of a sample of iron-stained material from a narrow shear or bedding zone in the adit appears in table 5 (sample 48).

Woodlawn-Kentucky-Utah Group (60-56)

The Woodlawn mine is in Honeycomb Fork northeast of the Honeycomb Cliffs. The portal of the main Gardner adit, in the NE¼ NE¼ NE¼ of section 33, T. 2 S., R. 3 E. at an elevation of 9,270 feet (2,825 m) above sea level, was later consolidated with the nearby Big Cottonwood Coalition group to form the Kentucky Utah company. At the time of consolidation, in 1928, total production was reportedly $30,000.

The first discovery of ore was prior to 1900 with the first significant production in about 1904. The mine was worked intermittently until the late 1920s. Later development was through the deeper Kentucky Utah (Cottonwood Coalition) adit at an elevation of 8,160 feet (2,489 m).

The earliest workings of the Woodlawn mine are the Manahansett and New Sensation tunnels, on the ridge between Honeycomb and Mill F East Forks, above Lake Solitude (figure 28). Copper and gold bearing ores reportedly were produced here (*Salt Lake Mining Review,* February 15, 1901; October 15,1901). The Clarke tunnel extended beneath this area from Honeycomb Fork, while the deeper main Gardner tunnel level extended south of the Clarke workings. A winze below the Clarke level produced a small tonnage of zinc ore. Ore was also produced from winzes below the Gardner level (*Salt Lake Mining Review,* November 30, 1919). One face of ore reportedly averaged 4.5 oz/ton Ag, 4.9% Cu and $5.40 Au, while the other contained mainly galena. Small shipments of both copper and lead-zinc ore were mined from several places in these workings. The workings were equipped with an electric hoist and compressor plant, located 400 feet (122 m) underground (*Salt Lake Mining Review,* October 30, 1916).

The lower tunnel passes through several dikes of varied composition, bleached and brecciated limestone, and a possible thrust fault. (Calkins and Butler, 1943, p. 115). Tremolite and other silicates are locally present. Dikes and fissures were closely associated with most of the ore mineralization at the property. All of the tunnels described thus far prospected a north 70° east striking fissure in limestone that dipped 60 degrees to the north. The deepest winze beneath the Gardner tunnel, apparently sunk after Figure 28 was made, reportedly yielded some 30% zinc sulfide ore. The last work done from the deep Kentucky Utah adit was intended to test beneath this winze.

The deep Kentucky Utah or Big Cottonwood Coalition adit is portaled on a moraine-covered slope immediately south of Big Cottonwood Creek. The lowest chairlift of the Solitude ski resort lies northeast of the portal. The tunnel, presently inaccessible, supplies local culinary water. Old reports state the first 7,000 feet (2,100 m) of the adit cut flat-lying marbleized limestones striking west-northwest and dipping northeasterly. It was first intended to develop the old Copper King prospect, and was later extended southward beneath the Woodlawn. The small scale outline of the workings (Figure 29) is believed to be accurate and was the only available map of these workings.

In the Copper King portion of the group, south of Big Cottonwood Canyon near Mill F East Fork, copper mineralization was developed by a tunnel, a shallow incline, and winzes (*Salt Lake Mining Review,* January 30, 1919, p. 23-24). Calkins and Butler (1943, p. 111) observed ore in fissures and in minor bedded replacement zones in Deseret Limestone. Minor calc-silicate minerals occur at the surface. A body of granodiorite similar to the Clayton Peak stock is exposed about 3,000 feet (915 m) to the southeast, and may extend to near the prospect area beneath alluvial cover. Several dikes are present underground (Calkins and Butler, 1943, p. 112).

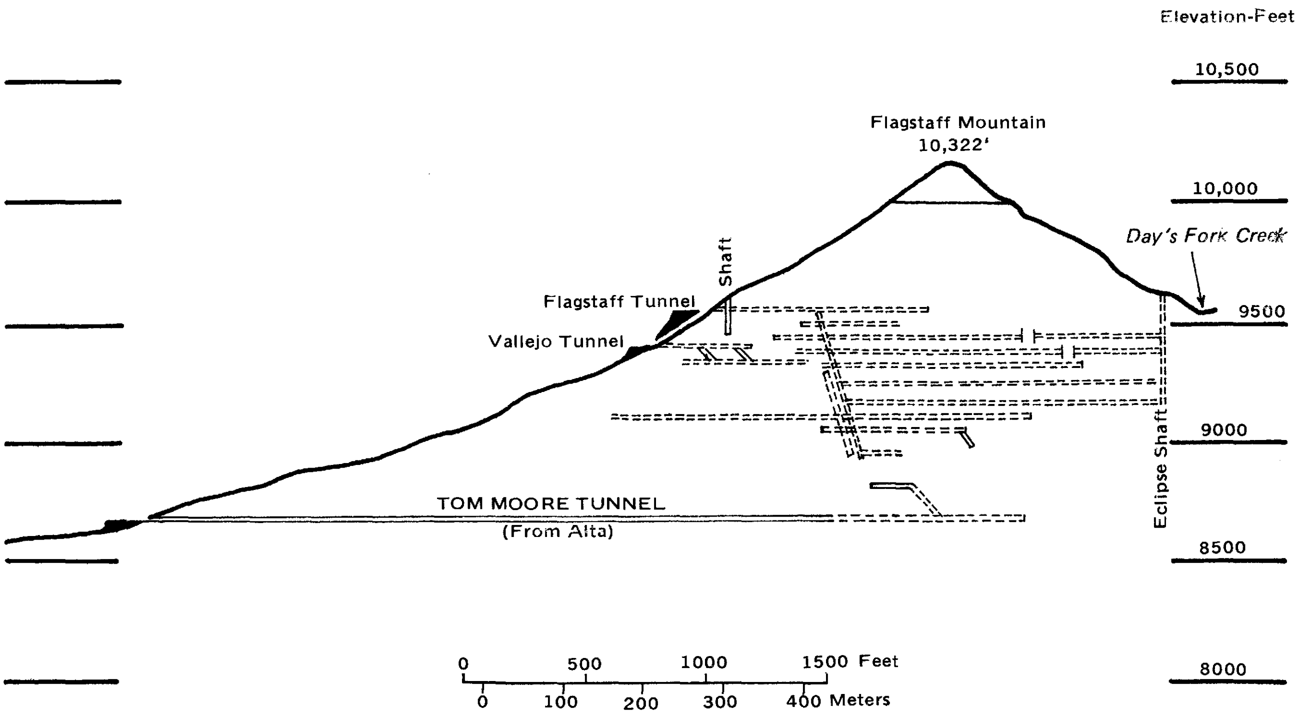


Figure 26. Simplified projection of workings of Eclipse and Flagstaff mines.

The long Kentucky-Utah (Big Cottonwood Coalition) adit passed beneath this area. A winze was sunk 25 feet (8 m) or more on a small showing of bismuth-bearing high-grade lead ore 4,800 feet from the portal, and a raise was also driven. Neither yielded a large ore body (*Salt Lake Mining Review,* December 30, 1924). About 5,600 feet (1,700 m) from the portal (about 1,000 feet (305 m) south of the surface workings) the adit intersected a northeast-striking fissure containing silver-lead ore a few inches to four feet (6 cm to 1.2 m) in width. The fissure was followed to the northeast under the advice of J.M. Boutwell (*Salt Lake Mining Review,* December 15, 1924, p. 15). Only minor ore production was attained.

South of the Copper King the workings encountered three narrow fissures, believed to be related to the Woodlawn mine above. These were unmineably narrow, and contained sphalerite and minor galena (L.W. Hoskins, personal communication).

Continuing southward, the last 1,000 feet (305 m) of the tunnel reportedly follows the third fissure, a weak but persistent N 70° W structure that dips 45-70° northerly. Throughout that length the fissure is intermittently mineralized with sulfides and oxides of lead and zinc, with local pyrite and manganese oxides, from less than one inch to about 18 inches (54 cm) wide. At two points along this drift small pipe-like masses of ore were encountered where the fissure crossed thin argillaceous limestone beds. Assays of partially oxidized ore from these masses are given in table 13.

The southern end of the adit apparently encountered badly broken granodioritic intrusive rock, and accompanying heavy flows of water. Some contact metasomatic ore containing magnetite, chalcopyrite and pyrite was encountered, yielding good assays for silver, copper and gold (Calkins and Butler, 1943, p. 112). By November 1941 the fissure containing these ores had been followed about 500 feet southwestward from the tunnel without encountering a sizeable body. Work apparently ceased prior to 1950.

West of the tunnel, on the ridge between Honeycomb Fork and Big Cottonwood the Queen Bess claims contain a northeasterly fissure that appears to be associated with a dike (Calkins and Butler, 1943, p. 114). Development was by an adit and shaft in the Humbug Formation, now inaccessible. A small production of lead-silver ore was reported in 1907-1909. Workings here totaled 200 feet (60 m) of shaft and 600 feet (108 m) of adits in 1912 (*Copper Handbook,* 1912). A short drift from the Kentucky Utah tunnel extends toward the workings (*Salt Lake Mining Review,* 1908, January 30, 1917, p. 24). Extensive prospecting has thus tested a variety of possible ore environments in Kentuchy Utah ground. Potential for major production or discovery is considered small.

Prince of Wales and Antelope Group (63)

This group of mines is near the head of Silver Fork Canyon, just west of the Honeycomb Cliffs and northeast of Davenport Hill (figure P-1, photo section). The

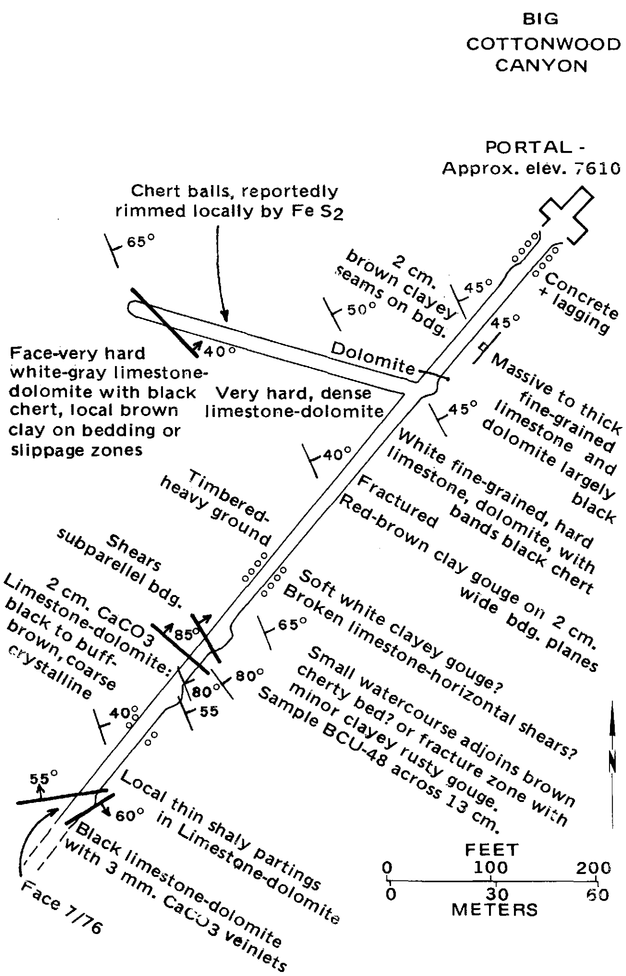


Figure 27. Geologic map of Lost Emma tunnel.

properties are presently held by several owners, but were once developed together by the Alta Tunnel and Transportation Company. The collar of the Prince of Wales Shaft is located in the NW¼ SW¼ SE¼ of section 33, T. 2 S., R. 3 E. at an approximate elevation of 9,875 feet (3,010 m) above sea level. Workings giving access to this group include the Alta tunnel, the Annie tunnel, the Highland Chief shaft, the Honeycomb tunnel, the Wellington tunnel, and the Boston tunnel (figure 30, Calkins and Butler, 1943, plate 37). The workings are partially caved and access to the old stopes was not possible.

History. The Antelope and Prince of Wales claim groups, discovered in 1870, were among the early producers of the district. Calkins and Butler (1943) list the property as a producer of lead and copper-lead ores. Litigation among owners of adjacent Highland Chief, Wandering Boy and Wellington properties was finally settled, and the Walker Brothers of Salt Lake City gained control of the mine (Copp, 1882, p. 162-175). The Prince of Wales inclined shaft (figure P-2), reportedly 930 feet (285 m) deep, followed the steeply dipping Prince fissure downward. An adjacent incline followed a similar fissure, less than one foot (0.3 m) in width at the surface. The nearby Highland Chief mine (figure P-3) connected with the Prince workings. In 1875 the Prince produced 2,000 tons of ore assaying 135 oz Ag/ton and 35% lead (Raymond, 1875). A decline in prices, caving ground and water at depth led to the cessation of operations by the 1880s, (*Salt Lake Mining Review,* March 15, 1915). Leasers worked the properties intermittently until 1910. Dividends from the Prince were reported as $500,000 (*Mining and Contracting Review,* September 15, 1934) which appears overstated.

In about 1916 R.L. Mack and G.T. Hansen extended the Annie tunnel from Honeycomb Fork to a depth of 140 feet beneath the old workings. A raise and an inclined winze followed a fissure (thought to be the Prince) downward, that yielded high grade argentiferous galena ore. A small underground compressor station was utilized during sinking. Trouble with water and avalanches ended the work.

F.V. Bodfish acquired a large claim block in the area in 1911. His Alta Tunnel and Transportation Company undertook a well-advertised deep tunnel project, intended to explore beneath a large segment of the Alta-Big Cottonwood region. Drainage and access was to be provided beneath the Solitude Tunnel workings and the mines of Alta. The tunnel cut the Lucky Dutchman fissure, associated with an altered dike, and other minor ore mineralization at about 1,200 feet (365 m) from the portal. The Dutchman fissure yielded several small ore shipments. About 3,800 feet (1,160 m) from the portal, the tunnel entered barren Tintic Quartzite, and driving was discontinued. A long drift was extended eastward in limestone, beneath the Highland Chief area. During 1919-1921 a 2 to 4 foot (0.7-1.2 m) wide body of copper-bearing lead carbonate ore was developed by four raises in the Christmas Stope area. More than 425 tons, valued at about $60,000, of silver-lead ore was shipped from these workings prior to 1924. The ore ended at a shattered black limestone hanging wall. Further exploration yielded similar production from a shale-limestone contact 1,000 feet (330 m) to the west near the main tunnel from a 60 foot (20 m) raise (*Salt Lake Mining Review,* August 31, 1929; and 1919-1923; *Western Mineral Survey,* August 15, 1929; September 6, 1929).

A second long lateral, the Quad Drift, was extended beneath the old Annie Tunnel area. A vertical raise connected with the old, flooded winze, and ore was mined from the 120 and 400 levels, below the winze. The raise passed through the Alta-Grizzly thrust zone. The Prince of Wales fissure was never positively identi-

Table 13. Ore production, Woodlawn Mine from 1915-1923, (from records, U.S. Bureau of Mines).

	Recovered metals		Gross metals in concentrates		
Short tons	Gold(oz)	Silver(oz)	Cu(lbs)	Pb(lbs)	Zn(lbs)
406	17.61	11,065	3,965	97,253	21,411

fied in any of the workings (Calkins and Butler, 1943, p. 116). A small gravity concentrator was erected to treat low grade ore and stope fillings (*Engineering and Mining Journal,* June, 1928, p. 1026). Two lots of smelting ore from a narrow vein below the Annie level reportedly assayed as follows:

17 tons: 43.4 oz/ton silver, 21.4% lead, $1.20 gold/ton
6 tons: 68.6 oz/ton silver, 25.5% lead, $5.60 gold/ton

(*Salt Lake Mining Review,* September 12, 1933; *Western Mining Survey,* various issues, 1929; L.W. Hoskins, personal communication, 1964). Analysis of a picked sample from the Alta Tunnel mill dump appears in table 5 (sample 58).

Production from the Prince group (table 14) began in 1870 and exceeded $1 million by 1884. From 1884 to 1918, approximately 10,459 tons of ore were produced. The grade of ore for five years after 1908 was 68 ounces of silver and $2 of gold to the ton, 29 percent lead, and 1 percent copper (Calkins and Butler, 1943, p. 82-115). Lease operations during the 1930s yielded a gross value of $66,747 to 1935, apparently with only minor production thereafter. Dump ore was shipped from the Prince shaft in the late 1930s. (R. Redden, personal communication). No work has been done in the property since that time. *The Western Mineral Survey* (June 20, 1929) stated that the Alta Tunnel portion of the property had shipped $120,000 worth of ore, with $80,000 coming from one stope on a thrust contact.

Geology. The workings cut a number of lower Paleozoic formations including the Ophir Shale, Maxfield Limestone, Fitchville Formation, Gardison Limestone, and Deseret Limestone. The underlying Tintic Quartzite is reached only by the southern end of the Alta Tunnel. The beds have a general northwestward strike. Several lamprophyre dikes cut through the sedimentary beds, and in the Christmas Stope had some relationship to ore deposition (Calkins and Butler, 1943, p. 116).

Calkins and Butler (1943) describe the structural setting:

The structure of the (Prince of Wales) ridge is far more complex than a casual inspection would indicate. The lower Grizzly overthrust, though very tight, can be followed around the basin southwest of the Prince shaft, and there is at least one higher overthrust. The lower overthrust can readily be traced to the north, as shown on the geologic map; the upper ones are more obscure. The thrusts where they are most distinct have placed Maxfield Limestone over Deseret Limestone. A lower overthrust, unmapped, which is crossed by the vertical shaft from the Alta tunnel, duplicates part of the Gardison and Deseret limestones. A great thickness, therefore, of Mississippian limestone is cut by the fissures passing through the ridge. The ridge is crossed by several northeast fissures, of which the Prince is the most conspicuous, its course being marked by a row of mine openings extending southwestward from the Prince of Wales shaft. This fissure dips about 60° to 65° N and is a normal fault of small throw.

Only a small part of the workings of the Prince mine is accessible, and the relations of the ore deposits to the different beds have not been fully determined. The ore that was being taken from the workings of the lower (Annie) tunnel level on the Honeycomb Fork side in 1916 and 1917 occurred in dolomite,

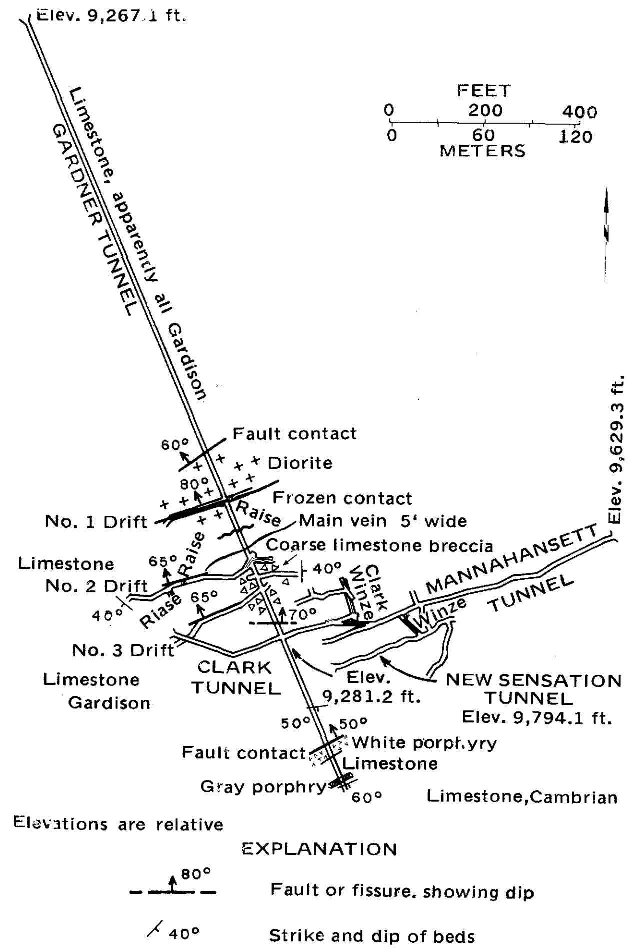


Figure 28. Geologic Map of Woodlawn mine.

probably of Fitchville age, which is ore-bearing in many parts of the district. In the workings on the lower level the ore-bearing stratum has apparently been repeated three times by relatively small reverse faults. So far as observed, mainly in the lower levels, the ore was formed by replacement of this dolomite, and the vein is nearly barren in the Cambrian beds and in the overlying blue and white Gardison beds and the cherty Deseret limestone.

The ore in these lower levels was partly oxidized but contained considerable galena. Its average value was about $140 a ton . . . silver content seemed to be as high as on the upper levels . . .

The ore deposits are largely in fissure veins, in which the ore typically occurs as chimney-like bodies, generally of high dip but variable trend. Ore minerals noted at the properties include galena, cerussite, sphalerite, smithsonite, wad, copper carbonates, and minor chalcopyrite, typically in a gangue of calcite and fine-grained quartz. Mineralized vein matter from the Prince shaft dump yielded analysis 59, table 5.

Huntley (1885, p. 428) gives the following description of the Prince of Wales deposits:

The ore-bearing formation is said to be a bedded vein, dipping about 45° NW in blue and white limestone. Four distinct chimneys or shoots of ore, 130 feet, 200 feet, and 260 feet apart, have been found. They occur where the limestone is white, metamorphic, and soft, while the barren spaces between these shoots contain the vein only as a narrow seam in hard blue limestone. These shoots outcropped at the surface, or were covered by a few feet of drift, as low-grade, ocher-stained seams of limestone and clay. Good ore was found by sinking a few feet. The Antelope and Prince of Wales shoot is from 2 inches to 4 feet (average, 12 inches) wide, 120 feet long, and has been followed on the dip 1,200 feet. The Highland Chief shoot is from 2 inches to 3 feet (average, 8 inches) wide, 75 feet long, and 800 feet deep. The Wellington shoots are each about from 2½ to 7 feet (average, 3 feet) wide, from 10 to 30 feet long, and 700 feet deep. The ore from the first assays about 140 ounces silver and 45 percent lead; that from the second, 100 ounces silver and 40 percent lead; and that from the third and fourth, 60 ounces silver and 50 percent lead. The ore is a soft brownish-yellow ocher, containing argentiferous cerusite and galena and occasional stains of oxides of manganese and copper.

Ore reserves in existing workings are probably minimal, although Heyl (1963, p. B46) notes that some oxide zinc ores might be present.

Richmond and Teresa Mine (68)

These two once-productive claims are located 1,000 feet (305 m) south-southwest of the Prince of Wales shaft and just east of Davenport Hill. The mine portal is located in the SE¼ SE¼ NW¼ of section 33, T. 2 S., R. 3 E at an elevation of 9,900 feet (3,018 m) above sea level.

This mine was worked early in the history of the district. Murphy (1872) reported 45 feet (14 m) of workings on the Teresa claim, exposing carbonate and galena. A year later the mine had encountered "chlorides" and three miners were building a substantial cabin, planning to work through the winter. The Richmond claim was shipping 8 to 10 tons of ore per day, averaging $115 per ton in silver and lead, from a shaft and tunnel. The tunnel encountered the vein, reportedly "carbonate", 52 inches wide (1.3 m) at 190 feet (58 m) *(Utah Mining Gazette,* September 27, 1873). The following summer the mine was the largest in Silver Fork, yielding 30 tons per day (*Utah Mining Gazette,* June 27, 1874). The Congress tunnel was projected to develop the ground at depth. The mine was reported to have produced ore valued at $150,000 to the end of 1880 (Butler, 1920, p. 257). The last reported production was in 1887. *(Director of the Mint,* 1887) with a little work in 1926 (*Minerals Yearbook,* 1926).

Access to the workings is by an adit, which was probably no longer than 250 feet (76 m) in length. Two small inclined shafts follow mineralization downward. The total length of workings is estimated at 1,400 feet (427 m) (Huntley, 1884, p.429). Prospecting may possibly have been conducted in the downward extension of structures in the group from the Alta Consolidated workings on the Little Cottonwood side of the divide.

The workings are in the Maxfield Limestone. Ore is found primarily in tabular and pipe-like deposits in fissure veins and replacements of limestone. Their extent is unknown but it is probably small. Ore mined was highly oxidized and rich in silver.

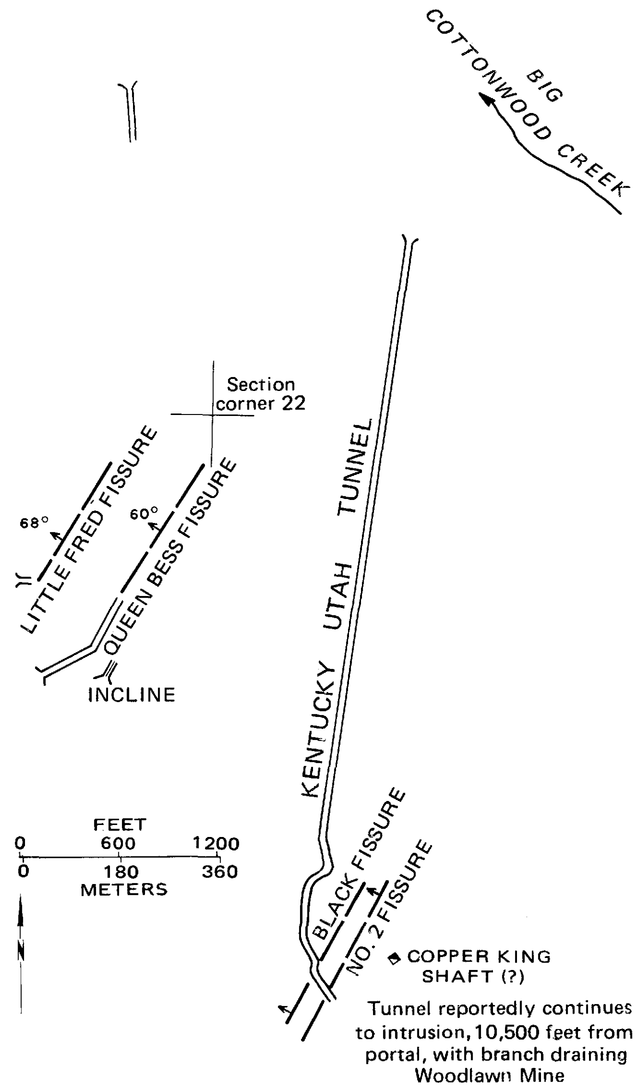


Figure 29. Plan of part of Kentucky Utah and nearby workings.

Michigan Utah (123, 124),
Solitude Tunnel (48)
Butte (47) and,
Oregon-Black Bess Group (48)

The Solitude tunnel, portaled just above and immediately west of Lake Solitude at the head of Mill F South Fork, is the lowest entrance to the Michigan Utah group of mines. Most of the development and ore production from this group was conducted on the Alta side of the divide, at the head of Grizzly Gulch. These workings are partially described by Calkins and Butler (1943, p. 131-133 and plate 46). Some ore from both sides of the Cottonwood Divide was hauled out the Solitude (Utah Mines Coalition) portal and down Big Cottonwood Canyon, but during most later work, which ceased in about 1928, ore was hauled out the Alta side and sent down an aerial tramway, first to Tanners Flat and later to a loading station on the narrow gauge railroad near

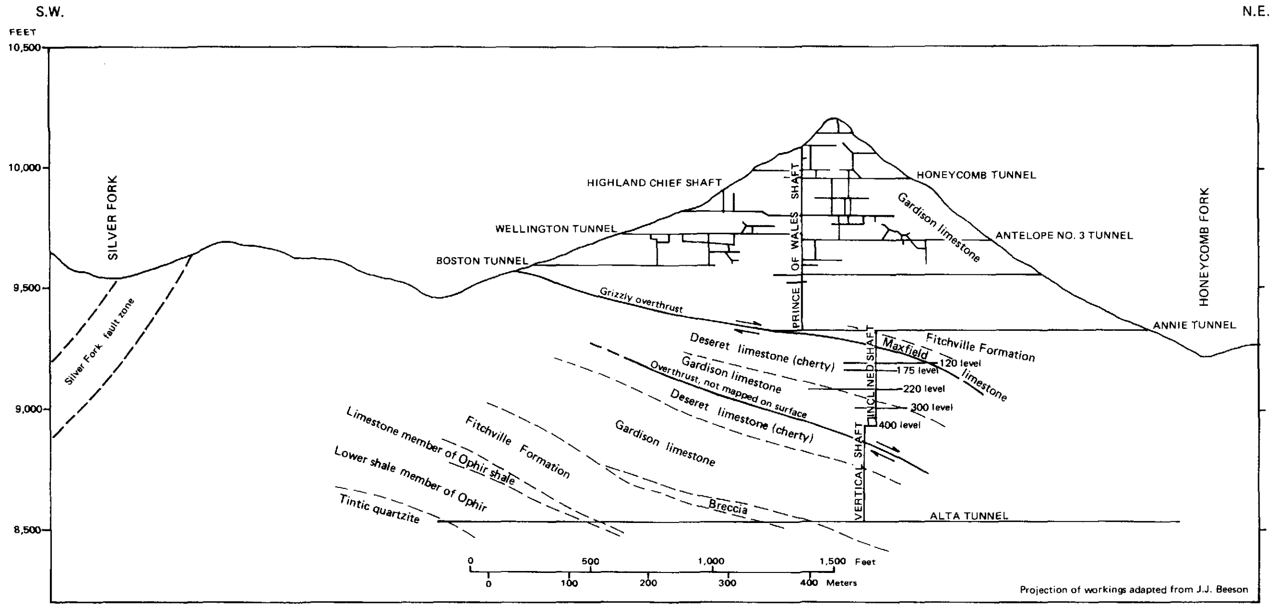


Figure 30. Geologic plan of Alta tunnel workings, with projection parallel to Prince of Wales fissure.

Peruvian Gulch. Surface rights on the property were recently (1970s) purchased by a Wisconsin group which reportedly plans ski resort development.

The Solitude tunnel extends westward through limestone for about 2,000 feet (600 m), and prospects the northeastward extension of the City Rocks fissure, productive on the Alta side of the divide. Nearly beneath the divide an inclined raise connects it with the Cleaves tunnel, three hundred feet above, portaled in Grizzly Gulch. Stopes and raises connect these workings with the Butte tunnel at the head of Honeycomb Fork, and the adjacent Black Bess inclined shaft, now caved.

The Utah Mines Coalition company, managed by Duncan MacVichie, a noted Canadian engineer, conducted much of the work on the tunnel. After a disastrous snowslide in 1911 deposited the compressor plant in Lake Solitude, an underground chamber was excavated for all electrical equipment. Most ore production on the Big Cottonwood side came from a winze below the Solitude level, on the City Rocks fissure. In September 1911, at a depth of 85 feet (25 m) below the tunnel, this winze was yielding ore assaying 134 oz silver/ton and 34% lead (*Mining World,* September 23, 1911). Exploration and production workings extended as much as 200 feet (60 m) below the tunnel (Calkins and Butler, 1934, p. 131).

The portion of the group at the head of Honeycomb Fork was first opened in 1869. According to Huntley (1885), p. 428), the Butte (or Bute) mine follows a fissure vein dipping 55 degrees north in limestone, which cropped out on the hillside as a soft, ochreous, manganiferous material. Ore occurred as eight to ten lenticular bodies on the footwall, which yielded an estimated $27,000 to 1880. The Oregon-Black Bess property, an extension of the Butte, also had ore in a steeply dipping northeast fissure, averaging 3 feet (1 meter) in width. The ore body was 120 feet in length (36 m), 0.25 to 3 feet (7-90 cm) wide and was followed to a depth of 300 feet. It assayed about 50 ounces silver per ton and 30% lead, and yielded an estimated $10,000 to 1880. (Huntley, 1885, p. 428).

The Black Bess Company reincorporated in 1901, and employed eight men and a steam hoist at its inclined shaft in Honeycomb Fork. By the spring of 1903 a crosscut on the 300 foot level was exploring a "porphyry" body (*Park City Miner,* quoted by *Salt Lake Mining Review,* April 15, 1903). That summer a shipment of two cars of ore was made, one reportedly assaying 9% copper and 100 oz silver per ton, the other 25% lead and 35 oz silver per ton. (*Salt Lake Mining Review,* June 15, 1903). No production is known thereafter. The ruggedness and isolation of the location must have greatly hampered all efforts.

Geology. Rocks exposed at the surface on the group include Maxfield, Fitchville, Gardison and Deseret Limestones, all intensely bleached and metamorphosed by the Alta stock, which lies close by to the south. The Black Bess shaft is nearly at the northerly contact of the pluton. Small bodies of copper oxides and local magnetite occur along the contact. The larger-scale metamorphic features have been described by Moore and Kerrick (1976) and Smith (1972).

The strong City Rocks and Grizzly fissures (figure 31) were the main mineralized structures of the group, and much of the best ore on the Alta side of the divide occurred in proximity to intersections with two (Alta and Grizzly) overthrust zones. Calkins and Butler (1943, p. 133) found that ore occurred mainly in shoots following intersection of the fissures with certain lime beds and brecciated (thrust) zones. The ore was said to be oxidized to the bottom of the winze below the Solitude level.

Swastika Copper (50)

The Umpire and "Plesant Star" (sic) claim groups along Mill F South Fork were developed in the early days of the district by the Blue Jacket Mining and Milling Company. An adit was begun in 1915 by the Swastika Copper Company. All of these workings prospected rocks near the contact of the small body of Clayton Peak granodiorite, all apparently without success. Copper carbonate staining and calc-silicate rocks occur in the area.

Upper Big Cottonwood Canyon

Utah Old Glory (27) Park City Western (28) and adjacent property

The Utah Old Glory group includes three patented claims in Beartrap Fork, north of Big Cottonwood Canyon. In 1908, outcrops reportedly yielded assays of silver, lead and copper. A few years later an adit had reached a length of 155 feet, apparently without finding ore.

Dawes (29)

About two miles to the southeast, on the Dawes claims, an adit portalled in moraine extends northward about 300 feet. It passes through hard Weber Quartzite into soft, uncemented sandstone, apparently at the top of the formation and then through an unconformity (?) into the Park City Formation. No mineralization was encountered. A caved adit higher on the same hillside was not examined.

Giles (Little Dollie, Cottonwood King) (30)

The Giles group lies on the north side of Big Cottonwood Canyon about one mile (1.61 km) north of Brighton. The main (Little Dollie) adit passes immediately beneath the Brighton highway (figure 32).

The Giles Mining and Milling Company was incorporated in 1902, and by 1904 had secured patents on 15 claims and completed 1,000 feet (305 m) of tunnel (*Salt Lake Mining Review*, September 30, 1904). Showings of copper gold ore, presumably along the contact of limestone with the Alta stock, were reported prior to 1913. In 1916 S. A. Parry's Cottonwood King Mining Company optioned the property, with considerable promotion and publicity. By the summer of 1916 the main adit was 1,400 feet (420 m) long with some raise work, and was believed to be following the Queen Bess fissure. Various showings of copper ore, galena, massive iron pyrite and 'brown carbonate', but no shipments, were reported. An upper adit, above the Little Dollie, reportedly revealed some mineralization also (Calkins and Butler, 1943, p. 88-113).

On the surface, a small patch of bleached Round Valley (Morgan) Limestone is exposed near the portal of the Little Dollie tunnel. A brief examination of accessible workings (figure 31) shows that they explored a rather narrow stratigraphic zone in this formation. A N 60° E shear zone is accompanied by argillization and local copper staining. A steep north-dipping N 70-80° W fault zone mentioned by Calkins and Butler (1943, p. 113) showed some iron sulfates. Most of the adit is in black, fetid well-bedded limestone, with local marbleized, bleached and wollastonite-bearing zones. Hornfels is more abundant in the outer 330 feet (100 m) of tunnel, in a lower stratigraphic horizon. A raise, apparently the last work done, followed a steeply dipping bleached zone to the southeast at a point about 600 feet (180 m) from the portal.

Table 14. Production from the Prince of Wales Group, 1909-1937. From U.S. Bureau of Mines Records.

Period (inclusive)	Operator	Recovered precious metals			Gross metals in concentrate	
		Tons Ore	Gold (oz)	Silver (oz)	Copper, (lbs)	Lead (lbs)
1909-1925	Prince of Wales Mining Company and lesseess	2,144	20.74	81,390	17,560	1,003,662
1926-1930	D.J. Walker Jr. and (?) Alta T&T. Co.	1,474	3.85	30,031	7,928	329,381
1931-1935	Walker, Alta T&T and lessees	319	0.60	9,574	6,335	90,041
1936-1938	Alta T&T, Michigan Utah Const. Mining Company and lessees**	545	9.50	5,313	5,341	34,620
Total		4,482	34.69	126,308	37,164	1,477,704

* Reported as gross in ore, prior to concentration, 1931-1938, when most ore was shipped to nearby milling plants.
** Probably includes shipments from Prince dump. No production recorded after 1938.

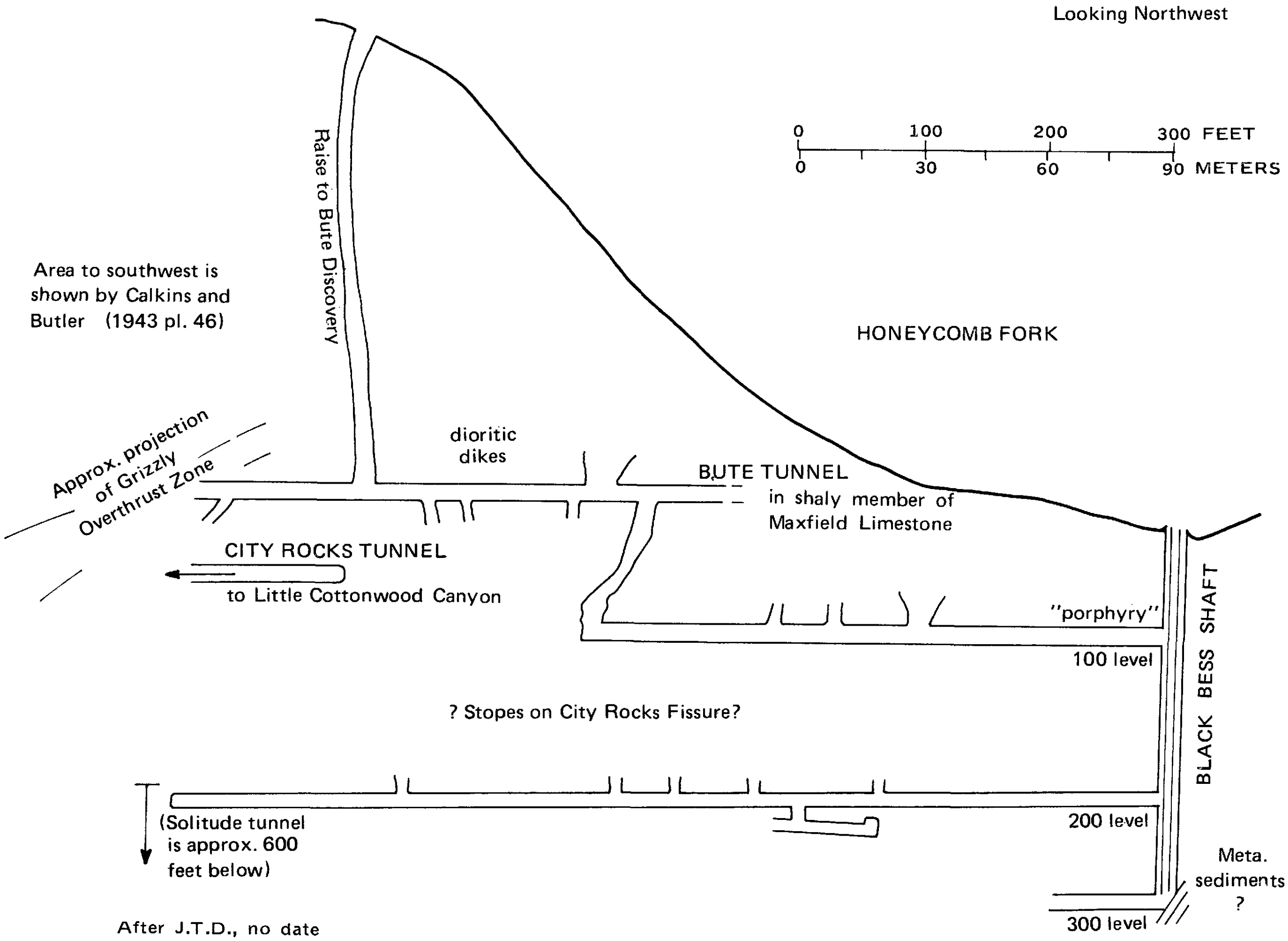


Figure 31. Section showing Black Bess mine, City Rocks fissure.

A tunnel on the Little Dollie No. 7 claim, caved at the portal, is in granodiorite of the Alta stock. An old report states it is 350 to 400 feet in length. The tunnel was apparently intended to pass beneath a surface cut, about 185 feet above, which shows local copper and silver bearing iron oxides in Weber Quartzite. A second caved adit on the Little Dollie No. 6 claim, extends 200 feet northeasterly, also in granodiorite. A 35 degree incline on the Little Dollie No. 2 claim follows a copper showing in limestone.

Silver King Mining Co. Group (118)

This group of mines covers a large area of patented claims on Scott Hill. Workings include the Iowa Copper tunnel, Copper Apex (35) or Elgin (Scott) mine (36), Crystal Elgin (36), the Scottish Chief (Insley) mine (33) and the American tunnel (31). The portal of the Iowa Copper tunnel is located in NW¼ SW¼ NW¼ of section 25, T. 2 S., R. 3 E. at an elevation of 9,000 feet (2,743 m) above sea level, and is reached by a jeep trail on the east side of Mill F East Fork. Total workings on the claim group exceed 1.5 miles (2.4 km), and are shown in figures 33 through 38.

The ground consists of many old claim groups. Some of the groups, e.g. the Barry-Coxe mine, lie mainly on the Park City side of the drainage divide.

History and Production. Croppings of ore were found in the area in the early 1870s, as prospectors worked eastward from discoveries on the divide north of Alta. By September, 1873 the Elgin mine reported 1,140 feet (347 m) of workings (*Utah Mining Gazette,* September 27, 1873). Little ore apparently was shipped prior to 1900.

The properties were consolidated in 1927 by major stockholders in the Silver King Coalition mine, Park City, who sought a possible extension of the rich bedded deposits of that district, (*Salt Lake Mining Review,* May 15, 1933). Prior to that time, the Iowa Copper Tunnel (figure 33) begun in 1906, was extended northward into Scott Hill. Mineralization was followed downward from a rusty surface outcrop. Small bodies of both lead and copper ore reportedly were developed. Production is shown in table 15. Most of the production is said to have come from sublevels from underground inclined shafts, presently flooded. The deepest incline

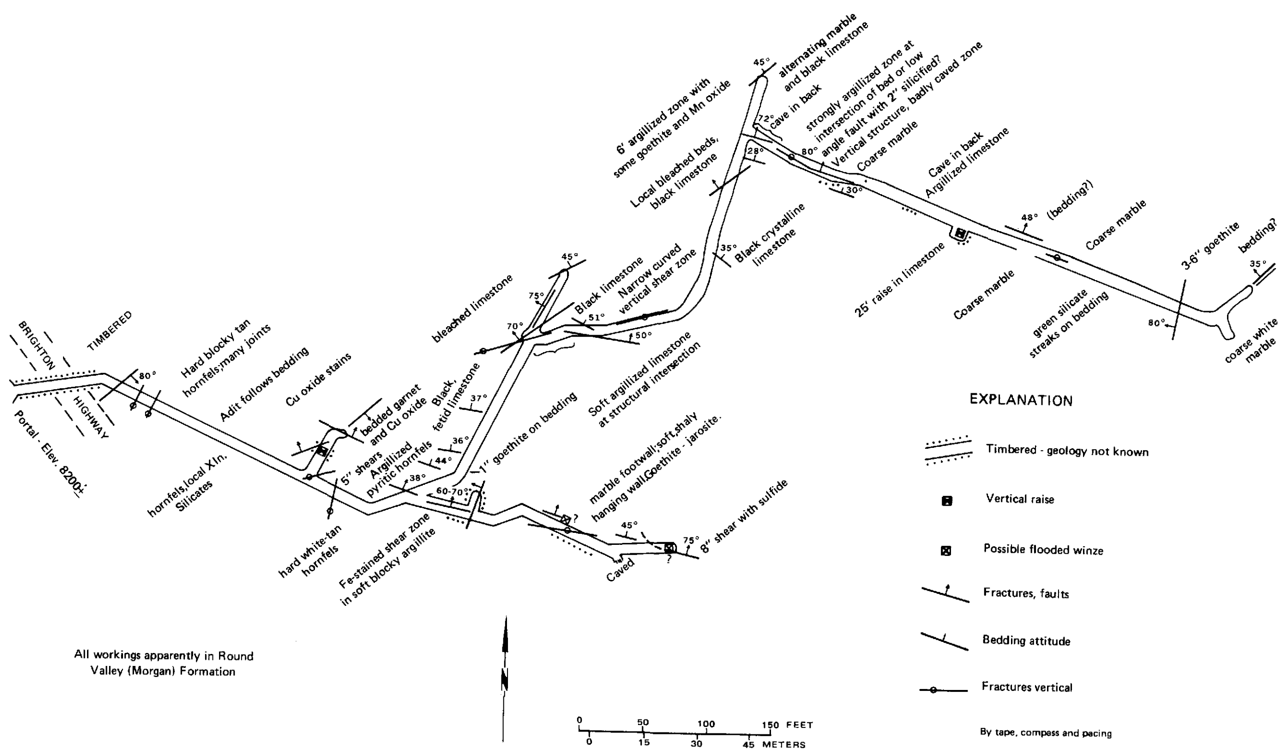


Figure 32. Map of accessible workings of the Little Dollie tunnel.

extends 125 feet vertically below the tunnel level. Higher on Scott Hill, the Scottish Chief (old Insley) property had been developed by an irregular incline following a locally mineralized zone down dip, in the vicinity of small, leucocratic dikes (*Salt Lake Mining Review*, April 15, 1903; January 30, 1904; November 15, 1904; October 30, 1905; November 15, 1906). The Scottish Chief (Insley) group (figures 34,35) yielded a few tons of ore from shallow workings prior to 1900 (*Intermountain Mining Review*, July 30, 1869). Recorded production, 40 tons of ore since 1902, is also shown in table 15. Boutwell (private report, 1934) estimated the total production at $20,000. Boutwell (1912, p. 223-225) described the geology of the mine:

> The croppings of ore are . . . along the upper part of a bed of coarse blue gray marble, which lies under a dense, finely banded gray-white metamorphic limestone and over a siliceous footwall of marble, which in some places is flinty, others sandy. In these croppings galena altered to anglesite and cerussite occurs in calcite, garnet, and limestone in an 8 inch (20 cm) bed in country rock of coarse marble. A bed 2 feet (0.6 m) lower shows copper stains in calcite. This ore bearing bed has been systematically followed underground and found to dip 23-30°N, 15°E. The general ore bed or zone is 24-40 inches (0.6-1.2 m) thick and the ore band within this bed averages 3-6 inches (7-15 cm). The ore is further localized into a sinuous pod-shaped shoot, which within the general zone pitches 30°E - 45°E. In its descent from the surface it has been caught on the first, second, and third levels, and was found at one point to be about 25 feet (7.5 m) wide on the plane of the ore bed. It had not been developed sufficiently at the time of visit to reveal its dimensions, and its course beyond a triplicate zone of faults at the head of the East winze below the third level also remained to be determined.

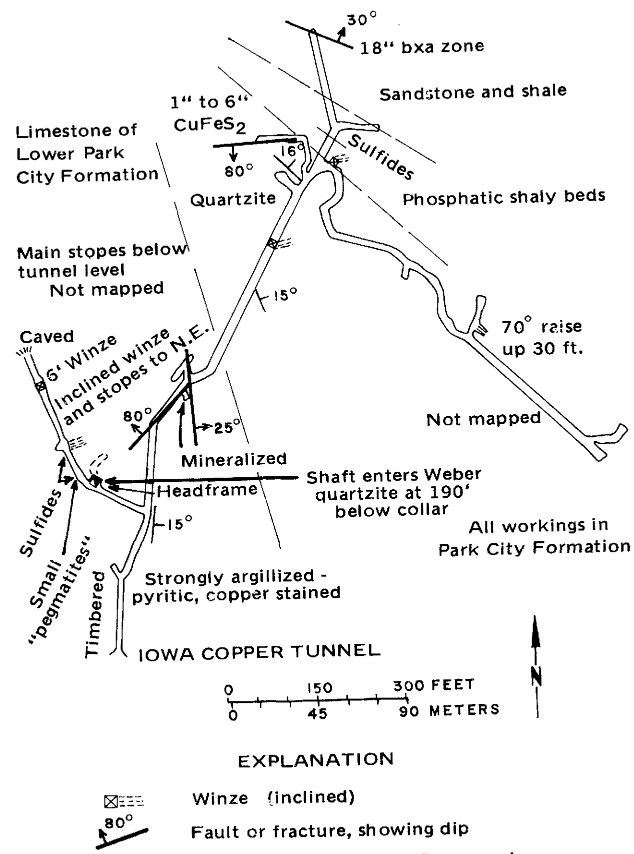


Figure 33. Geologic Map of the Iowa Copper mine.

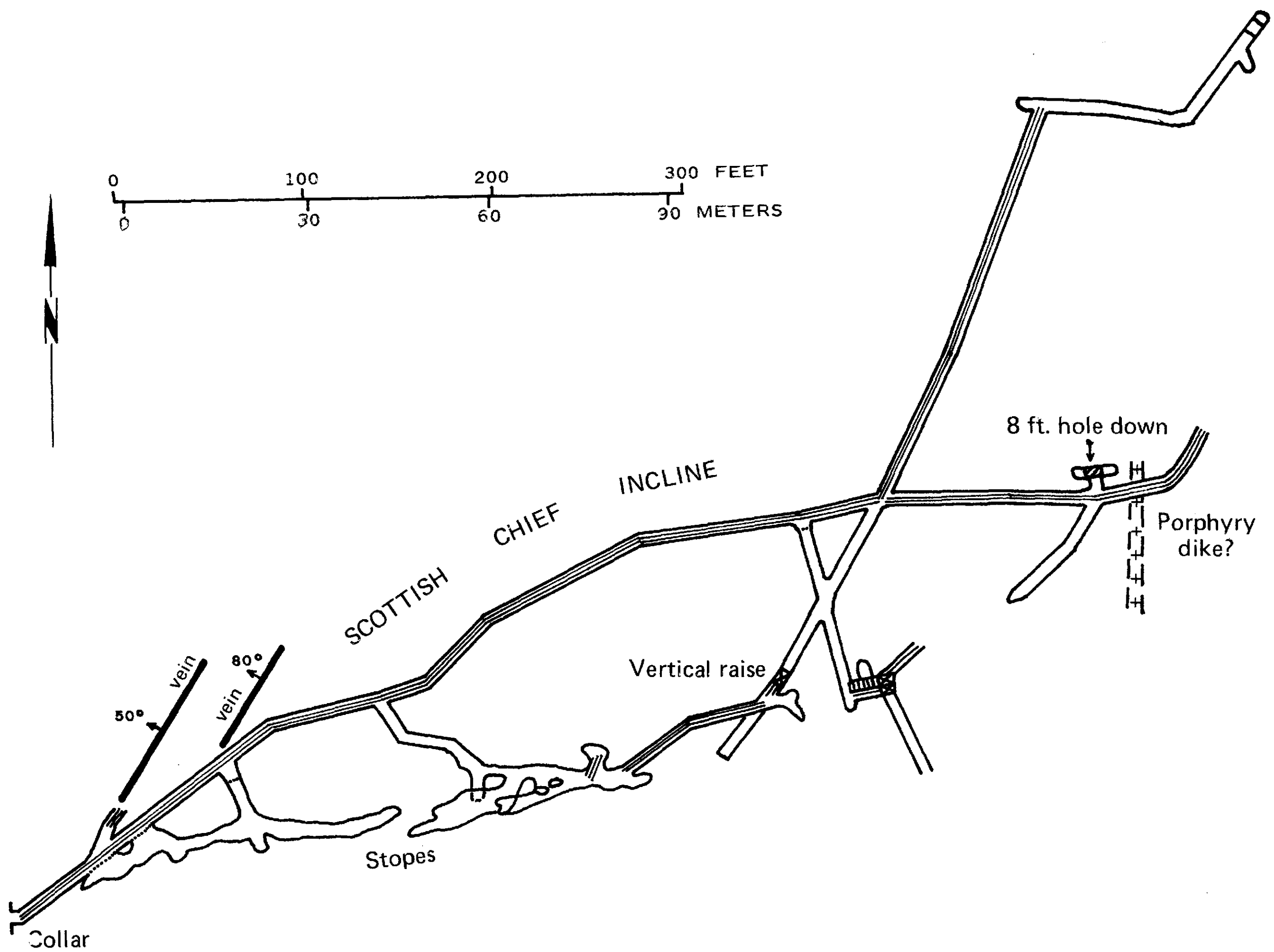


Figure 34. Workings of the Scottish Chief mine.

The caved Colorado Boy adit from the northwest slope of Scott Hill, 350 feet below the mouth of the incline, was intended to connect with the bottom of the Scottish Chief mine. It extends at least 400 feet, and its dump consists of Woodside hornfels. Total workings of the Scottish Chief in 1909 included 1,600 feet (488 m) of inclines and 1,400 feet (430 m) of tunnel. Work ceased about 1910.

The American Tunnel (figure 36) extends 450 feet, (136 m) cross cutting several bedded showings of oxide copper minerals. An underground inclined winze, reportedly 200 feet (60 m) in vertical depth and 500 feet in length, also exposes copper showings (*Salt Lake Mining Review,* March 15, 1913). Assays across a two foot (0.6 m) zone in the incline reportedly showed 16.5% copper, 7.5 oz/ton silver and $4.80 gold/ton. Two lots of silver-lead ore reportedly were shipped 1916-1918, and little work has been done since. Calkins and Butler (1943) describe two winzes, 90 (27 m) and 130 feet (40 m) deep, in an area of calc-silicate alteration near dioritic dikes. One of the inclines, extending northeastward, is still accessible, and was examined by the writer to about 270 feet (82 m) downslope below the tunnel. Bad air prevented examination below this point. This incline follows the strongest showing of copper mineralization seen in the mine, localized in a thin limy bed characterized by chert and bleaching. The copper oxide seam varies from less than one inch (2 cm) to two feet (0.6 m) in thickness, and was further explored by a short drift, a secondary incline and other workings, now filled, extending west from the main incline. The main incline follows bedding, and flattens from a 30° decline at the collar to about 22 degrees. Minor faulting offsets the copper bedding slightly. The workings are essentially dry.

In the early 1930s the long Spiro (King Consolidated) tunnel from Park City was extended from 4000 feet (1200 m) into Silver King Western ground to the down-dip extension of these prospects. Two hundred and three feet (62 m) of raises and 173 feet of crosscuts revealed mineralization but no commercial ore (*Salt Lake Mining Review,* May 30, 1933). Bad ground and ventilation difficulties prevented complete evaluation of this area (James Ivers Jr., personal communication, 1976).

Table 15a. (revised 2/78.) Recorded Production from Silver King Mining Company Properties, Big Cottonwood District, Utah

Mine	Years of Production	Recorded Output - Short Tons crude ore	Recovered Precious Metals		Gross Metals in Ore or Concentrates		
			Gold (oz)	Silver (oz)	Copper (lbs)	Lead (lbs)	Zinc (lbs)
Iowa Copper*	1909- 1916-20	1,093	56.29	3,861	138,234		(No payment for zinc until after September 1953).
Scottish Chief	1895**	13.54	0.09	558	------	8,144	
	1902**	40.00	4.80	720	2,800	20,800	
	1930-1906*	218	5.05	4,792	4,025	47,877	
Copper Apex*	1906-08	174	3.16	2,086	5,381	44,894	
Crystal Elgin Incline	1956***	29	1.0	156	399	4,751	2,894

* Data from U.S. Bureau of Mines. Published with permission.
** From Salt Lake Mining Review, November 30, 1902 and April 15, 1903.
***Data for 1956 from Bureau of Mines. Earlier data from records of Hogle-Kearns, Inc.
Ore from this incline yielded 3 tons of lead concentrates, 2 tons zinc concentrates and 2 tons iron concentrates.

Table 15b. Average ore grade from recovered metals Crystal-Elgin Incline, Silver King Mining Co., Big Cottonwood district, Utah.

Year	Short tons crude ore	Silver oz/ton	Copper %	Lead %	Zinc %
1948	341.80	11.03		15.89	
1949	1,491.93	10.00		14.88	
1950	331.78	8.79		14.10	
1951	660.73	6.40		10.79	
1952	243.24	4.56		9.01	
1953	333.71	6.28	0.64	5.85	7.09
1954	257.16	6.10	0.94	3.56	4.62
1955	480.74	5.46	1.00	6.25	8.58

1948-1955 production was valued at $110,059.00.

The Copper Apex (Scott, Crystal Elgin) portion of the group is developed by adits and inclines on east-trending fissure systems (figure 37). Substantial production of lead-zinc ore associated with calc-silicate minerals was made from the Forlinski lease incline in the early 1950s *(Mineral Yearbook,* 1954, table 15). A sample from this dump (table 5, sample 38) showed traces of tungsten in the calc-silicate material. According to Boutwell (unpublished report, 1925) the lower Kennelly adit on this group followed a strong mineralized fracture zone striking N 30° E and dipping 70° E. The upper tunnel on the Crystal claim followed a similar N 45° E fracture dipping 80° W. containing quartz veining and some copper carbonates. These structures were never tested in the underlying more favorable Park City beds.

Geology and Ore Deposits. Rock formations exposed on the property include the Triassic Thaynes Formation, the Woodside Shale, the Pennsylvanian Park City Formation and the Weber Quartzite, which all strike northwest and dip east-northeast, toward the Park City district. Deeper sedimentary units are masked by moraine deposits and alluvium. The southern part of the Iowa Copper workings are believed to lie within the lower 200 feet of the Park City Formation (Boutwell, private report 1925). The northern, or inner, part of the adit may be in the upper Park City Formation. The American tunnel is also portalled high in this unit, immediately beneath the Elephant ore horizon beds, and passes deeper into the formation as it extends southward.

On the southern end of the group, the porphyritic phase of the Alta stock and small bodies of the Clayton Peak granodiorite stock are exposed. Aphanitic to fine-grained dikes, presumably related to these bodies, are exposed in mine workings and surface cuts at several places on the property. Ore minerals and small bodies of calc-silicates occur near these dikes in several localities. Minor chalcopyrite was found in aplite dikes on the Iowa Copper dump. The southern end of the Iowa Copper workings, near the old vertical underground shaft (figure 33) are in intensely bleached and argillized limestones near the bottom of the Park City Formation. Pyrite and iron oxides are abundant here.

Ore minerals noted on old dumps include galena, sphalerite, chalcopyrite, and various oxides and carbonates of lead and silicates, oxides and carbonates of copper. Boutwell (1912) noted minor massicot and possible pyromorphite and native silver in the Scottish Chief workings, Calkins and Butler (1943, p. 113) briefly describe the Iowa Copper ores.

Recorded production thus far has come from fissures, many of them trending northeasterly, and from bedded replacement deposits. The rock units present on the properties are similar or identical to those which have been highly productive in the Silver King Coalition mine and other large producers of the Park City district, and may offer potential for the development of similar ore bodies (J.M. Boutwell, personal communication, 1962). The generally high copper content, the local presence of calc-silicate minerals, and the proximity to large igneous bodies are not identical to geologic con-

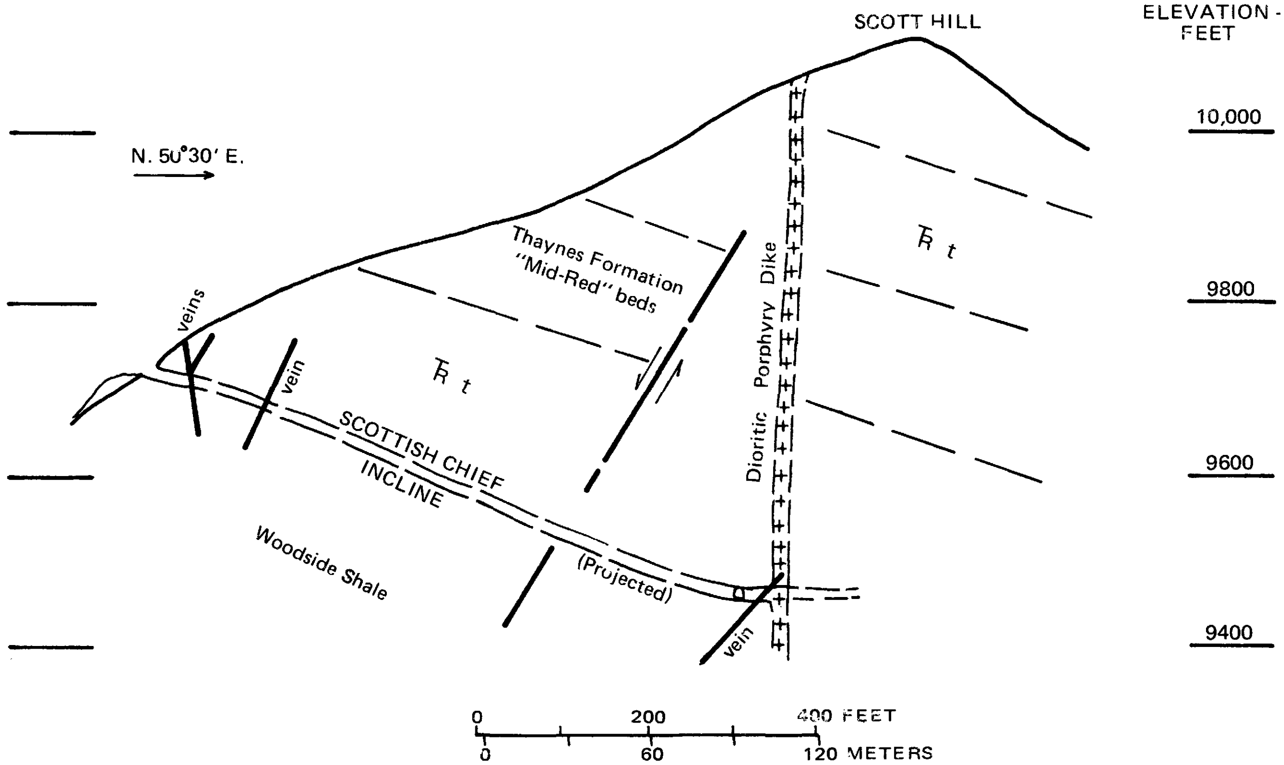


Figure 35. Section through Scottish Chief mine.

ditions in much of the Park City district. Ore potential on this property thus remains unknown.

Evergreen (51, 52)

The Old Evergreen Mining and Tunnel Company conducted work in two adits northwest of Brighton, the New York tunnel and the lower Evergreen drainage and transportation tunnel. The 1931 Mines Handbook states that the latter adit was 2,700 feet long. It now provides water for homes in the area. Both adits are caved. Calkins and Butler (1943) note some lateral works were driven from one tunnel, and that some production of copper ore was made prior to 1918.

As shown by Baker and others (1965) the tunnels are on the southeast flank of a plug or offshoot of the Clayton Peak granodiorite stock, the northerly contacts of which are concealed by glacial moraine. On the surface in the vicinity of the New York tunnel, contact alteration of adjacent Deseret and Gardison Limestones is intense and a variety of hydrous and anhydrous calc-silicate minerals are present. The dump of the lower tunnel contains some unusual coarse grained mafic igneous rocks, possibly resulting in part from assimilation of carbonate rocks by the magma. Minor showings of oxidized copper minerals accompany some calc-silicate rocks in the area.

Prospects on Mt. Millicent

As discussed by Wilson (1962, 1961) the Alta granodiorite or quartz monzonite stock was intruded as two phases. The second, a more porphyritic, silicic and fluid-rich phase, forms an almost dike-like mass, sigmoidal in shape, extending through the Big Cottonwood district from the edges of the Alta and Park City districts. Wilson believes that fluids from the cooling of the latter phase were sources of mineralization for some of the ore deposits of the region.

A few small prospects have explored both phases of the stock. One, a caved adit extending southwesterly beneath Mt. Wolverine, is driven in the early phase. It may possibly be the Tuscarora Chief (43) prospect, which was under development in 1900. The dump shows sericitized granodiorite cut by bull quartz containing crystalline chalcopyrite and pyrite. An analysis of a picked sample of this material appears in table 5. Only a minor amount of such mineralized rock appears to be present.

Several adits and prospects east-southeast of Brighton, now part of the Great Western group, apparently followed minor mineralized areas in Clayton Peak granodiorite adjacent to the above-cited porphyritic Alta granodiorite. Some minor production of copper ores by

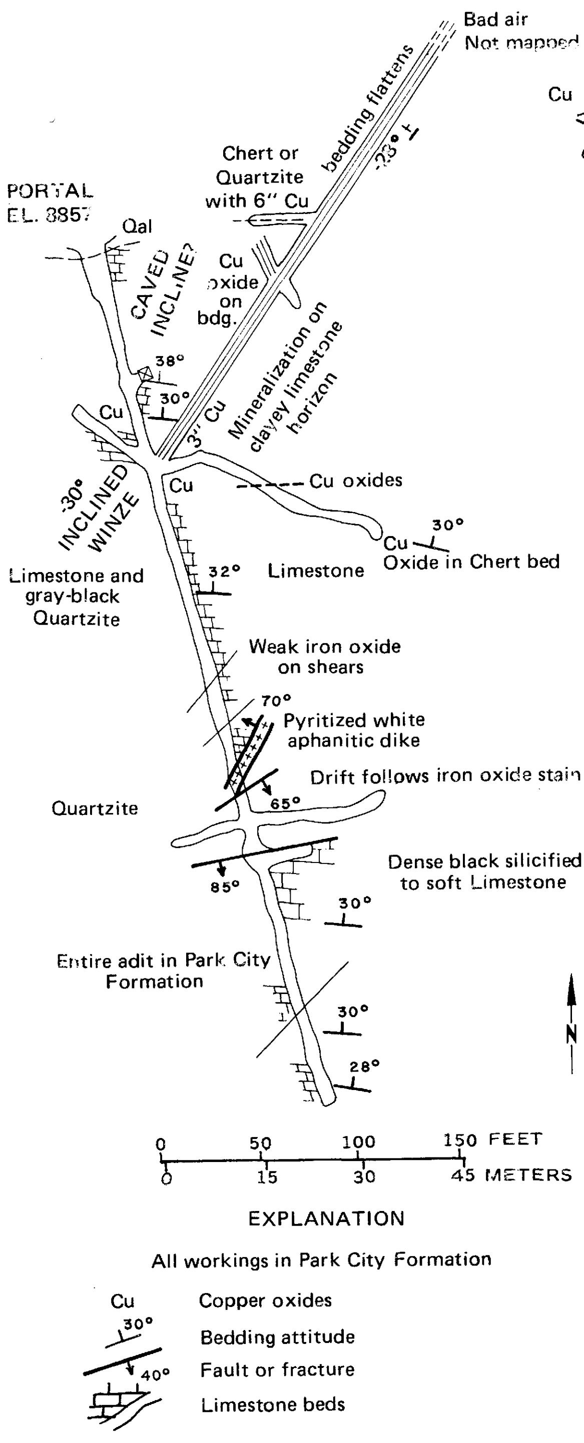


Figure 36. Geologic Map of the American tunnel.

the Great Western Mines Company, prior to its consolidation with the Mountain Lake Mining Company (discussed below) may have come from these workings. They were not visited during this study.

Great Western (Mountain Lake Group (38,40)
Big Cottonwood Mine (39)

This group incorporates about 98 claims near the head of Big Cottonwood Canyon on which the surface rights (1385 acres) have been sold to the Wasatch National Forest. Some production from this group came from the Big Cottonwood mine (39) located approximately 1,500 feet (450 m) south of Dog Lake, and 2,000 feet (610 m) southeast of Lake Martha. The portal is located in the unsurveyed SE¼ NE¼ SW¼ of section 2, T. 3 S., R. 3 E. at an approximate elevation of 9,600 feet (2,930 m) above sea level. The Mountain Lake mine portals and a shallow shaft lie immediately to the northwest. Information on the workings is minimal. The total workings are estimated at approximately 6,000 feet (1,830 m) in length.

History and production Mineralized calc-silicate rocks were recognized in this vicinity as early as the 1870s. Interest in copper showings developed in about 1900. In 1903 the Mountain Lake-Great Western property was developed by a tunnel that crosscut strong copper mineralization at 700 feet (213 m) from the portal. The two adits that definitely expose mineralization are just south of Dog Lake (Plates 1 & 2). The Big Cottonwood adit is described by Everett (1961, p. 22) as driven chiefly in the Clayton Peak granodiorite. The Mountain Lake or Great Western adit, to the west and 50 feet above, penetrates 200 feet of limestone and Clayton Peak and Alta stock intrusive rocks.

By 1907 the Steamboat tunnel (figure 39) from the Snake Creek side of the divide was 3,500 feet (1,070 m) long. Jesse Knight of Provo, owner of the property, let a contract for further development using a primitive eight foot diameter Karns tunneling machine, which apparently failed to perform well. (*Salt Lake Mining Review,* various issues, 1900-September 1907). The tunnel cuts 1,000 feet (300 m) of Clayton Peak "diorite" and 2,000 feet (610 m) of granodiorite, and minor mineralization (Calkins and Butler, 1943, p. 113).

By 1908 the Mountain Lake portion of the property had shipped several carloads of carbonate, and ore had been followed downward for 300 feet (91 m) on an incline. Several railroad cars, reportedly of copper-iron-gold ore, were shipped to Knight's Tintic Smelter in 1907. The shipments carried as high as 5% copper, plus minor gold and silver. By 1939 the main adit tunnel, plus "side drifts and slopes" totaled 900 feet (300 m) in length (Crawford and Buranek, 1957). Further development was planned, but never conducted, via the long Snake Creek drainage tunnel (*Salt Lake Mining Review,* May 15, 1910, December 30, 1910; October 30, 1915: Calkins and Butler, 1943). None of these workings are now accessible. The adjacent Big Cottonwood workings, then under separate ownership, prospected similar rocks.

Geology. The ore deposits are localized at and near the contact of carbonate rocks (Gardison, Deseret and

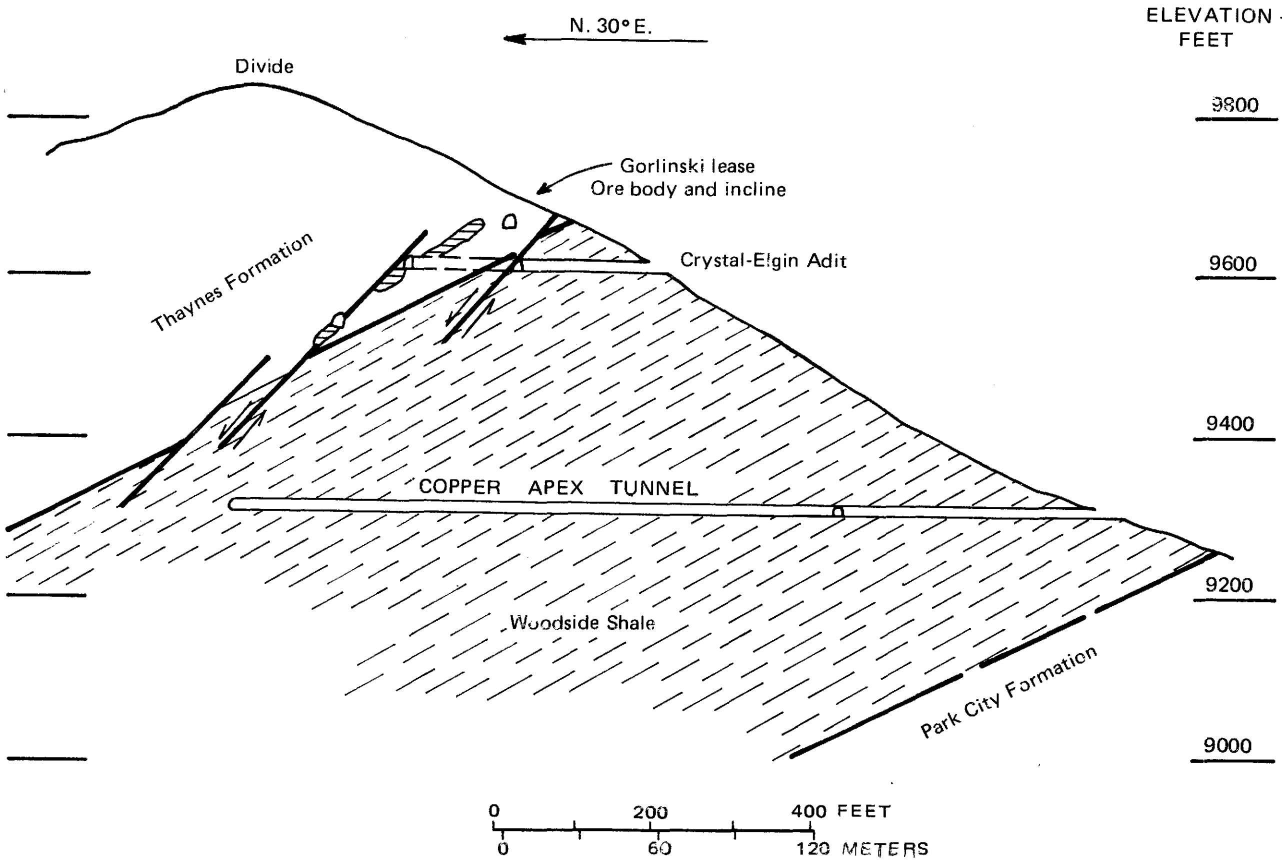


Figure 37. Section through Copper Apex and Elgin workings.

Humbug Formations) with the Alta and Clayton Peak stocks. Copper, lead, and minor gold and tungsten values have been of interest in the past. The massive bodies of magnetite containing these metals may be of interest as iron ores. Their geometry, in prospects and at the surface, is very irregular; thick continuous bodies appear to be uncommon. Crawford and Buranek (1957, p. 8-9) describe the Mountain Lake deposit:

The strike of the contact zone is roughly northeast, with an apparent vertical dip. The ore-body is exposed on the surface for approximately 100 feet in length and 50 feet in width . . . The estimated percentage of copper in the magnetite body is placed at 1½ per cent . . . The possibilities of this deposit being capable of yielding great tonnages of iron ore is problematical. Nevertheless, from all appearances this deposit represents a potential ore body of magnetite . . .that may be of future economic significance.

Other, similar copper showings are present in prospects along the ridge between here and Clayton Peak (Plate 2). Everett (1961 p. 22) describes the tungsten potential:

(In) the Great Western Tunnel, scheelite was observed in altered limestone in a tactite zone at the contact of limestone and granodiorite. Samples of the 50 foot zone penetrated by the tunnel contained 0.25 to 0.30 percent WO_3 (In) the Cottonwood tunnel . . . a 15 foot sample cut by an engineer of the Bureau of Mines across the sedimentary beds at the (Clayton Peak pluton) contact assayed 0.78 percent WO_3, 0.22 percent molybdenum, 0.11 ounce of silver and 0.01 ounce of gold per ton. If the need for tungsten were great enough, more development would be warranted on this property.

Ore minerals seen include bornite and chalcopyrite, pyrite, possible pyrrhotite, and minor malachite and galena. Crawford and Buranek (1957, 1944) noted bornite masses three inches across in some portions of the magnetite, and detected small amounts of scheelite, by ultraviolet lamp, in the main tunnel of the Mountain Lake mine. A wide variety of contact minerals, including garnet, epidote, actinolite-tremolite, talc, chlorite, phlogopite, and serpentine were noted on the property; some of the above identifications were confirmed by x-ray diffraction. The unusual borates, ludwigite and magnesioludwigite, are abundant. Periclase, brucite and forsterite have been identified (Smith, 1972). A glassy, silvery mineral associated with garnet and pyroxene at the surface south of the Big Cottonwood portal was tenatively identified by x-ray diffraction as ephesite, a brittle mica. J.D. Stephens (personal communication, 1977) reports small amounts of sussexite, xanthophyllite and hydromagnesite, identified by x-ray diffraction, in specimens from the vicinity of the Mountain Lake mine.

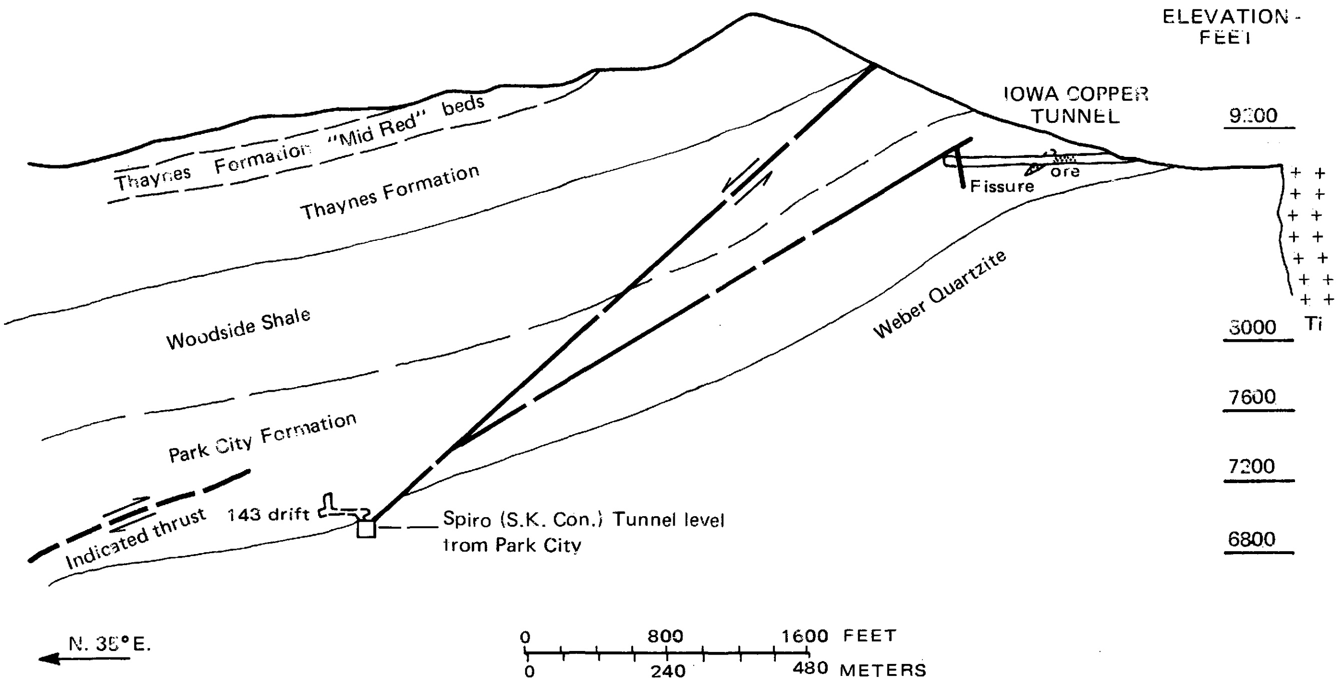


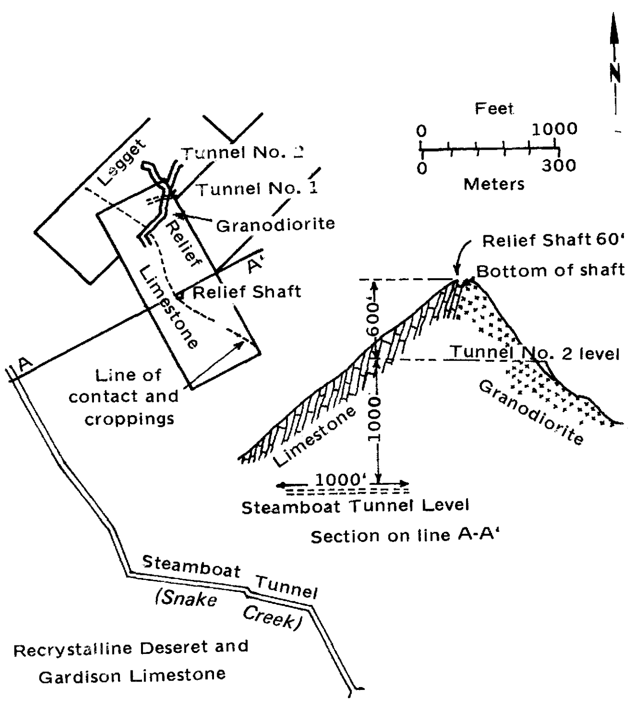
Figure 38. Section through Iowa Copper and Spiro Tunnel Workings.

AREAS FOR FUTURE EXPLORATION

Individual mine descriptions in this volume and in Heyl (1963) suggest that small reserves remain in several properties. Further exploration might expand these somewhat. Three areas for further exploration can be tentatively suggested:

1. There is a possibility that additional deposits, similar to those at Park City, exist beneath the north and northeast sides of Big Cottonwood Canyon. Such deposits are characterized by few surface indications.
2. Unexplored areas along the Alta overthrust zone and the probable north-northwesterly extension of the Superior fault zone (Argenta intrusive complex area) have potential for undiscovered Cardiff-type ore bodies. Unsuccessful exploration, some without geologic guidance, has already been conducted in parts of this area. Several ore bodies found near or below the level of the deepest nearby canyon suggests the ore system apexed near the present surface.
3. Finally, deep and shallow contact metasomatic deposits along the borders of the major plutons of the district may someday be of interest. Substantial tonnages of low grade ore can be inferred from outcrops.

The most promising surface exploration technique appears to be the search for dispersed trace metals in soils and water (i.e. geochemical prospecting). Geophysical methods should prove useful in mapping contact deposits. Improved drilling techniques should allow testing of deposits that in the past could be found only by underground exploration.



After **Calkins** and Butler, 1943, P. 114.

Figure 39. Plan and section of Steamboat tunnel, Mountain Lake group.

If prices and costs again favor small silver-lead-zinc operations, the delineation and testing of deeper targets (e.g. the limestone member of the Ophir Formation), and down-dip extension of ores on the Alta thrust zone) in old mines may prove worthwhile. Careful geologic studies based on good, surveyed mine and surface maps will greatly increase the chance of finding ore. Today mining companies routinely employ fulltime geologists to guide the exploitation of small, structurally-controlled ore bodies, but Big Cottonwood operations rarely had such guidance.

While silver has always been the most economically important metal of the Big Cottonwood District, and any future mining will probably be tied to price trends in that metal, recreation and water supply are at present much more important than mineral production in the area and can be predicted to remain so.

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APPENDIX I

Names of mines and prospects located on plate 1.

Argenta Area

1. Mutual tunnel (Mineral Fork area)
2. Logger mine
3. Maxfield mine, James drain tunnel
4. Maxfield mine, upper tunnel
5. Baker mine, nos. 1 and 2 tunnels
6. Baker mine, inclines
7. Newport claim
8. Afton tunnel
9. Newman main tunnel
10. Upper Newman (Monarch) tunnel
11. Old Monarch shaft
12. Colonial tunnel
13. Dolly Varden tunnel
14. Dolly Varden upper workings
15. Gold Coin tunnel
16. City tunnel
17. Sunnyside tunnel
18. Cottonwood King tunnel
19. Red Bell mine
20. Cottonwood Grand Central upper (main) tunnel
21. Confidence mine tunnels
22. Cottonwood Exchequer prospect

Main canyon Area

23. Big Cottonwood Bonanza tunnels
24. Cottonwood Metals tunnel
25. Belden tunnels
26. Lost Emma tunnel
27. Utah Old Glory prospect
28. Park City Western (?) prospect
29. Dawes tunnel, Silver King group
30. Lower Giles (Little Dollie) tunnel
31. American tunnel
32. Colorado Boy tunnel
33. Scottish Chief incline
34. Iowa Copper mine
35. Copper Apex tunnel
36. Crystal-Elgin inclines
37. Ottumwa and Snyder prospects
38. Great Western prospect
39. Big Cottonwood mine
40. Mountain Lake mine tunnels
41. Relief shaft
42. Thor, Agathos and Russel prospects
43. Tuscarora Chief (?) prospect
44. Unnamed tunnel
45. W.S. Brighton prospects
46. Dolphin and Carioca (Hilton and Dobie) prospect
47. Butte (Bute) tunnel
48. Black Bess incline
49. Solitude tunnel
50. Swastika Copper prospects
51. Evergreen Mine, New York tunnel
52. Old Evergreen drainage tunnel

Silver Fork - Honeycomb Fork Area

53. Copper King tunnel and shaft
54. Scotia prospect
55. Queen Bess mine
56. Kentucky Utah (Big Cottonwood Coaliton) tunnel
57. Clarke tunnel (Woodlawn mine)
58. New Sensation tunnel (Woodlawn mine)
59. Manahansett tunnel, (Woodlawn mine)
60. Gardner tunnel (Woodlawn mine)
61. Annie tunnel
62. Cooper tunnel
63. Antelope No. 3 tunnel
64. Wellington tunnel
65. Highland Chief shaft and tunnel
66. Boston tunnel
67. Lucky Dutchman shaft
68. Richmond and Teresa mine
69. Clements (Handsom) group
70. Alta (Bodfish) tunnel
71. Star tunnel
72. Unidentified prospects

Days Fork

73. St. Louis (?) (R and B North Extension) tunnel
74. Silver Moon prospect
75. Victory Lode tunnel
76. Gypsy Blair prospect
77. Days Fork (Alice) tunnels
78. Eclipse shaft
79. Sampson claim

Mill D South Fork

80. Kennebec (Goodspeed) tunnel
81. Craig (upper Kennebec) tunnel
82. Reed and Benson tunnel and shafts
83. Tom Jones prospect
84. Mountain Chief and South Fork Consolidated workings
85. Cardiff No. 3 tunnel
86. Cardiff Main (600 level) tunnel
87. Cardiff Beefsteak raise
88. Howell Lower tunnel
89. Howell upper tunnel
90. Baby McKee (Howell) incline
91. Monte Cristo shaft
92. Neva prospect
93. Rexall tunnels
94. Branborg (Am. Con. Copper, Meadow) tunnel
95. Last Chance tunnel
96. Thor, Venus and Bright Point prospects
97. Upper Tar Baby tunnel
98. Lower (Main) Tar Baby (and American Metals) tunnel

99. South Price (Victor) tunnel
100. Price main tunnel (Clara M group) and North Price tunnel
101. East Price tunnel
102. Malmborg tunnel
103. East Carbonate lower adits
104. East Carbonate upper tunnel
105. Big Cottonwood Consolidated tunnel
106. Reeds Peak Consolidated lower tunnel
107. Reeds Peak upper tunnel (Elgin Adit)
108. Mineral Park Group main tunnel
109. Mineral Park Group, tunnels and shafts
110. Little Cora (?) tunnels
111. Jefferson, Home Ticket, Bearson tunnels
112. Carbonate mine, Homeward Bound tunnel

Mineral Fork

113. Carbonate mine, Carbonate tunnel
114. Carbonate mine, Little Giant tunnel
115. Silver Mountain Mine, inclined shaft
116. Silver Mountain Mine, tunnel
117. Wasatch Gold (Mountain Mines) lower tunnel
118. Silver King (Regulator Johnson) main tunnel
119. Regulator Johnson (West) adit, Silver King fissure

Tunnels Portaled In Other Districts (with extensive workings in Big Cottonwood)

120. Columbus Rexall (Howland) tunnel
121. Tom Moore tunnel
122. Wasatch drain tunnel (Snowbird Resort)
123. Cleaves tunnel, Michigan Utah mine
124. City Rocks tunnel, Michigan Utah mine
125. Steamboat tunnel, Mountain Lake mine

Little Willow (Gold City) Area

126. Alix mine
127. Dipper (Clementine) lower tunnel
128. Golden Porphyry tunnel
129. New State (Con. Jefferson) shaft and tunnel
130. Wasatch Utah glory hole
131. Jefferson Extension (?)
132. "Tungsten" adit
133. Glenwood intermediate tunnel
134. Gold Willow tunnels
135. Utah Mammoth tunnels
136. Josephine workings
137. Blue Point (?) adits & Big Mitt
138. Murray Copper and Victor prospects
139. Cottonwood Gold Eagle prospect
140. Silica mine
141. St. Patrick prospect
142. Jones prospect
143. Galloway prospect

Peripheral Areas

144. Flagstaff tunnel
145. Emma tunnel
146. Shaw prospect
147. Venus (?) adit
148. Hayes mine
149. Scott prospects
150. Jones
151. Maxfield claim tunnel site; Squirrel (?)

APPENDIX 2

ALPHABETICAL LISTING
OF MINES AND PROSPECTS
BIG COTTONWOOD MINING DISTRICT

Adelaide (between 4 and 5)
Afton tunnel (8)
Agathos prospect (Thor & Russell) (42)
Alice tunnels (77)
Alix mine (Utah Philadelphia) (126)
Alta tunnel (70)
American Consolidated Copper tunnel (94)
American tunnel (31)
American Metals workings, portal (98)
Annie tunnel, Prince of Wales mine (61)
Antelope No.. 3 tunnel, Prince mine (63)

Baby McKee (Howell) incline (90)
Bachelor claim (21)
Baker mine (5)
Baker mine, inclined shafts (6)
Baker mine, tunnels no. 1 and 2 (5)
Bearson tunnel (111)
Belden tunnels (25)
Big Cottonwood Bonanza tunnels (23)
Big Cottonwood Coalition tunnel (56)
Big Cottonwood Consolidated tunnel (105)
Big Cottonwood mine (39)
Big Cottonwood Monarch
Big Mitt (137)
Black Bess incline (48)
Blue Jay (132)
Blue Point adits (137)
Bodfish (Alta) tunnel (70)
Boston tunnel, Prince of Wales mine (66)
Branborg tunnel (94)
W. S. Brighton prospects (45)
Bright Point prospects (96)
Butte or Bute tunnel (47)

Carbonate mine: Homeward Bound tunnel (112)
Carbonate mine - Carbonate tunnel (113)
Carbonate mine - Little Giant tunnel (114)
Cardiff Extension (Cottonwood Exchequer) (22)
Cardiff mine - Beefsteak raise (87)
Cardiff mine, main tunnel (86)
Cardiff mine, No. 3 tunnel (85)
City Rocks tunnel, Michigan Utah mine (124)
City tunnel (Newman group) (16)
Clara M group (100)
Clarke tunnel (Woodlawn mine) (57)
Cleaves tunnel, Michigan Utah mine (123)
Clementine mine (127)
Clements (Handsom) Prospects (69)
Colonia tunnel (12)
Colorado Boy tunnel (32)
Columbus Rexall (Howland) tunnel (120)
Confidence mine - tunnels (21)
Consolidated Jefferson (129)
Contention (109)
Cooper tunnel (62)

Copper Apex tunnel (35)
Copper King tunnel and shaft (53)
Cottonwood Coalition tunnel (56)
Cottonwood Exchequer prospect (22)
Cottonwood Gold Eagle prospect (139)
Cottonwood Grand Central upper (main) tunnel (20)
Cottonwood King (30)
Cottonwood King (Union Associated) tunnel (18)
Cottonwood Metals tunnel (24)
Craig tunnel (81)
Crystal-Elgin inclines (36)

Days Fork tunnels (77)
Dawes tunnel, Silver King group (29)
Dipper (Clementine) mine, lower tunnel (127)
Dolly Varden tunnel (13)
Dolly Varden mine - upper workings (14)
Dolphin and Carioca prospects (46)
Dragon (30)

East Carbonate lower tunnels (103)
East Carbonate upper tunnel (104)
East Price tunnel (101)
Eclipse shaft (78)
Elgin tunnel (Scott) (36)
Emma tunnel (145)
Evergreen mine, New York tunnel (51)
Evergreen drainage and development tunnel (52)
Excelsion (82)

Flagstaff tunnel (144)

Galloway prospect (142)
Gardner tunnel, Woodlawn mine (60)
Giles (Little Dollie) tunnel (30)
Glenwood (Pelican) intermediate tunnel (133)
Gold Coin tunnel (15)
Gold Willow (Johnson) tunnels (134)
Golden Porphyry drain tunnel (128)
Goodspeed tunnel (80)
Great Western prospect (38)
Gypsy Blair prospect (76)

Hayes (148)
Highland Chief shaft and tunnel (65)
Hilton and Dobie prospect (46)
Hirschman group (78)
Homestead claim (104)
Home Ticket (111)
Homeward Bound tunnel (112)
Howell lower tunnel (88)
Howell upper tunnel (89)

Insley (Scottish Chief) (33)
Iowa Copper mine, main adit (34)

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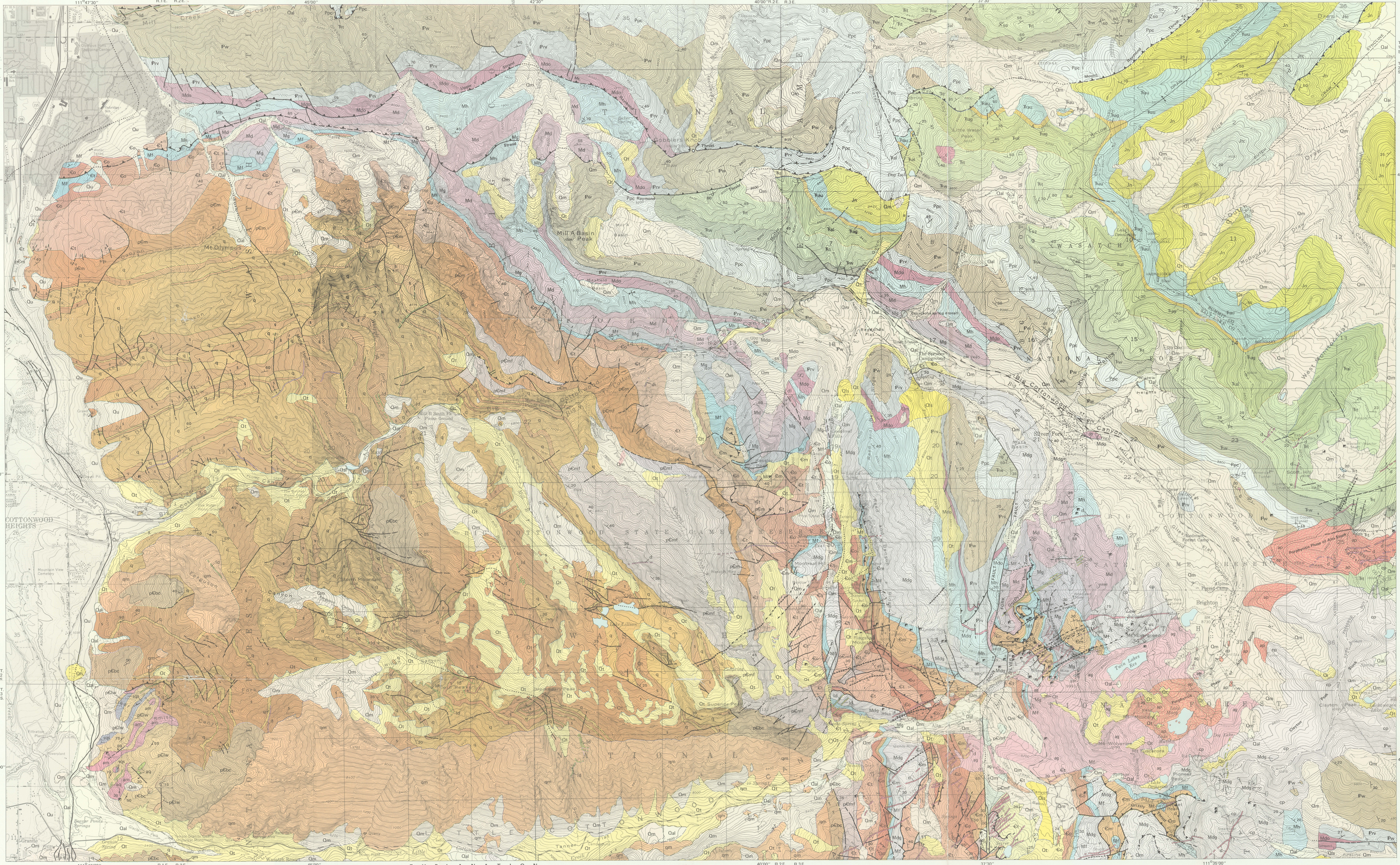
STATE OF UTAH
Department of Natural Resources
Utah Geological and Mineral Survey

Plate 1
Bulletin 114
L.P. James, Geology of
Big Cottonwood Mining District



E X P L A N A T I O N

QUATERNARY

- Qal — Alluvium
- Qt — Talus
- Qls — Landslide debris
- Qu — Undifferentiated alluvium
- Qm — Glacial moraine

TERTIARY

- d — Intrusive dikes, *Granodioritic to granitic (?)*
- ld — Intrusive dikes, *Lamprophyres*
- di — Dioritic intrusive rocks, *Mainly Argenta intrusive complex*
- qm — Quartz monzonite intrusive rocks, *Mainly Little Cottonwood stock*
- ag / ap — Alta Stock, ag, *granodiorite phase;* ap, *porphyritic phase*
- cp — Clayton Peak Stock

JURASSIC

- Jtc — Twin Creek Limestone *(uncommon in area)*
- Jn — Nugget Sandstone

TRIASSIC

- Ꝛau — Ankareh Formation, *Upper member*
- Ꝛag — Ankareh Formation, *Gartra Grit Member*
- Ꝛal — Ankareh Formation, *Mahogany Member*
- Ꝛt — Thaynes Formation
- Ꝛw — Woodside Shale

PERMIAN

- Ppc — Park City Formation

PENNSYLVANIAN

- ℙw — Weber Quartzite
- ℙrv — Round Valley Limestone

MISSISSIPPIAN

- Mdo — Doughnut Formation
- Mh — Humbug Formation
- Md — Deseret Limestone
- Mdg — *(Undifferentiated)*
- Mg — Gardison Limestone
- Mf — Fitchville Formation

CAMBRIAN

- Ꞓm — Maxfield Limestone, Ꞓmd - *dolomite at top of lower member*
- Ꞓo — Ophir Formation
- Ꞓt — Tintic Quartzite

PRECAMBRIAN (younger Y and Z)

- pꞒm — Mutual Formation
- pꞒmf — Mineral Fork Tillite
- pꞒbc (q, s) — Big Cottonwood Formation, q - *quartzites*, s - *shales and slates*

PRECAMBRIAN (older X)

pꞒlw — Little Willow Formation

- am — Amphibolites, *Former sills and dikes (?)*
- aq — Metasediments, *Mainly quartzites including arkosic to aplite-like gneiss*
- sqs — Sericite schist, *(Locally with stretched cobbles)*

SYMBOLS

- Strike and dip of beds
- Strike and dip - overturned beds
- Vertical beds (or vein)
- Strike and dip of metamorphic foliation
- Contact, *Dashed where approximately located; dotted where concealed*
- Fault, *Dashed where approximately located; dotted where concealed showing dip*, U - *upthrown side* D - *downthrown side*
- Fissure
- Thrust fault, *Sawteeth on upper plate*
- Tunnel (adit)
- Prospect pit
- Shaft, *Vertical or inclined*

SCALE 1:24000

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

GEOLOGY OF BIG COTTONWOOD MINING DISTRICT

compiled by Max D. Crittenden, Jr., Frank C. Calkins, Byron J. Sharp, Arthur A. Baker, and Calvin S. Bromfield

Modified by Larry P. James

1978

Base from U.S. Geological Survey topographical quadrangles: Sugar House, 1969pr; Mount Aire, 1955; Park City West, 1955; Draper, 1969pr; Dromedary Peak, 1955; and Brighton, 1955.

Drafted by : Brent R. Jones, Greg F. McLaughlin

Appropriations No. 01-61-03
Archives Approval No. 7800218

17°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1955

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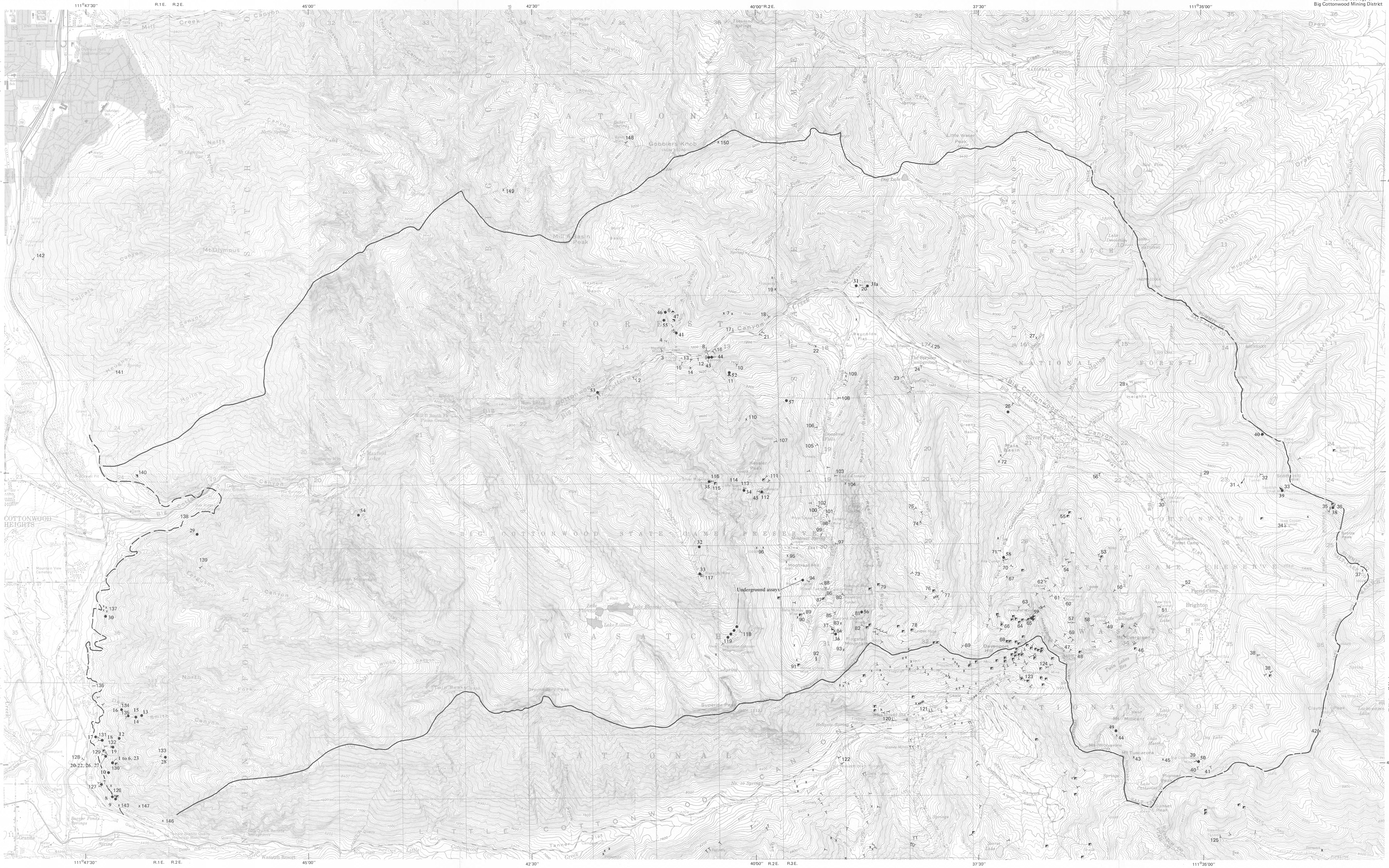

EXPLANATION

133 — See Appendix I, Approximate Locations of Mines and Prospects.

28 — See Table 5, page 15, Trace element analyses.

LOCATIONS OF MINES, PROSPECTS, AND GEOCHEMICAL SAMPLES, BIG COTTONWOOD DISTRICT

SCALE 1:24,000

1 ½ 0 1 Mile

1000 0 1000 2000 3000 4000 5000 6000 7000 Feet

1 .5 0 1 Kilometer

Contour interval 40 feet
Datum mean sea level

Base from U.S. Geological Survey topographic quadrangles: Sugar House, 1969pr; Mount Aire, 1955; Park City West, 1955; Draper, 1969pr; Dromedary Peak, 1955, and Brighton, 1955.

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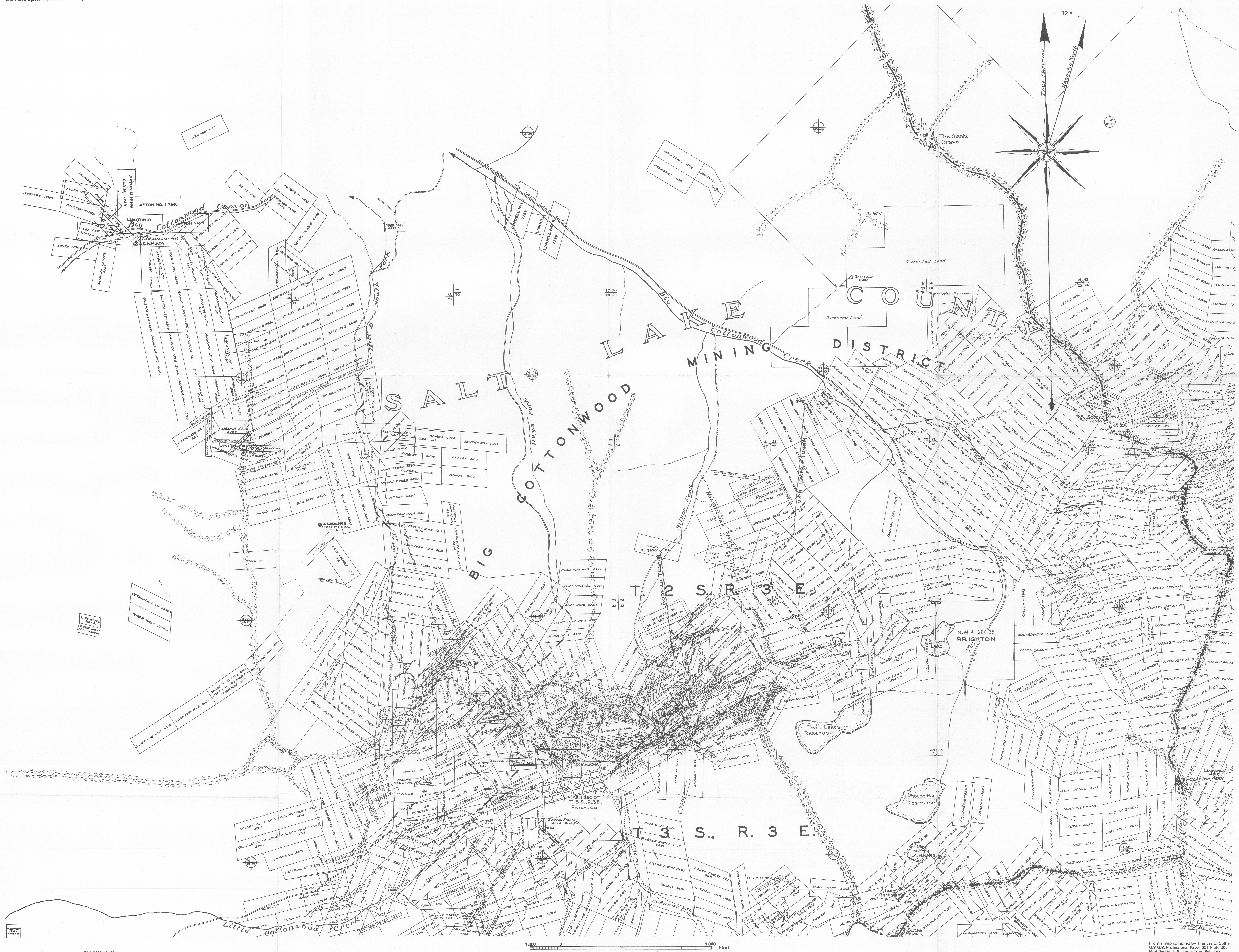
PLATE 3
Bulletin 114
L.P. James, Geology Of Big
Cottonwood Mining District



EXPLANATION

Section Corner

Numbers corresponding to the district sheets in the Cadastral Engineer's Office

CLAIM MAP OF BIG COTTONWOOD AREA, UTAH

From a map compiled by Frances L. Collier, U.S.G.S. Professional Paper 201 Plate 30. Modified by L.P. James from Salt Lake County and U.S.B.L.M. records.

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Plate 4
Bulletin 114
L.P. James, Geology Of
Big Cottonwood Mining District

WORKINGS OF MAXFIELD AND BAKER PROPERTIES, BIG COTTONWOOD DISTRICT, UTAH

Based on U.S.G.S. Professional Paper 201, Plate 31 and map by A.G. Burritt, August 1938. Geology added by L.P. James.

Appropriations No. 01-6103
Archives Approval No. 78-00218

UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
Salt Lake City, Utah 84108

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The Survey publishes bulletins, maps, a quarterly newsletter, and a biannual journal that describe the geology of the state. Write for the latest list of publications available.

The Survey also sells the colored geologic map of Utah (Army Map Service base, 1:250,000, in four quarters), a project of the College of Mines and Mineral Industries of the University of Utah from 1961 through 1964. It acts as sales agent for publications of the Utah Geological Association and its predecessor organizations, the Utah Geological Society, the Intermountain Association of Geologists, and the Intermountain Association of Petroleum Geologists.

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