GOLDSTRIKE MINING DISTRICT, WASHINGTON COUNTY, UTAH

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ABSTRACT

The Goldstrike mining district is located in western Washington County, about 35 miles northwest of St. George. Gold was discovered in the district sometime in the late 1800s and the area was being actively prospected by 1895. This early work did not lead to any significant production although a total of 40 lode claims and 1 placer claim were brought to patent as a result of the early work. The area was largely ignored until the mid-1970s when a search was begun for disseminated gold deposits of the type then being actively mined in central Nevada. This search was successful and led to the production of approximately 200,000 ounces of gold and a somewhat smaller amount of silver from 12 near-surface deposits. The bulk of the ore in eight of these deposits was found in a sandstone host rock occurring at the base of the early Tertiary Claron Formation. High-angle faults appear to have been important in localizing ore in these deposits as well as in the other four deposits, where most of the ore occurred in brecciated and silicified Paleozoic limestone units.

The pre-Tertiary rocks in the district are complexly folded and faulted and record a long history of tectonic activity that culminated in extensive overthrusting of the Paleozoic rocks onto a sequence of clastic rocks of Mesozoic age. This overriding thrust is not exposed in the Goldstrike district but most likely underlies the entire district. Following this period of thrusting the area was nearly beveled by erosion. The Claron Formation was then deposited across the beveled surface, followed by extrusion of large volumes of volcanic tuffs. Later high-angle faulting offset the Tertiary rocks and formed conduits for the mineralizing solutions that produced the gold-silver ore bodies.

INTRODUCTION

The Goldstrike mining district is an informal name for an unorganized district lying in northwestern Washington County, Utah, along the East Fork of Beaver Dam Wash. It is a southwestern extension of the equally informal Bull Valley iron district, which is essentially undeveloped and will not be discussed herein. Gold ore was mined from near surface deposits occurring in silicified rocks generally lying along or adjacent to high-angle faults.

The district can be reached by traveling north from St. George on the old U.S. Highway 91 to the Gunlock road, taking this road north another mile or so and then following the Motoqua road to the DI Ranch road. The good graded gravel road to the district continues on north from the DI Ranch road to the property. The route has been marked by signs, many of which are now missing, pointing to the USMX mine and is accessible the year round. An alternate route extends up Grapevine Wash and over the divide into the district from the east.

HISTORY

Early Exploration and Development

Prospecting activity began in Washington County as early as the 1870s, but its inception in the Goldstrike district or the first discovery of gold in the district is not recorded. Prospecting with indifferent success had certainly begun by the late nineteenth century. Newspaper accounts published in late 1895 report that "assessment work on gold mines in the Bull Valley region is being pushed with a vim, and it is expected that the mines will soon prove to be quite rich" and that "prospects in that vicinity are in a flourishing condition" (The Union, St. George,

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Willden, Ronald, 2006, Goldstrike Mining Distict, Washington County, Utah, in Bon R.L., Gloyn, R.W., and Park, G.M., editors, Mining Districts of Utah: Utah Geological Association Publication 32, p. 458-476.

Dec.14, 1895, Dec. 21, 1895). The district had attracted the attention of the U. S. Geological Survey by 1906, which reported (Heikes, 1907, p. 362) that "considerable work was done on gold properties in the western edge of the county during the year, and it is stated that mines of merit are being developed there." Activity was again reported in 1908 when "a new gold district known as 'Bull Valley' claimed attention" (Heikes, 1909), but there must have been some falling off of activity because the district was not mentioned again until 1912 (Heikes, 1913) even though some of the claims that were later taken to patent were located in 1910. The renewed prospecting activity in the district is mentioned by Heikes (1913, p. 913) who reported that "gold discoveries in the Bull Valley section created interest and several mining companies were prospecting with results reported as encouraging." Some of the claims taken to patent bear the same names as claims located and recorded much earlier, but the descriptions of those early claims generally are so vague as to defy their proper identification.

Patents were issued from 1914 to 1922 for a total of 40 lode claims and one placer claim shown on figure 1. The owners of the lode claims were: Bull Valley Gold Mines Company, 16 claims; Barker Gold Mining Company, 9 claims; Goldstrike-Searchlight Mining Company, 7 claims; Gold Strike-Virginia Mining Company, 4 claims; and Bull Run Mining Company, 4 claims. None of the companies survived and most of the claims were eventually sold by the County to recover back property taxes.

Some gold, including specimen ore, pictured in Butler (1920, pl. XLIX), was found and a three-stamp mill (figure 2) was erected on the property of the Gold Strike-Virginia Mining Company in 1914 (Heikes, 1915), but very little gold production resulted from this activity. The district was described briefly by Butler (1920) and by Cook (1960), but otherwise escaped the attention of the geologic community until the mid-1970s when the search for disseminated gold deposits began. However, the district did not escape the attention of a visionary prospector, Paul Lamoreaux who, with his wife ArJean, began

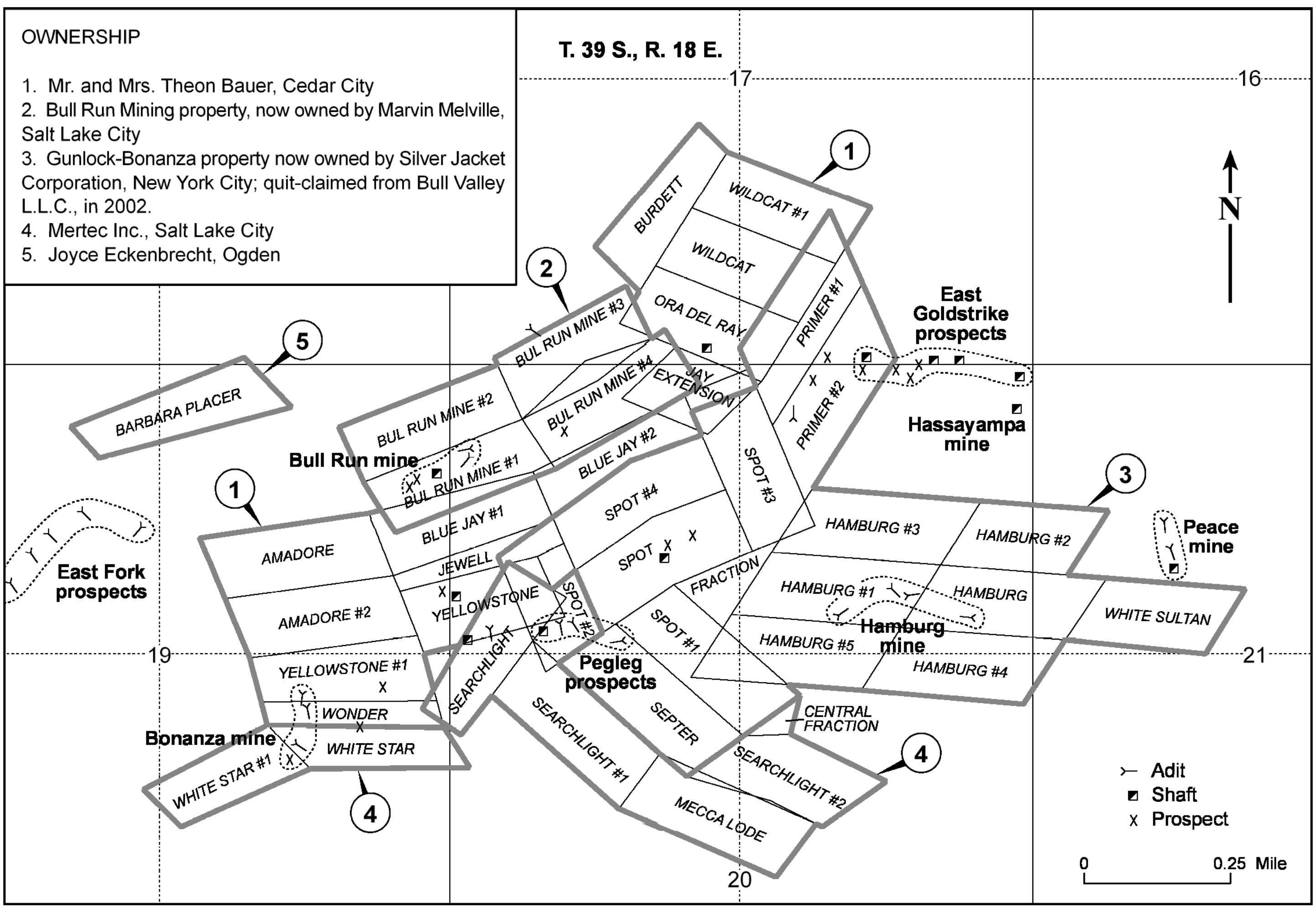

Figure 1. Patented claims in the Goldstrike district and historical mines.

Figure 2. Three stamp mill at Goldstrike as it appeared in 1986. Photograph by R. Willden.

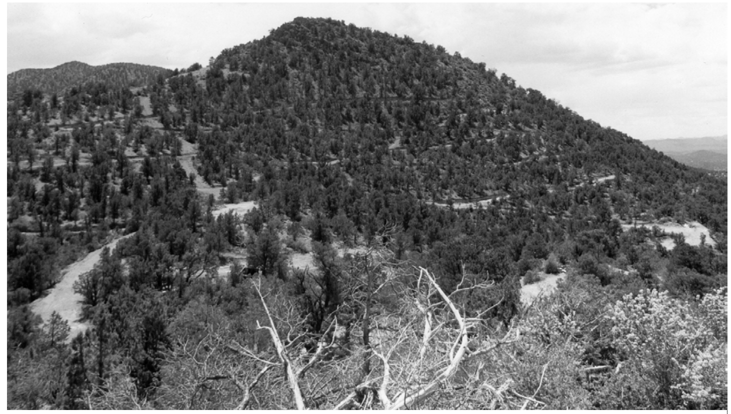

Figure 3. Hamburg Hill as it appeared in 1986; view looking south at drill roads. Three adits out of site on west side of ridge; northern adit at scar on ridge crest. Contrast this with figure 4 taken after mining.

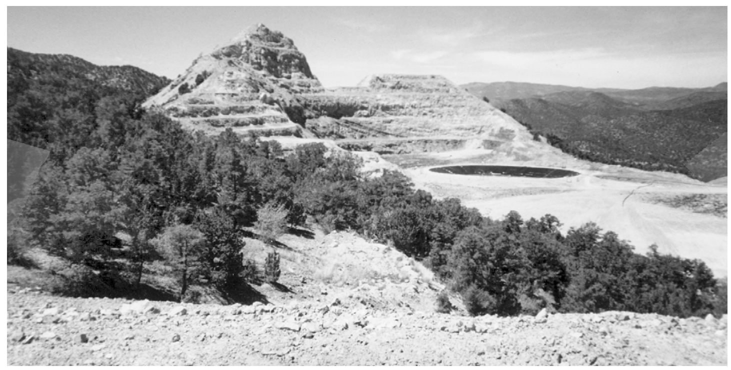

Figure 4. Hamburg open pit mine after partial reclamation. Plastic-lined pit in right center developed to hold flood waters.

staking claims in the late 1960s to cover most of the old prospects that were not sited on patented claims. They eventually acquired 53 claims that adjoined the patented claims on the east, north and, to a limited extent, on the south. This block of unpatented claims known as the Padre Mining Company property was the first block to be acquired when the modern program described below began. The initiative and foresight of Mr. Lamoreaux was rewarded when more than 100,000 ounces of gold were produced from open pit mines located on the Padre Mining Company property.

The early prospecting led to the development of several underground mines. The largest of these was the Hamburg mine located on Hamburg Hill (pictured in figure 3) on claims owned by Bull Valley Gold Mines Company. It was opened by adits on 3 levels on the west side of the peak and one adit on the east side. The Hamburg open-pit mine, shown in figure 4, destroyed all of these openings except the lowermost adit when it was mined between 1990 and 1993. The high-grade gold specimen mentioned by Butler (1920) came from this mine. The Bul Run mine, on claims owned by Bull Run Mining Company, was the second largest underground mine; it shows evidence of stoping along a shallow dipping shear zone that evidently hosted the gold mineralization. This mine is the only mine other than the Hamburg mine to have been credited with any production in the old records (Gerry and Miller, 1935, p. 342). Some of these mine sites and access roads are shown on the reproduced aerial photograph (figure 5). The Bonanza mine situated on the WhiteStar patented claim originally owned by the Goldstrike-Searchlight Mining Company, was developed by short adits and drifts on 3 levels. This mine became the site of the Covington open-pit in 1992. The other early mines include the Hassayampa and Peace mines, both on claims that were not taken to patent, and several other unnamed prospects. The Hassayampa mine was opened by a shaft that was destroyed by development of the larger of the two Hassayampa open pit mines shown in figure 6. The workings on these mines or prospects were not accessible and the dumps generally were small, indicating only minor underground development.

Figure 5. Copy of aerial photograph taken in 1985 showing old mines and drill roads (B-Bul Run mine, Hb-Hamburg mine, Hs- Hassayampa mine, Mz-site of future Main Zone pit, P-Peace mine). Photo courtesy of Inspiration Mines.

Figure 6. Hassayampa pit as it appeared at dedication of plant in May 1989 after mining had been completed and as it was being back-filled. Black unit is Chainman Shale overlain to left by quartzite identified as Scotty Wash, which is in turn overlain by Claron beds farther to the left.

Modern Exploration Program

Modern prospecting in the district has been described in some detail by Willden and Adair (1986). This prospecting began because of the reported occurrence of antimony and arsenic minerals in proximity to gold occurrences in the Goldstrike district (Butler 1920). The association of arsenic, antimony and mercury with gold is almost universal in the generally low-grade, disseminated gold deposits that have been found in the western United States, and particularly in Nevada, since the mid-1960s. This association at Goldstrike prompted an examination of the district for disseminated gold deposits. This examination began in 1975 by Gold Resources Inc., (GRI), with reconnaissance mapping of the old Bull Valley special topographic map and rock chip sampling of the jasperoids and other altered rocks exposed in the district. This sampling found widespread gold mineralization over a 20-square-mile area that included the Goldstrike district proper and much adjacent ground in and west of the Bull Valley district. The most significant gold values were found in jasperoids that occurred along faults or at the contact between limestone and overlying clastic or volcanic rocks.

Leases were then obtained on the Padre Mining Company property and on some of the patented claims and a soil sampling program covering the better exposed jasperoid areas was begun. This sampling identified several broad, high-amplitude gold anomalies, but later follow-up rock chip sampling of the soil anomalies found gold only in silicified rocks. The jasperoid bodies were thought to be too small to host gold ore bodies of sufficient size to support an open pit mining operation and, therefore, these anomalies were not tested by drilling and GRI relinquished their leases.

Occidental Minerals acquired leases in 1978 and began drill testing of the gold-in-soils anomalies that had been identified by GRI. This drilling encountered ore-grade intersections but most were thin and the company concluded they were unlikely to find ore bodies large enough to satisfy their corporate objectives and they abandoned the project early in 1979. Continued exploration described by Willden and Adair (1986) that included drilling, mapping and sampling by Houston International Minerals Company from 1979 through 1981, and then by Permian Exploration Account (PEA) from 1982 to 1985 provided sufficient encouragement that Inspiration Mines, Inc. subleased the properties from PEA and conducted an extensive exploration-development drilling program from late 1985 to mid-1987. Inspiration sold their lease to Tenneco Minerals, who continued the exploration and development drilling and in 1988 commenced open-pit mining operations and heap leaching of the ore. Tenneco continued as operator until late 1992 when they turned the property over to United States Mineral Company (USMX), who mined out the remaining known ore, did some exploration drilling without adding to the reserves, and through their successor company, Dakota Mines, completed physical reclamation of the property in late 1999. The pits developed by Tenneco and later by USMX are shown on figure 7.

USMX terminated their lease with Bull Valley L. L.C.--the successor in interest to PEA--in 1996, after having mined most of the known ore, and reconveyed the mining properties to the Lessor after completing physical reclamation of the property (figure 8 shows the reclaimed haul road after reclamation had been completed. Bull Valley management considered this termination to have been premature; almost no effort had been made to explore the district for deep and possibly rich ore bodies similar to some that had been found in Nevada at depth beneath the generally low-grade, near-surface deposits. North Mining, Inc., was persuaded that a search for deep ore bodies might be worthwhile, and they undertook a detailed study of the district, which culminated in 1997 with the drilling of one core-hole each in three of the open-pit mines. These holes, which were sited to intersect known structures at depths of about 300 ft beneath the pits, failed to cut any ore-grade mineralization and North promptly abandoned the project.

Bull Valley undertook a limited deep drilling program in 1999 because efforts to interest other ex-

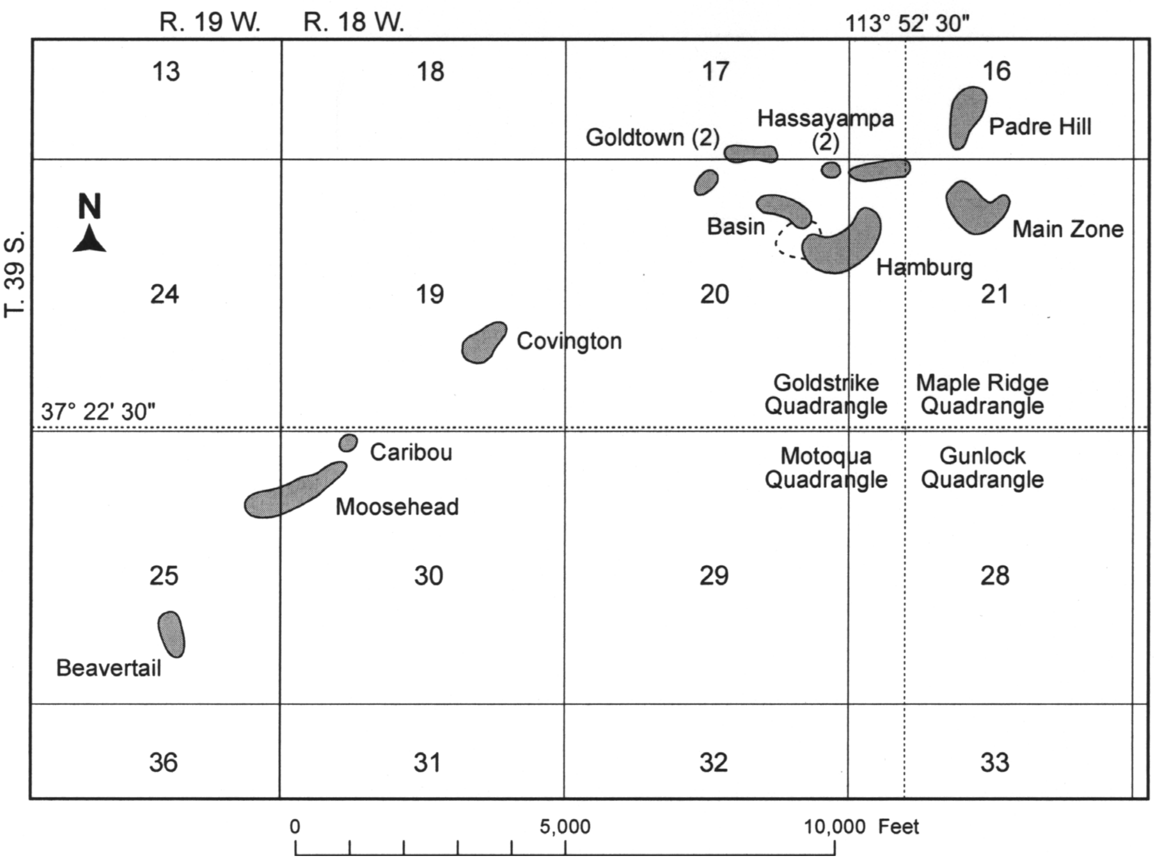

Figure 7. Location of open pit mines, Goldstrike district, Washington County, Utah.

Figure 8. Eastern part of Goldstrike district looking across reclaimed haul road in foreground at number 1 heap in center of view and number 2 heap above and to right; Hamburg pit highwall near right edge of picture.

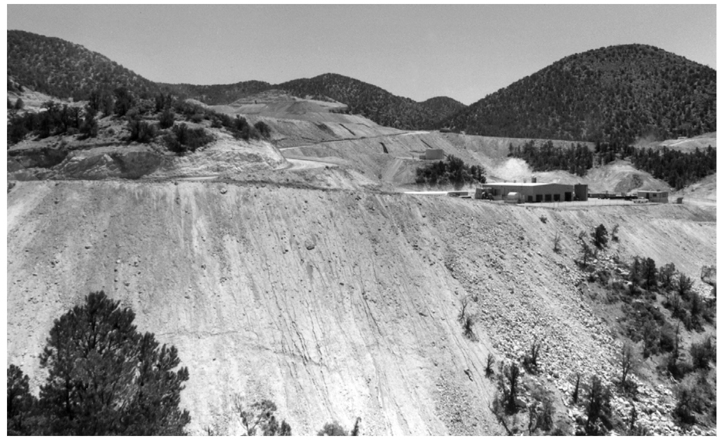

Figure 9. Plant site as it appeared in May 1989.

ploration companies in further deep exploration had failed. Bull Valley drilled six holes to depths of 1200 to 1680 ft using reverse-circulation techniques to test projected fault intersections at depth. Obvious fault zones or other mineralized intervals encountered at depth in these holes showed geochemically anomalous amounts of gold, arsenic, antimony or mercury, but intersected no ore-grade or near ore-grade material and Bull Valley also abandoned their effort. Although exploration companies continue to profess interest in the area there has been no significant exploration since 1999 and the district is idle.

Modern Mining and Milling

Open-pit mining of the gold deposits discovered during the exploration program began in 1988 with development of the Hassayampa pits and leveling of sites for an office complex, a heap-leach pad, a crushing plant, and a solution processing plant (shown in figure 9). The twelve pits developed on the Goldstrike ore bodies are shown on figure 7. The mining, crushing, and hauling of ore was done by contractors, but all the engineering and processing activities were performed by company personnel.

Ore from the two Hassayampa pits was leached on the initial pad, which was then expanded by filling and leveling the two Hassayampa pits (see figure 6) to accept ore from the Main Zone pit. When the ore from the Main Zone pit was mined out, the pit was partially back-filled with waste from stripping the Hamburg and Padre Hill ore bodies and a new leach pad was constructed on this back-filled pit. The two leach pads (Hassayampa and Main Zone), the processing plant, and some of the pits are shown in an aerial photograph taken in 1991 as the Hamburg and Padre Hill ore bodies were being mined (figure 10). Ore from all the remaining ore bodies was trucked to the Main Zone pad for leaching. It became necessary to move the crushing plant to a back-filled portion of the Hamburg pit as mining continued in order to further expand this pad, and even with this expansion some ore was left in some of the pits because of lack of space on the Main Zone heap. The Hassayampa pad was unusable because of cracks in the pad liner and the danger of solution leakage from the pad. It also became necessary to move the office complex southeast to the recovery plant site in order to mine the larger of the two Goldtown ore bodies. After leach pad construction was completed, waste from stripping the various ore bodies was used for back filling pits to create positive drainage from the pits and for haulage road construc-

Figure 10. Copy of aerial photograph taken in 1992 showing from left to right office site, Heap No. 1, crusher plant site, Heap No. 2 and high wall of Main Zone pit through center of photo. Padre Hill pit in upper right and Hamburg pit in lower left. Photo courtesy of Dakota Mines.

tion, so that only one permanent waste dump remained on the property when mining ceased in 1996.

PRODUCTION

The early production from the Goldstrike district certainly was not large. The only official records of the early production that have been found are in various editions of Mineral Resources of the United States (U.S. Geological Survey, 1901-1912; U.S. Geological Survey and U.S. Bureau of Mines, 1913-1931) and in Minerals Yearbooks (U.S. Bureau of Mines, 1931-present), but these records are far from complete and generally do not ascribe production to any specific property. The original stamp mill, which remained in the district until sometime after 1986, had no tailings pile associated with it, and the underground workings that were accessible during the exploration programs during the 1970s and 1980s were not extensive. There were no large waste dumps associated with any other underground openings that would suggest extensive workings. Tailings from the stamp mill may have been washed away by floods along East Beaver Dam Wash, but because the stamp mill was not close to the wash some tailings should remain if the production had been significant. Gold and silver production reported in the Mineral Resources of the United States publications from Washington County, if any, for the years 1903 to 1908 were combined with that from Sevier, Grand and Box Elder Counties and was not large. Production of 9.39 ounces of gold and 4 ounces of silver contained in siliceous ore was reported for Washington County in 1912 (Heikes, 1913, p. 886-887) and likely was from Goldstrike although not specifically identified. The 1914 volume reported the construction of the stamp mill and reported that some bullion had been made (Heikes, 1916, p. 755), but the actual production figures are generalized for the county at 23.22 ounces of gold from 35 tons of siliceous ore (Heikes, 1916, p. 720-721), again most likely from Goldstrike. The gold and silver production known to have come from Goldstrike or most likely to have come from Goldstrike for the years from 1912 to 1942 is shown in table 1.

Private company reports on the Hamburg mine (Bible, 1924, 1935) reported that several pockets of ore with a market value of several thousand dollars per ton in gold had been produced and that significant amounts of ore remained in the mine. This report prompted an exploration program by Lustre Gold Mines, Inc. in 1977 (Willden and Adair, 1986). Results proved disappointing to Lustre and they terminated their lease. Similarly, a private report on the Bonanza mine (Wyman, 1961) mentions the lack of production data but also records that an estimated

Table 1. Gold and silver production from Goldstrike distict, 1912 through 1942.

Year	Source	Tons	Gold (ounces)	Silver (ounces)
1912	Heikes, 1913	18	9.39	4
1914	Heikes, 1916	35	23.22	9
1915	Heikes, 1917	173	593	222
1916	Heikes, 1919	15	10.49	4
1918	Heikes, 1921	15	9.87	4
1919	Heikes, 1922	1	0.97	2
1928	Gerry and Miller,	6	19.01	6
1929	Gerry, 1932		39.43	15 1/
1931	Gerry and Luff, 1934	1	1.3	0
1933	Gerry and Miller,	3	11.27	11
1934	Gerry and Miller, 1935	3	41.80	20
1935	Gerry and Miller, 1937	5	1.8	
1936	Gerry and Miller, 1937	20	13.6	9
1937	Miller, 1938	4 2/	4 2/	4 2/
1939	Miller and Luff, 1940	1	18	3
1949		11	8	
1941	Woodward and Luff, 1943	17	2	14
1942	, 1943	10	6	6
		Total	813.95	333

1/ Part of this may have come from Apex mine.
2/ Estimated from total Bull Valley production.

$40,000 in coarse gold had been produced from pods of bonanza ore. The Bul Run mine was also rumored to have produced rich ore, and stoping visible in the near surface workings of the Bul Run mine suggests that some gold was produced. Only one production reference was found for the Bul Run mine, and no records were found for other early mines and prospects. The speculative reports cited above are not supported by the available production figures. Only about 815 ounces of gold are known to have been produced and the reports by Bible and Wyman, cited above, would require much more than this.

The open-pit mining conducted in the district from 1988 to 1996 first by Tenneco Minerals and later by USMX resulted in the loading on the leach pads ore containing approximately 280,000 ounces of gold (table 2). The figures in the table are not entirely consistent because the average grade of ore from each mine when multiplied by the tonnage and then added together do not match the total shown in the table, but both numbers are significantly higher than the gold recovered and sold. Between 1988 and 1996, the district produced 209,835 ounces of gold and approximately 197,654 ounces of silver from nearly 7 million tons of ore (table 3). The nearly equal amounts of silver and gold in the ore is demonstrated by the dore ingot on display at the mill dedication in May 1989 shown in figure 11, which also shows in the background the recovery plant that can also be seen in figure 9. It should be noted that, in addition to the gold production listed in table 2, 15,590 ounces remain in the undeveloped Hamburg West Extension deposit (the drill roads used to define this reserve are shown in figure 12), 5,000 ounces in the Beavertail pit, and an estimated 5,000 ounces were left behind in various pits because of unsafe highwall conditions and because of a lack of space on the leach heaps.

Some of the silver was produced from a Merrill-Crowe recovery cell in the mill during the early stages of mining and some mercury was recovered and sold, because of the need to retort the sludge from the Merrill-Crowe cell prior to smelting the Dore ingots. The sale of mercury recovered only the cost of obtaining it and no royalties were paid on mercury production.

GEOLOGIC SETTING

The geology of the Goldstrike district and the surrounding region has been described in three papers in Utah Geological Association Guidebook 15 on Southwestern Utah (Adair, 1986, Hintze, 1986, and Willden and Adair, 1986). The paper by Will-

Table 2. Production from Goldstrike district, 1988 through 1996 by individual open-pit mines.

Pit	Crusher (tons)	Head grade 2/	ROM 1/ (tons)	Head grade	Mined (ounces)	Waste (tons)
Hassayampa 3/	121,200	.038	144,400	.022	7,420	1,019,500
Main Zone	1,263,000	.048	295,600	.021	66,350	2,764,600
Hamburg	1,349,900	.042	937,400	.023	78,240	6,462,000
Padre Hill	481,100	.039	331,400	.022	23,710	2,241,000
Goldtown 3/	111,520	.043	275,960	.023	8,980	383,000
Basin	272,620	.038	73,949	.020	12,380	1,769,700
Covington	150,000	.048	240,510	.025	13,200	463,000
Moosehead & Caribou	547,000	.048	866,000	.025	54,000	2,875,000
Beavertail			576,600	.028 4/	16,140	720,700
Total 5/	4,296,340	.042	3,741,819	.023	280,420 6/	18,698,500

1/ ROM = run of mine ore, loaded on heaps without crushing.
2/ Head grade = grade in ounces gold per ton.
3/ Two pits combined.
4/ All of this ore was treated as run-of-mine although much was of high enough grade to be crushed had the haul to the plant been shorter.
5/ An undeveloped ore body lying between the Hamburg and Basin pits was calculated to total 433,100 tons at an average grade of 0.036 opt.
6/ There is some unresolvable inconsistency in the tonnage and grade figures because an overall grade calculated by multiplying the tonnage by the grade for each deposit does not equal the total shown in the figure as contained ounces.

Table 3. Gold and silver production from Goldstrike district, 1988 through 1996.

Year	Tons	Gold (ounces)	Silver (ounces)
1988	98,440		
1989	1,015,260	22,709	21,303
1990	956,150	44,202	37,069
1991	665,585	35,658	54,542
1992	1,539,960	34,376	45,667
1993	1,465,000	32,844	20,462
1994	1,117,995	34,486	15,600 (est.)
1995		5,000	3,000
1996		560	none
Total	6,858,390	209,835	197,654

Source: Tons - Utah Division of Oil, Gas and Mining permit files.
Gold and silver- U.S. Bureau of Mines Mineral Industry in Utah in Minerals Yearbook and Utah Geological Survey files.

Figure 11. Emma L. Willden holding dore ingot on display at plant dedication, May 1989. Ingot had a distinct silver color indicating high silver content. Recovery plant visible in distance. Photo courtesy Tenneco Minerals.

den and Adair (1986) discusses the gold deposits at Goldstrike. Several unpublished Master's and Ph.D. theses discuss the geology of the general area or the mine area in particular (Blank, 1959; McCarthy, 1959; Wiley, 1963; Eliopulos, 1974; Morris, 1980; Greenan, 1992; Effner, 1992).

A generalized geologic map of the Goldstrike area is shown on figure 13 and a stratigraphic column is shown in table 4. Locations of the open pit gold mines are shown on the planimetric map of figure 9. Most of the gold that has been mined in the Goldstrike district to date has come from deposits associated with a major unconformity between the basal sandstone and conglomeratic sandstone member of the Claron Formation and the underlying folded and thrust faulted upper Paleozoic rocks of various lithologies. Gold mineralization occurred in Tertiary time, probably during the Miocene, following repeated episodes of block faulting and transcurrent faulting along structures with east-west, northeast, and northwest orientations. The gold mineralization was accompanied in most areas by widespread silicification and the principal host rock for the mineralization was the basal sandstone and conglomeratic sandstone member of the Claron Formation. Considerable mineralization is also present in the underlying Paleozoic rocks where they are highly fractured or where certain favorable stratigraphic units are present. Only three of the 12 deposits that have been mined were hosted entirely by Paleozoic rocks; the Covington, Caribou and Beavertail deposits. One deposit, the Basin deposit, is entirely in basal Claron. All other deposits are dominantly in the Claron, but also partly in Paleozoic rocks. The undeveloped Hamburg West Extension deposit also is partly in Claron and partly in Paleozoic rocks.

Figure 12. Goldtown pit in foreground, high wall of Basin pit in center and Hamburg pit in distance, June 4, 1992.

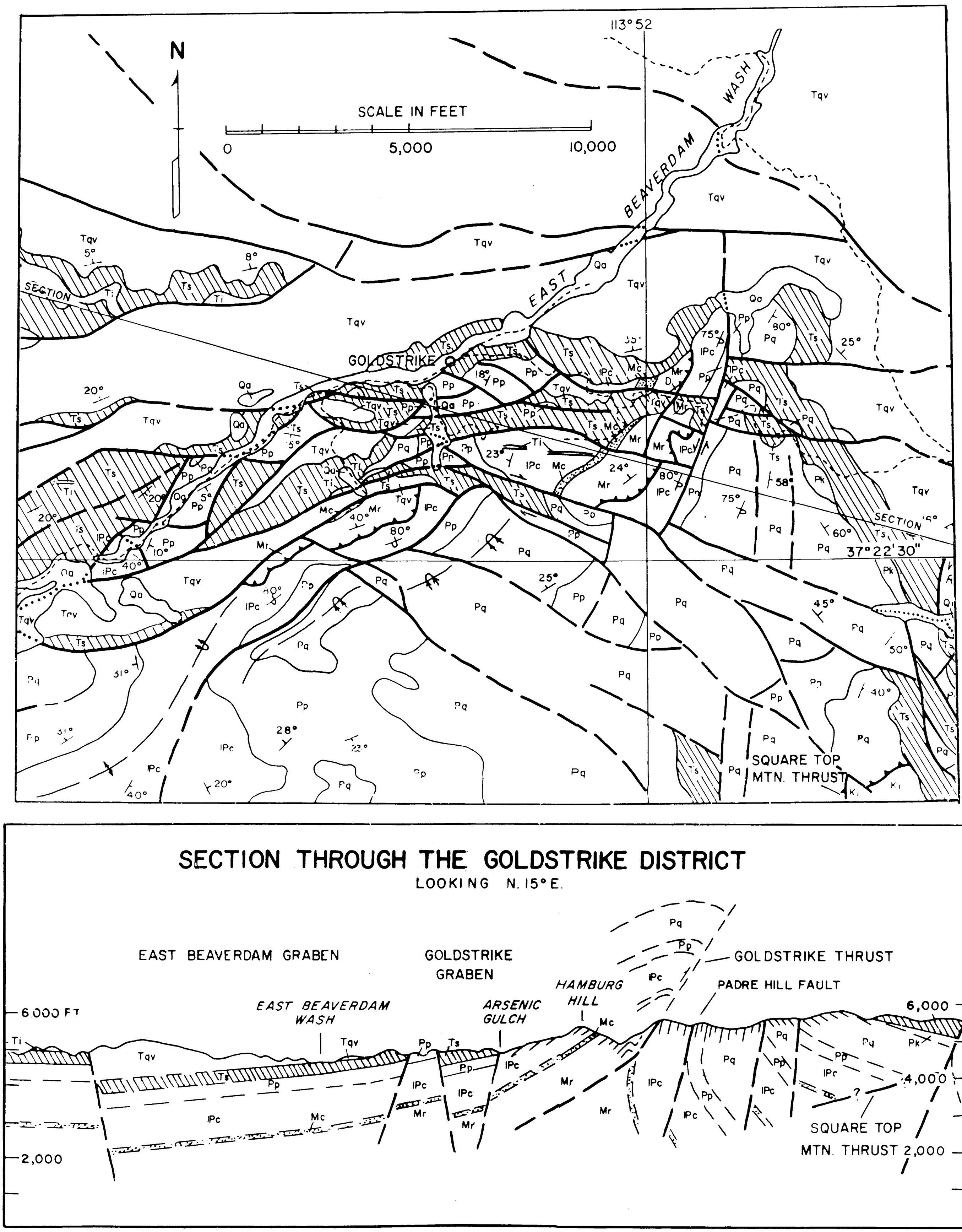

Figure 13. Generalized geologic map of Goldstrike district and vicinity (after Adair, 1986). Map symbols as on table 4. Claron Formation including Isom and Needle Range tuffs shown by diagonal ruling pattern.

Table 4. Generalized stratigraphic column, Goldstrike district, Washington County, Utah (after Adair, 1986). Asterisks indicate units used on geolgic map (figure 7).

AGE	MAP UNIT		DESCRIPTION	FT. THICK
QUATERNARY	Qa *		Alluvium, bench gravel, and landslide debris	0–50
MIOCENE	Tqv *		Rencher & younger tuffs	100 +
		Quichapa Group	Harmony Hills Tuff	50–350
			Bauers Tuff & related units	0–150
			Leach Canyon Tuff	50–400
OLIGOCENE	Ts *	Claron Fm.	upper gray limestone	40–80
			Isom Tuff	15–70
			middle gray limestone	30–90
			Needles Range Tuff	25–65
			lower gray limestone	15–45
EOCENE			red mudst., cgl. & limestone	20–150
			white ss. & qtzite cgl.	0–90
PALEOCENE ? - CRETACEOUS	TKs	conglomerate in Grapevine Wash	red cgl. & white ss.	950–1,700
CRETACEOUS	Ki	Iron Springs Fm	yellow-gray, calc. ss.	800–1,000
JURASSIC	Jc	Carmel Ls.	limestone & shaly limestone	160
		Temple Cap Fm.	reddish brown siltstone	150
TRIASSIC	JTR n	Navajo Sandst.	massive, eolian sandstone	700+
		Kayenta Fm.	stream deposited ss. & sltst.	250
	TR m	Moenave Fm.	red sandstone & siltstone	400
		Chinle Fm. Moenkopi Fm.	not exposed in district	
PERMIAN	Pk *	Kaibab Fm. Toroweap Fm.	cherty limestone & gypsum	100+
	Pq *	Queantoweap Ss.	tan to brown sandstone	1,000+
	Pp *	Pakoon Dolomite	upper lt. gray dolomite middle dolomitic sandstone lower lt. gray dolomite	400–450
PENNSYLVANIAN	IPc *	Callville Limestone	lt. to med. blue-gray limest. & cherty limest., interbedded sndy limest, slty limest. & rare dolomite	900+
MISSISSIPPIAN	Mc *	Scotty Wash Qtz	gray to brown quartzite	40–80
		Chainman Shale	lt. to dark gray & greem sh.	60–70
	Mr *	Redwall or Monte Cristo Limestone	lt. to med. to dark gray limestone, interbedded ss. & yell. gray dolo. in middle	450+
DEVONIAN	D *	Muddy Peak Dol.	brown to dark gray dolomite	80+

Stratigraphy

Hintze (1986) described the stratigraphic units exposed in the Beaverdam Mountains. Some of these units exposed in the Goldstrike district differ in part from those described by Hintze. These rocks were described by Willden and Adair (1986, p. 139-142) as follows:

Paleozoic Rocks

"The Devonian, Mississippian, Pennsylvanian, and Permian systems are represented in the Goldstrike district by eight formations. The oldest of these is the Devonian Muddy Peak Dolomite which is exposed in a small area north of Quail Canyon in the northwestern part of section 21, T. 39 S., R. 18 W. This formation attains a thickness of about 80 ft; its base is missing owing to a fault contact with Pennsylvanian rocks, and it is overlain by the Redwall Limestone of Mississippian age.

"The Redwall Limestone is exposed at several places in the district. At each of these it appears to lie on the upper plate of a thrust identified as the Goldstrike thrust by Adair, and is in thrust fault contact with younger Paleozoic rocks. It is overlain by younger Mississippian rocks or by Tertiary rocks at its eastern exposures and is faulted against Tertiary at its western exposures.

"The younger Mississippian rocks include a dark gray or greenish-gray (black on fresh surfaces) shale unit up to about 80 ft thick that we have called Chainman Shale, and 40 to 80 ft of gray or tan to dark brown orthoquartzite, with occasional thin sandy shale partings, that we have identified as the Scotty Wash Quartzite." [These 2 units can be seen as dark lines trending obliquely across the benches of the Hamburg pit in figure 14 and as steeply inclined layers at the far end of the Hassayampa pit in figure 6.] " The Chainman and Scotty Wash formations have not been recognized in the area studied by BYU and have not been seen in the subsurface in oil tests in southwestern Utah (Campbell, 1952; Moulton, 1982, Moulton, personal comm., 1986). Their presence in the Goldstrike district on the upper plate of the Goldstrike thrust may imply large displacement on this thrust relative to the rocks that it overrides.

"The Callville Limestone is the only Pennsylvanian formation recognized in the Goldstrike district. It rests on the Scotty Wash Quartzite at the east end of Hamburg Hill and is overlain by Permian rocks along Pegleg Gulch west of Hamburg Hill. This block of Callville Limestone is on the upper plate of the Goldstrike thrust. Farther east, the formation is exposed beneath the Goldstrike thrust, and rocks assigned to the Callville in the two areas are much alike, which suggests that displacement on the Goldstrike thrust has not been large." [Steeply dipping Callville Limestone is exposed in the Moosehead open pit as shown in figure 15 where it was an important host for gold mineralization.]

"The three formations assigned a Permian age in the Goldstrike district, from oldest to youngest, are the Pakoon Formation, the Queantoweap Sandstone, and the Kaibab Formation. The Pakoon appears to be conformable on the Callville Limestone and is, in turn, conformably overlain by the Queantoweap

Figure 14. Hamburg pit in center, Basin pit beyond recovery plant in right center, heap number 2 in left center and heap number 1 at right edge, June 4, 1992.

Figure 15. Covington Hill fault exposed in west part of Moosehead pit. Steeply dipping Callville Limestone beds on the left, altered Leach Canyon volcanics on the right. Horst of Callville surrounded by altered volcanics within the fault zone near left center of view.

Sandstone. The Pakoon Formation is dominantly dolomite in the area south of Goldstrike, but in the Goldstrike district two dolomite members are separated by a sandy dolomite member. The upper and lower members commonly are cherty, especially the lower member. The sandy dolomite middle member occurs throughout much of the Goldstrike district. This member displays a pervasive de-carbonatization and silicification at most exposures in the district. This alteration phase is particularly well developed in the lower part of Arsenic Gulch where the altered rocks are separated from the lower dolomite member of the Pakoon by a breccia zone that contains locally prominent concentrations of realgar. A similar breccia, lacking realgar, occupies the same stratigraphic position at the Bul Run mine; and the accessible workings of the mine were developed along this horizon. At places, the middle member is so sandy that it is nearly indistinguishable from the basal sandstone member of the Claron Formation.

"The Queantoweap Sandstone is widespread in the east and south part of the Goldstrike area where it may be in excess of 1,000 ft thick. It is commonly quartzitic and forms the high ridges and peaks south of Quail Canyon. Jackson Peak and Square Top Mountain are capped by this formation. The Queantoweap is overlain by the Kaibab Formation at two places near Quail Spring. Elsewhere, it is either overlain unconformably by Tertiary rocks or is faulted against these or older rocks.

"The Kaibab Formation is exposed only at these two rather small areas near Quail Spring where it is light gray to pinkish gray cherty limestone and unconformably overlain by Tertiary rocks."

Tertiary Rocks

"The Tertiary system in the immediate Goldstrike area is represented by one largely sedimentary formation, one ash-flow unit and, several small intrusive bodies of andesitic to basaltic composition. Several other volcanic units occur to the west, north, and east of the district; and a very thick, coarse clastic unit, the Grapevine Wash Conglomerate (Wiley, 1963, p 23-34), outcrops over a large area southeast of the district. We identify the largely sedimentary unit at Goldstrike as the Claron Formation and the ash-flow tuff as the Leach Canyon Tuff.

"The Claron Formation at Goldstrike is divisible into seven members that generally are quite distinctive and laterally continuous. The thickness of each member is quite variable but, wherever they have not been removed by erosion or faulting, all of the members, except the basal clastic member, can be identified at each exposure. The Claron lies unconformably on all Paleozoic rocks at Goldstrike except the Muddy Peak Dolomite, and to the southeast it is unconformable on the Grapevine Wash Conglomerate. The Claron is unconformably overlain by the Leach Canyon Tuff.

"The basal clastic member of the Claron is a white-to-yellow sandstone or conglomeratic sandstone that is missing at some localities. The Claron appears to have been deposited on a rather irregular surface, and this basal member probably filled local depressions on this surface. The basal member is coarsely conglomeratic at some localities, and at such places the fragments can be related to adjacent Paleozoic rocks. They are commonly angular to poorly rounded suggesting abrupt local relief on the pre-Claron surface. This basal clastic member of the Claron is the host for almost all of the disseminated gold mineralization found thus far in the district. Where this member is gold-bearing, it commonly is silicified; at some places the silicification is so intense that it is difficult to recognize the rocks as belonging to the basal Claron." (Mining operations and continued exploration work in the district after 1986 showed that much ore also occurs in Paleozoic rocks, particularly in the southwestern part of the district.)

"The basal clastic member is overlain by a sequence of maroon-to-yellow calcareous mudstone interbedded with varying amounts of argillaceous sandstone and limestone-pebble conglomerate. Because the maroon color is persistent at most localities, even where the mudstone is not present and the interval is represented only by limestone-pebble conglomerate beds, we refer to this sequence as the red beds member of the Claron.

"Above the red beds member is a lower limestone member, a lower tuff member (probably equivalent to the Needles Range Tuff), a middle limestone member, an upper tuff member (probably equivalent to the Isom Tuff), and an upper limestone member. The lower limestone member, 15 to 30 ft thick, is light gray and commonly shows thin wavy bedding thought to be of algal origin. The lower tuff member is about 20 to 35 ft thick and, at most places, is deeply weathered, forming a covered slope between the lower and middle limestones. The middle limestone is light to medium gray, 30 to 90 ft thick, often conglomeratic, and commonly a ledge-former. The upper tuff member ranges from about 15 to 75 ft thick and appears to be a welded tuff with the lower part densely welded with abundant flattened vesicles. This material produces slabby float that is distinctive and readily recognized. The upper limestone is about 40 to 80 ft thick, light to dark gray, displays some wavy algal-like bedding, and contains bright red jasper and chalcedony, some of which is locally opaline, and some contains small pyrite grains."

Adair (1986) and other more recent workers (see for example Greenan, 1992) have restricted the name Claron to the lower three members described above, identified the lower tuff unit as the Wah Wah Springs Member of the Needles Range Tuff, and have identified the three uppermost members as the Isom Formation or pre-Isom lacustrine unit, Isom tuff, and post-Isom lacustrine unit.

Willden and Adair (1986, p. 142) state that "The Leach Canyon Tuff usually rests on the upper limestone member of the Claron in the central part of the Goldstrike area, but to the east and west it rests on lower units of the Claron. It rests on Paleozoic rocks in the vicinity of Mineral Mountain about 5 miles northwest of Goldstrike, and it may rest on Paleozoic rocks at some places along East Beaver Dam Wash southwest of Goldstrike." . . . "The Leach Canyon Tuff is a crystal-lithic rhyolite to quartz-latite welded tuff and is light purple where unaltered. Within the central part of the Goldstrike district, it is extensively bleached with iron oxide films along fractures.

"Small intrusive bodies, usually so altered their composition cannot be determined, cut the Paleozoic rocks and the Claron Formation at several places from Hamburg Hill westward. The less altered bodies appear to be andesite porphyry, but others may have been basaltic. One such dike is exposed in the upper workings of the Hamburg mine, and the specimen-ore veins appear to have developed along the contact between the dike and the Callville Limestone."

Structure

Adair (1986) described the structural setting of the Goldstrike district and postulated two different periods of tectonic activity as having produced the structures found. He said: "The oldest structures to form in the Goldstrike area were those which were related to a southeasterly directed compressional episode of tectonism. This was presumably a local phase of the Sevier orogeny and probably occurred in late Cretaceous to early Tertiary time. During this event, the Square Top Mountain thrust was formed and it carried miogeosynclinal Paleozoic rocks over a Colorado Plateau assemblage of Mesozoic rocks. Some of the rocks that occur immediately below the thrust were locally overturned as a result of the thrust movement (p. 133-134)." He also describes assymetrical folding of the upper plate rocks, overturning and development of a thrust fault, the Goldstrike thrust, in these Paleozoic rocks. The Square Top Mountain thrust probably extends west beneath the entire Goldstrike district. The Goldstrike thrust generally emplaces the Mississippian Redwall Limestone on Pennsylvanian and Permian rocks through the central part of the Goldstrike district (see figure 13 and figure 16 on which the more prominent structural features are shown by name).

The presence of the Chainman and Scotty Wash formations on the upper plate of the Square Top Mountain thrust implies large displacement on this thrust fault. These two formations, with affinities for rocks exposed in the Great Basin of Nevada and northwestern Utah, have not been reported in southwestern or southern Utah (see Hintze; 1988).

The younger period of tectonic activity consisting of several episodes of extension and later compression produced a network of intersecting northeast, northwest and east-west trending block faults that probably formed in Miocene and later time and add to the complexity of the geology in this area. Some of these faults have had up to a mile of well-documented transcurrent displacement along them. Most of the displacements, however, were largely extensional and resulted in the formation of several horsts and grabens and a variety of variously tilted fault blocks.

The principal structural features in the Goldstrike mine area are two grabens defined by somewhat arcuate, generally east-west to southwest or southeast trending high-angle faults that affect all of the rock units identified in the district. The northernmost of these grabens is the Goldstrike graben bounded on the north by the Hassayampa fault and on the south by the Hamburg fault. These bounding faults are thought to be important in controlling mineralization because eight of the known ore bodies occur along or near them (figure 16). The southernmost graben, the

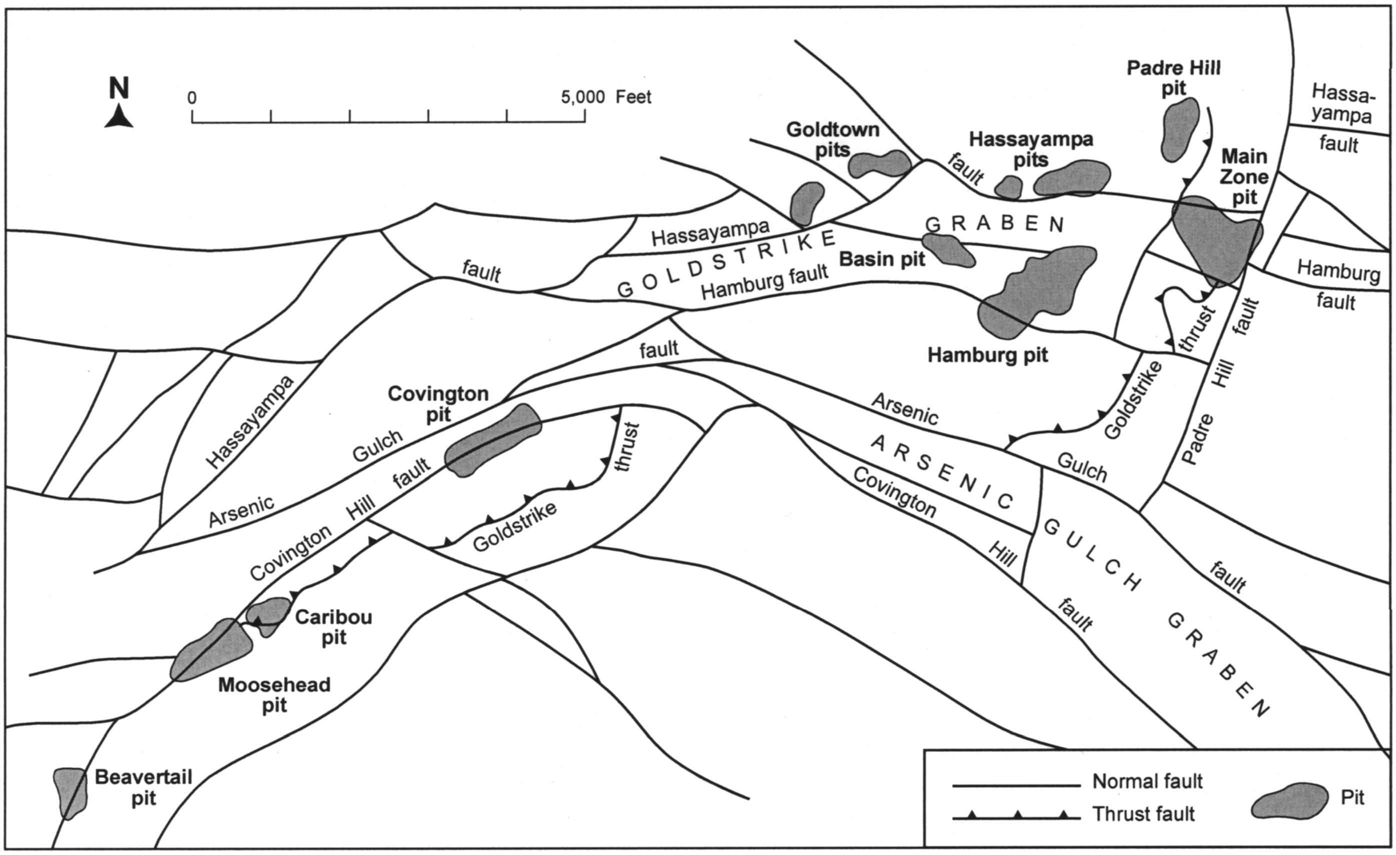

Figure 16. Structure map of Goldstrike district showing relationship of open pit mines to faults (faults from Adair, 1986 and G.P. Parsley, 1996).

Arsenic Gulch graben, is bounded on the north by the Arsenic Gulch fault and on the south by the Covington Hill fault. No ore bodies have been developed within this graben despite the presence of arsenic, mercury and gold soil geochemical anomalies within it, but the remaining four ore deposits occur along the southwest extension of the Covington Hill fault, which forms the south bounding fault of the graben. A series of high-angle faults offset and disrupt the grabens, and some of these post-graben faults also may be important ore controls. Further evidence that these faults were important mineral conduits was found in the extended soil geochemical surveys. Linear gold, arsenic and mercury anomalies were found along the graben-bounding faults even where the sampling was extended into areas where no evidence of silicification of the rocks was seen.

The Hassayampa fault and the Hamburg fault are marked by massive calcite veins, particularly in the eastern portion of the Goldstrike graben. A calcite vein 50 ft wide is exposed along the Hamburg fault where that fault crosses Quail Canyon east of Hamburg Peak. These calcite veins are thinner or missing altogether in the western part of the graben. The calcite vein that marks the Hassayampa fault is shown in figure 17.

ORE DEPOSITS

The early mines in the Goldstrike district, although considered to be vein mines, were actually developed on intensely silicified rocks lying along generally high-angle faults. The single exception

Figure 17. Reclaimed number one heap, which had been developed on back-filled Hassayampa pits. Note calcite vein marking Hassayampa fault along right edge of picture.

was the Hamburg mine; the Hamburg vein was coarse-grained calcite developed along the contact between a highly altered dike and the Callville Limestone. It is quite likely that the gold occurred in both the calcite and the altered dike rock. Early reports on the district refer to pockets of high-grade ore. One such pocket was intersected in an exploration hole drilled near the Hassayampa shaft by Tenneco which contained several ounces of gold per ton over about a 15-ft interval (J.P. Hebert, verbal communication, 1989). Other high-grade intervals were found in blast holes drilled in several of the pits as mining progressed (P.G. Parsley, verbal communication, 1997). With the exception of these pockets of high-grade, gold was not seen in the rocks and could not be concentrated by panning the cuttings from drill holes. No mercury minerals have been identified in the district, but realgar and stibnite were seen at some localities and several attempts had been made to mine antimony (Conrad Bowler, verbal communication, 1995).

Most of the open pits were developed on disseminated gold deposits that were identified by geochemical soil sampling that showed generally coincident gold, arsenic, antimony, and mercury anomalies. An exception was the Padre Hill deposit, which was found by drilling close to jasperoid bodies that contained anomalous gold. Most of these pits were developed on or near the Claron Formation (the ruled unit on the geologic map.) The Claron is extensively exposed in the Goldstrike district and in the surrounding area with most exposures located in a broad, slightly arcuate belt that extends east-west across the region (figure 12). Paleozoic rocks are exposed south of this belt and post-Claron Tertiary volcanics occur to the north. There are gold occurrences associated with the basal Claron clastic member at scattered localities throughout this broad belt as well as in the less extensive belt in the northwest part of the map area. However, all of the deposits that have been mined to date are located in a relatively narrow east-northeast oriented zone that extends diagonally across the arcuate, east-west belt of Claron exposures. This east-northeast-trending zone of mineralization coincides closely with a zone of structural complexity characterized by arcuate, generally east-west high-angle faults that are intersected by or cut off by northeast or northwest-trending faults. The oldest structural element in this zone is the Goldstrike thrust (figures 13 and 16), which emplaces Mississippian and Pennsylvanian age units over Pennsylvanian and Permian age units. The thrust trends essentially parallel to and, in part, almost coincident with the northeast alignment of gold deposits. The thrust pre-dates the Claron Formation and appears to have been a product of the southeast-directed compressional stresses that affected this region during the Sevier orogeny in Late Cretaceous to early Tertiary time.

The northeast-oriented zone in which the principal Goldstrike gold deposits are located may reflect part of a regional structural trend that extends through this area. The trend is reflected in the region northeast of Goldstrike by an approximate alignment of many scattered centers of mineralization, including the long northeast belt of large iron deposits in the area west of Cedar City (Delamar-Iron Springs belt). This trend probably is related in some manner to the well-known and repeatedly active hingeline that extends from southern Nevada through west-central Utah and beyond, forming the boundary between two very different geologic provinces over a long span of geologic time.

A number of arcuate, east-west trending high-angle faults and some of the northwest or northeast-trending cross faults appear to have provided conduits for the mineralizing solutions that produced the gold deposits. The presence of so-called vein mines along some of these structures attest to their importance as conduits for mineralizing solutions. In the northeast part of the district, eight deposits are closely associated with faults that form the north and south boundaries of the Goldstrike graben. The four deposits in the southwest part of the district are developed along the Covington Hill fault, an east-northeast-trending, high-angle fault that can be projected farther to the east where it has an east-southeast trend and forms the southern boundary of the Arsenic Gulch graben.

The four deposits in the southwest part of the district also are controlled in part by fault intersections whereby northwest-striking faults intersect and locally offset the Covington Hill fault. Breccia pipes formed at these intersections and where silicified, particularly in the Moosehead pit, form relatively high-grade ore bodies. Although these four deposits are hosted by Paleozoic limestone (Redwall and Callville) they likely were close to the Claron contact at the time of ore deposition. The Claron Formation almost surely underlies the more or less altered

Leach Canyon volcanic rocks that occur on the down thrown side of the Covington Hill fault and most probably rested on the Paleozoic rocks on what is now the upthrown side of the fault at the time of ore deposition.

Intrusive igneous rocks may have played an important role in the formation of the Goldstrike gold deposits. Such rocks are not widely exposed in the area, but a discontinuous belt of locally quite altered small, dark dikes and intrusive masses extends northeast in a gentle arc from immediately west of the Covington deposit to immediately south of the Hamburg pit, where an east-west dike was exposed in the old Hamburg mine workings. This highly altered dike is reported to have carried enough gold to be mined as ore. An extension of the belt of intrusive rocks southwest of the Covington pit is suggested by a ground magnetic survey that was done by USMX, but no intrusive rocks are known to be exposed. Several holes have been drilled to test the dike exposed just west of the Covington pit. One of these cut a zone within the dike that averaged 0.179 ounces per ton gold over 30 ft in the interval from 200' to 250'. Other holes gave lower values and suggest that the zone within the dike is narrow and steeply-dipping. The extent of this zone along strike and down dip has not been determined. The occurrence of gold in these dikes indicates that the dikes were not the source of the mineralizing solutions, but that these solutions may have used the same structures as the dikes. The mineralizing solutions ascended along high-angle faults until they encountered the permeable and receptive basal Claron sandstones and where continued rise was impeded by the clay-rich red beds unit of the Claron.

Silicification is the most obvious and common alteration in the district, and was responsible for guiding most of the exploration in the district. The middle member of the Pakoon Formation commonly is decarbonatized and exhibits locally intense silicification. Early prospectors dug many adits and shallow shafts on these altered Pakoon rocks, but no disseminated deposits were found. Greenan (1992, p 142-145) studied the alteration and reported that the "assemblages seen at the Goldstrike mine . . . suggest a temperature of formation between 150-220 degrees C. Illite and interlayered illite-montmorillonite are found in the highest temperature alteration in the Padre pit." He also suggested that the mineralization took place in early Miocene time and was related to extensional tectonics. Clay alteration also is seen in the Leach Canyon volcanic rocks and gold was found in some samples of altered Leach Canyon rocks so the age of the mineralization must post-date the Leach Canyon (i.e. younger than 24.7 Ma).

Greenan noted that decarbonation is not widespread in the district, but it certainly is widespread in the middle member of the Pakoon Formation. The massive calcite veins found along the Hassayampa and Hamburg faults suggest significant decarbonation. The veins could represent a carbonate front that has been displaced upward from decarbonatized rocks occurring at depth in the Goldstrike graben. The linear soil anomalies along these faults indicate that they were conduits for mineralizing solutions; however, rock chip samples from the calcite veins generally lack gold. Such decarbonatized rocks thought to occur at depth were the target of the drilling conducted by Bull Valley in 1999. Although this drilling encountered no ore or intensely mineralized material, it seems likely that a much more extensive drilling program would be successful.

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