MINERALIZATION IN THE GOLD HILL MINING DISTRICT, TOOELE COUNTY, UTAH

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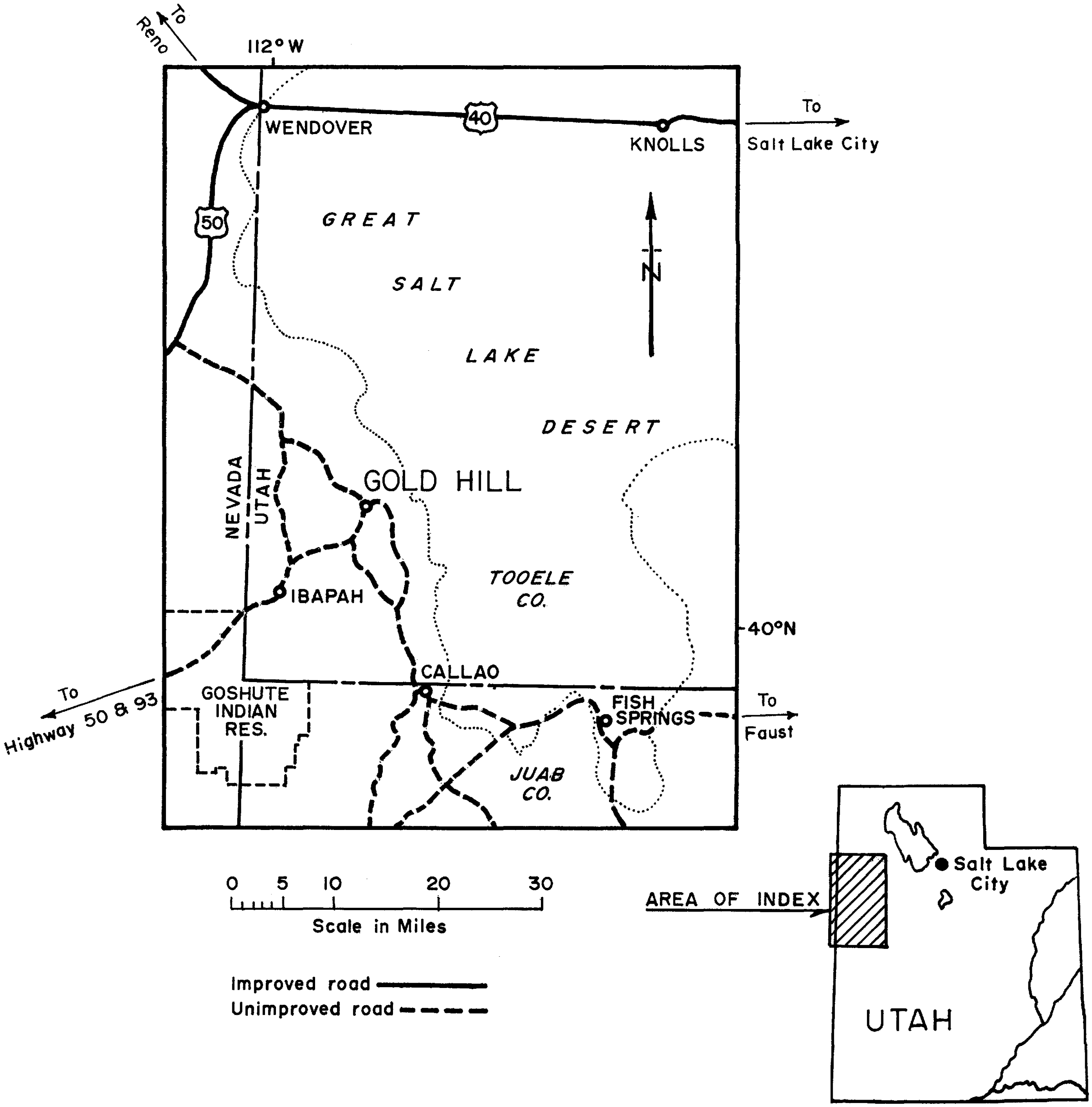

Figure 1. Index map showing location and accessibility to the Gold Hill mining district, Utah.

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by H. M. El-Shatoury[1] *and J. A. Whelan*[2]

ABSTRACT

The Gold Hill area, in Tooele County, northwest Utah, is one of the oldest mining sites in the state. Principal minerals removed since 1857 are lead, copper, silver, gold, arsenic, zinc and tungsten.

This area lies in the east central part of the Great Basin section of the Basin and Range Province. The sediments, severely thrusted, comprise a relatively complete stratigraphic sequence from Lower Cambrian through Lower Triassic. They have been intruded by a quartz monzonite stock and porphyry dikes, and include acidic lavas and pyroclastics of Tertiary age.

Evaluation of the potential for the district shows that, based on current information, most of these minerals are present in quantities too small for large scale commercial exploitation. This area contains impressive quantities of beryllium; the writers postulate that the beryllium is in feldspar. The low grade of the mineralization makes it uneconomical at this time to mine it.

INTRODUCTION

This study, a doctoral dissertation by Hamed El-Shatoury, Department of Mineralogy, University of Utah, reevaluates the potential of the Gold Hill mining district for the production of gold, copper, tungsten, arsenic, lead, zinc and beryllium. It was supported by the Utah Geological and Mineralogical Survey. The maps in the paper by Nolan (1935) on the district were used in this study. The writers concentrated on the examination of properties not described by Nolan and on alteration patterns, using newer instrumental methods. The beryllium-bearing quartz-adularia-carbonate veins, first described by Griffitts (1965), were studied in detail.

The village of Gold Hill (figure 1) is located in Tooele County, northwestern Utah. It is 55 miles southeast of Wendover over 27 miles of paved road and 28 miles of graveled road; it can also be reached from the east over 94 miles of dirt road from Utah Highway 36 near Faust, via Callao.

The Gold Hill area lies in the east central part of the Great Basin section of the Basin and Range Province, at the north end of the Deep Creek Mountains. The area is composed of a highly dissected group of hills of relatively low relief. The elevation of Gold Hill village is 5,321 feet. The Gold Hill area is bounded on the east by the Great Salt Lake Desert at an altitude of about 4,300 feet, on the north by Dutch Mountain with a highest elevation of 7,735 feet, on the west by Clifton Flat, at an approximate elevation of 6,600 feet, and on the south by Montezuma Peak with an elevation of 7,369 feet. The group of relatively low hills at Clifton merges westward into Ochre Mountain whose highest elevation is 7,541 feet. The area is characterized by an interior drainage system typical of the eastern Utah-western Nevada part of the Great Basin.

The area has a semiarid climate. Summers are usually hot and winters are mild, generally permitting fieldwork throughout the year.

Lead-zinc-silver ores may be milled at the United States Smelting, Refining and Mining Company mill at Midvale or directly smelted at the International Smelter at Tooele. Copper ores may be marketed at Great Falls, Montana, at Tacoma, Washington, and at Douglas, Arizona.

About 1857, when travel to California through the Overland Canyon was heavy, samples rich in galena attracted the attention of travelers who stayed to prospect for minerals. From Overland Canyon, prospecting gradually extended to the north. Finding and developing the many rich surface deposits resulted in the establishment of the town of Clifton and the Clifton mining district. The ore removed at that time was hauled by rail to the smelter at Stockton.

In 1872, a lead smelter was constructed at Clifton and 1,500 tons of high-grade lead-silver ore were reduced (Gold Hill Standard, 1917). In 1874, the smelter was moved to Gold Hill where an additional 500 tons of ore from the Western Utah Copper Company were treated and four carloads of lead-silver bullion were produced. In 1892, the Cane Spring Consolidated Gold Mining Company built an amalgamating mill for the treatment of ores from the Alvarado and Cane Spring mines. According to the Gold Hill Standard in 1917, the mill was in operation for 23 months during the years 1892-1895. The average grade of the ore treated in the mill is reported to have averaged $20.00 to $30.00 per ton in gold ($20.67/ oz, pre-1935 price). The total net receipts from bullion and concentrate from the Cane Spring mine were $117,907.23.

Significant geologic information on the Gold Hill mining district was published as early as 1892 when Kemp described a hornblende-granite and an andalusite horn-

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fels from the area. Kemp and Billingsley (1918) published a geologic report accompanied by a generalized map of an area extending from Dutch Mountain to the north to Overland Canyon to the south, with a brief description of some of the mining properties in operation at that time.

Butler (1920) made a reconnaissance study of the area in 1912 and recommended detailed geologic investigation. The U.S. Geological Survey performed the work in 1925 when topographic mapping of the area was completed.

In 1916, construction of the railroad to Wendover for the benefit of the mines in the area was started. A boom followed and formerly idle workings were developed and many new enterprises started. According to the figures given by Butler (1920), the gross value of ore production from 1892 to 1917 was $951,803, in gold, silver, copper and lead.

Removal of tungsten ore from the Lucy L. mine started in 1912, where production is estimated to have been about 500 tons of ore containing 1 percent WO_3. The Reaper mine was discovered in 1914. The net receipts from ore from this mine have been estimated to be $75,000, $70,000 of the sum during World War I. The Yellow Hammer mine was operated for tungsten starting in 1917; the total value of production during World War II is estimated to be between $25,000 and $45,000. An additional 400 tons of ore were mined during 1954-1955 from which 97 units of WO_3 were recovered (Everett, 1961). According to the same author, about 1,500 tons of carefully sorted ore containing sulfides and oxides of copper with scheelite were mined during 1958. From 1923 to 1933, a high-grade, direct-smelting gold ore (7-10 oz/ton) was removed from the Rube Gold mine.

Between 1923 and 1925 the area produced arsenic, mainly from two mines originally opened for copper, the Gold Hill mine of Western Utah Copper Company and the United States mine of the U. S. Smelting, Refining and Mining Company. The gross value of arsenic produced during this period is estimated by Nolan (1935) to be $2,500,000. A drop in the price of arsenic early in 1925 caused the operations to be abandoned. Operation of the United States mine was resumed during World War II, with production estimated by S. R. Wilson (personal communication) of about 98,784 tons assaying 15.2 percent arsenic.

In 1928 Nolan abstracted the stratigraphic and the structural setting of the area. Foshag and others (1930) reported the occurrence of a considerable amount of scorodite as an alteration product of arsenopyrite in the district. Schaller and Nolan (1931) reported the world's second occurrence of spadaite replacing wollastonite in the contact metamorphic rocks of the area.

Nolan published his work in 1935 on the Gold Hill area as U.S. Geological Survey Professional Paper 177. In the same year Staples (1935a,b) reported the occurrence of adamite and named austinite as a new arsenate mineral from Gold Hill. The mineral veszelyite was added later in an unpublished report by Buranek.

In 1960, Flint put out an unpublished report for the Woodman Mining Company on some of the mining properties in the area. Griffitts (1965) reported the occurrence of beryllium in the quartz-carbonate veins of Rodenhouse Wash. Parry and Nackowski (1963), in the course of their investigation of trace analysis of copper, lead and zinc in biotite of quartz monzonite intrusions from mining districts in the Basin and Range, included eight samples from the Gold Hill stock.

The fieldwork for this study was conducted during the summers of 1965 and 1966 with occasional visits to the area in the interval between these periods. Nolan's work (1935) was a valuable aid in understanding the geologic setting of the area.

Area-wide sampling of the rock units, alteration zones and associated mineral deposits was performed and accurately located on aerial photographs at a scale of 1 inch to 400 feet. Mining properties were examined, sampled and mapped, if not done previously or if additional workings were found.

The underground workings of the Rube Gold, Rube Lead and Frankie mines, and the small-scale workings of the Rustler adit were mapped on a scale of 1 inch to 40 feet with tape and compass. Recent maps of the Cane Spring and the Alvarado mines, furnished by C.R. Woodman of Gold Hill, were used for sampling and examining those properties.

The Yellow Hammer and Gold Hill mine open pits were mapped by Brunton and tape on scales of 1 inch to 40 feet and 1 inch to 50 feet, respectively. The quartz-carbonate-adularia veins of Rodenhouse Wash were sampled in detail and the area mapped on a scale of 1 inch to 400 feet, using the plane table and alidade (figure 2). The surface area around the Rustler claims was mapped on the same scale.

Petrographic studies were made of 115 thin sections. The quinalizarin stain test (Ampian, 1962) was used to check for beryllium in minerals. Quantities of potash feldspar in the beryllium-bearing adularia-quartz-carbonate veins of Rodenhouse Wash were determined using the sodium cobaltinitrite stain test (Gabriel and Cox, 1929, and Chayes, 1952). The arsenic trioxide test of Gruner (1944) was used to check for helvite.

X-ray diffraction was used routinely for mineral identification. Quantitive X-ray fluorescence analysis was used to determine amounts of silver, molybdenum, lead, arsenic, zinc, copper and manganese in 158 samples. Infrared absorption spectroscopy was used for identification of clay minerals. Beryllium assays were made by berylometer, emission spectrograph, and colormetric methods. Gold and silver determinations were made by fire assaying. Standard analytical methods were used for other elements.

GENERAL GEOLOGY

The geologic setting of the district is abstracted below chiefly from the previous data on stratigraphy and the structural elements as described by Nolan (1935).

Rocks include sedimentary, igneous (intrusive and extrusive) and metamorphic types. The structural elements include folds, fractures and the emplacement of an igneous body.

The sediments of the Gold Hill quadrangle comprise a fairly complete stratigraphic sequence from Lower Cambrian through Lower Triassic with a total thickness of about 30,000 feet. The sediments are intruded by a quartz monzonite stock and related porphyry dikes and include volcanic flows and pyroclastic rocks.

The dominant rock unit within the Cambrian system is the Prospect Mountain quartzite. The Middle and Upper Cambrian include limestone and dolomite.

A geologic section, after Nolan (1935), is shown in figure 3.

An erosional unconformity occurs between the Upper Cambrian and the base of the Ordovician. The Lower Ordovician series exposed in the Deep Creek Mountains is represented by the Chokecherry Formation. This is essentially a siliceous dolomite. Its variable thickness and its absence on Dutch Mountain indicate an unconformity between it and the overlying Fish Haven dolomite of the Upper Ordovician.

The Silurian Laketown dolomite, generally overlying the Fish Haven dolomite, outcrops in several places in the Deep Creek Mountains and on Dutch Mountain. An erosional unconformity occurs between the basal Devonian and the underlying Silurian. The Middle Devonian series is represented by three formations, the Sevy dolomite, the Simonson dolomite and the Guilmette Formation. The latter is composed essentially of dolomite with thick beds of limestone and lenticular masses of sandstone. The distribution of this series is restricted mainly to the Deep Creek Mountains with minor exposures of the latter two formations in the northern part of Dutch Mountain.

Rocks of Carboniferous age have been assigned by Nolan (1935) to six formations: three Mississippian, two Pennsylvanian and one Permian. These formations fall into three facies. These facies are not clearly differentiated and have been brought into more or less close contact with each other by two large thrust faults. A brief definition of each of these facies follows:

1. The eastern facies is represented by the Mississippian Woodman Formation and resembles lithologically the overlying Ochre Mountain limestone.
2. The central facies is younger than the Woodman Formation and lies between the two thrust faults that brought the different facies into close proximity and includes:
    - a. The Ochre Mountain limestone (Mississippian).
    - b. The Manning Canyon Formation (Pennsylvanian).
    - c. The Oquirrh Formation (Permian-Pennsylvanian).
3. The western facies is considered to contain representatives of all of the six formations and lies above the upper thrust.

No accurately dated Cretaceous or Tertiary formations have been found; this fact gives credence to Nolan's belief that the deformational events spanned the Cretaceous-Tertiary boundary (1935).

Igneous rocks include an extensive Tertiary intrusion which is principally quartz monzonite in composition, with some related porphyry dikes and aplites, and late Pliocene (?) acidic lavas and pyroclastics.

The structural history of the quadrangle is complex. Eardley (1962) pointed out the significance of Nolan's work in making clear the complexity of deformation in the geanticlinal areas:

> The structural history is characterized by at least four and possibly five phases of folding and faulting, each phase composed of an initial stage in which compressive forces were active and a final stage in which normal faulting was dominant. The first two phases predate the Eocene by a long interval of erosion and are regarded provisionally as Cretaceous by Nolan. It is probable that they are related to the Nevadan and Post-Nevadan Cretaceous disturbance to the west and to the sinking of the Utah trough during the time that the Indianola, Kelvin, Aspen, and Frontier and other formations were deposited in it.

Recent studies by Lovering at Eureka, Utah, show the same succession of events (Eardley, 1962). The geologic histories of the Gold Hill district and the Tintic Mountains near Eureka are considered typical of the east central part of the Great Basin Province. The region, a geosyncline during the Paleozoic and a broadly uplifted geanticline during the Mesozoic, has been subjected to intense compressional forces and severe deformation.

ECONOMIC GEOLOGY

The Gold Hill mining district has produced gold, copper, arsenic and tungsten, and minor amounts of lead, zinc, silver and bismuth. The total value of production from 1901 to 1964 of 25,000 oz gold, 832,000 oz silver, 1,700 short tons of copper, with minor quantities of lead and zinc, is $2,878,084[1]. Production values of bis-

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[1] U. S. Bureau of Mines, Minerals Yearbook and related publications.

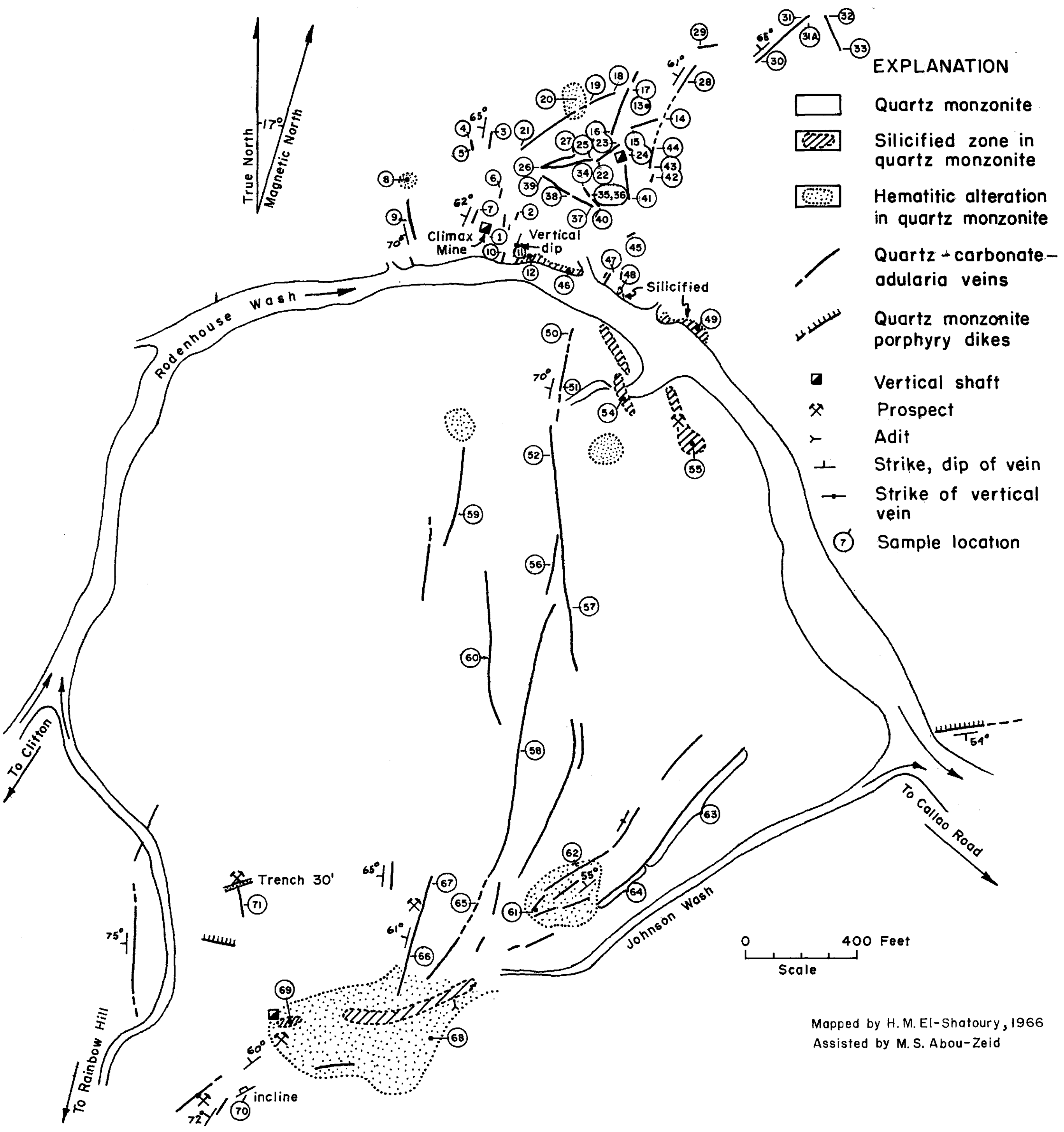
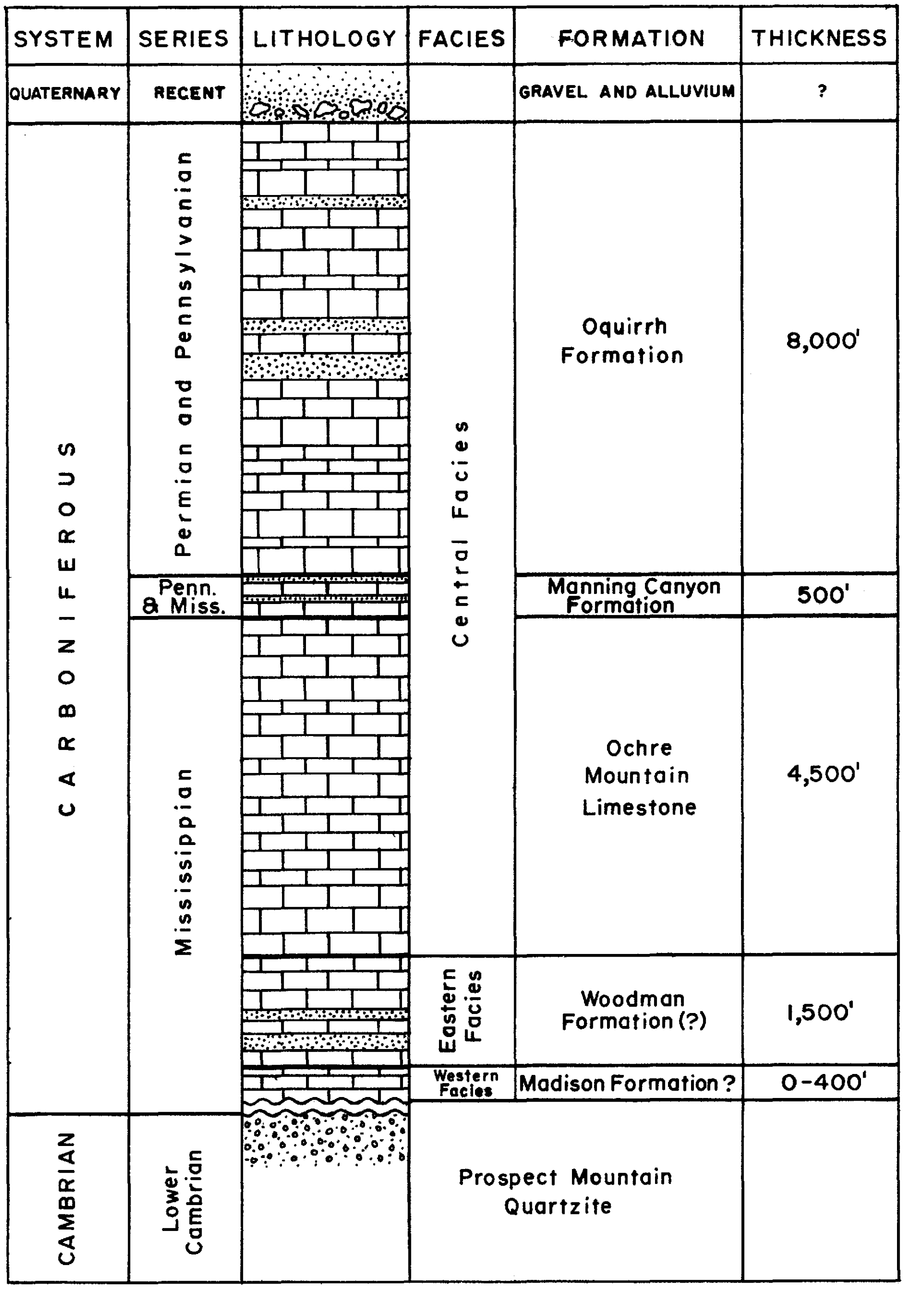


Figure 2. Geologic map of Rodenhouse Wash area, showing occurrences of berylliferous quartz-carbonate-adularia veins and sample locations.

Figure 2. Continued See opposite page for location.

Sample No.*	Description	Percent BeO
1	Grab sample, Climax mine dump	nil
2	Chip sample across the vein (4" thick	0.12
3	Chip sample across the vein (1½' thick	0.23
4	Grab sample from float of vein	0.02
5	Chip sample along length of vein	0.04
6	Chip sample 2" wide across the vein	0.02
7	Chip sample across the vein (4' thick)	0.04
8	Grab sample from quartz monzonite	tr.
9	Grab sample along length of vein	0.03
10	Chip sample 1' wide across vein	0.15
11	Chip sample along length of vein	0.20
12	Composite sample from silicified zone	tr.
13	Grab sample for quartz monzonite	tr.
14	Chip sample across the vein (3' thick)	nil
15	Chip sample along the vein	0.07
16	Chip sample across the vein (7' thick)	0.09
17	Grab sample from float of vein	0.08
18	Chip sample along length of vein	0.07
19	Chip sample from the middle of the vein	0.07
20	Grab sample from altered quartz monzonite	nil
21	Grab sample from the float	0.11
22	Chip sample across a vein (3' thick)	0.04
23	Chip sample across the end of above vein	0.03
24	Grab sample from dump of mine shaft	nil
25	Chip sample across the vein	0.11
26	Chip sample across end of same vein	0.04
27	Grab sample along the vein	0.03
28	Chip sample across the vein (3' thick)	0.05
29	Grab sample along the vein	0.07
30	Chip sample across the vein (6' thick)	0.03
31	Grab sample from float of the vein	tr.
31A	Grab sample from float of the vein	tr.
32	Grab sample from the vein	0.03
33	Grab sample from the vein	nil
34	Chip sample across a vein (1' thick)	0.10
35	Chip sample across the vein	0.05
36	Grab sample from hanging wall above vein	nil
37	Chip sample across a vein (3" thick)	nil
38	Chip sample across a vein (4' thick)	0.02
39	Grab sample along the vein	0.03
40	Chip sample across a vein (3' thick)	0.07
41	Chip sample across a vein (1' thick)	0.04
42	Grab sample of the float of vein	0.08
43	Chip sample across a vein (½' thick)	0.09
44	Grab sample from the float	0.09
45	Composite sample along the vein	0.14
46	Composite sample along silicified zone	0.11
47	Chip sample across the vein (8" thick)	0.12
48	Chip sample across the vein (2½' thick)	0.04
49	Chip sample across the vein (5' thick)	nil
50	Chip sample across the vein (½' thick)	tr.
51	Composite sample along the vein	0.12
52	Grab sample from the float along the vein	0.18
54	Composite sample from silicified zone	nil
55	Composite sample from silicified zone	0.09
56	Composite sample along the strike of vein	0.11
57	Composite sample along the strike of vein	nil
58	Grab sample from the float of vein	0.24
59	Grab sample from the float of vein	0.15
60	Chip sample across vein (1' thick)	0.06
61	Composite sample from brecciated zone (20' thick)	0.04
62	Composite sample same brecciated zone	tr.
63	Chip sample along part of the vein	tr.
64	Chip sample along part of the vein	0.10
65	Grab sample from quartz monzonite	nil
66	Grab sample from quartz monzonite	nil
67	Grab sample from vein aside from prospect	nil
68	Grab sample from altered quartz monzonite	nil
69	Grab sample from silicified zone	nil
70	Grab sample from prospect	nil
71	Grab sample from float of vein	nil

* All samples carry field notation (GH-RH) which for simplicity has been omitted from the plan.



SYSTEM	SERIES	LITHOLOGY	FACIES	FORMATION	THICKNESS
QUATERNARY	RECENT			GRAVEL AND ALLUVIUM	?
CARBONIFEROUS	Permian and Pennsylvanian		Central Facies	Oquirrh Formation	8,000'
	Penn. & Miss.			Manning Canyon Formation	500'
	Mississippian			Ochre Mountain Limestone	4,500'
			Eastern Facies	Woodman Formation (?)	1,500'
			Western Facies	Madison Formation ?	0-400'
CAMBRIAN	Lower Cambrian			Prospect Mountain Quartzite	

Figure 3. Stratigraphic units occurring in the vicinity of Gold Hill, Utah (adapted from Nolan, 1935).

muth are not available. Production values of intermittent shipments of tungsten from the Reaper and Yellow Hammer mines were estimated by Everett (1961) to be about $120,000. The known total production of tungsten from the Lucy L. mine was about 500 tons of ore containing 1 percent WO_3. Because of the change in the price of tungsten during times of production, no estimate of the dollar value can be made. A tentative estimate by Nolan (1935) of the value of arsenic produced was $2,500,000.

The ore deposits in the Gold Hill district are associated with the quartz monzonite. Some deposits are localized along contacts of favorable horizons of Carboniferous limestone and the intrusive body. Mineable vein deposits are restricted to the intrusion. The solutions responsible for the formation of replacement ore bodies of locally high-grade tungsten and copper were introduced through fractures within the stock.

Kemp and Billingsley (1918), Butler (1920) and Nolan (1935) have used slightly different classifications for the ore bodies of the district. The ore deposits of the area fall into three classes, outlined below:

1. Contact metasomatic deposits. These ore deposits show an intimate relationship to the quartz monzonite-limestone contact and are indicated by their characteristic contact metasomatic mineralogy. This class conforms with that of Kemp and Billingsley and of Butler; it includes the ore deposits described by Nolan as "veins with silicate minerals in the gangue" and those restricted to limestone beds near contact with the quartz monzonite. In this class, the general features of the Alvarado, Cane Spring, Frankie and Bonnemort ore bodies will be discussed.

2. Vein deposits. These deposits occur as lenticular ore bodies with definite walls that separate them from the country rocks. This class conforms with that of Kemp and Billingsley (1918), Butler (1920) and partly with that of Nolan (1935). The quartz-bearing gold, bismuth and scheelite of the Lucy L. mine, the quartz-carbonate-bearing galena and sphalerite of the Climax mine and the berylliferous quartz-carbonate veins of Rodenhouse Wash are included in this class.

3. Replacement deposits. These are divided into:

    a. Replacement deposits in the limestone include arsenic replacement ore bodies in the Gold Hill and United States mines, replacement gold deposits in the Rube Gold mine, and oxidized lead ore in the Rube Lead mine.

    b. Replacement deposits in the quartz monzonite include the scheelite-chalcopyrite-molybdenite deposits in the Yellow Hammer and Reaper mines, described by Butler (1920) as pegmatitic (?) and by Nolan (1935) as pipe-like deposits. The molybdenite deposits of the Rustler claims are included in this group (figure 4).

Contact Metasomatic Deposits

Contact metasomatic deposits containing native gold associated with sulfides of various metals occur in the contact zone between the quartz monzonite stock and the Paleozoic limestone. They have contributed most of the ore from the area. These deposits are located in the limestone side of the contact zone. The limestone may be merely recrystallized, replaced by quartz, or may be highly silicated. The intensity of alteration varies from one mine to the other depending upon the distance from the intrusive mass. In each case, however, characteristic contact minerals are indicative of the type of the deposits. The characteristic mineral association consists of native gold, pyrite, chalcopyrite, bornite, covellite, molybdenite and scheelite. Magnetite is common. The most prominent gangue minerals are wollastonite, tremolite, garnet, tourmaline, diopside and quartz.

The two principal gold-producing mines of this type are the Alvarado and the Cane Spring. The Frankie mine was worked for copper and tungsten; the gold content of its ores was minor (report of the Woodman Mining Company, 1916). The Bonnemort mine is reported by Nolan (1935) to have produced copper and gold. Several small prospects were developed along the contact zone. All show the same mineralogy.

The earliest workings in the Gold Hill mine from 1892 to 1895 are reported by Kemp and Billingsley (1918) to have developed an ore body similar to that of the Alvarado and the Cane Spring mines. The ore body consisted of wollastonite and small amounts of oxidized copper minerals associated with native gold.

Characteristic relationships in these contact metasomatic deposits are given on the following page.

Veins

There are three types of veins in the Gold Hill area: quartz-carbonate-adularia, quartz and calcite. The first type is confined to the quartz monzonite stock; the other two occur both in the quartz monzonite and the surrounding rocks.

Quartz-Carbonate-Adularia Veins

Quartz-carbonate-adularia veins are restricted to Gold Hill quartz monzonite stock. They are found in the

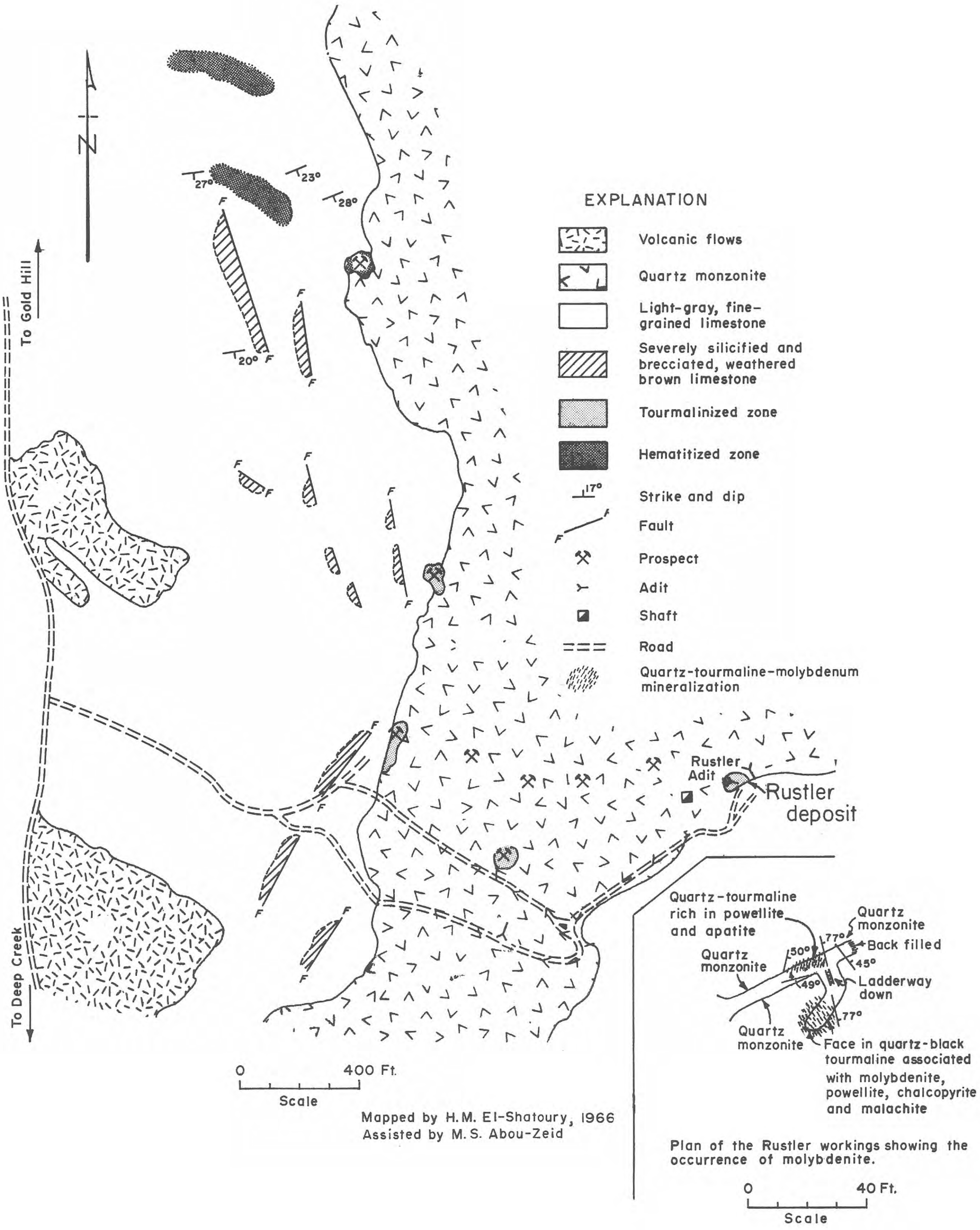


Figure 4. Geologic map of the surface, vicinity of the Rustler molybdenite deposit, Gold Hill, Tooele County, Utah.

Mine	Ore Minerals	Associated Gangue Minerals	Stratigraphic Relation
Alvarado	Native gold Chalcopyrite Malachite Bornite Galena	Wollastonite Tremolite Garnet Quartz Idocrase	Contact between quartz monzonite and Ochre Mountain limestone.
Cane Spring	Native gold Chalcopyrite Malachite Bornite Molybdenite	Wollastonite Garnet Quartz Idocrase	Ochre Mountain limestone. The quartzite monzonite crops out 1,000 feet northwest of the main shaft.
Frankie	Native gold Chalcopyrite Malachite Bornite Scheelite Conichalcite	Wollastonite Tremolite Garnet Tourmaline Quartz Idocrase	Contact between Oquirrh Formation and quartz monzonite.
Bonnemort	Native gold Chalcopyrite Malachite	Wollastonite Garnet Quartz	Contact between Oquirrh Formation and quartz monzonite.

central part of the main mass and are concentrated in the area of Rodenhouse Wash. A few veins of the same type occur on the Reaper claims, about two miles southwest of Rodenhouse Wash, and north to Clifton. A geologic map (figure 2) shows the occurrence of these veins in Rodenhouse Wash.

A description of these veins has been reported by Butler (1920) and Nolan (1935). In 1962 Vanguard Research Company, using a field berylometer, discovered anomalous amounts of beryllium in these veins. Griffitts (1965) thought the beryllium to be in bertrandite.

The veins show a wide variation in their physical and mineralogical characteristics. They vary in thickness from a fraction of an inch to several feet. Their strike length varies from a few inches to about 1,400 feet, interrupted by a slight change in strike and intermittently covered by float of the same material.

The general strike of these veins is northeasterly and their dip is westward. The strike varies from N5° E to N 80° E and from N 5° W to N 30° W. The dip varies from 39° to 65° westward, but some are vertical.

Megascopically, they are fine-grained, stained brown on the weathered surfaces but milky white on fresh surfaces with fine hematitic bands stained light brown. Some of the veins show minute microlitic cavities in which minute euhedral, colorless and brown quartz crystals protrude. Some veins show indistinct banding that is commonly contorted and is rarely parallel to the walls. This contortion is not characteristic of the whole system of veins. Generally, banding is more distinct in the thin veins than in the thick ones which are jointed and fractured.

The contact between the veins and the surrounding quartz monzonite is best shown in the thin veins. The contact is marked by a fine-grained border zone about one inch thick separating the vein from the coarse-grained quartz monzonite. This border zone is greenish in color and is similar in appearance to the quartz monzonite. Examination of thin sections from this zone reveals a fragmental lithic breccia in a fine matrix of quartz in which are embedded small laths of biotite altered to chlorite and sericite.

Microscopic examination of 10 thin sections of the veins shows a wide variation in texture and composition, ranging from allotriomorphic-granular to hypidiomorphic-granular and from fine-grained to porphyritic types. They are composed of quartz, adularia and a carbonate which is either calcite or siderite. The proportion of these minerals varies widely from one specimen to another. Some veins are composed of alternating bands of anhedral fine-grained quartz and coarse-grained, euhedral, prismatic crystals of quartz about 0.8 to 1.0 mm long, and are completely devoid of adularia. Others are composed of quartz in its two previous forms accompanied by adularia.

Adularia, a late mineral since it develops upon the surface of quartz and bordering cavities lined by chalcedonic quartz, is erratically distributed. It occurs as well-developed rhombic crystals about 0.2 mm in diameter.

Calcite occurs as fine- to coarse-grained crystals with perfect rhombohedral cleavage.

Siderite is identified from the type of veins occurring in the Reaper claims. It is distinguished from calcite by dark brown stains along the borders of the individual rhombohedrons.

An unidentified mineral occurring as minute acicular crystals having a refractive index of about 1.68 appears rarely. It is similar to muscovite, but it is optically length fast, eliminating this possibility. Because of the minute size of the crystals, no interference figure has been obtained. On the strength of the above characteristics, the mineral could be dumortierite ($HBAl_8Si_3O_{20}$).

Pyrite is a common accessory mineral, associated with magnetite and hematite and rarely with chalcopyrite.

Chemical analysis of one sample of the quartz-carbonate veins (GH-RH-2) has been made by Lester Butcher. Table 1 shows the results of this analysis:

Table 1. Analysis of quartz-carbonate-adularia vein from Rodenhouse Wash (Lester Butcher, analyst).

SiO_2	Al_2O_3	K_2O	CaO	MgO	Fe	CO_2
80.80	5.00	5.20	4.00	0.10	0.90	3.10
Total= 99.10						

The mineral percentage is computed from this analysis and is shown in table 2 below:

Table 2. Computed mineral percentage in a quartz-carbonate-adularia vein (based on the analysis of table 1).

Mineral	Percent
Quartz	60.90
Potash feldspar	30.80
Calcite	7.10
Pyrite	1.90
Total	100.70

Quartz-carbonate veins carrying commercial amounts of sphalerite and galena have been described from the Climax mine in the Rodenhouse Wash area.[1]

The occurrence of beryllium in the quartz-carbonate veins of Rodenhouse Wash was checked by gamma activation analysis for beryllium of 73 samples from the beryllium-bearing veins and surrounding rocks. Sixty-three of the samples were from the beryllium-bearing veins, eight from quartz monzonite and two from volcanic rocks. The beryllium oxide content of the quartz veins ranged from the lower limit of detectability by gamma activation (about 0.02 percent beryllium oxide) to 0.24 percent beryllium oxide, with a mean of 0.065 percent. Beryllium could not be detected in the quartz monzonite or volcanic rocks by the gamma activation method of analysis.

Different analytical methods often yield different results unless detailed studies of the analytical procedures are made. For example, in this study, various methods used on the same samples produce various amounts of BeO:

Sample No.	Percent of BeO		
	Spectro-graphic	Gamma Activation	Colormetric
GH-RH-46	N.D.*	0.11	0.08
GH-RH-52	N.D.	0.18	0.13
GH-RH-58	0.02	0.24	N.D.

*Not determined.

It is not part of this study to calibrate analytical results. The conclusion that the veins are not ore-grade in the foreseeable future is based on gamma activation analyses and is therefore conservative. The correlation between adularia content and beryllium oxide content is based on spectrographic analyses.

The low content of beryllium oxide in these samples makes it doubtful that these veins will yield a marketable beryllium ore in the foreseeable future.

Previously reported quantitative spectrographic analyses of some of these veins appear in Griffitts' paper (1965), with beryllium oxide occurring in amounts up to 500 ppm. G.M. Park (personal communication, 1967) reported only 50 ppm of beryllium oxide, determined spectrographically, on a single sample from the veins.

In petrographic studies no discrete beryllium minerals were identified by the writers; this fact led to an investigation of the rock-forming minerals as possible hosts for beryllium.

The amount of carbonate in the veins was determined by solution in acetic acid. The evaporated filtrate was checked spectrographically for beryllium and found to be negative. Adularia in the residue was selectively stained with sodium cobaltinitrite. The quartz and the adularia were then separated by hand-picking under the binocular microscope. Only the adularia was found to contain beryllium in amounts large enough to be detected spectrographically.

Twenty-two samples from the veins were selected from among the 63 that had been analyzed for beryllium by gamma activation. The samples were chosen to cover a wide range of beryllium oxide content. These samples were crushed and sized; the -65 + 100 mesh size

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[1] Eng. Mining Journal, 1917

fraction was used in the study described below. This fraction was chosen because it was fine enough to provide good sampling, it liberated the various minerals and yet was coarse enough to allow microscopic counting of grains without difficulty.

Mineral segregation occurred on crushing, but since adularia content and beryllium oxide content of the size fraction were used, it should not have affected results. The amount of adularia was determined by staining the sample with sodium cobaltinitrite followed by point counting of three slides prepared from the sample. The beryllium oxide content of each size fraction sample was determined spectrographically. The resulting adularia content-beryllium oxide content data approximated a straight line with the following formula:

Percent adularia= 2.05 + 62.2 percent beryllium oxide.

If the above formula is correct, adularia could be carrying as much as one and a half percent beryllium oxide. Warner and others (1959) report that microcline (microperthite) can carry up to 0.04 percent beryllium oxide. Unless the beryllium in the adularia studied is associated with inclusions of other minerals too fine to detect with a microscope, adularia can carry a considerably higher content of beryllium oxide than had been anticipated previously for the feldspars.

From the fact that minerals other than beryllium were identified in these samples and that beryllium oxide content correlates rather well with adularia content, we can postulate that the beryllium is in the feldspar structure.

The following minerals were checked for beryllium by emission spectrography:

> Apatite: From the Rustler adit where it occurs in large crystals about 2 inches long, associated with molybdenite and black tourmaline.
>
> Black tourmaline: From the above locality.
>
> Biotite: From the quartz monzonite stock (sample GH-2-3) separated during preparation of samples for accessory mineral studies.
>
> Actinolite: Occurring as long bladed crystals in the Yellow Hammer open pit.
>
> Perthite: Occurring as massive crystals in the dump of the Reaper mine.

Only the black tourmaline, actinolite and biotite contained traces of beryllium.

Quartz Veins

Quartz veins occur in the quartz monzonite and in the surrounding limestone areas. In some places they cut the aplite dikes and hence are younger. Quartz veins cutting the limestone are generally fine stringers a few inches wide and occupying joint planes. In the quartz monzonite, they are generally of larger dimensions and occupying fissures. They are fine- to medium-grained, grayish to milky white in color, and occasionally show brownish to red staining. Thin sections show that they are composed principally of anhedral quartz grains showing strain shadows and well-defined fractures. The fractures are filled with secondary quartz veinlets and sometimes contain hematite after pyrite or magnetite, all indicated by the presence of relics of these minerals.

Quartz veins also occur as a microscopic feature, cutting all rock units studied and carrying economic quantities of scheelite, chalcopyrite, bismuth and gold. They have been worked in the Lucy L. mine, in the Wilson mine about two miles southwest of Gold Hill village, and in the Doctor group of claims adjoining the Yellow Hammer mine. The mineralogy of the gold-bismuth veins is rather simple. According to Nolan (1935), metallic minerals are native bismuth, bismuthinite (both partially oxidized to bismutite), pyrite and native gold, all in a matrix of quartz. Kemp and Billingsley (1918) described a gold telluride from these veins.

Calcite Veins

The calcite veins cut many rock types, occurring in a massive form and in a chevron arrangement associated with the quartz-carbonate adularia veins in Rodenhouse Wash. They also occur on a microscopic scale, cutting the various rock types.

Replacement Deposits

Replacement Deposits in the Ochre Mountain Limestone

The major production of arsenic and part of the copper, lead, silver and gold has come from the Gold Hill and United States mines. These mines have similar mineralogy and differ only in their oxidized zones. They occur in unaltered Ochre Mountain limestone where replacement is controlled largely by the presence of fissures perpendicular and parallel to the bedding planes of the host limestone beds. Their hypogene minerals consist of massive and bladed arsenopyrite, galena, sphalerite, chalcopyrite, pyrite, pyrrhotite and tetrahedrite. The primary minerals had been oxidized and yielded a variety of arsenate minerals, particularly in the Gold Hill open pit (figure 5), which include adamite, arsenosiderite, austinite, beudantite, conichalcite, clinoclasite, mimetite, olivenite, pharmacosiderite, scorodite and veszelyite.

Replacement gold deposits of the Rube Gold mine east of Gold Hill village, shown in plates 1, 2 and 3, are present in thick-bedded Ochre Mountain limestone. Ore shoots are associated with strong hematitization and local strong silicification and brecciation. The marked difference between this deposit and the contact metasomatic gold deposits represented by the Alvarado, Cane Spring and Bonnemort mines is the absence of the characteristic contact silicate minerals. Quartz monzonite does not appear in the workings of the mine.

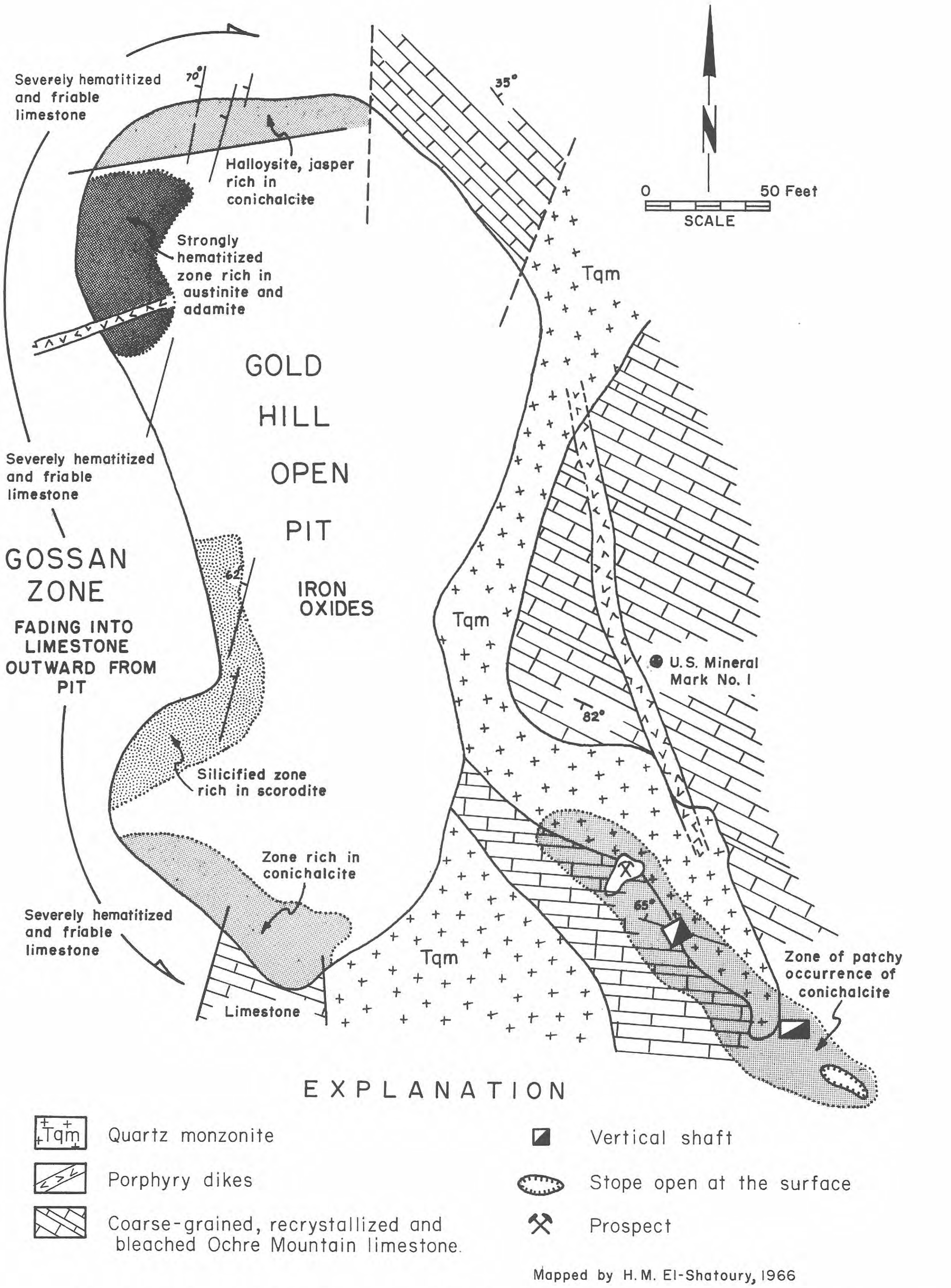


Figure 5. Surface geology of the Gold Hill open pit mine showing occurrence of arsenate minerals.

Replacement Deposits in the Quartz Monzonite

This type of replacement deposit accounts for the major production of tungsten from the area. The country rock is quartz monzonite. The present ore body of the Yellow Hammer, shown in figure 6, seems to be restricted to northeasterly fractures. Evidence in the workings suggests that these were the conduits followed by the mineralizing solutions. The development of perthitic orthoclase, large crystals of bladed actinolite, and the abundance of apatite led Butler (1920) to classify the deposit as pegmatitic. The boundaries of the replacement ore body along the fractures are not sharp but consist of a change in the grain size and mineralogy and mark the limits of the replaced quartz monzonite. We do not agree with Butler's classification of these ore bodies as pegmatitic, but classify them instead as replacement ore bodies.

The Reaper and Yellow Hammer deposits are mineralogically similar. Tungsten is present as scheelite, and molybdenum as powellite and molybdenite. The latter occurs sparsely, impregnated in bladed actinolite in specimens from the dump of the Reaper mine. Associated minerals are chalcopyrite, pyrite, oxide copper minerals and abundant magnetite. The gangue minerals are actinolite, perthite, garnet, apatite, black tourmaline and quartz.

A similar type of ore occurs in small workings on the Rustler claims north of the Frankie mine. The ore body occurs in a contact quartz-tourmaline zone. The ore minerals consist of molybdenite, powellite and chalcopyrite, with pyrite in a gangue of quartz, black tourmaline and apatite. No scheelite has been recognized in this locality.

HYDROTHERMAL ALTERATION

Nolan (1935) recognized four types of alteration in the limestone roof pendants intruded by the quartz monzonite stock. A brief description of these types follows:

1. Recrystallization. Recrystallization of sedimentary beds as a result of metamorphism by igneous intrusion caused an increase in the grain size in the Ochre Mountain limestone and quartzite. It also caused the development of allotriomorphic texture and marked bleaching. The effect on the Manning Canyon Formation was the development of andalusite hornfels in which biotite and sericite have been formed.

2. Silication. Silication, or the type of alteration that resulted in the development of contact silicate minerals, occurs locally. The result of such an alteration produced two distinct varieties of rocks: a diopside-garnet rock with zoisite, humite, titanite, actinolite and apatite; and a bladed wollastonite rock which in great part is replaced by the mineral spadaite.

3. Silicification. Silicification of the limestone and its alteration to jasperoid is a rather widespread phenomenon in the area. Associated minerals are barite (local), sericite, calcite and opal.

4. Dolomitization. The alteration of Cambrian carbonate rocks into dolomite is rather common in the Deep Creeks and in Dutch Mountain but localized in areas far from igneous contacts. In the Gold Hill mine, dolomitization of the Ochre Mountain limestone was recognized by Nolan (1935) as limited.

The alteration types associated with the quartz monzonite stock are classified by Nolan (1935) into three mineralogic facies:

1. Diopside-orthoclase alteration associated with garnet and actinolite. This facies is restricted to a narrow belt extending from the Yellow Hammer and Reaper mines to the vicinity of the United States mine area.

2. Sericitization and chloritization. This type of alteration affects chiefly the area of quartz monzonite that lies east of and roughly parallel to the north-sloping portion of Rodenhouse Wash and south to Goshute Spring. It affects the minerals of the diopside-orthoclase facies.

3. Silicification. Silica is introduced in the form of veinlets or of irregular masses of quartz that form a matrix among the remnants of the unaltered minerals.

Microscopic criteria established during the study of thin sections of the quartz monzonite and its altered equivalents, of dikes, veins, contact zones and volcanic rocks, form a basis on which arbitrarily defined limits can be assigned to distinguish and classify six stages of alteration that largely affect the quartz monzonite stock. These stages are to some extent imposed on sedimentary, volcanic, dike, and contact metamorphic rocks. For convenience in description of these stages and their effects, each will be treated separately.

Alteration of Quartz Monzonite

Alteration of the quartz monzonite of the Gold Hill stock is arbitrarily divided into six stages that are numbered in order of progressive alteration.

These stages, in particular the first three, are of a microscopic nature, and the boundaries between them are gradational.

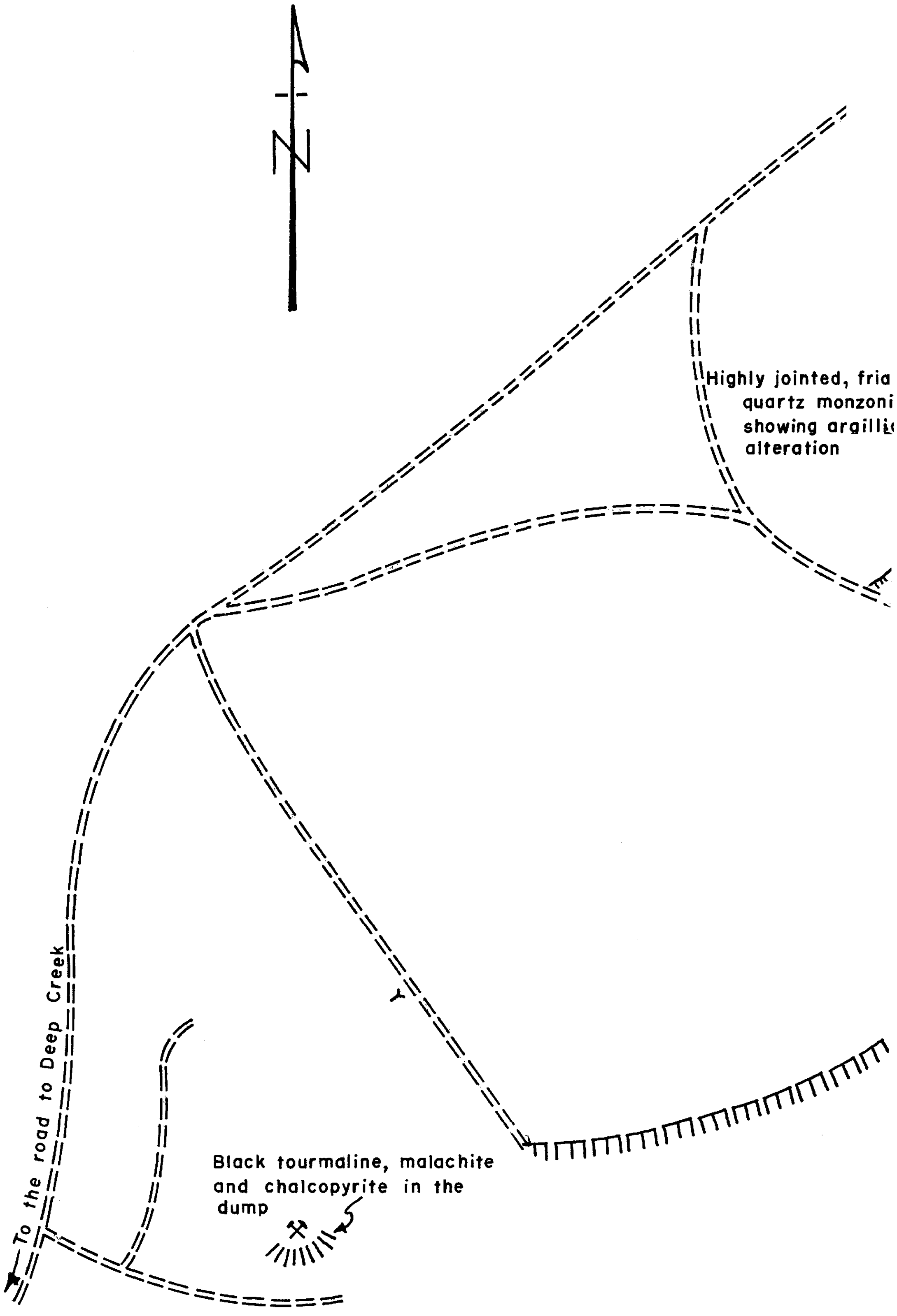
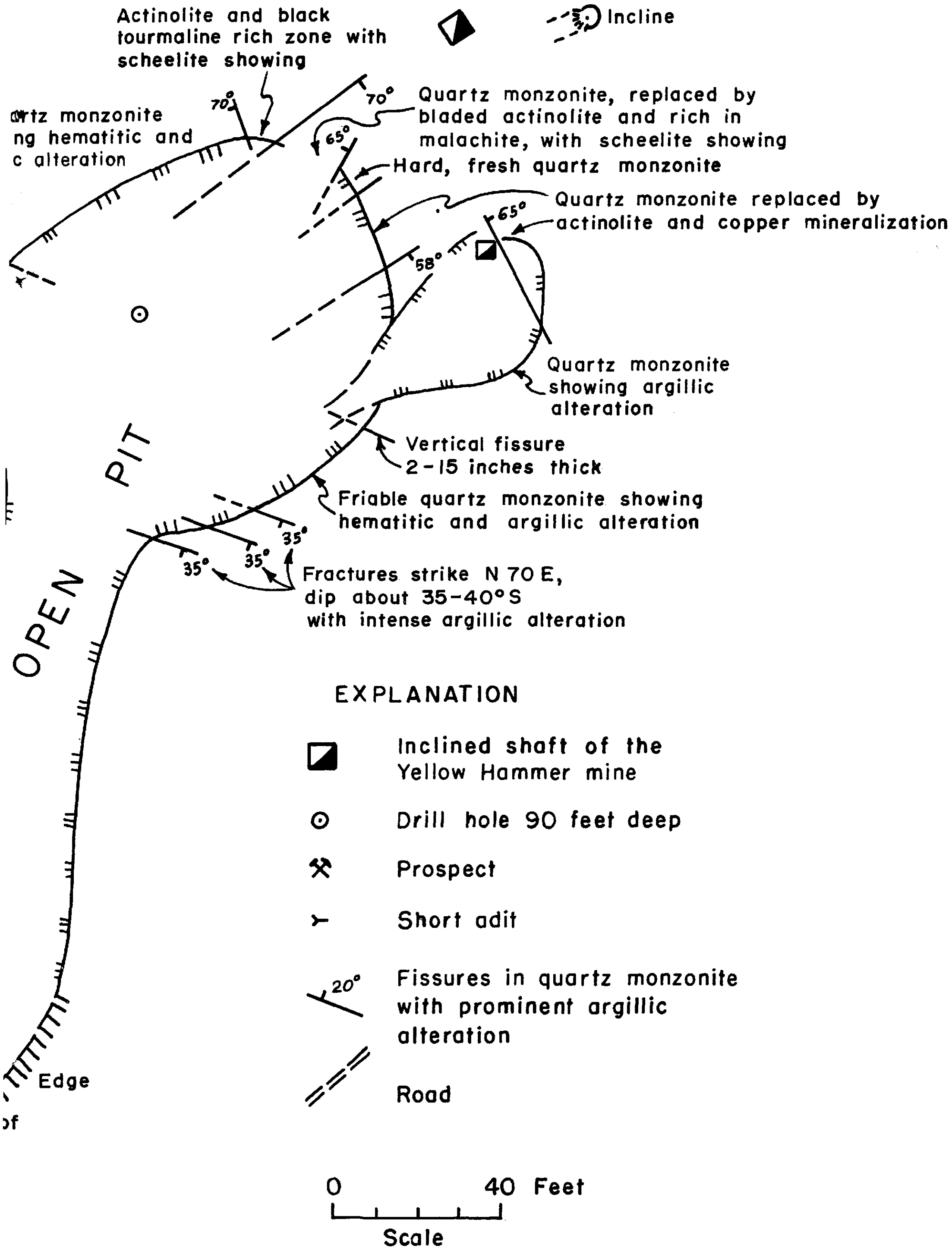


Figure 6. Geologic features of the Yellow Hammer open pit, Gold Hill, Tooele County, Utah.



Mapped by H. M. El-Shatoury, 1966

Alteration stages IV and V may be recognized megascopically. Stage VI, however, produced compositional and textural variations in the altered areas great enough to be recognized in the field.

The early stages of alteration are identified by the degree and type of alteration of the phenocrysts since the groundmass (quartz and orthoclase) does not show any distinctive alteration except fracturing and incipient cloudiness.

The distribution of mineral constituents in the various stages of alteration in the quartz monzonite is shown in table 3. A summary of these stages follows:

STAGE I	A deuteric stage, characterized by incipient alteration of feldspars, resorption of the quartz phenocrysts, development of the graphic texture, albitization of the potash feldspar, and myrmekitization.
STAGE II	Plagioclase feldspar shows an increased degree of sericitic alteration. Biotite shows partial chloritization along its rims or cleavage plane with the development of magnetite grains. The texture of the rock is preserved.
STAGE III	Plagioclase feldspar is completely altered to sericite and perthite to kaolinite and allophane. Hornblende (if present) is partially altered to biotite and biotite is remarkably altered to a mixture of pennine, pyrite, magnetite and sphene with fine-grained carbonate. The original texture of the rock is preserved.
STAGE IV	Introduction of chalcedonic veins.
STAGE V	Introduction of carbonate veins.
STAGE VI	Silication of the rock with the development of sulfides and scheelite. The texture of the rock is obliterated. Silication included development of tourmaline, actinolite, garnet, perthite, euhedral quartz, diopside and associated apatite and associated mineralization included pyrite, chalcopyrite, molybdenite and scheelite.

Stage I:

Stage I is represented by the deuteric or the high-temperature hydrothermal alteration stage. The position of the deuteric stage in the crystallization of an igneous rock is a validated concept among petrologists. The specific limits of the deuteric stage are not defined and its boundary with the hydrothermal phase is rather vague beyond the descriptive terms of "selective" and "pervasive" for each of these stages, respectively.

The deuteric stage of alteration in the quartz monzonite of the Gold Hill area is represented by the development of:

1. Myrmekite texture, characterized by the presence of vermicular bodies of quartz enclosed in a continuous crystal of plagioclase.

2. Microperthite. Albitization of the potash feldspar in the quartz monzonite is a common feature in the thin sections studied. Perthite is present as phenocrysts that have undergone slight sericitization and kaolinization in contrast to the fresh, but sometimes fractured, orthoclase of the groundmass.

3. Incipient alteration in the plagioclase feldspar, generally accepted to be a result of deuteric action. During this stage of alteration the plagioclase feldspar has developed small amounts of sericite, sometimes restricted only to the outline of the crystals and sometimes along lamellar twinning.

Stage II:

Alteration phenomena marking stage II are the pronounced sericite development on the plagioclase feldspar as irregular patches that are not controlled crystallographically. Sericitization is usually associated with fine-grained disseminated carbonate alteration.

Biotite in this stage is partially chloritized along its rims and sometimes along its cleavage. The chlorite gives "Berlin blue" interference colors and is probably pennine. Chloritized biotite is associated with anhedral grains of magnetite partially altered to hematite.

Stage III:

The advancement of hydrothermal alteration in stage III is marked by the intensity of alteration affecting the plagioclase feldspar, perthite and biotite, although the texture of the rock is still preserved. Development of sericite on the plagioclase feldspar is complete; identification of the plagioclase composition is impossible. Perthite shows almost complete replacement by allophane and kaolinite. Hornblende, when present, is partially altered to chloritized biotite. Biotite retains its lath-shaped habit but is altered into bands of chlorite (pennine ?), fine-grained leucoxene and fine-grained carbonate. Altered biotite is associated with abundant pyrite and magnetite which are partly weathered to hematite. Biotite is also replaced by chlorite and fine-grained quartz. Chlorite veinlets from the altered biotite cut through the sericitized plagioclase. In the same samples phenocrysts of deep brown biotite, without cleavage, have been altered into clusters of fine laths of pale brown biotite that show perfect cleavage. These phenocrysts, as well as the "recrystallized" clusters of biotite, are surrounded by halos of chlorite with magnetite and pyrite. Stringham (1953) described a similar occurrence at Bingham which he concluded to be hydrothermal in origin.

Table 3. Distribution of mineral constituents in the various stages of alteration of the quartz monzonite.

MINERAL	ALTERATION STAGE					
	1	2	3	4	5	6
Rock Forming						
Phenocrysts						
Mica						
Unaltered biotite	—					
Partial chloritization		—				
Complete alteration to chlorite, carbonate, magnetite			—			
Veined by chalcedony				—		
Veined by fine-grained carbonate					—	
Feldspar						
Euhedral orthoclase						—
Perthite	—					
Partial argillic alteration		—				
Veined by chalcedony				—		
Veined by calcite					—	
Plagioclase feldspar						
Incipient alteration	—					
Myrmekitization	—					
Increased sericitization		—				
Veined by chalcedony				—		
Veined by calcite					—	
Quartz						
Resorbed	—					
Euhedral						—
Graphic intergrowth	—					
Veined by chalcedony				—		
Veined by carbonate					—	
Groundmass						
Fresh quartz	—	—	—	—	—	—
Fresh orthoclase	—	—	—	—	—	—
Accessory Minerals						
Sphene	—					
Introduced						
Chalcedony				—		
Opal				—		
Calcite					—	
Tourmaline						—
Actinolite						—
Apatite						—
Garnet						—
Diopside						—
Perthite						—
Metalliferous						
Magnetite		—	—	—	—	—
Pyrite		—	—	—	—	—
Chalcopyrite						—
Molybdenite						—
Scheelite						—

Stage IV:

Stage IV is not to be considered an alteration stage by itself. It is introduced as a separate phase to account for the microscopic quartz veins cutting the rock-forming minerals. Quartz occurs as chacledony filling cracks in the rock-forming minerals and following grain boundaries. Opal veinlets are associated with chalcedony and the chalcedony veins are sometimes opalized. The relationship between these two varieties of silica has not been established because of lack of cross-cutting relationships.

Silicification varies from a microscopic feature to that which can be recognized in the field. Jasperoid veinlets cutting the quart monzonite around the United States mine and the Rustler adit are prominent. The quartz monzonite has acquired a red coloration and is highly silicified and hardened through almost complete silicification, although the texture of the rock is preserved.

Stage V:

Stage V also is not to be considered an alteration phase, but represents the introduction of late secondary calcite veinlets cutting through the rock-forming minerals. From cross-cutting relationships with chalcedony veins, it is regarded as later than the chalcedony.

Stage VI:

The advancement of stage VI caused the obliteration of the original texture of the rock and hence is a megascopic stage. The original rock is replaced by silicate minerals including tourmaline, actinolite, garnet and perthite, all of which are associated with apatite, magnetite and quartz.

This stage, associated with molybdenite, scheelite, chalcopyrite and pyrite, is confined to areas of prominent fractures and to areas in close proximity to the limestone contacts. The effect produced during this stage is confined largely to the area surrounding the Yellow Hammer and Reaper mines, but extends northward to the vicinity of the Rustler-Frankie mine area in intermittent outcrops.

In the vicinity of the Yellow Hammer open pit, replacement of the quartz monzonite with actinolite, garnet, sphene, apatite, perthite, black tourmaline and quartz is extensive. Pyrite is abundant around garnet crystals and also replaces quartz; chalcopyrite replaces pyrite. Scheelite as disseminated crystals up to one inch in diameter occurs in the actinolite-rich rock. In the Reaper dump, molybdenite impregnations about one-half inch in size are embedded in actinolite.

Tourmalinization is associated with extensive silicification and locally abundant apatite. Tourmaline occurs in tabular crystals, in columnar aggregates, and in the form of radiating needles on the surface of quartz or orthoclase, forming "tourmaline suns." Some crystals show hexagonal zoned cross sections. Under the microscope the color varies from light to deep green; absorption varies from light to deep green and in some varieties from light green to deep brown.

Silicification of the tourmalinized rock is relatively complete. Quartz occurs in the form of euhedral crystals showing double terminations and hexagonal cross sections with zoned inclusions parallel to the crystal outline. It also occurs as medium-grained feathery chalcedony in the groundmass and as fine-grained chalcedony veinlets cutting through the tourmaline. The chalcedony veinlets are cut by calcite veins. The three varieties of quartz occur in the same thin sections. Molybdenite and chalcopyrite are associated with the tourmalinized rock. Powellite is abundant as an oxidation product of molybdenite. Apatite is a common constituent of the altered rock, and in the Rustler claims occurs as prismatic crystals about two inches long and associated with molybdenite (figure 4). Under the microscope, the apatite is found to contain small blebs of molybdenite as inclusions.

Alteration of Limestones

The Ochre Mountain limestone intruded by the quartz monzonite shows essentially the types of alteration described by Nolan: recrystallization and bleaching, silicification, silication and dolomitization. Alteration to dolomite is confined to the Gold Hill mine in the lower levels farthest from the quartz monzonite contacts.

Recrystallization of the limestone forms a white marble consisting of a coarsely crystalline calcite. Dolomite or dolomitic marble is not recognized in any of the samples studied. The presence of diopside or tremolite in the marbleized rock, however, may indicate that the original rock was dolomitic or an impure limestone. Magnetite is found to be a common accessory in the marbleized limestone.

The limestone exhibited alteration stages IV, V and VI, somewhat equivalent to those stages in the quartz monzonite.

Stage IV is represented by the introduction of secondary chalcedony veins cutting the rock in many directions. The degree of silicification varies from a few thin veins of chalcedony to almost complete replacement by a coarser-grained feathery chalcedony associated with fine grains of magnetite. The walls of the chalcedony veins are opalized.

Stage V is represented by the introduction of secondary calcite veinlets cutting the chalcedony veinlets.

Stage VI is marked by the development of the characteristic contact silicate minerals: garnet, diopside, zoisite, wollastonite, actinolite, locally tourmaline associated with native gold, scheelite, and the sulfides of iron, lead, zinc and molybdenum. This stage is directly related to the end stage emanations from the intrusive.

Alteration of the Manning Canyon Formation

Outcrops described by Nolan as the Manning Canyon Formation form the eastern slopes of the hill near the Gold Hill mine and the foothills below the Cane Spring mine and appear megascopically as a fine-grained, dark gray, dense and poorly foliated rock. Microscopic examination of these localities shows a hornfelsic texture. The rock is decussate and nonschistose, and is poorly banded. The bands are the result of the alignment of sericite and fine-grained biotite laths completely altered to chlorite. The groundmass is clouded by carbonaceous matter. Porphyroblasts of poorly developed andalusite clouded by carbonaceous matter are embedded in the fine-grained matrix and are partly replaced by fine-grained quartz.

Kemp and Billingsley (1918) described in detail the effects of the intrusive on this argillaceous formation and illustrated the development of andalusite hornfels from it. According to them:

> The first effect of the granite is shown in the aggregation of the carbonaceous matter into blotches which form a mosaic with clearer spots between. Little brown spots of biotite next develop, sometimes in the midst of rude outlines of andalusite crystals, sometimes without the latter. The andalusites gradually assume more and more definite outlines until sharp, square prisms with the curious characteristic inclusions of carbonaceous matter are the last result.

Alteration of Quartzite

The only change in the Prospect Mountain quartzite is the development of a strain phenomenon shown by the development of a small 2V angle in quartz, the undulatory extinction of the quartz, and the development of a mortar texture. The fine-grained matrix contains minute laths of biotite with high birefringent colors resulting from alteration to sericite. The rock is cut by secondary chalcedony veins of stage IV, affecting the quartz monzonite and the limestone. Limonite occurs as aggregates on the surface of the quartz and as veinlets filling cracks in the quartz grains.

Alteration of Volcanic Rocks

There is some similarity between the early stages of alteration in volcanic rocks and the early stages of alteration in the quartz monzonite. The plagioclase feldspar shows slightly argillic alteration associated with fine-grained disseminated carbonate. Augite phenocrysts show partial to complete uralitization (?) or chloritization associated with magnetite. The magnetite is partially weathered to hematite. Schwartz (1939) reports that uralitization or the formation of fibrous amphibole as an alteration product of pyroxene is not a stable product of hydrothermal or other types of alteration, and so in turn alters to, or is replaced by, chlorite, sericite, or other minerals.

Introduction of partly opalized chalcedonic quartz of stage IV is common along lamellar twinning in the plagioclase phenocrysts. Chalcedony also replaces marginal areas in the augite phenocrysts and sometimes replaces their cores.

Alteration of Dike Rocks

The porphyry dikes related compositionally to the quartz monzonite intrusion are similar to it in the sequence of their alteration. Stage I of the alteration is represented by the highly resorbed quartz phenocrysts and incipient alteration in the plagioclase feldspar. Stages II and III are marked by partial to complete sericitization and carbonatization of the plagioclase feldspar and the partial to complete chloritization of biotite with the associated alteration minerals of sphene, magnetite, pyrite and disseminated carbonate.

A peculiar feature found in a porphyry dike cutting the quartz monzonite in the vicinity of the Reaper open pit is the occurrence of minute vesicles of elliptical to irregular shapes ranging from 0.5 mm to 2.5 mm in diameter. These vesicles are filled with secondary minerals in concentric bands. The order of these minerals from the wall of the vesicle to its core is: fine-grained calcite, fibrous fan-shaped green chlorite, fine-grained quartz, fine-grained calcite, with coarser quartz in the center. This series is not complete in all of the vesicles.

Alteration of Quartz-Carbonate Veins

The quartz-carbonate veins of Rodenhouse Wash are characterized by the occurrence of adularia with erratic distribution.

Adularia is known to be formed in several districts as a hydrothermal mineral during alteration of igneous rocks. Adularia and secondary orthoclase are terms often used to describe the occurrence of potash feldspar in veins and replacement deposits. The term adularia is used to describe the development of the rhombic habit, whereas secondary orthoclase is applied whenever the rhombic habit is lacking (Schwartz, 1939).

The quartz monzonite at the walls of the veins has been strongly silicified with chalcedony and by the development of porphyroblasts of euhedral quartz showing inclusion bands parallel to their crystal outlines. Plagioclase feldspar is either absent or it occurs in accessory amounts. Where present it is almost completely obliterated through sericitization. Orthoclase feldspar constitutes about 50 percent of the whole rock. Biotite is present in accessory amounts as minute laths completely altered to chlorite.

OXIDATION OF ORES

The behavior of the ore minerals in the process of oxidation to yield supergene enrichment requires specific conditions regulated by climate, time, physiographic development and the occurrence of ores amenable to the chemical action of the atmosphere and the altering circulating water. The extent of the oxidation process is dependent upon and regulated by such geologic parameters as the position and stability of the water table, the rate of erosion and the physical-chemical properites of the ore and the enclosing rock.

None of the ore bodies developed in the Gold Hill area has had a significant amount of secondary sulfide enrichment. The oxidation of some ore bodies has been extensive, however, and the major part of ore production has come from oxidized ore bodies.

Two mines in the area have been developed to the water table. These are the Gold Hill mine which has reached the 760-foot level, corresponding to an altitude of about 5,125 feet, and the United States mine which has reached the 234-foot level, corresponding to an altitude of about 5,430 feet. In these mines the bottom of the completely oxidized zone is about 100 feet above the water table. This has been explained by a widespread lowering of the water table level resulting from a recent normal faulting which has influenced the present topography (Nolan, 1935).

The ore deposits in the area have undergone oxidation characterized and limited by the stability of the hypogene minerals. The types of oxidation of these deposits are discussed below.

Oxidation of the Copper-Lead-Arsenic-Zinc Replacement Deposits

The oxidation of the primary chalcopyrite, galena, sphalerite and associated pyrite in close proximity to arsenopyrite produced a group of basic arsenates of zinc, lead, copper, iron and calcium. Buranek (1964) states that cuprite (Cu_2O) and native copper occur in the oxidized zone of the Gold Hill mine.

Butler (1920) described the occurrence of scorodite ($FeAsO_4 \cdot 2H_2O$), beudantite ($(Pb_1Fe)_3(AsO_4)(OH)_6$), conichalcite ($CaCu(AsO_4)(OH)$) and olivenite ($Cu_2AsO_4(OH)$). Staples (1935a,b) described adamite ($Zn_4(AsO_4)(OH)_2$) and determined a new mineral austinite ($CuZnAsO4(OH)$) from the oxidized zone of the Gold Hill mine. Nolan (1935) described mimetite, clinoclasite, arsenosiderite and pharmacosiderite. Buranek (1946) reported the occurrence of the mineral veszelyite as identified by the U. S. Geological Survey from a specimen sent by him from the Gold Hill mine open pit to J. D. Sears. The X-ray diffraction pattern of this mineral is reported to be identical with that of veszelyite from Tsumeb, Southwest Africa.

The U. S. Smelting, Refining and Mining Company permitted the writers to sample and study the ore in the United States mine. Specimens of fresh and altered arsenopyrite were collected from the haulage tunnel level. Altered arsenopyrite is an earthy mass of scorodite forming a thick outer layer on a massive arsenopyrite core. Creamy-white hard minute crystals about 2 to 3 mm in diameter were embedded in the scorodite portion of the ore. X-ray diffraction, confirmed by optical studies and microchemical test, showed this mineral to be monimolite, $(Pb, Ca)_3Sb_2O_8$.

The basic arsenates of the Gold Hill mine open pit (figure 5) occupy a zone of intense hematitic and limonitic alteration. This suggests a pyrite-rich primary ore that supplied the solutions that caused oxidation. Native copper and cuprite are reported by Buranek (1946) to occur in this zone but neither of these minerals was recognized in this study.

In conclusion, the sequence of events suggested in the development of the oxidation zone in the copper-lead-zinc arsenic replacement deposit of the district may be outlined as:

1. Mineralization of the host limestone by hypogene epigenetic processes responsible for the introduction of the primary sulfides of iron, copper, lead, zinc and arsenic.
2. Oxidation of pyrite and the liberation of the sulfuric acid and ferrous and ferric sulfate which acted as oxidizing agents on the primary sulfides.
3. At least partial secondary sulfide enrichment that generated chalcocite and covellite and added to the production of metal sulfates.
4. (Contemporaneous with or later than 3 above.) Complex reactions among the oxidizing solutions to yield the suite of arsenates and other minerals described.

Oxidation of Tungsten and Molybdenum Deposits

Deposits containing scheelite and molybdenite are associated with chalcopyrite, pyrite and magnetite in a gangue of actinolite, garnet, tourmaline, apatite, perthite and quartz. Microscopic examination revealed that pyrite is partly oxidized to hematite but grains of chalcopyrite are unaltered. Chalcopyrite altered to malachite and copper pitch can be recognized, however, in the outcrops. Scheelite, on the other hand, looks fresh although it is fractured. Local alteration to cuprotungstite has been reported by Hess (Nolan, 1935). There is no secondary enrichment of tungsten ore.

Molybdenite, the only primary ore mineral of molybdenum, is relatively resistant to oxidation. Powellite rims surrounding a core of molybdenite are recognized wherever molybdenite occurs in the district. Wulfenite is recognized at the Rube Gold mine but molybdenite is not found there. Michell (1945) found that molybdenite oxidizes very slowly and that the metal does not migrate readily in any form. Molybdenum values show no appreciable change in passing from the oxide to the sulfide zone.

Oxidation of the Lead-Zinc Deposits

The bulk of the lead ore shipped from the oxidized zone of the Gold Hill district contained the minerals cerussite and plumbojarosite as represented by the type of ore mined in the Rube Lead mine. Galena surrounded by rims of anglesite and cerussite is known, however, from many places in the area. Galena occurring in close proximity to arsenopyrite has been oxidized and yields beudantite (Butler, 1920) and mimetite (Nolan, 1935).

Sphalerite weathered to hemimorphite and smithsonite is reported from the northernmost part of the Gold Hill quadrangle. The primary sphalerite is weathered in the presence of arsenopyrite into the zinc arsenates adamite and austinite (Staples, 1935).

MINERALOGY

The minerals from the area are described below. The composition and genesis of each mineral are shown. This genetic classification is based on field observations, microscopic examination, and in case of minerals not recognized by the writers, on data previously published by Kemp and Billingsley (1918), Butler (1920), Nolan (1935) and Buranek (1946).

MINERAL LOCALIZATION

The confinement of the ore bodies to fracture zones in the quartz monzonite, and to the contact zones between quartz monzonite and the Carboniferous Ochre Mountain limestone and the Oquirrh Formation, gives a strong indication of the role of the igneous intrusion as a source of the ore-forming fluids.

The quartz monzonite stock is marked by a group of fractures filled with mineable replacement deposits, veins and dikes. Intersecting veins and dikes may indicate fracturing at different times. Measurements of the strikes and dips of the berylliferous quartz-carbonate-adularia veins centered around Rodenhouse Wash (figure 2) disclose that they occupy fissures with a general northeast strike. In detail, the strike varies from N 5° E to N 80° E, with a few that strike N 5° W to N 30° W. The dip generally varies from 39° W to 65° W; some are vertical. Similar veins outcropping near the Reaper mine strike slightly west of north and dip westward. Quartz veins bearing galena reported from the Reaper area strike northeast and dip to the south (Nolan, 1935). The tungsten-molybdenum replacement deposits of the Yellow Hammer occupy prominent fractures that strike N 60° E and dip steeply to the south (figure 6). The similar Reaper deposit on the other hand is reported by Nolan (1935) to have a northeast trend with a vertical dip.

Nolan in his work correlated these fissures according to their strikes and dips with their regional distribution and their type of mineralization. He selected at random and analyzed nearly 100 strikes and dips representing mineralized and nonmineralized fissures. He concluded that the nonmineralized faults and shear zones showed a strong tendency to strike either nearly east or nearly north. In the mineralized group there was no uniformity in strike or dip within a group, nor was there any pronounced regional pattern of fracturing discernible.

Cross fractures filled with mineralization are as characteristic of the limestone replacement deposits as they are of the quartz monzonite. In the Alvarado mine, cross fractures striking slightly east of north and dipping to the west are a conspicuous feature in most of the stoped areas. In the Cane Spring gold deposit, mineralized fractures striking nearly east to northeast and dipping steeply to the south are prominent within the ore shoots. The quartz-sulfide veins of the Gold Hill mine are reported by Nolan (1935) to occupy fissures in the Ochre Mountain limestone striking northeast and dipping to the east. Kemp and Billingsley (1918) reported that the upper ore body of the Gold Hill mine is controlled by a northeasterly fracture dipping to the northwest. Moreover, the arsenate deposits of the Gold Hill open pit (figure 5) follow a group of fractures that strike N 10° - 30° E and dip about 70° NW. The pyrometasomatic deposit of the Frankie mine (figures 7 and 8) occupies a north-trending fracture dipping steeply to the east.

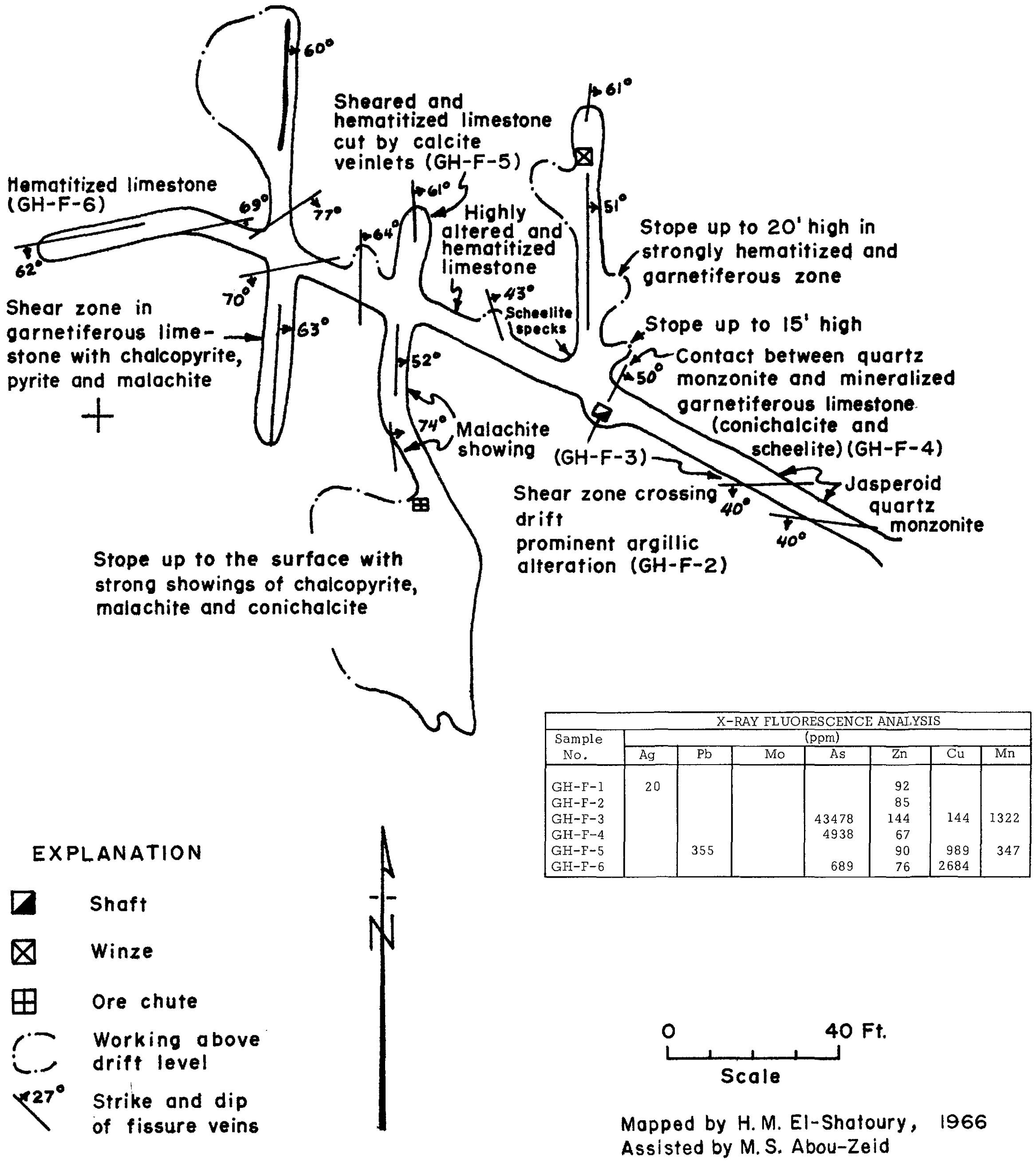
The above analysis of mineralized fractures discloses that they have only slight variations from the general northeast trend but exhibit variable dips. A northeast-trending fracture system may be considered favorable for prospecting in the area.

ZONAL ARRANGEMENT OF ORE DEPOSITS

The ore deposits of the area have been plotted according to their metal association and are shown in figure 9. A zonal arrangement can be recognized around a central zone characterized by high-temperature mineral assemblages of scheelite, molybdenite and chalcopyrite. These zones occur outward from this central zone: tungsten-molybdenum-copper, copper, copper-gold, copper-lead-arsenic, and lead-zinc-gold.

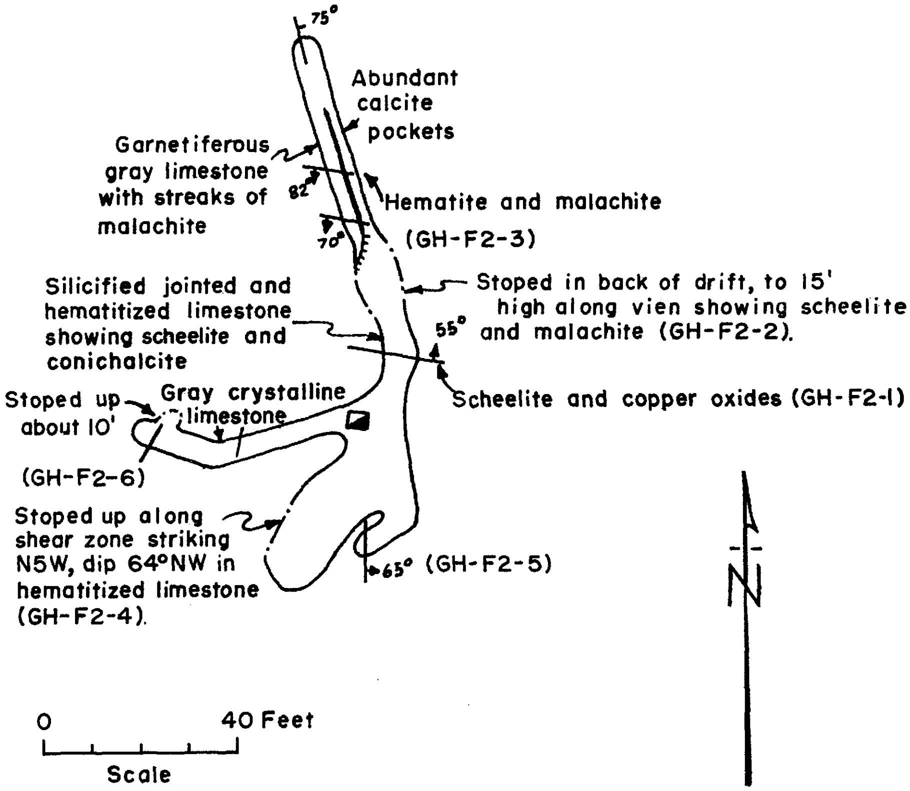
The tungsten-molybdenum-copper zone occupies a narrow belt comprising the area around the Yellow Hammer, Reaper and Doctor claims north of Clifton and extends north to cover the Rustler, Frankie and Lucy L. mines. This zone coincides with a belt of normal faulting which Nolan (1935) believes may represent the primary channels through which the quartz monzonite was intruded. The ore minerals of this zone consist of scheelite, molybdenite and chalcopyrite with their oxidation products. The quartz monzonite host rock is replaced by black tourmaline, actinolite, garnet, apatite and perthite in varying proportions.

The tungsten-molybdenum-copper zone grades into the copper zone with the loss of scheelite and molybdenite. The ore minerals are chalcopyrite and pyrite and their oxidation products in a gangue of black tourmaline, garnet, perthite and actinolite. This zone comprises a narrow area to the west of the scheelite-molybdenite



Sample No.	X-RAY FLUORESCENCE ANALYSIS (ppm)						
	Ag	Pb	Mo	As	Zn	Cu	Mn
GH-F-1	20				92		
GH-F-2					85		
GH-F-3				43478	144	144	1322
GH-F-4				4938	67		
GH-F-5		355			90	989	347
GH-F-6				689	76	2684	

Figure 7. Plan of the workings of the adit level of the Frankie mine, Gold Hill mining district, Tooele County, Utah.



EXPLANATION

⊞ Ore chute

◪ Shaft

◌ Workings above drift levels

26° Strike and dip of fissure veins

X-RAY FLUORESCENCE ANALYSIS							
Sample No.	(ppm)						
	Ag	Pb	Mo	As	Zn	Cu	Mn
GH-F2-1				443	70	3951	
GH-F2-2				14160	111	16441	
GH-F2-3				581	235	16219	
GH-F2-4					430	9563	1485
GH-F2-5					238	8906	
GH-F2-6				6815	132	4193	

Mapped by H. M. El-Shatoury, 1966
Assisted by M. S. Abou-Zeid

Figure 8. Plan of the workings of the shaft level of the Frankie mine, Gold Hill mining district, Tooele County, Utah.

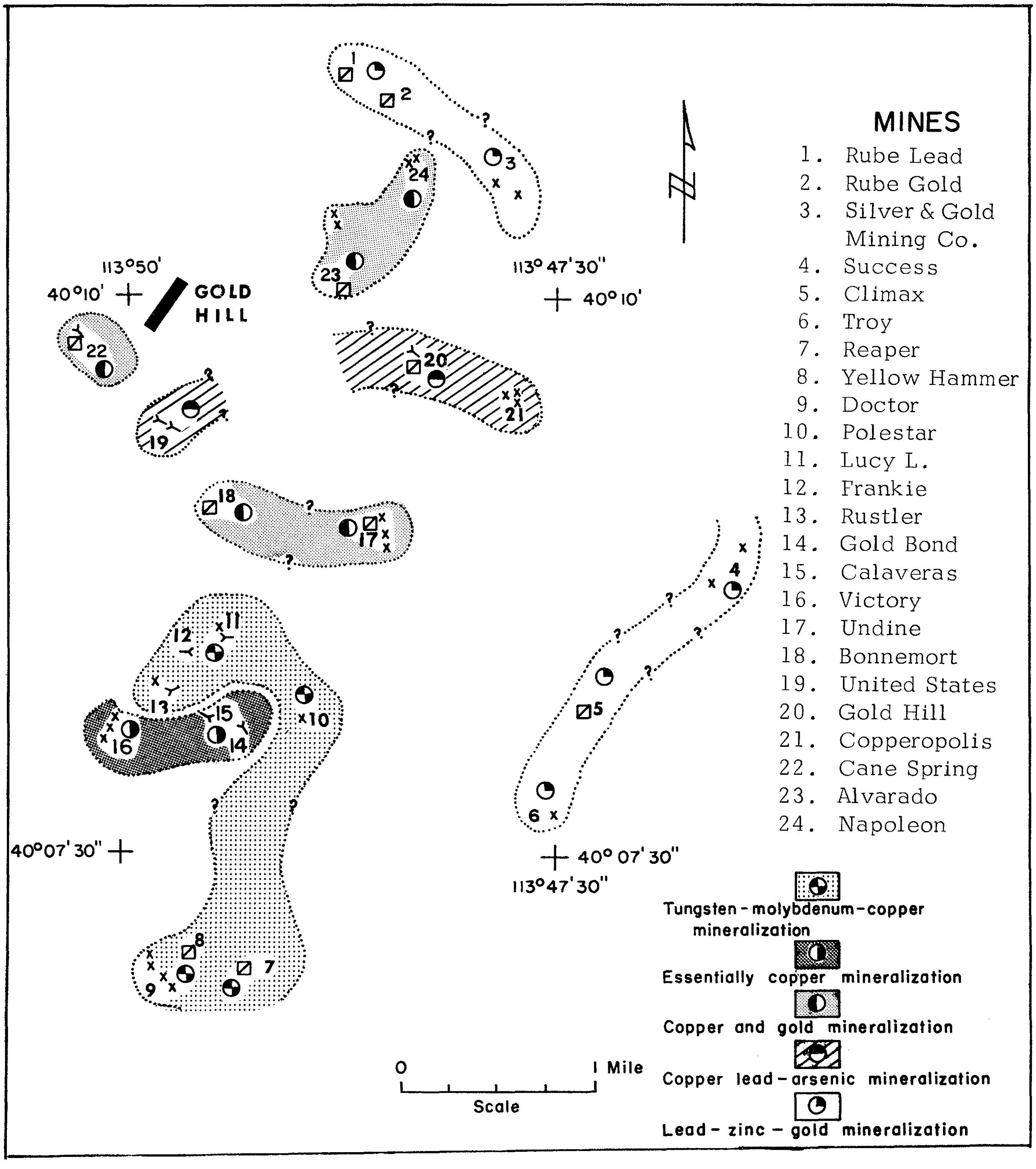


Figure 9. Zonal arrangement of mineral deposits in the Gold Hill mining district, Tooele County, Utah.

zone and is developed by the prospect workings of the Victory and Gold Bond claims (figure 9).

The copper-gold zone to the north is of different mineralogy and is of the contact metasomatic type. Ore minerals are native gold and chalcopyrite in a gangue of wollastonite, garnet, zoisite, diopside, magnetite and pyrite. This zone is exposed by the workings of the Bonnemort and Undine prospects to the southeast. The Cane Spring and Alvarado mines are of the same nature.

The copper-lead-arsenic zone marks the replacement deposits developed by the workings of the United States and Gold Hill mines. The Copperopolis (Bamberger) mine is included in this zone on the basis of Nolan's (1935) description of the mineralogy of the ore and on the identification of conichalcite in the mine dump and its vicinity during this study.

The outermost zone is characterized by the lack of copper and the predominance of lead, zinc and gold. This zone is not a continuous belt, but is rather defined as two fringe zones marking the eastern boundary of the area. The northern part of this zone is developed by the workings of the Rube Lead and Rube Gold mines, and adjacent prospects of the Silver and Gold Mining Company. The southern part of this zone is developed by the workings of the Climax and the Success mines. Samples collected from the northern part of this zone and analyzed by X-ray fluorescence indicate a large amount of arsenic. Nolan (1935) reported the occurrence of arsenical boulangerite ($Pb_5Sb_4S_{11}$), identified by Short in a specimen from the Rube Gold mine, and described scorodite and arsenopyrite from the prospects of the Silver and Gold Mining Company to the southeast. The mines of the southern part of the zone (Climax and Success) are inaccessible for sampling.

In summary, a zonal arrangement of ore deposits is exhibited in the area when a gradational difference is created by predominance of one metal over the other, or another metal appears, marking the boundary between successive zones.

This picture of zonal arrangement of ore deposits around a central zone of high-temperature mineral assemblage is slightly and locally distorted by the presence of galena-bearing quartz-carbonate veins in the vicinity of the Reaper mine and by the presence of bismuth-gold quartz veins in the Lucy L. mine. Emmons (1936) explained the irregularities and reversals in the zoning of ore deposits, summarized as follows:

1. Overlapping of deposits from two or more magmatic centers.
2. Retreat or advance of magmatic centers during the period of deposition.
3. Deposition in a single area in different epochs of mineralization.
4. Other causes not understood.

Butler (1920, p. 484) explained the spatial association of the high-temperature deposits with the low-temperature types in the district as a consequence of the cooling of the quartz monzonite stock. Accordingly, a drop in the pressure and temperature in the zones previously filled with high-temperature minerals accounts for the deposition of the quartz-carbonate veins bearing galena. On the other hand, Nolan (1935, p. 107) explained this overlapping by the cyclic or periodic fracturing in the quartz monzonite that provided channels for ore solutions to be formed in regions previously mineralized by high-temperature minerals.

GENESIS OF ORE DEPOSITS

Evidence of a direct relationship among the types of mineral deposits in the Gold Hill area with the quartz monzonite intrusion is demonstrated by the nature of the contact metasomatic deposits, the replacement deposits in the quartz monzonite, and by the hydrothermal type veins directly related to the intrusive body. Northeast-trending fractures were important conduits for ore solutions and were sites of ore deposition.

A characteristic feature of the Gold Hill district is the low quantity of fluorine present in the ore-forming solutions. Fluorine, which although present isomorphously in the lattice of some minerals of Gold Hill such as apatite and actinolite that developed abundantly during the process of mineral formation, is not present as a mineral of its own in any of the samples studied. This is in spite of the availability of calcium in the wall rock and the favorable physical-chemical conditions for crystallization of fluorite.

The quartz-carbonate veins localized in the quartz monzonite in the vicinity of the Reaper mine and in Rodenhouse Wash represent the close of hydrothermal activity in the area.

Supergene weathering process had a differential degree of influence in altering the hypogene character of the ores, with profound results on the lead-zinc-copper-arsenic replacement deposits, but the molybdenum and tungsten deposits escaped oxidation and leaching.

DESCRIPTION OF PROPERTIES

The mines and prospects in the Gold Hill area are shown in figure 9. The features of most of them have been described by Nolan (1935). Additional workings in some of the accessible mines are discussed here. These are the Alvarado and Cane Spring mines (with information furnished by C. R. Woodman), the Rube Gold, Rube Lead, Frankie and Rustler mines, the Yellow Hammer and Gold Hill mine open pits.

The Alvarado Mine

The Alvarado gold mine is located about one mile east of Gold Hill village and less than a half mile northwest of the Gold Hill mine (figure 9). Entrance to the mine is through an inclined shaft 252 feet deep at an inclination of about 60° to 65°, the collar of which is at an elevation of 5,480 feet. The mine workings are in good condition and permit access to all parts of the mine except for a few filled places. About 1,750 feet of drifts and cross cuts connect the inclined shaft in five levels: the 40-, 60-, 100-, 150-, and 200-foot levels.

The mine has been described by Kemp and Billingsley (1918), Butler (1920), Nolan (1935) and Flint (1960). The latter mapped the workings on the 200-foot level (figure 10), developed after Nolan's report. Flint's report to C. R. Woodman, the owner of the mine, includes the assays for gold, silver and copper of 17 samples located on the map. These data are included in this report with permission of Mr. Woodman.

Rocks exposed in the mine and outcropping on the property are the Ochre Mountain limestone and the quartz monzonite. The Ochre Mountain limestone is recrystallized to white coarse-grained marble; silication, silicification, and introduction of secondary calcite veinlets all are associated with local hematitic alteration resulting from leaching and weathering of pyrite and magnetite. Silication of the limestone resulted in the development of two distinct varieties of rocks, a bladed wollastonite rock and a diopside-garnet-actinolite rock. These types of alteration are of erratic distribution and show no direct relation with proximity to igneous contacts, but are probably controlled by the original composition of the metamorphosed sediments.

The quartz monzonite exposed in the mine workings is similar to that in surface outcrops and shows alteration of stages III, IV and V: the complete sericitization and carbonation of the plagioclase feldspar, the complete chloritization of biotite with the formation of sphene or leucoxene and finely disseminated carbonate, magnetite and pyrite, and the introduction of chalcedony and secondary carbonate veinlets. The igneous masses exposed in the bottom of the shaft and at the 200-foot level are slightly different. They are composed of plagioclase feldspar, biotite, resorbed phenocrysts of quartz in an aphanitic groundmass of quartz and orthoclase. The rock-forming minerals show the same types of alteration mentioned above but more than 10 percent of the total rock is pyrite.

Most of the ore produced from the Alvarado mine came from ore shoots that generally pitch and strike northwesterly and dip steeply to the east concordant with the general strike and dip of the host metamorphosed Ochre Mountain limestone. The main ore body (figure 10) has been mined from the surface to the 200-foot level with a maximum width of about 30 feet and average of 13 feet. A second ore shoot has been stoped upward from the 108-foot level to the surface, and downward where it is now filled with rock debris to an undetermined depth. The width of the stope is about 12 feet with an average thickness of about six feet. These two ore shoots join together above the 60-foot level. A third ore shoot, designated by Nolan as the "foot-wall ore shoot" is stoped upward from the 40-foot level north of the inclined shaft and is entirely in the Ochre Mountain limestone. Its position is thought to be related to the quartz monzonite exposed in the walls of the inclined shaft, which is thought by Flint (1960) to have guided the upward migration of the ore-bearing solutions to the area of this ore shoot.

A notable feature in most of the stoped areas is the presence of cross fractures which generally strike northeast and dip steeply to the west.

The ore minerals are native gold, associated with chalcopyrite, pyrite, bornite, chalcocite and minor galena, replacing a favorable horizon in the metamorphosed limestone. Gold, reported previously, was not recognized during this study. Sparsely distributed streaks and knots of pyrite, chalcopyrite, galena, chalcocite and malachite, however, can be observed filling fractures in the metamorphosed parts of the limestone that forms the walls of the stoped areas.

The past history of the mine as abstracted from a 1916 report of the Woodman Mining Company indicates that the mine was a gold producer from August 1892 to May 1894. The mill receipts, according to the above source, ran from \$1.03 to \$638.70 per ton. According to Nolan (1935) the mine is supposed to have produced about \$120,000 in gold during that period. Small shipments of ore, 25 tons in 1909 and 35 tons in 1916, are on record.

In 1931, the Aurum Mining Corporation operated the property but no production figures are available for this period.

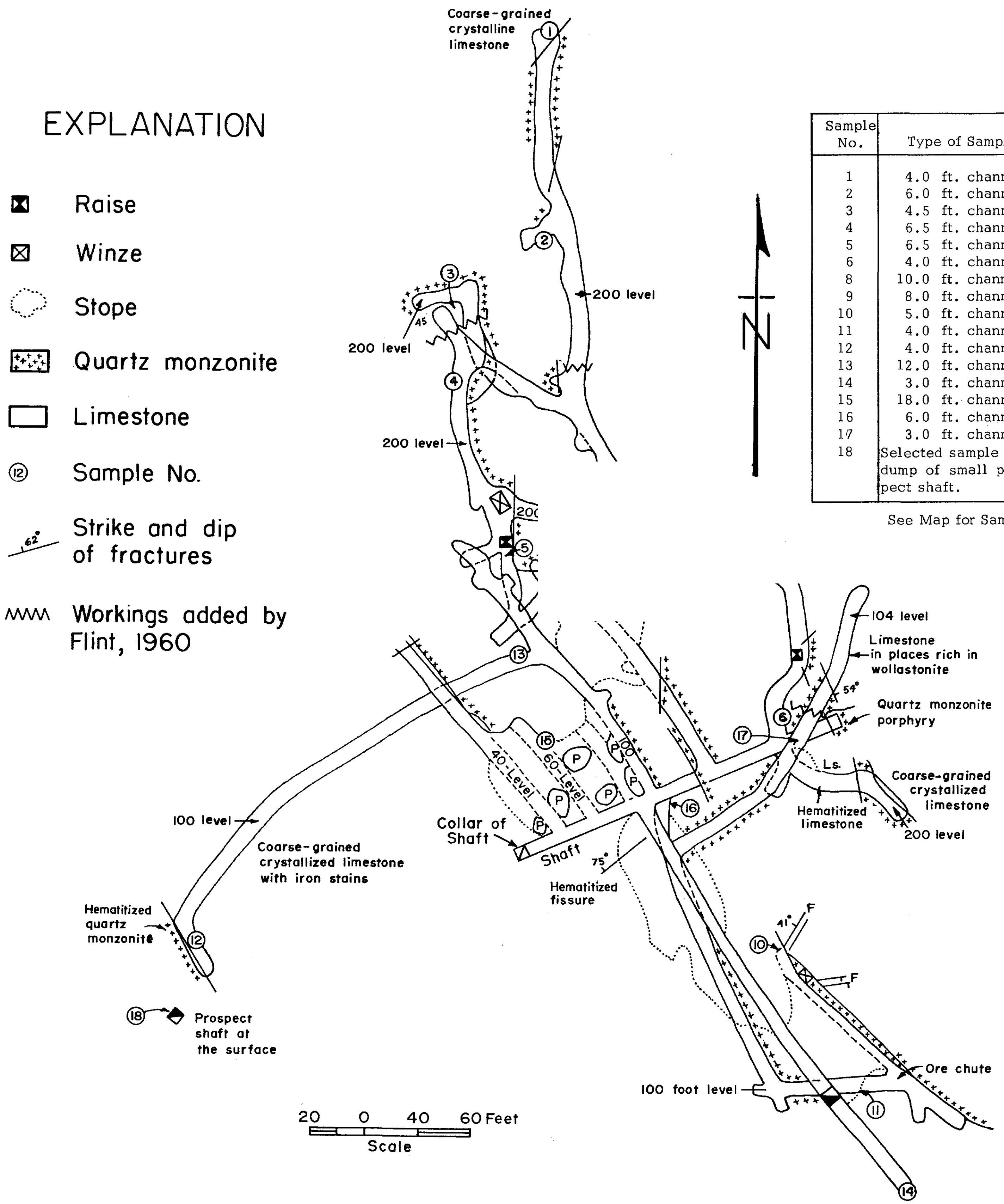
Recent assays of 17 samples from the mine, reported by Flint (1960) in an attempt to determine if significant amounts of ore remain in the mine, are shown in table 4.

The possibility of ore discovery in the mine is most likely to occur at the extremities of the present mine workings, either laterally or downward from the ends of the stoped areas. Drilling perpendicular to the dip might determine the presence of other beds favorable for replacement.

The Cane Spring Mine

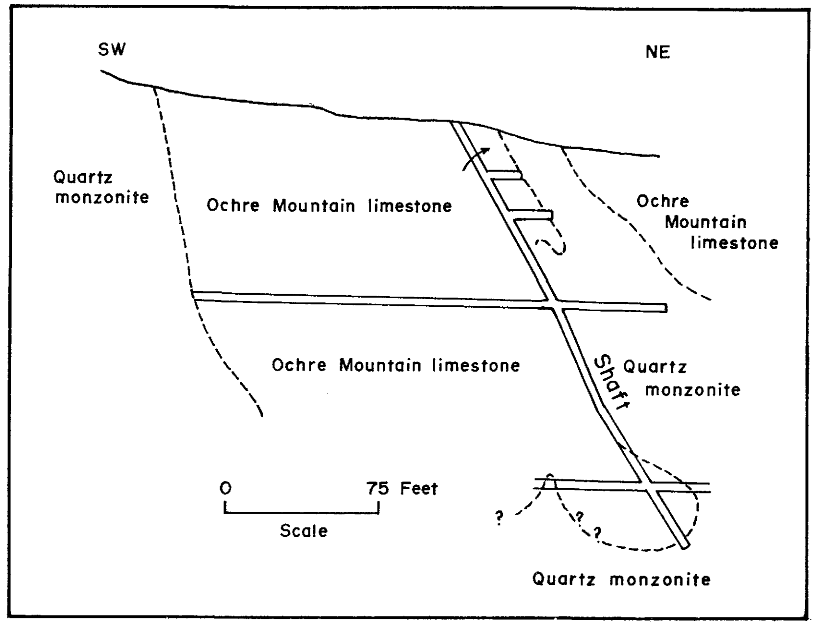
The Cane Spring mine is located about one-half mile west of Gold Hill village (figure 9). The mine workings consist of about 1,250 feet of drifts and cross cuts of which at least 280 feet are at present under water. These workings are connected by a vertical shaft 225 feet deep located near the southeast end of the mine and an inclined shaft 150 feet deep near its northwest end. These shafts are closed. Entrance to the mine is through a tunnel that enters the mine at the first level and is located at the extreme northwest end of the mine.

The mine has been described by Kemp and Billingsley (1918), Butler (1920) and Nolan (1935). Flint (1960) described and sampled the mine for the Woodman Mining Company. His unpublished report contains a mine map prepared by Mathez (1935) showing the present workings of the mine and including five assays for

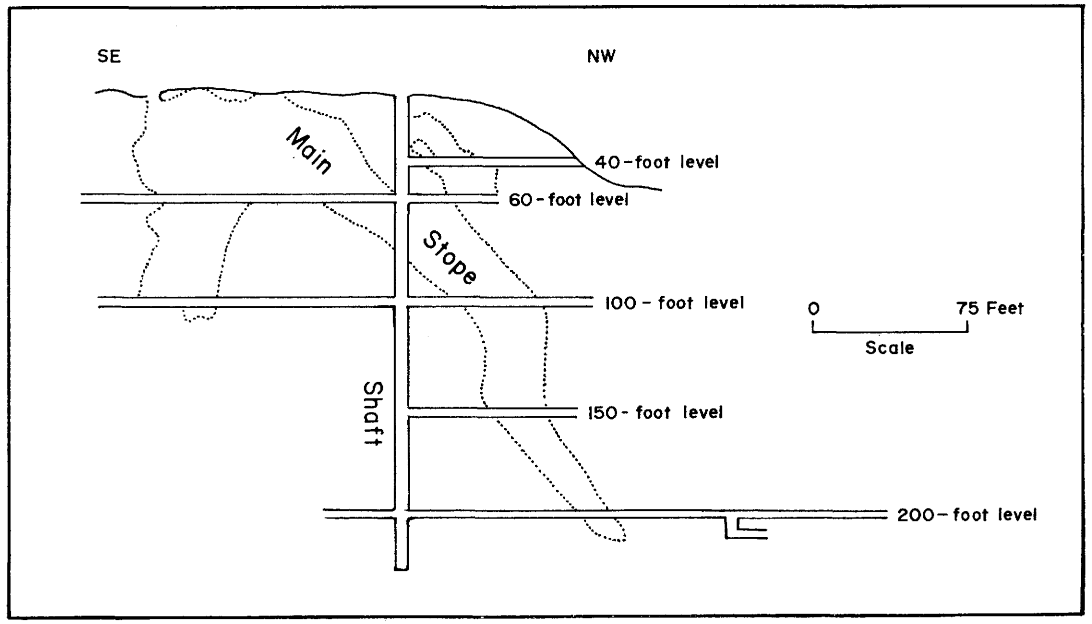


Sample No.	Type of Sample	Oz/Ton		Percent
		Gold	Silver	Copper
1	4.0 ft. channel	Tr	Tr	Tr
2	6.0 ft. channel	0.02	0.2	0.3
3	4.5 ft. channel	0.03	1.85	0.22
4	6.5 ft. channel	Tr	0.10	Tr
5	6.5 ft. channel	0.01	0.20	0.25
6	4.0 ft. channel	0.11	2.70	0.95
8	10.0 ft. channel	0.06	0.10	Tr
9	8.0 ft. channel	0.08	0.10	Tr
10	5.0 ft. channel	0.02	0.10	Tr
11	4.0 ft. channel	0.02	0.10	0.20
12	4.0 ft. channel	Tr	Tr	0.22
13	12.0 ft. channel	0.09	Tr	Tr
14	3.0 ft. channel	Tr	Tr	0.20
15	18.0 ft. channel	0.03	0.10	Tr
16	6.0 ft. channel	0.17	0.10	0.10
17	3.0 ft. channel	0.02	3.40	0.90
18	Selected sample from dump of small prospect shaft.	0.13	11.30	1.90

See Map for Sample Locations



Geologic Cross Section through the Alvarado shaft (after Nolan, 1935), SW to NE.



Projection of the stopes of the Alvarado mine on the plane of the shaft (after Nolan, 1935), SE to NW.

Figure 10. Plan of the Alvarado mine workings, Gold Hill mining district, Tooele County, Utah (after Nolan, 1935, and Flint, 1960).

Table 4. Gold, silver and copper content of samples from the Alvarado mine.

Sample No.[a]	Oz/ton Gold	Oz/ton Silver	Copper Percent	Type of Sample (ft-channel)
AL-1	Tr	Tr	Tr	4.0
AL-2	0.02	0.20	0.30	6.0
AL-3	0.03	1.85	0.22	4.5
AL-4	Tr	0.10	Tr	6.5
AL-5	0.01	0.20	0.25	6.5
AL-6	0.11	2.70	0.95	4.0
AL-8	0.06	0.10	Tr	10.0
AL-9	0.08	0.10	Tr	8.0
AL-10	0.02	0.10	Tr	5.0
AL-11	0.02	0.10	0.20	4.0
AL-12	Tr	Tr	0.22	4.0
AL-13	0.09	Tr	Tr	12.0
AL-14	Tr	Tr	0.20	3.0
AL-15	0.03	0.10	Tr	18.0
AL-16	0.17	0.10	0.10	6.0
AL-17	0.02	3.40	0.90	3.0
AL-18	0.13	11.30	1.90	Selected sample from dump near small prospect shaft

[a] Sample locations are shown in figure 13.

gold and silver by Mathez and seven by Flint. The writers have permission of C. R. Woodman, the owner of the mine, to use these data.

Rocks exposed in the vicinity of the mine consist of the Ochre Mountain limestone, the Manning Canyon Formation and quartz monzonite.

The mine is entirely in the Ochre Mountain limestone which here strikes northwesterly and dips about 60° to the northeast. The mineralogy of the ore is similar to that of the Alvarado. Native gold constitutes the principal ore mineral and is associated with pyrite, chalcopyrite, bornite, chalcocite and covellite in a gangue of wollastonite, garnet, vesuvianite, zoisite and diopside. Molybdenite is reported by Kemp and Billingsley (1918).

The ore body has a maximum width of about 20 feet with an average of about 6 feet. It has been faulted in several places by low-angle faults but the movement was small with a maximum displacement of 20 feet along the fault plane. Prominent cross fractures occur in the stoped areas and occasionally contain chalcopyrite, pyrite and streaks of malachite.

The mine was in operation from 1892 to 1895. Nolan (1935) estimated a total value in gold produced during that period to be from $50,000 to $70,000. A statement of the total value received from the mine during the above period, however, is taken from a 1916 report of the Woodman Company and is shown below:

Year	Month	Value
1892	Sept - Dec	$ 25,047.56
1893	Feb - Dec	62,654.45
1894	Jan - Dec	47,294.41
1895	Jan - Nov	42,909.81
		$177,906.23

In 1914 the mine resumed operation and 46 tons of ore were shipped which assayed 1.07 oz gold, 3.0 oz silver and 5.5 percent copper. From 1931 to 1935 the mine was operated again by lessees, and Mathez (1935) estimated a total production of 1,302 tons of $10.66 value (pre-1933 gold price) and 329 tons of $9.45 value (new price) per ton.

For information about the mine workings now under water, Flint (1960) quoted from Mathez (1935) that commercial ore was found along the 223-foot drift and that he infers 1,446 tons of ore with $14.00 value in gold between the 149-223-foot levels.

Recent assays of 7 samples from the mine reported by Flint (1960) combined with 5 samples quoted by him from Mathez (1935) are shown in table 5. The locations of these samples in the mine are shown in figure 11.

Table 5. Surface geology of the Gold Hill open pit mine showing occurrence of arsenate minerals.

Sample No.	Oz/ton Gold	Oz/ton Silver	Copper percent	Type of sample
				(ft-channel)
CS-1	0.52	0.10	0.12	5.0
CS-2	0.26	Tr	0.13	4.0
CS-3	Tr	Tr	0.27	3.5
CS-4	Tr	Tr	0.11	3.5
CS-5	0.07	Tr	0.20	5.5
CS-6	0.05	0.10	0.24	3.5
CS-7	0.18	0.20	1.03	3.0
				(ft-wide)
CS-36M[a]	0.04	0.11		2.0
CS-37M	0.00	0.00		2.0
CS-38M	0.00	0.00		1.9
CS-39M	0.62	0.15		3.2
CS-40M	0.10	0.15		4.0

[a] Samples assayed by Mathez are marked with "M."

From the above analysis it appears that only low-grade rock remains. Additional sampling of areas marked A, B, and C on figure 11 should be done to verify high values reported in samples 1, 2 and 7 above. The mine workings now under water reported to contain ore carrying $14.00 in gold should be examined and sampled. C. R. Woodman states that the lower workings are still above the water table and that the accumulated water is surface water, and that the mine could easily be drained.

The Bonnemort Mine

The Bonnemort mine is about one-half mile southeast of the United States mine. The mine workings consist of an inclined shaft 100 feet deep (C. R. Woodman, personal communication) and one stope extending from the 45-foot level to the surface. No drifts below this level have been reported. The shaft which is the only entrance to the mine is filled by rock debris and entry to the mine is impossible.

The country rock is highly crystalline coarse-grained limestone of the Oquirrh Formation forming the south end of a roof pendant in which the United States mine is located. Quartz monzonite outcrops on both sides of this pendant. The limestone is completely recrystallized into coarse-grained marble with bladed wollastonite and diopside.

The ore body appears to be similar to those of the Alvarado and Cane Spring mines. The ore is reported to be native gold associated with chalcopyrite, malachite and pyrite, disseminated in and occurring as thin seams in a limestone bed which strikes north and dips 55°-60° west. As indicated by the surface workings, the ore sheet has been mined for about 60 feet along the strike and to a maximum width of about 15 feet with an average width of about 5 feet. Minor malachite streaks and chrysocolla following the bedding planes of the limestone were the only mineralization recognized during this study.

No production data are recorded for this mine. The 1916 report of the Woodman Mining Company mentions, however, that the ore from the shaft averaged 1.10 oz of gold with paying values in copper.

The Rube Gold Mine

The Rube Gold mine is located about one and one-half miles northeast of Gold Hill village (figure 9). Entrance to the mine is through an inclined shaft 300 feet deep at 65° inclination, the collar of which is at an elevation of about 4,975 feet. From this inclined shaft three levels were driven at 65-, 150-, and 300-foot levels. These are about 2,300 feet of drifts and cross cuts.

The mine has been described by Nolan (1935) but since that time the accessible workings have been nearly doubled. All of the mine openings are in good condition and are accessible (plates 1, 2 and 3).

In the vicinity of the mine, the Ochre Mountain limestone is bounded by the quartz monzonite on the west and south and by the Prospect Mountain quartzite on the northeast. The mine workings are entirely in the Ochre Mountain limestone.

The ore body of the mine consists of two tabular ore shoots designated as the east and west ore bodies. The footwall of these ore shoots is in thick-bedded, highly fractured and strongly hematitized limestone which is locally heavily silicified. The hanging wall is a dike with a nearly east-west strike dipping 60° north. It is stained by iron oxides and according to Nolan (1935) is a hornblende andesite. The thickness of the dike varies greatly from a few inches to about three feet.

Three types of ore have been shipped from this mine. The most common is an oxidized lead ore consisting of anglesite and cerussite with native gold in a fine-grained silicified and hematitized limestone. This ore grades into a less oxidized ore of galena and minor pyrite, where native gold is reported to occur either enclosed in galena or embedded in a bluish-gray fine-grained limestone. The third type, a sulfide ore, is reported to occur in the stoped area of the western drift of the 150-foot level. Pyrite, galena, sphalerite, chalcopyrite and molybdenite are reported to occur abundantly in this stope. Minerals identified during this study are chalcopyrite, pyrite, sphalerite, wulfenite and native gold. Molybdenite and galena were not recognized. Native gold was found by panning samples taken from the stope which opens to the surface south of the main shaft.

The results of X-ray fluorescence analysis of 22 samples from the different levels of the mine are shown in table 6.

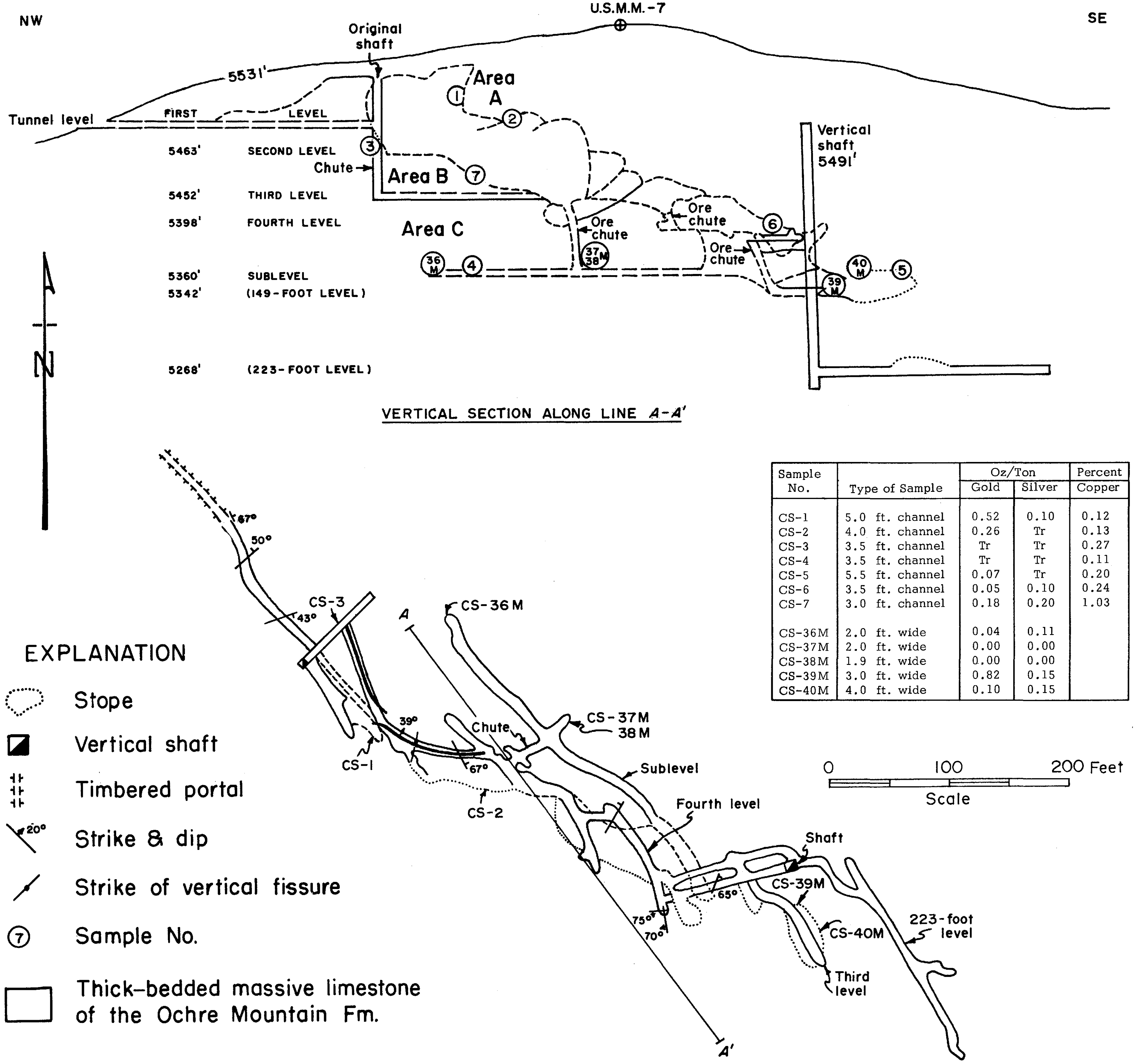
The high arsenic content in some of these samples is unusual since no arsenic minerals were recognized in the mine during this study. One shipment made from the eastern ore body is reported to have contained more than 6.0 percent arsenic, and Nolan (1935) identified boulangerite from the mine. Samples from the 65- and 150-foot levels show anomalous amounts of zinc, lead, silver and molybdenum. The high manganese content also appears anomalous and is probably the result of the association of manganese with the iron oxides filling fractures in most parts of the mine.

The mine is known to have produced a high-grade direct smelting gold ore. It is said that from 1921 to 1927, the mine produced 22 shipments of ore averaging about 7.0 oz of gold per ton. It is reported that in 1931 a carload of nearly 37 dry tons sampling 10 oz gold per ton was produced (Mining Review, Sept. 29, 1931, p. 9). In 1932, the mine was sold to Gold Hill Mines, Incorporated. The production of the mine from the sale to 1933 is estimated to be $148,930 in gold, silver and lead (C. A. Ramey, Gold Hill, personal communication).

The Frankie Mine

The Frankie mine is located immediately west of the Lucy L. mine and about two miles south-southeast of Gold Hill village (figure 9).

The mine is described by Nolan (1935) but was mapped for the first time in this study (figures 7 and 8). Entrance to the mine is through an adit whose portal is at an elevation of 5,972 feet. The mine workings in the adit level consist of drifts and cross cuts of a total of about 514 feet that had been stoped in many



Sample No.	Type of Sample	Oz/Ton		Percent
		Gold	Silver	Copper
CS-1	5.0 ft. channel	0.52	0.10	0.12
CS-2	4.0 ft. channel	0.26	Tr	0.13
CS-3	3.5 ft. channel	Tr	Tr	0.27
CS-4	3.5 ft. channel	Tr	Tr	0.11
CS-5	5.5 ft. channel	0.07	Tr	0.20
CS-6	3.5 ft. channel	0.05	0.10	0.24
CS-7	3.0 ft. channel	0.18	0.20	1.03
CS-36M	2.0 ft. wide	0.04	0.11	
CS-37M	2.0 ft. wide	0.00	0.00	
CS-38M	1.9 ft. wide	0.00	0.00	
CS-39M	3.0 ft. wide	0.82	0.15	
CS-40M	4.0 ft. wide	0.10	0.15	

Figure 11. Plan and vertical section of the Cane Spring mine, Gold Hill mining district, Tooele County, Utah (after Mathez, 1935, Nolan, 1935, and Flint, 1960).

Table 6. X-ray fluorescence analysis of samples from the Rube Gold mine.

	ppm						
Sample	Ag	Pb	Mo	As	Zn	Cu	Mn
RG-1-1	100	267	116	422	1505	-	1260
RG-1-2	760	558	404	517	890	-	1395
RG-1-3	880	751	295	696	1991	-	2034
RG-1-4	500	971	135	1249	3595	-	1278
RG-1-5	360	1253	129	952	6894	-	1197
RG-1-6	580	1034	2444	560	2105	-	1152
RG-1-7	740	698	193	549	795	188	1215
RG-1-8	-	100	-	825	701	-	-
RG-1-9	-	1403	-	-	3596	-	-
RG-2-1	180	302	110	2297	1198	-	1017
RG-2-2	520	584	244	316	3112	43	1215
RG-2-3	600	734	327	496	1248	12	10180
RG-2-4	580	65	244	411	8147	55	1368
RG-2-5	240	602	295	655	2891	264	1422
RG-2-6	-	3694	-	210	609	-	1008
RG-2-7	60	135	52	2278	502	330	-
RG-2-8	-	514	-	92	858	35	1908
RG-2-9	-	285	-	-	278	-	-
RG-2-10	-	1834	-	390	807	313	936
RG-3-1	540	882	116	51	1150	-	1512
RG-3-2	-	1059	135	292	10602	-	1152
RG-3-3	-	188	-	-	800	-	891

places. An interior vertical shaft 47 feet deep connects the adit level with the shaft level about 68 feet from the portal of the adit level. The shaft level consists of drifts totaling about 155 feet stoped in two areas. The mine workings are generally in good condition except for parts of the stoped areas.

Rocks exposed in the mine and its surface vicinity are the quartz monzonite and limestone of the Oquirrh Formation. The quartz monzonite in contact with limestone has been replaced by euhedral garnet showing anomalous interference colors, apatite and abundant sphene. Jasperoid and calcite veinlets cut through the altered rock in several directions. The quartz monzonite not in contact with limestone exhibits minor alteration in the form of moderate sericitization and chloritization, silicification by jasper, and late calcite veinlets.

The limestone is metamorphosed into a silicate rock rich in actinolite, black tourmaline, apatite, garnet and wollastonite.

The ore minerals consist of pyrite, chalcopyrite, bornite, malachite and chrysocolla. Scheelite was not recognized by Nolan (1935) but it was found in this study by use of ultraviolet light in the adit and shaft levels of the mine. Conichalcite is locally abundant in the stoped areas of both levels and at the surface.

The ore bodies occur in the contact zone between the quartz monzonite and the limestone and in the limestone not in contact with the quartz monzonite. The ore bodies strike to the north or slightly west of north and dip steeply to the east. Cross fractures in the stoped areas have a generally east-west strike and dip to the north.

The mine is reported to have been active from 1916 to 1919. In 1916, during development work, samples are reported to assay 0.12-0.24 oz gold, 0.24-4.72 oz silver and 5.9-23.5 percent copper (report of the Woodman Mining Company, 1916). According to this source, the following shipments were made during 1916:

Shipment No.	Dry wt. Pounds	Oz/ton		Percent Copper	Net receipts
		Gold	Silver		
1	50,830	0.12	2.15	8.91	$ 757.45
2	72,436	0.11	1.27	6.92	764.50
3	50,894	0.11	2.45	9.17	654.69
4	57,156	0.14	1.90	7.90	759.33
Total	240,316				$2,935.97

During 1917-1919 the mine produced 3,056 tons of ore assaying 0.008 oz gold, 1.5 oz silver, 4.8 percent copper and 9.7 percent lead.

The results of X-ray fluorescence analysis of 15 samples taken from the mine and the surface are shown in table 7.

The Yellow Hammer Mine

The group of claims that includes the Yellow Hammer open pit is located about seven miles south of Gold Hill and about one mile northwest of Clifton. They adjoin the Reaper claims to the west.

The workings consist of an open pit and an inaccessible inclined shaft reported to be 90 feet deep which connects to 125 feet of drifts. The features of the open pit were mapped during this study and are shown in figure 6.

The country rock is quartz monzonite, severely altered and replaced along fractures by long bladed crystals of actinolite, black tourmaline, garnet, perthite, sphene, apatite and magnetite. Where not in contact with the fractures, the quartz monzonite shows strong chloritization and sericitization.

The ore body exposed in the open pit occupies two prominent sets of fractures that strike N 60°-70° E and N 55° W, and dip about 70° S and 40° SE, respectively. The ore minerals consist of chalcopyrite and oxide copper minerals, scheelite, molybdenite and powellite. Native gold was previously reported but

Table 7. X-ray fluorescence analysis of samples from the Frankie mine.

	ppm						
Sample	Ag	Pb	Mo	As	Zn	Cu	Mn
GH-F-1	20		-	-	92	-	-
GH-F-2	-		-	-	85	-	-
GH-F-3	-			43978	144	144	1322
GH-F-4				4938	67	-	-
GH-F-5		355		-	90	989	347
GH-F-6				698	76	2684	-
GH-F2-1				443	70	3951	-
GH-F2-2				14160	111	16441	-
GH-F2-3				581	235	16219	-
GH-F2-4				-	430	9536	1485
GH-F2-5				-	238	8906	-
GH-F2-6				6815	132	4193	-
GH-FT-1				-	93	2253	-
GH-FT-2				-	435	32873	-
dump of the mine				-	595	5689	1980

was not recognized in this study. Scheelite was recognized through use of ultraviolet light. It occurs as erratic nodules disseminated in the replaced quartz monzonite.

According to Nolan (1935) the only recorded production of tungsten from this mine was made in 1917 as 1,646 pounds of scheelite averaging 69.5 percent WO_3.

According to the Gold Hill Standard (Dec. 28, 1917), one ton of high-grade tungsten concentrate was sold for $1,400 and one carload of copper ore containing large amounts of cuprite was shipped in 1917. Since then mining has been on a small scale and shipments were made intermittently. According to Everett (1961), the total value of ore shipped from this property is estimated to be from $25,000 to $45,000. Some of the ore was shipped during World War II to Metals Reserve Company's chemical treatment plant at Salt Lake City. During 1954-1955, about 400 tons of ore were mined and 97 units of WO_3 were recovered. During 1958, about 1,500 tons of carefully sorted ore containing copper sulfides and oxides and scheelite were mined and shipped. Flint (1960) reported assay values of gold, copper, and tungsten trioxide in four channel samples from the pit. Gold was present in traces to 0.24 oz/ton, copper from 0.82 to 2.60 percent and tungsten trioxide from 0.12 to 2.07 percent. The result of gamma activation analysis of beryllium on one sample of actinolite from the open pit was 0.034 percent BeO. The property is famous for large scheelite crystals, some more than a foot in diameter.

The Rube Lead Mine

The Rube Lead mine is northwest of the Rube Gold mine and about one and one-half miles northeast of Gold Hill village (figure 9). Entrance to the mine is through an inclined shaft 200 feet long at 65° inclination. The collar is at an elevation of about 5,025 feet. The inclined shaft connects four short levels with a total of about 318 feet of drifts and cross cuts, stoped in places, on the 58-, 100-, 150-, and 200-foot levels. The mine workings are in fair condition except for some of the stopes (figure 12).

Rocks cropping out on the surface and exposed in the mine workings are the Prospect Mountain quartzite, the Ochre Mountain limestone and quartz monzonite. The quartz monzonite occurs only in the 200-foot level where it is in contact with limestone and quartzite.

The ore body occupies prominent fractures in a thick-bedded, intensely silicified, hematitized and locally brecciated limestone of the Ochre Mountain Formation. The ore minerals consist of cerussite and plumbojarosite. No galena has been recognized from the mine, but it is claimed that a few pockets with nodules of galena were recognized during the development work in the mine. No production figures are available but small shipments of lead carbonate carrying small amounts of silver were made (C. R. Woodman, personal communication).

FUTURE OF THE DISTRICT AND RECOMMENDATIONS

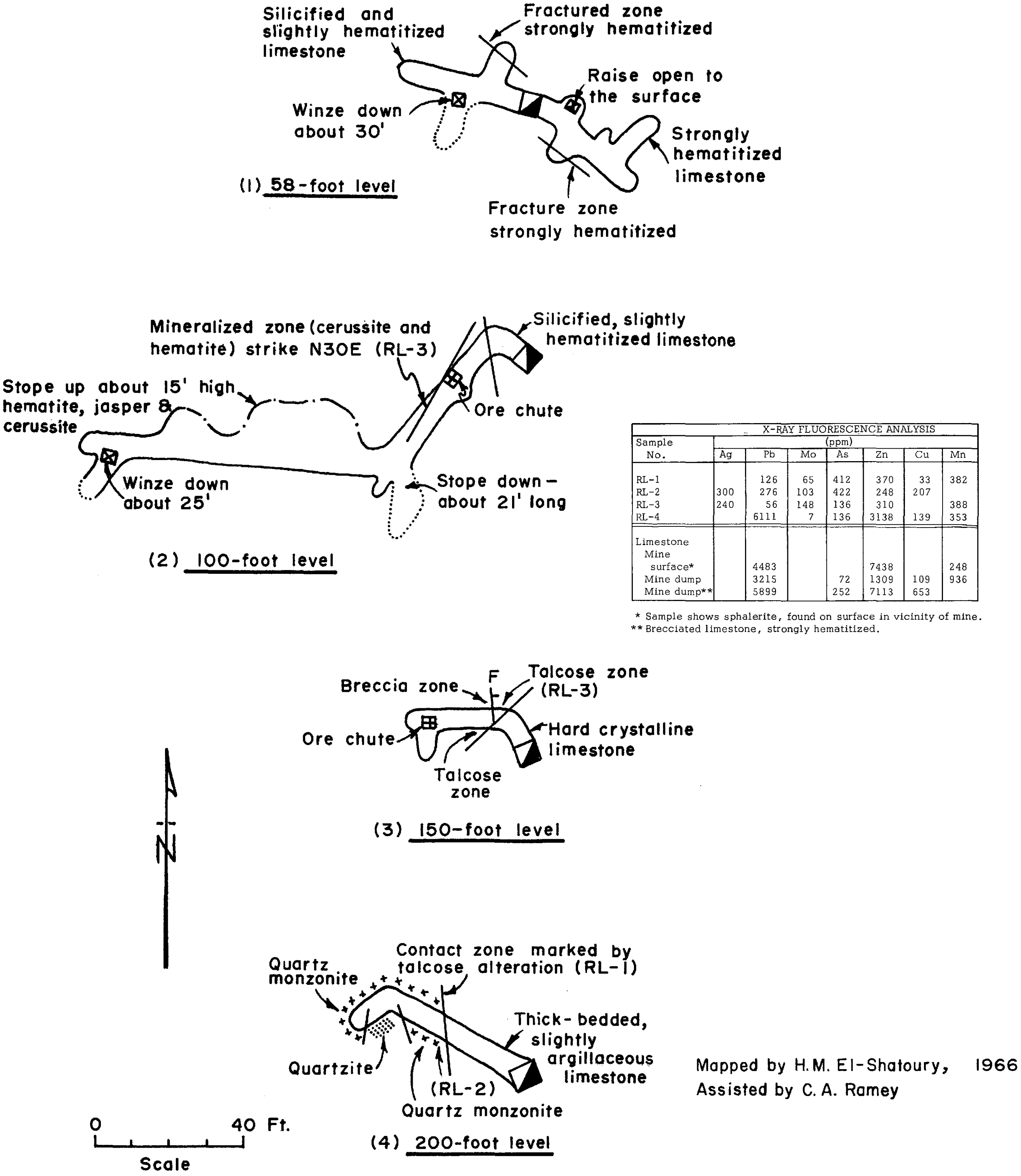
The occurrence of anomalous amounts of beryllium in the quartz-carbonate-adularia veins of Rodenhouse Wash discovered in 1962 has resulted in the district being considered part of the western Utah - eastern Nevada beryllium belt. This study indicates the grade of the beryllium-bearing veins to be too low to be considered marketable ore in the foreseeable future.

At times of high tungsten prices, the district has potential for small to moderate production. The Yellow Hammer mine contains exposed ore and some drilled reserves. Other mines in the district that have contributed to tungsten production, and probably have potential for it, are the Reaper, the Lucy L. and the Frankie. The estimated reserves of tungsten ore in the area are 6,600 tons, averaging 0.61 percent tungsten trioxide (Everett, 1961), containing 4,026 units of tungsten trioxide.

Except for the Yellow Hammer, Reaper, Lucy L. and Frankie mines, the zone of scheelite mineralization is developed through small prospects and shallow cuts. Further exploration of this zone and shallow drilling along the extension of the northeasterly mineralized fractures of the Yellow Hammer are recommended.

The area has potential for arsenic production, but adequate arsenic usually is produced as a byproduct of copper smelting and there is no market for arsenic ores at present.

The small size and capricious nature of the skarn type copper deposits have made them amenable only to



X-RAY FLUORESCENCE ANALYSIS							
Sample No.	(ppm)						
	Ag	Pb	Mo	As	Zn	Cu	Mn
RL-1		126	65	412	370	33	382
RL-2	300	276	103	422	248	207	
RL-3	240	56	148	136	310		388
RL-4		6111	7	136	3138	139	353
Limestone							
Mine surface*		4483			7438		248
Mine dump		3215		72	1309	109	936
Mine dump**		5899		252	7113	653	

* Sample shows sphalerite, found on surface in vicinity of mine.
** Brecciated limestone, strongly hematitized.

Mapped by H. M. El-Shatoury, 1966
Assisted by C. A. Ramey

Figure 12. Plan of the workings of the Rube Lead mine, Gold Hill mining district, Tooele County, Utah.

small-scale mining operations. Skarn type deposits may be high grade. The fact that these skarn deposits are rich in magnetite suggests the use of the magnetometer in traversing contact zones for further exploration.

Recent assays of several samples from the Alvarado and Cane Spring mines by Flint (1960) indicate that only low-grade rock was left behind in the original mine workings. The strong relationship between the ore shoots and the quartz monzonite in the Alvarado mine, however, suggests further exploration east of the inclined shaft where copper mineralization in the recrystallized limestone occurs. This area extends to the west side of the road to Callao.

In the Cane Spring mine Flint (1960) recommended sampling of three blocks of unstoped ore marked A, B and C on figure 11, to verify milling grade ore indicated by the relatively high assays obtained from nearby samples. Moreover, it is recommended that a careful study and shallow drilling should be conducted along the surface extension of the main ore bed to check for a possible extension of the ore body. Flint (1960) states that Mathez (1935) estimated 1,466 tons of $14.00 in gold per ton in the workings now under water.

In summary, it is probably safe to say at present that the likelihood of finding ores of a quality high enough to make their removal profitable is small. If economic conditions or demand for specific minerals change, or if production processes improve, then mining in the Gold Hill district could become a profitable operation.

ACKNOWLEDGMENTS

Mr. Cecil R. Woodman of Gold Hill provided valuable background information on the district, assisted El-Shatoury in the field, and allowed the field parties to live at his home. Mr. Claude A. Ramey assisted with the mapping of the Rube Gold and Rube Lead mines.

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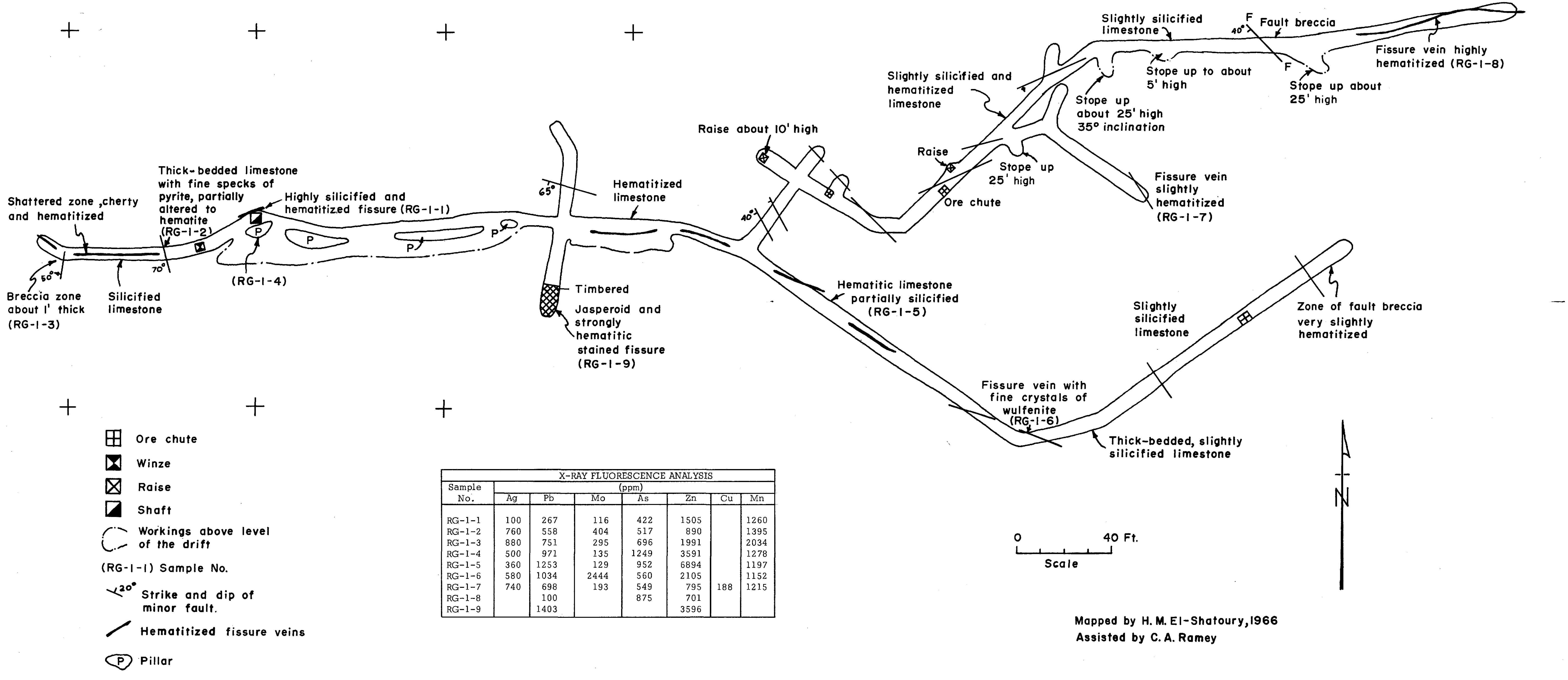
Plate 1

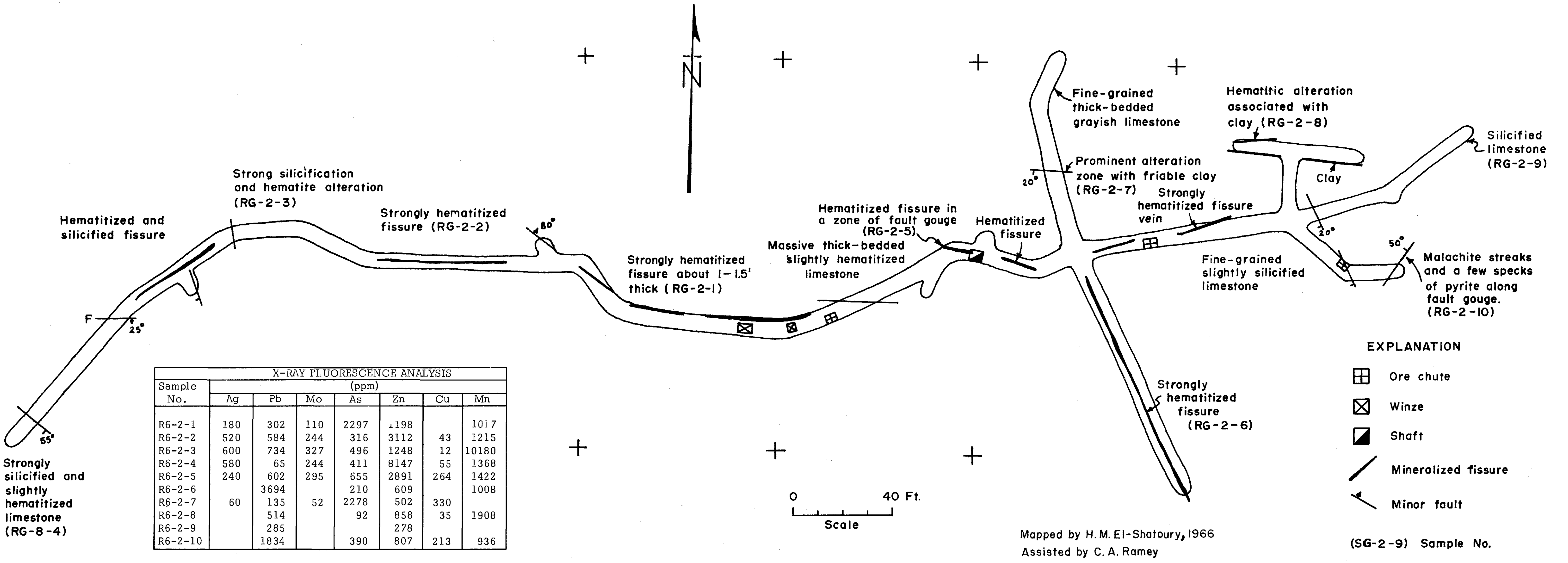


X-RAY FLUORESCENCE ANALYSIS							
Sample No.	(ppm)						
	Ag	Pb	Mo	As	Zn	Cu	Mn
RG-1-1	100	267	116	422	1505		1260
RG-1-2	760	558	404	517	890		1395
RG-1-3	880	751	295	696	1991		2034
RG-1-4	500	971	135	1249	3591		1278
RG-1-5	360	1253	129	952	6894		1197
RG-1-6	580	1034	2444	560	2105		1152
RG-1-7	740	698	193	549	795	188	1215
RG-1-8		100		875	701		
RG-1-9		1403			3596		

Mapped by H. M. El-Shatoury, 1966
Assisted by C. A. Ramey

Plan of the workings of 65-foot level of the Rube Gold mine, Gold Hill mining district, Tooele County, Utah.

Plate 2

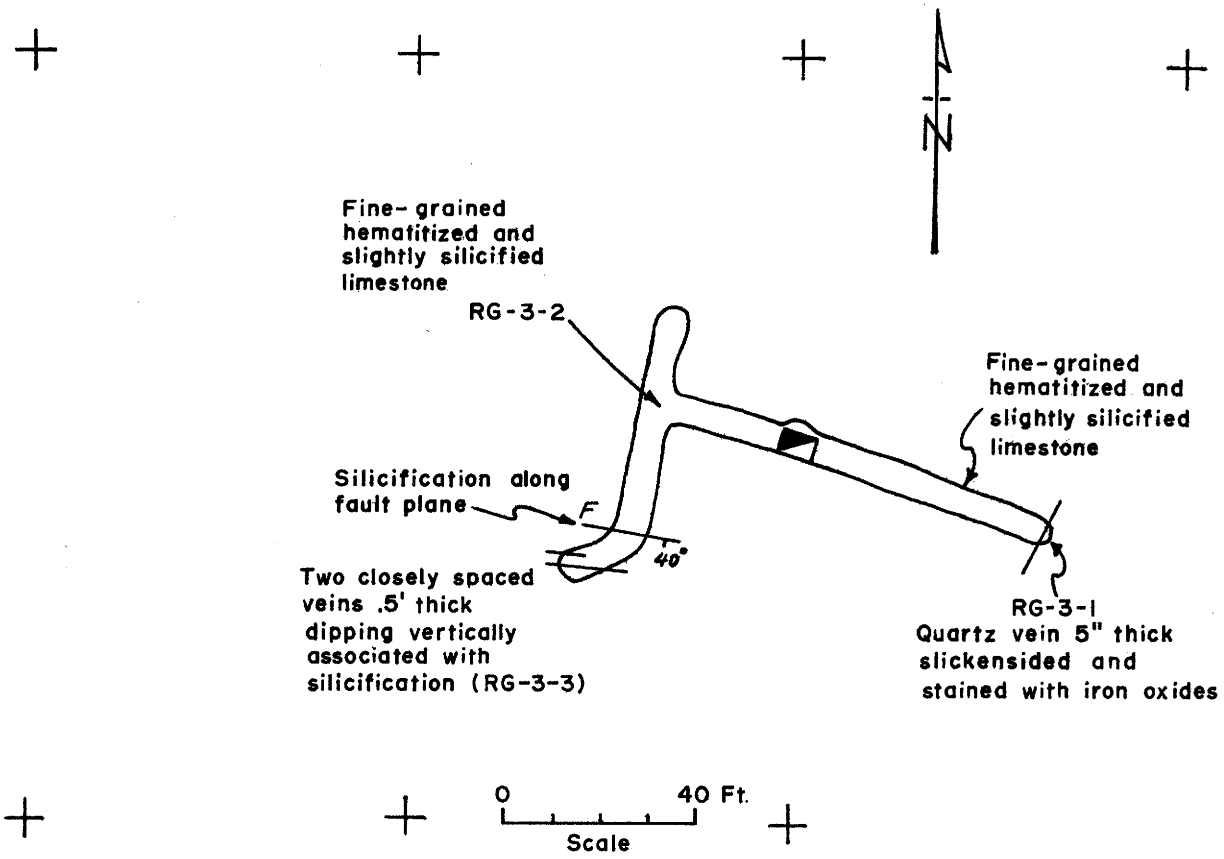


X-RAY FLUORESCENCE ANALYSIS							
Sample No.	(ppm)						
	Ag	Pb	Mo	As	Zn	Cu	Mn
R6-2-1	180	302	110	2297	1198		1017
R6-2-2	520	584	244	316	3112	43	1215
R6-2-3	600	734	327	496	1248	12	10180
R6-2-4	580	65	244	411	8147	55	1368
R6-2-5	240	602	295	655	2891	264	1422
R6-2-6		3694		210	609		1008
R6-2-7	60	135	52	2278	502	330	
R6-2-8		514		92	858	35	1908
R6-2-9		285			278		
R6-2-10		1834		390	807	213	936

Mapped by H. M. El-Shatoury, 1966
Assisted by C. A. Ramey

Plan of the workings of the 150-foot level of the Rube Gold mine, Gold Hill mining district, Tooele County, Utah.

Plate 3



X-RAY FLUORESCENCE ANALYSIS							
Sample No.	(ppm)						
	Ag	Pb	Mo	As	Zn	Cu	Mn
RG-3-1	882	116	51	1150		1512	
RG-3-2		1059	135	292	10602		1512
RG-3-3		188			800		891

Mapped by H. M. El-Shatoury, 1966
Assisted by C. A. Ramey

Plan of the workings of the 300-foot level of the Rube Gold mine, Gold Hill mining district, Tooele County, Utah.