NATURAL RESOURCES

INACTIVE AND ABANDONED MINE LANDS— Republic Mining District, Ferry County, Washington

by Fritz E. Wolff,
Donald T. McKay,
and David K. Norman

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Information Circular 110
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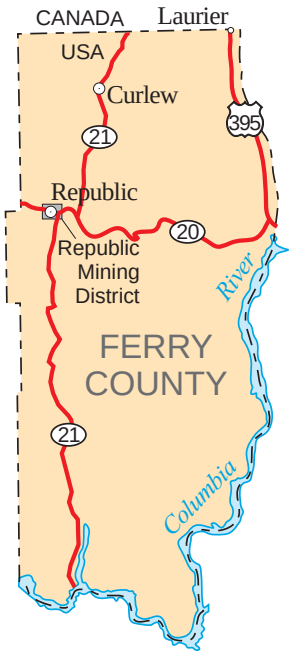

INTRODUCTION

The Washington State Department of Natural Resources (DNR), Division of Geology and Earth Resources (DGER), has built a database and geographic information system (GIS) coverage of major mines in the state. Site characterization was initiated in 1999 (Norman, 2000). Work was funded through interagency grants from the U.S. Forest Service (USFS), Region 6. Other agencies sharing in the project are the Washington Department of Ecology (DOE), U.S. Bureau of Land Management (BLM), and U.S. Environmental Protection Agency (EPA).

More than 3800 mineral properties have been located in the state during the last 100 years (Huntting, 1956). Many are undeveloped prospects of little economic importance. Therefore, in considering the population to include in the Inactive and Abandoned Mine Lands (IAML) inventory, we have identified approximately 60 sites that meet one of the following criteria: (a) more than 2000 feet of underground development, (b) more than 10,000 tons of production, (c) location of a known mill site or smelter. This subset of sites includes only metal mines no longer in operation.

We have chosen to use the term *inactive* in the project's title in addition to the term *abandoned* because it more precisely describes the land-use situation regarding mining and avoids any political or legal implications of surrendering an interest to a property that may re-open with changes in economics, technology, or commodity importance.

The IAML database focuses on physical characteristics and hazards (openings, structures, materials, and waste) and water-related issues (acid mine drainage and/or metals transport). Accurate location, current ownership, and land status information are also included. Acquisition of this information is a critical first step in any systematic approach to determine if remedial or reclamation activities are warranted at a particular mine. Reports such as this one provide documentation on mines or groups of mines within specific mining districts or counties. These reports state what we believe to be the known facts at the time of publication. Changes brought about by future events must be taken into consideration by the reader.

IAML reports are available online through our Publications List at http://www.dnr.wa.gov/Publications/ger_publications_list.pdf. Look under *Information Circulars* (2005–present) and *Open File Reports* (2001–2004).

SUMMARY

At the time Hecla's Golden Promise mine closed in 1994, the Republic mining district had produced approximately 2.8 million ounces of gold and 15.8 million ounces of silver, making it by far the largest precious metal producing district in the State of Washington. Mining in the district was continuous with few exceptions for more than a century. Total dollar value is estimated at approximately $376 million at historic metal prices. Approximately 85 percent of the total gold produced in the district came from the Knob Hill and Golden Promise mines.

Discovery of gold-bearing quartz veins began in the early 1890s at the confluence of Granite Creek and the Sanpoil River, a site that eventually became the town of Republic, but at the time was part of the Colville Indian Reservation. The northern half of the reservation opened to mineral entry on February 21, 1896, and in the following nine days, 30 claims were staked along a series of northwest–southeast-striking outcrops. The network of mineralization, referred to in this report as the 'Eureka Trend', occupies all of Eureka Gulch north and several sections south of the town. It is approximately 4.5 miles long and 1 mile wide (Fig. 1; Appendix C). Production data for all the Republic mining district mines are shown in Appendix E.

Some outcrops contained bonanza-type ore grading 1.0 ounce per ton (opt) gold and higher. Production flourished at most mines until 1912 to 1915, when failure to develop economically viable ore reserves, voluminous litigation over extralateral rights, and inability to realize satisfactory recovery from most milling processes available at the time brought the district to a virtual standstill. Several attempts at property consolidation were made, but most were not successful; the one exception being the purchase of the Lone Pine, Surprise, Pearl, and Black Tail claims by Northport Smelting and Refining Co., Inc., as a means of providing siliceous flux to the company's lead smelter located on the Columbia River. Northport and Aurum Mining Co., Inc, wholly owned subsidiaries of the Day family interests of Wallace, Idaho, played major roles in the district's development. The Northport smelter was dismantled in 1922, and over time Aurum became the dominant presence in the district in terms of acquisition.

The 1934 U.S. government-mandated increase in the price of gold from $20 per ounce to $35 per ounce revitalized mining in the Republic camp and renewed interest in developing the large tonnage of milling-grade ore left underground by using the flotation process in conjunction with cyanidation and improved grinding equipment. Sustained production on a large scale came

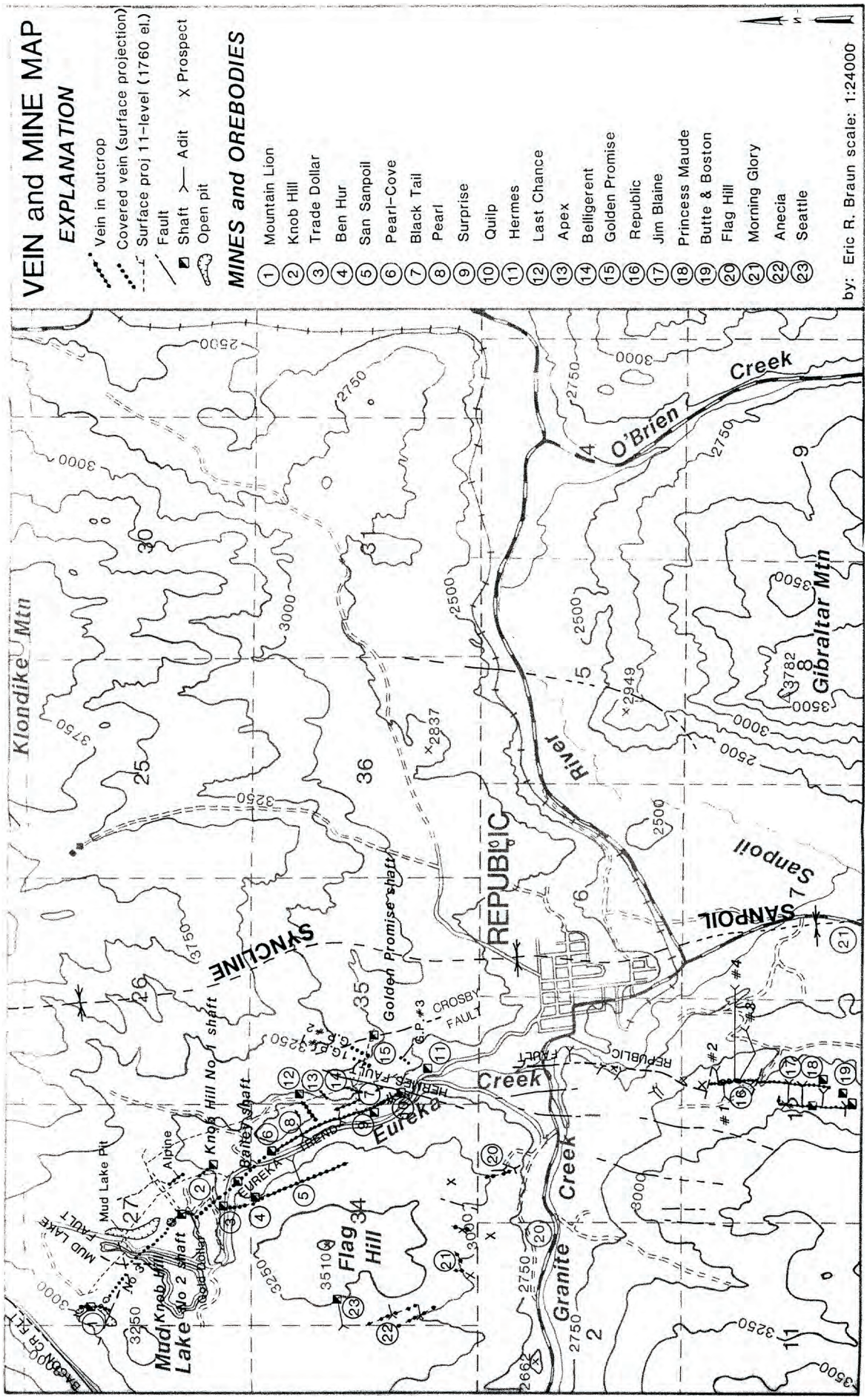

Figure 1. Vein and mine location map, Republic mining district. (Reprinted from Braun, 1989.)

to fruition in 1936 when Knob Hill Mines, Inc., of San Francisco purchased the long-idle Knob Hill mine and constructed a 400 ton per day (tpd) mill to concentrate low-grade ore found in surface lake bed sediments. Fissure veins discovered in the bottom of the pit, in combination with ore mined jointly on the Day holdings, led to continuous production at the Knob Hill mine until 1984.

In 1947, the Day interests consolidated twelve separate mining companies, including Aurum, under the umbrella of Day Mines, Inc. In 1959, Day Mines and Knob Hill signed a joint operation and profit sharing agreement allowing underground access to ore on several of Day Mines' adjacent claims, most notably the Gold Dollar and Ben Hur claims. The Gold Dollar vein proved to be the thickest, highest-grade portion of the Eureka Trend with grades locally as high as 100 opt gold. In 1978, Knob Hill relinquished all of the property, mineral rights, and the surface plant to Day Mines.

Hecla Mining Co., Inc., acquired all of Day Mines' properties in Republic and Idaho during a stock transaction in 1981. By 1984, ore reserves at the Knob Hill mine appeared depleted; however, Hecla geologists discovered a blind orebody about a mile southwest of the Knob Hill shaft in pyroclastic rocks thought to be an unfavorable host. This discovery, named the Golden Promise, extended Hecla's operation in the district until closure in 1995.

Gold and silver mineralization at Republic is cited as a classic example of an epithermal hot-springs precious metal deposit. Understandably, the district has been studied in great detail, beginning with Umpleby (1910) and Lindgren and Bancroft (1914). Their early observations agree in many respects with the epithermal model developed by a number of investigators over a half-century later: "A paleosurface of porcelaneous silica sinter underlain by a circuate zone of breccia grading downward and outward into a stockwork of chalcedonic veinlets, and finally to a series of coalescing veins which form a large vein gradually decreasing in width and grade" (Tschauder, 1989). (See Figure 2.)

Braun's (1989) conclusions regarding ore genesis in the district are that mineralization began with the development of a deeply circulating geothermal system in the waning stages of middle-Eocene volcanism [Sanpoil Volcanics]. Upwelling 300ºC solutions venting at a paleosurface ". . . produced epithermal hot-spring type mineralization along the Eureka Trend. Solubilized gold and associated complex sulfides were transported west and upward along the active Eureka fault system, where the fluid plume vented in a basin conforming to the west flank of the Sanpoil syncline. Hydrothermal breccias and evidence for episodic vein sealing and overpressuring indicate that thermal fluids boiled intermittently in open space structures, resulting in metal precipitation." Where this occurred, dark bands of massive gold-bearing sulfides and gold were deposited: Tschauder's 'throttle' zone shown in Figure 2. The dark banding is characteristic throughout the district. It also occurs with little or no mineralization—probably a chalcedonic phase that appears black under ordinary light due to microscopic porosity. Above and below the throttle zone, ore minerals tend to be finely disseminated and concentrated in discontinuous lenticular ore shoots along the vein's plane.

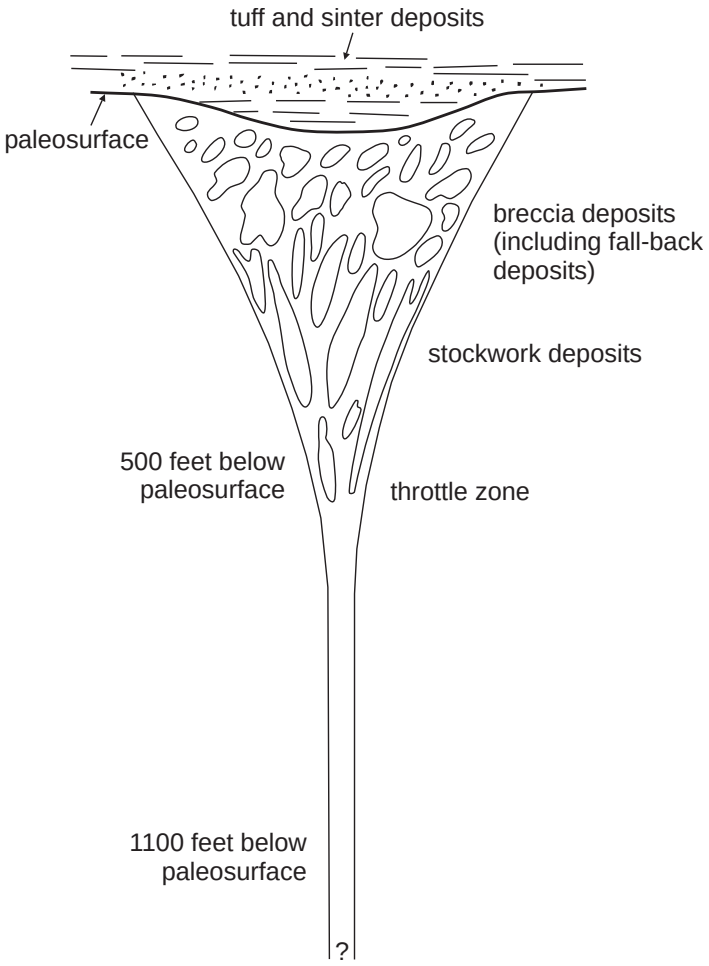

Figure 2. Components of an epithermal precious metal hot spring system modeled after the deposits in the Republic mining district. No scale is implied. (Adapted from Tschauder, 1989.)

Water quality in Eureka Creek has been impacted by the surrounding mining activity, but a 1999 study indicated that the receiving water courses during periods of high flow and low flow remained within Washington State water quality standards (Raforth and others, 2000). We observed no water discharging from the sites visited. Water quality at the Knob Hill site is under the oversight of the Department of Ecology (DOE).

The district is replete with mine openings and highwalls of various descriptions. Some have been fenced, some backfilled, some remain open; a few dozed and backfilled stopes continue caving to the surface. All of the openings are hazardous.

A total of seven concentrating mills operated at various times in the district; three were located at the Republic mine site. Others are the San Poil, Mountain Lion, North Washington Power and Reduction Co., and Knob Hill. With the exception of the Knob Hill mill, which operated successfully for more than 50 years, most failed to extract more than 40 to 50 percent of the precious metals—leading to production runs of only a few years, oftentimes ending in company foreclosure. Tailings samples show elevated levels of arsenic, antimony, selenium, and zinc, depending on location and environment, that exceed Washington State standards for unrestricted use. Samples from the waste rock dumps of the Ben Hur and Quilp mines show exceedances for arsenic and selenium (see Table 7).

Because of the immense amount of information published on the Republic mining district, we suggest the following sources to those seeking additional detail not covered in this Information Circular: For pre-1930 detail, see Joseph (1900a,b), Umpleby (1910), Bancroft (1914), and Patty (1921). For post-1930 to present detail, see Martin (1988), Braun (1989), Muessig (1967), and Tschauder, (1989). The University of Idaho Special Collections Library contains data spanning both eras for the Aurum Mining Co. (1916–1953) and Northport Smelting and Refining Co. (1898–1936). Huntting (1956) is a good reference for dates and company names relating to changes in ownership. Differential spelling herein follows conventions used in the literature of the district, and as recognized place names: that is, the San Poil mine and mill; the Sanpoil River and Sanpoil Volcanics. Swamp Creek is a local name for North Fork Granite Creek.

ACCESS

The Republic mining district begins about 1 mile south of the town of Republic and continues north on the Knob Hill–Trout Creek Road for about 3.5 miles. Access is by two-wheel drive. Almost all the lands formerly mined are privately held and should be approached with that fact in mind. DGER personnel performed field work in the district in July 2001 and June 2007. The location of the mines discussed below as superimposed on color aerial photographs can be viewed in Appendix C.

OWNERSHIP

A network of approximately 100 patented claims owned in fee simple dominates the town of Republic environs, and some claims underlie the town itself (Appendix D). In some cases, agreements have been made over time such that mineral rights have been separated from surface rights, or ownership has been divided into fractions. However, two generalizations can be made for the Republic mining district at the time of publication: (a) Most patented claims in or adjacent to Eureka Gulch proper from the north city limits of Republic to the Tom Thumb group are owned by Hecla Mining Co., Inc., Coeur d'Alene, Idaho, and (b) The area immediately contiguous to the Town of Republic on the south and west and formerly worked as the Republic–Jim Blaine–Princess Maude group of claims is owned by Vaagen Brothers Logging Co., Inc., Colville, Wash. (Ferry County Assessor, written commun., May 2008). Most of the widely separated patented claims on Flag Hill northwest of the Republic city limits are owned by private parties or held in trusts. Because property ownership is constantly changing and complex, contact the Ferry County Assessor's Office for specific information on any real estate.

DISTRICT HISTORY

Of the 23 properties classified as recognized mines, we have selected 12 of the largest producers for the discussion below. Some have produced as stand-alone operations; some adjoining mines with interconnected workings eventually became in essence one property. At a minimum, 40 different companies played a part in the mining and milling activity at various times; unraveling the complexity of who did what and when and documentation of the complete record for each is beyond the scope of this report. The following information is a condensation of what can be determined from reliable sources concerning a century of activity in the Republic mining district, including field data collected by DGER, DOE, and consultants.

From 1896 to 1902, the Republic mine, located near the southwest Republic city limits, was the district's leading producer, but it entered an extended period of decline between 1903 and 1911 when the initial bonanza-grade ore reserves were depleted and continued development failed to find milling-grade ore to feed the expensive and elaborate "Red" mill built by Republic Gold Mining and Milling Co., Inc. In the center of Eureka Gulch proper, the Quilp, Lone Pine, Surprise, Last Chance, Black Tail, Insurgent, and Knob Hill mines became producers. The San Poil, Ben Hur, Mountain Lion, and South Penn mines also have recorded production—they are located on a separate but parallel vein system a few hundred feet west of the others. Collectively these mines paid significant dividends to investors from ore grading 1.0 opt gold and higher until about 1912. At this juncture, court arguments concerning extra-lateral rights and claim boundaries began to increasingly stifle production and drain company resources.

In order to quash litigation and expand production, some consolidations took place as early as 1901, but most failed, as did one of the largest attempts—purchase of the Lone Pine, Pearl, Surprise, and Black Tail mines by Republic Consolidated Gold Mining Co. Northport took the properties out of receivership in 1916 for a consideration of $150,000. This purchase enabled Northport to direct-ship all the production from these mines as a high-silica flux for use in the company's lead smelter located on the Columbia River. Although the smelter was dismantled in 1922, Northport's successor, Aurum, continued to acquire property in the district throughout the 1930s and 1940s and maintained a sporadic production record through World War II by leasers. Aurum ultimately acquired 104 patented claims by 1945, including virtually the entire Eureka Trend with the notable exception of the Knob Hill mine (DGER mine file).

Sustained production on a large scale in the district came to fruition in 1936 when Knob Hill Mines Inc. of San Francisco took ownership of the long-idle Knob Hill mine and constructed a 400 ton per day (tpd) mill to concentrate low-grade ore mined at two open pits in tuffaceous lake beds near Mud Lake. Fissure veins discovered in the bottom of the Stewart pit led to the construction of the Knob Hill No. 2 inclined shaft in 1942. A network of veins subsequently discovered during operations from this shaft provided ore reserves sufficient to sustain continuous mining until the mid-1980s.

In 1947, the Day interests consolidated twelve separate mining companies, including Aurum, under the umbrella of Day Mines, Inc. Day Mines and Knob Hill signed a joint operation and profit-sharing agreement in 1959 that enabled Knob Hill to mine ore bodies on claims held by Day Mines, one of which was the Gold Dollar. The Gold Dollar vein proved to be the thickest, highest-grade portion of the Eureka Trend, with grades locally as high as 100 opt gold (Tschauder, 1989). This business arrangement continued until 1978 when future profitability of the district appeared bleak and Knob Hill relinquished all of the property, mineral rights, and surface plant to Day Mines for one dollar (*Wallace Miner*, 4/13/78).

Hecla Mining Co., Inc., acquired all the Day Mines properties in Washington and Idaho during a stock takeover in 1981 (Fahey, 1990). By 1984, ore reserves at the Knob Hill mine again appeared depleted; however, Hecla geologists discovered a blind orebody in pyroclastic rocks located about a mile southeast of the Knob Hill No. 2 shaft. The 'Golden Promise' discovery extended Hecla's operation in the district until 1995, which is the last reported date of production (Derkey, 1996).

PRINCIPAL MINES

Eighteen mines in the Republic district have reported production in excess of 10,000 tons (Appendix E). The following discussion pertains to a subset of 12 of the largest properties, beginning with the Republic mine near the southern edge of the district and progressing incrementally northward (Fig. 1; Appendix C).

Republic mine

This mine lies in sec. 12, T36N R32E, approximately one-quarter mile south of the Republic city limits. The Republic Gold Mining and Milling Co. formed in 1896 to develop the property and in a short time had driven four major cross-cutting adits in the hillside below the outcrop at about 100 foot intervals. A map in Umpleby (1910) shows the No. 1 adit entering the ridge-forming discovery from the west, the other three adits enter from the east on the slope above Granite Creek. The lowest adit, No. 4, is 2500 feet long and reaches the vein at a depth of 600 feet (Fig. 3).

Very little public information is available on the ore tenor or length and width of the vein on level 4 or on exploration drilling beyond the north and south end lines of the Republic claim. Bancroft (1914) reported that a winze had been sunk to a fifth level, which was flooded in 1913 at the time of his examination, but stated that the vein at the top of the winze was 15 feet wide.

Rich surface ore was initially transported by horse team over a circuitous wagon road to the closest railhead at Marcus, Wash., where it was shipped to the Trail, B.C., smelter. The freight cost proved prohibitive and the company soon constructed a cyanide-based mill on Granite Creek, known as the 'Patsy Clark' mill. For reasons discussed below (Milling Operations), the facility processed only about 3000 tons of ore before being abandoned.

In 1899, the mine was sold to a group of Montreal investors doing business as the Republic Consolidated Gold Mining Co. for the then unheard of sum of $3.5 million (Norman, 1918; *Mining and Engineering World*, 7/16/1912). D. C. Jackling (later known for geologic interpretation of large scale porphyry copper deposits, such as Bingham Canyon, Utah) designed the impressive 'Red' mill, built at a cost of $350,000. Unfortunately the timing of the Red mill's construction coincided with rapidly diminishing ore reserves, and the company failed in July 1901, nine months after the mill was completed. The mine passed into receivership for unpaid taxes and lay idle until purchased by the New Republic Co. at a forced sale held by Ferry County in 1909. The company mined a high-grade lens discovered on the No. 3 level and then abandoned the property in 1911 (Bancroft, 1914).

The last known production at the Republic mine by lessors and the Eureka Mining and Milling Co., Inc., took place in the years 1934 through 1949. Braun (1989) reported 42,444 tons were mined during this period, grading 0.214 opt gold and 1.11 opt silver. Total production of the Republic mine is 140,000 tons valued at $2.3 million. Development has been estimated at about 10,000 feet (Huntting, 1956).

A timbered open stope at the vein's outcrop is located on the knoll above the mill. The site, which is in the process of collapsing, has a surface expression approximately 50 feet long by 35 feet wide (Fig. 4). It strikes N35ºE and dips 60ºSE. The glory hole described by Umpleby (1910) lies on strike about 100 feet north of the open stope. A circular depression indicates the floor is caving into underlying stopes (Fig. 5). As shown in (Appendix C, Fig. C1), the entire hillside is shot-holed with open cuts, short caved adits, subsidence features, and two caved shafts. Second-growth fir and larch have taken over the property. We observed no water discharging from any openings.

The Republic vein continues south through the Jim Blaine, Princess Maude, and Butte and Boston claims (Fig. 1). Bancroft (1914) contains the best and probably the last descriptions made while these adjacent properties were accessible. He indicated that the character of the vein differs somewhat from others in the district in that it narrows to about 2 feet in width, alternates between sugary masses of silica and hard fine-grained quartz, and contains predominantly silver and almost none of the lead, zinc, or copper sulfides found elsewhere. The record is sparse on these mines, even though several thousand feet of development work was accomplished at each site.

Quilp mine

The Quilp claim is situated on the east side of Eureka Gulch, partly within the northern city limits of Republic (Appendix C, Fig. C2). It was one of the first properties to be located after the opening to mineral entry in 1896. The Quilp mine produced about 24,000 tons of ore in the first 10 years of operation, at an average grade of 0.4 opt gold and 5 opt silver. In 1906, the property fell into litigation with Republic Consolidated over extralateral rights. The lawsuit was finally settled in favor of Quilp Gold Mining Co. in 1909, at which time the property was leased to the Imperator-Quilp Mining Co. and production continued at the rate of about 80 tons per month (Bancroft, 1914). The surface infrastructure, which is no longer evident, included a hoist house and steam plant, and a covered adit-level surface tramway. As shown in Figure F6, these structures were literally jammed within the confines of Eureka Gulch.

The Quilp deposit was worked through two vertical shafts: one at the extreme north end of the claim and the other, 400 feet in depth, at the south end. Wall rock is dark green andesite, and the vein is composed of the crenulated black-banded chalcedony and milky quartz typical of the district. "The width of the vein varies from two to fifteen feet and consistently averages about eight feet. It has been explored on dip to a depth of 900 feet below the outcrop, where it continues to be well mineralized including larger amounts of pyrite and chalcopyrite than observed elsewhere in the District (Patty, 1921)." Information in Braun (1989) indicates that the ultimate depth reached at the Quilp was 950 feet, that is, the same elevation as the Knob Hill 11-level lateral (elevation 1800 feet). A glory hole 200 feet long

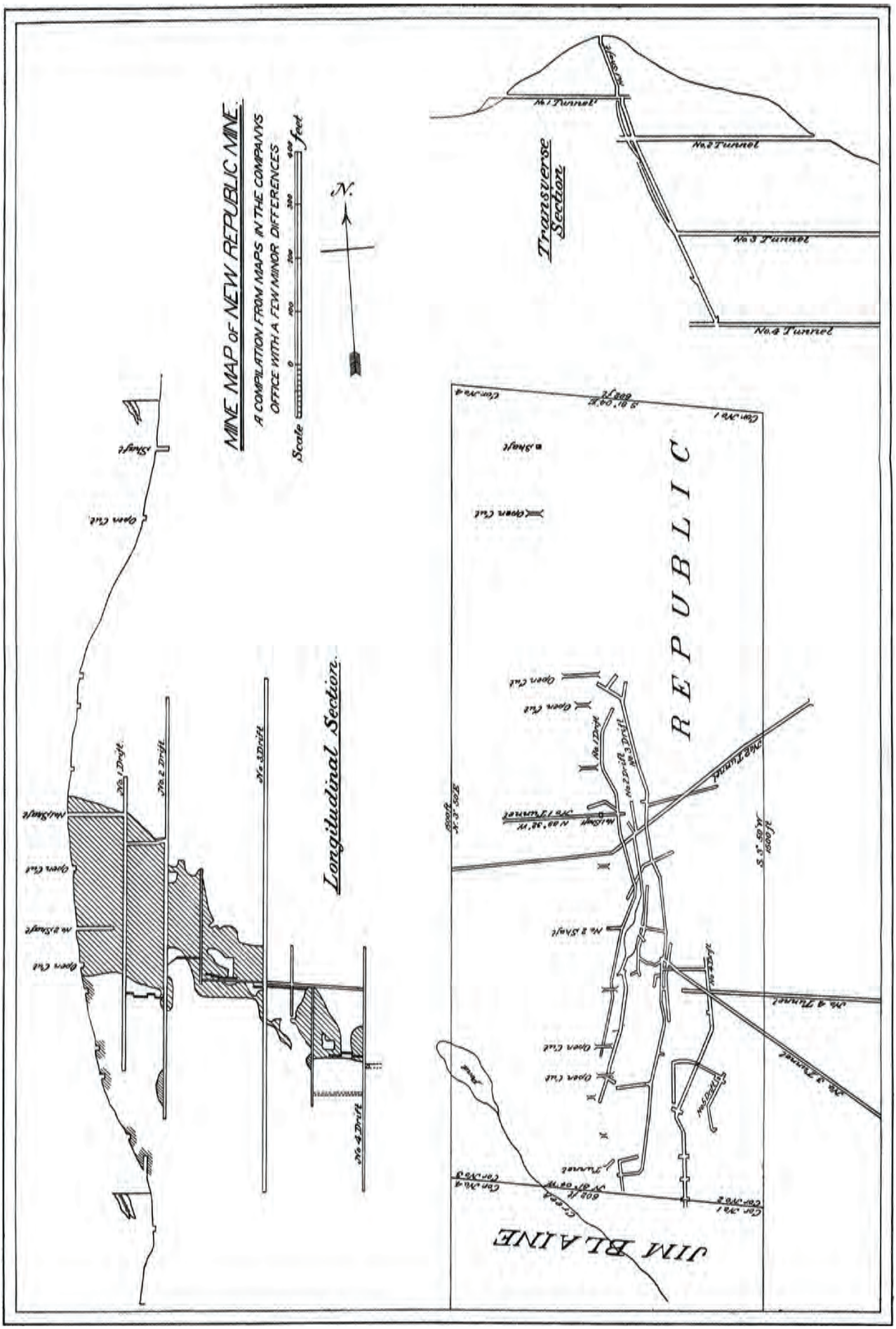

Figure 3. Plan view and section of the Republic mine, New Republic Mining Co. (Reprinted from Umpleby, 1910.)

by 60 feet wide near the outcrop appears to have been filled with waste rock from the Golden Promise.

The principal developer of the property was the Quilp Gold Mining Co., Inc. The mine saw a resurgence of activity in 1936 when the Eureka Mining and Milling Co., Inc., took the property out of receivership through purchase of Quilp Mining's authorized stock, dewatered the mine to the 900 level, and began production. The company also leased the Republic mine at this time, reconditioned the Red mill, and trucked approximately 50 tpd from the Quilp through town to the mill. Concentrates were shipped to the Tacoma smelter. However, at the beginning of 1939, Eureka Mining reorganized and the new management, in cooperation with the Great Northern Railway, ran a spur from Eureka Gulch to a storage bin opposite the south Quilp shaft. This enabled mine production to be dumped directly into gondolas and shipped to the Trail, B.C., smelter, thereby eliminating re-handling and the milling step altogether. This change of operation probably marks the last time the Red mill was used; historical documents indicate that mill equipment was salvaged and the buildings demolished soon afterward (DGER mine file). The Golden Promise waste rock dump now covers almost all of the historic Quilp surface exposure with the exception of the hazardous openings shown in Figures 6 and 7.

From discovery to the last documented operation in 1940, total production was 161,255 tons grading 0.384 opt gold and 2.5 opt silver valued at $1,662,617. Current ownership is Hecla (Braun, 1989).

Figure 4. Vein outcrop and open stopes at the Republic mine. Geologist at top left center for scale. View is to the northeast.

Figure 5. Republic mine discovery site and glory hole. Geologist for scale. View is to the south.

Lone Pine, Surprise, Black Tail, and Last Chance mines

These mines are located on claims and claim fractions contiguous with one another on the east side of Eureka Gulch, north of and adjacent to the Quilp mine (Appendix C, Fig. C2). Originally independent mines, as development continued it became evident early on that the companies in some instances were mining the same vein(s), and by 1910, the mines had been interconnected to greater or lesser extent underground. For example, the northeast-striking Lone Pine No. 2 vein extends through the east side line of the Lone Pine claim, passes through the Insurgent Fraction, and enters the Last Chance claim through its west side line where it provided the bulk of that mine's production (Fig. 8; Patty, 1921). This situation resulted in litigation between adjoining owners, stemming from the Mining Law of 1872 'Apex Rule' and disputes over extra-lateral rights; it engendered chaos in the production cycle, drained owners' cash, and created a revolving door of ownership.

As described above, Republic Consolidated's attempt in 1911 to merge the properties and quash litigation ended in failure. By 1916, the tables had turned to such a degree that the Lone Pine–Surprise Consolidated Mining Co. Inc. owned only the Last Chance mine (Norman, 1918), and Northport controlled the Lone Pine and Surprise mines, including the Black Tail, Pearl, and Insurgent Fraction (Patty, 1921).

Initial production from this latter group of mines came from the northwest-trending main vein running the entire length of the Surprise and Pearl claims paralleling Eureka Creek. The Surprise mine was developed by one major adit and an inclined shaft located near the center of the claim, which was sunk to a

distance of 700 feet on the vein (Patty, 1921). The record indicates that the Pearl vein was essentially mined through the Surprise workings, and therefore the production figures for the Pearl in Appendix E are skewed. The Surprise mine is credited with approximately 173,000 tons production grading 0.501 opt gold and 3.17 opt silver, most of which occurred during Northport/Aurum ownership. The Pearl is credited with 6,800 tons production grading 0.25 opt gold and 1.00 opt silver.

Four veins striking at almost right angles to the Surprise–Pearl vein system, (N40ºE and dipping 89ºSE), were discovered on the Lone Pine claim immediately east of the Pearl claim. These veins ranged in thickness from 4 to 14 feet, averaging about 8 feet. Principal development on the Lone Pine came from a 200-foot pay shoot mined to the surface on the No. 2 vein through an adit whose portal is located at the junction of Lone Pine Gulch and Eureka Gulch. Near the side line common to the Insurgent Fraction, a winze was sunk to a depth of 600 feet on the vein to a point near the 500-foot level. Patty (1921) reported that "Practically all 'commercial ore' above this level has been stoped to the surface. South of the winze . . . the vein begins to show evidence of intense movements along plane. Streaks of quartz ground into a sugary mass and mixed with gouge trend through the vein parallel to the walls." The Lone Pine mine is credited with approximately 62,000 tons of ore grading 0.352 opt gold and 2.26 opt silver (Appendix E).

The Black Tail claim was worked through a crosscut tunnel running through the east end line of the Surprise claim. It intersects the N40ºW-striking Black Tail vein 350 feet from the portal where drifts were carried along a vein of "irregular width and values". About 120 feet south of the intersection, Patty (1921) reported that the vein was cut by a fault of vertical displacement exhibiting ". . . a soft crumbly formation which probably represents the tuffaceous lake bed series" [described below]. Total production credits are 13,600 tons grading 0.288 opt gold and 3.08 opt silver (Appendix E).

Maps of Last Chance circa-1936, while it was still under the ownership of Lone Pine–Surprise Mining Co., show large masses in the vein's plane labeled "low grade". An attached letter indicates "these masses grade in the range 0.18 to 0.23 opt gold and 1.5 to 3.4 opt silver" (DGER mine file). Aurum purchased the Last Chance claim in 1938 for $39,500 (*Northwest Mining*, 12/1/38). It is unknown if this lower-grade material was mined in the 1934 to 1942 period shown in Appendix E. Open stopes in this area (Fig. 9) may extend 500 feet or more downdip; the openings are hazardous, as is the threat of sudden surface collapse along strike.

Figure 6. Stope opening at the surface at the Quilp mine. Eight-foot timber at center for scale.

Figure 7. Vein and opening at north end of Quilp open pit. Geologist at right center for scale. View is to the north-northwest.

Ben Hur mine

This property, consisting of one claim, is located between the Trade Dollar and San Poil claims, a few hundred feet west of the Knob Hill mine entrance road (Appendix C, Fig. C2). The mine was developed in 1907–08 by a 700-foot vertical shaft with levels at 100-foot intervals (Norman, 1918). Aurum acquired the property in 1935 after it had lain idle for many years. In 1939, the shaft was rebuilt and dewatered, requiring two months of continuous pumping to discharge 5 million gallons of water—much of it piped

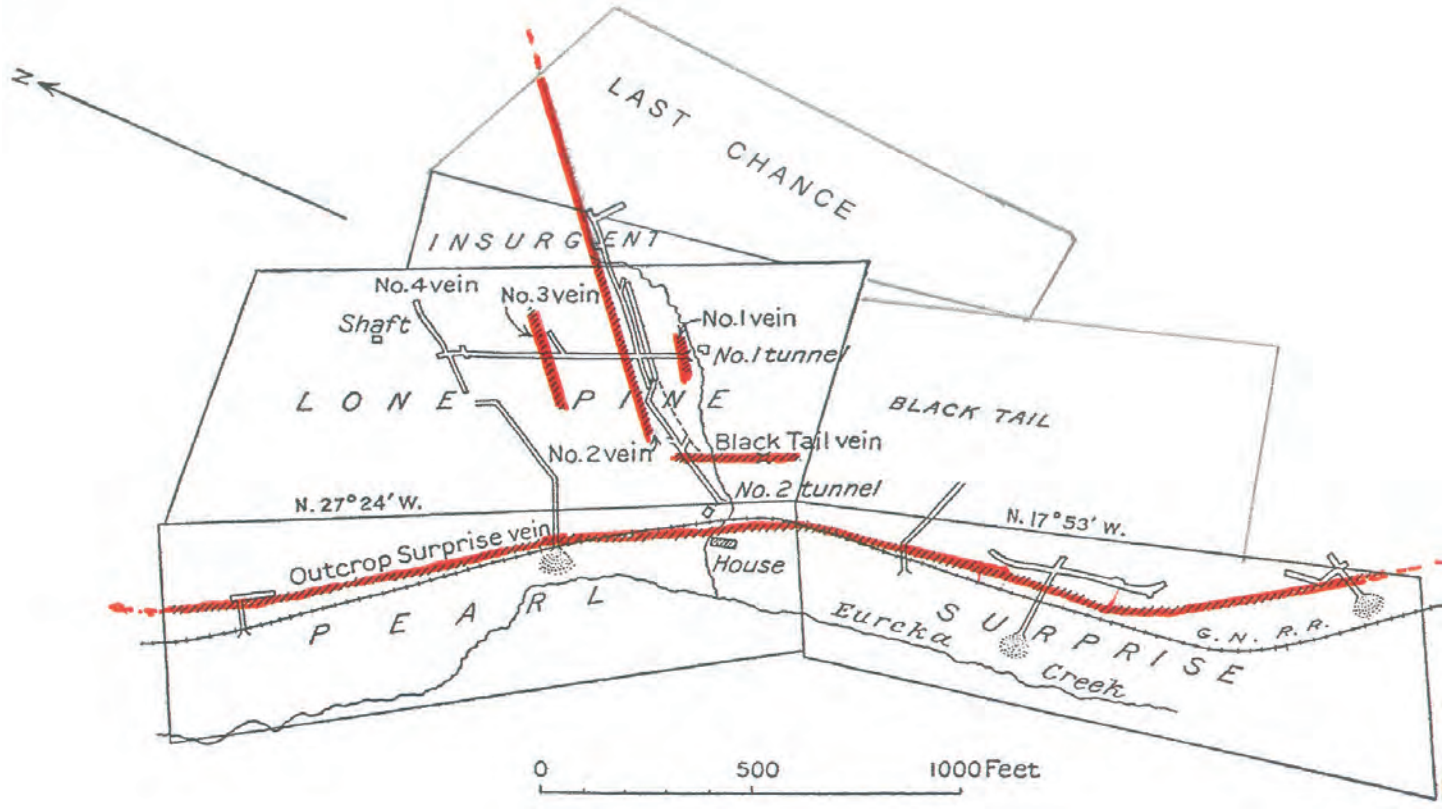

Figure 8. Plan view of the Lone Pine–Surprise–Last Chance claims showing the relative location and bearing of the vein structures. (Adapted from Patty, 1921.)

from the 100 level through the interconnected San Poil mine's main haulage way (Aurum Mining Co, 1916–1953). From inception to 1950 as a stand-alone mine, the mine produced 90,024 tons of ore grading 0.375 opt gold and 2.43 opt silver (Braun, 1989). A stope map in Braun (1989, p. 116) indicates that Knob Hill accessed the abandoned Ben Hur workings in the 1960s on level 6 and mined ore grading 0.3 to 3.0 opt gold down to level 13. Total production from this later era is included in Knob Hill production statistics.

We located footings of the historic Ben Hur surface plant and headframe. A statement made in 2009 by the Hecla on-site manager indicated that the vertical shaft, now buried under the mine access road, is plugged with concrete and located about 40 feet northeast of the 14 x 16-foot hoist foundation shown in Figure 10 (Hart Crowser, written commun., 2009). Open stopes trending south toward the San Poil claim have been backfilled by Hecla in the recent past, but are now breaking through to the surface (Fig. 11). A grab sample taken at the outcrop assayed 0.06 opt gold and 0.25 opt silver.

San Poil mine

The San Poil patented lode claim and the San Poil Fraction are located on the west side of Eureka Gulch, south of, but on the same vein as, the Ben Hur (Appendix C, Fig. C2). The vein was reported to be about 8 feet wide at the surface and extends the full length of the claim (Aurum Mining Co, 1916–1953). The company was taken over from the original Spokane owners in 1911 for $90,000. The new company, Sanpoil Consolidated Mining Co., erected a 125 tpd cyanide-based mill the following year.

Figure 9. Open stope on the Lone Pine No. 3 vein. View downdip is ~200 feet. Pack at upper left for scale. View is to the northeast.

The mine was developed by two crosscut tunnels and attendant drifts. The lower one intersects the vein 550 feet from the portal at a depth on the vein of 300 feet. A winze at the end of the crosscut was sunk to a depth of 110 feet. In 1911, smelter shipments of hand-sorted ore averaged about 1 opt gold from a high-grade ore shoot of limited extent. With liabilities of $165,000 and 10,000 tons of broken ore in the stopes, the property was operated successfully by a bond holders syndicate in 1914 and 1915. In spite of this, financial difficulties reached a crisis in 1918; the property passed to a receiver and was sold to Consolidated Mining and Smelting Co., Trail, B.C. (now Teck, Inc.). By 1934, the San Poil and adjacent claims had been taken by Ferry County for unpaid taxes and were purchased by Aurum (Aurum Mining Co, 1916–1953). A consultant's map from a 1934 examination indicates that the vein is discontinuous within the lower drift; where found, it ranged in width from 12 to 48 inches and was "badly mixed with country rock". Four samples taken at the time assayed 0.03 to 0.15 opt gold (DGER mine map file).

Production as a stand-alone mine is 101,000 tons of ore grading 0.303 opt gold and 1.30 opt silver. As shown in Appendix E, the tenor of ore dropped precipitously in the last known period of operation by Aurum leasers (1933–1945) to 0.19 opt gold and 1.00 opt silver.

Figure 10. Hoist pad and foundations at the Ben Hur mine site. View is to the north.

Figure 11. Subsidence over backfilled stope openings at the Ben Hur mine. Vein outcrop at upper left. View is along strike to the southeast.

Knob Hill mine

A small dome-shaped hill at the upper end of Eureka Gulch gives the Knob Hill Mine its name (Appendix C, Fig. C3). The original claims staked were the Knob Hill, Alpine, and Mud Lake; later the Rebate, Trade Dollar, and Mountain Lion claims were included in the holdings (Huntting, 1956). Knob Hill Mining Co. began active development in 1910 by driving three adits crosscutting the vein at 100-foot intervals below the outcrop. This operation is the Knob Hill No. 1 mine. The company paid regular dividends on ore averaging 1.5 opt gold and 4.5 opt silver until 1924, at which time Balaklala Consolidated Copper Co. Inc. acquired the property (Aurum Mining Co, 1916–1953). The record is unclear as to activity at the Knob Hill during the late 1920s and early 1930s.

Shortly after the Federal Reserve increased the price of gold to $35 per ounce in 1935, a group of San Francisco investors formed Knob Hill Mines, Inc., and took control of the property. Knob Hill Mines constructed a 400 tpd cyanide mill to process a large tonnage of near-surface disseminated gold mineralization found in lake bed sediments at the base of the Klondike Mountain Formation (Appendix F, Fig. F4). Surface mining at the Stewart open pit continued until 1940 when removal of the glacial overburden became uneconomic and mining had progressed to a point where gold-bearing quartz veins were exposed in the pit floor. A decision was made to continue underground via an inclined shaft. The development following this discovery became known as the Knob Hill No. 2 mine. The network of veins discovered during operations from this shaft was mined continuously by Knob Hill Mines (1936–1978), Day Mines Inc. (1978–1981), and Hecla Mining Co., Inc. (1981–1984).

In 1959, Knob Hill and Aurum's parent company, Day Mines Inc., signed a joint operations and profit-sharing agreement. Two major projects were implemented: (1) Knob Hill Mines connected their production levels with historic development on Day Mines' Trade Dollar, Gold Dollar, and Ben Hur claims [Braun's thesis (p. 116) contains stope maps showing the

spatial relationship of mining on these other properties superimposed on the Knob Hill No. 2 development]; and (2) Knob Hill drove a deep-level exploration lateral southeast beneath all the Day properties in Eureka Gulch to the Quilp workings, a distance of about 7000 feet. In 1963, core holes approximately 1000 feet long were drilled east and west from this lateral at about 600-foot intervals. One horizontal hole drilled from the Surprise–Quilp area cut mineralization and alteration a few feet from the end of an east-oriented 1350-foot hole—3 feet of chalcedonic quartz grading 6.6 opt gold and 32.5 opt silver. No follow-on work was done at the time, apparently because the intercept was in pyroclastic rocks of the upper Sanpoil formation—a host lithology considered unfavorable at the time. At places in the Knob Hill Mine, these rocks caused ground-control problems and were generally thought to lack the competency necessary to remain open during periods of fissure filling (Braun, 1989).

Figure 12. Golden Promise ramp portal, 1995. View is to the east.

Knob Hill ceased operations at Republic in 1978 and relinquished all of the property, mineral rights, and surface plant to Day Mines for one dollar (*Wallace Miner*, 4/13/78). Hecla Mining Co. Inc. of Coeur d'Alene, Idaho, acquired all of Day Mines' properties in Washington and Idaho during a stock takeover in 1981 (Day Mines Group Records, 1890–1981).

Golden Promise mine

Although Hecla announced plans in November 1983 to close the Knob Hill Mine due to shrinking ore reserves, determined work by the company's exploration staff continued to push for re-examining the mineralization discovered in the 1963 deep-lateral exploration. This project's information when revisited in the 1980s led to the Golden Promise discovery, which although mined and milled by Hecla, is sufficiently removed from the Knob Hill Mine to be considered a separate mine altogether.

Hecla staff geologists drilled a fence of eight vertical holes on a southwest/northeast-bearing line from the surface projection of the high grade intercept described above. These holes penetrated about 500 feet of east-dipping debris flows and lakebed sediments before intersecting the Klondike Mountain Formation/Sanpoil Volcanics contact. The drilling found major gold-mineralized structures at depths ranging from 900 to 1500 feet below ground surface in the Sanpoil Volcanics. Information gained through the use of directional drilling technology and core orientation equipment suggested an ore trend at least 2500 feet long, striking N30ºE and dipping 50º to 70ºSE. Hecla called the new discovery the 'Golden Promise'. Braun's (1989) thesis contains maps and a detailed account of the Golden Promise discovery.

In a newspaper article, geologist Richard Tschauder stated that "initial exploration drifting along these veins in May 1985 revealed only marginally encouraging results, but a few months later . . . enough data had been assembled to make an apparently correct interpretation indicating that where only two veins were thought to be present there were four, and that faulting of limited extent had offset the veins and thus affected the initial drilling targets" (*Wallace Miner*, 12/18/1986).

Hecla bored a 6-foot diameter shaft in 1986 to transport men and materials underground. At that time, all production was trammed to the Knob Hill No. 2 shaft on the 11-level, approximately a mile northwest. In 1991, Hecla sank an 11 x 13 foot ramp at the Golden Promise, enabling the use of rubber-tired diesel equipment for mining and tramming; ore was transferred at the portal to trucks for the mill haul, thereby eliminating the lower volume and higher costs of traditional underground handling. The ramp is a series of straight stretches with several hairpin curves at intervals—about 6600 feet in length overall (Appendix C, Fig. C2). Rock bolts provided adequate ground support in the pyroclastic host rock. Mining was carried out with cut-and-fill shrinkage stopes, thereby limiting the amount of ground open at any one time. The decline portal circa-1995 is shown in Figure 12 and the closed adit as it appears today in Figure 13. Some ore-grade mineralization was discovered by diamond drilling east of the Golden Promise.

Ore grade mineralization (>0.25 opt gold) at the Golden Promise bottomed out approximately 1500 feet from the surface and was mined continuously from 1986 until January 1995 when Hecla closed the mine. The final figures for tonnage and grade produced from the Golden Promise are a matter of Hecla corporate records, however data in DGER publications and Department of the Interior Minerals Yearbooks agree closely with the ore-reserve estimate in Hecla's 1987 annual report: ~500,000 tons grading 0.87 opt gold and 4.4 opt silver. Hecla dismantled the mill in 1999. Total dollar value of production over the life of the Knob Hill Mine, including the Golden Promise, exceeds $158 million.

DGER visited the Knob Hill–Golden Promise sites in July 2001. The main features remaining at the Knob Hill site are the mill foundations, shop buildings, and three tailings impoundments (Ecology and Environment, 2001).

Mountain Lion and South Penn mines

As shown in Appendix C (Fig. C3), these adjoining properties are located about 1 mile northwest of the Knob Hill Mine at a wye between the Knob Hill and Knob Hill–Trout Creek Roads. The mineralization is bounded on the immediate west by the Bacon Creek fault. Three fissure veins occur on the Mountain Lion property. The principal development took place on the center vein, which attained a thickness of 26 feet in places (Joseph, 1900b). The host rock is andesitic breccia. A 1260-foot adit bearing S50ºE cuts the principal or center vein at a depth of 310 feet below ground surface, where it joins a double-compartment 700-foot vertical shaft and continues on to intercept the parallel east vein. The shaft has levels at approximately 125, 300, 400, 600, and 700 feet from the collar (Umpleby, 1910). The principal Mountain Lion vein strikes north and dips 65ºW, the only west-dipping vein in the district. Although the Mountain Lion Gold Mining Co., Inc., built a 100 tpd mill in 1900, it appears the cost of infrastructure, none of which remains today, and low recovery outweighed the economics of the orebody; the mill was not used after 1908 (Weston Solutions, Inc., 2003). The underground operation shut down in 1913, at which time 20,000 tons of ore had been mined at an average grade of 0.24 opt gold and 2.00 opt silver. Considerable additional detail on the Mountain Lion mine's early development is contained in Joseph (1900b).

The property lay idle until 1939 when Knob Hill Mines formed Mountain Lion Consolidated Mines, Inc., as a wholly owned subsidiary and began an open pit operation immediately south of the Mountain Lion shaft to supplement mill feed from the Stewart pit described above. From 1941 to 1945, 30,000 tons of ore were mined, grading 0.116 opt gold and 0.23 opt silver from selvages of highly altered surface rocks as described by Martin (1988): "These selvages in which quartz and sericite have flooded the host, may be wide (in excess of 150 feet) in the upper part of the precious metal horizon, as at the Mountain Lion mine... " (Fig. 14). In places, partially concealed openings of underlying stopes daylight in the pit.

Figure 13. Plugged and abandoned Golden Promise ramp site, 2001. The portal is to the left of the geologist, near the foundation of a former dry house and storage building.

Figure 14. Altered volcanic rock in the Mountain Lion open pit. South Penn pit and roasting kiln are in the center background. View is to the west.

At the South Penn and South Penn Fraction claims, Chemgold, Inc.–Crown Resources mined 33,000 tons of surface ore grading 0.03 opt gold in 1987. The pit is in essence a downslope continuation of the Mountain Lion pit. The altered rocks display a heavy pyrite content (Fig. 15). This is the last known activity at the site as of date of publication.

Tom Thumb mine

This property of six patented claims is the northernmost ore deposit in the Eureka Trend. It is situated near the headwaters of North Fork Granite Creek, about 1.4 miles beyond the Mountain Lion (Appendix C), where the continuation of epithermal hot springs bend around from a north-northwest strike to the northeast. The main vein, about 9 feet wide striking N30ºE and dipping 40ºSE, outcrops on a 200-foot high bench a quarter mile east of the Knob Hill–Trout Creek Road. A complex system of smaller veins runs parallel to the main vein but seldom continues for more than 50 feet. The host rock is Sanpoil Volcanics andesite flow breccia similar to that found in the upper levels of the Knob Hill Mine. And similarly, a series of tuffaceous lake beds overlies the andesite breccia, striking parallel to the vein and dipping in the same direction but at a much lower angle.

Umpleby (1910) reported that prior to 1909 a total of 1600 feet of development work had been done on the Tom Thumb, including three shafts, one of which intersects the vein 365 feet from the collar. A fire in 1938 consumed the entire surface plant. The shaft locations currently exhibit only shallow depressions, indicating that they are either caved near the surface or filled. Three other openings, probably caved adits, and a 50-foot long open cut on the vein were found during DGER site characterization. Aurum reported that the mine was flooded in 1936, which necessitated dewatering prior to leasing (Aurum Mining Co, 1916–1953). Total production was 25,407 tons grading 0.334 opt gold and 1.61 opt silver, most of which was produced in the period 1934 to 1949 (Appendix E).

Figure 15. View of South Penn open pit (foreground) and Mountain Lion pit (upper center) showing heavy pyritization and hydrothermal alteration. View is to the east.

GEOLOGIC SETTING

The Republic/Eureka Gulch deposits are proximal to the Bacon Creek fault forming the westernmost boundary of the Republic graben, a downdropped block 6 to 10 miles wide extending from near the Canadian border south to the Columbia River. Muessig (1967) described the Bacon Creek fault as ". . . a 60 degree, or steeper, east-dipping normal fault with a minimum 19,000 feet vertical offset. It is not mineralized even near mineralized areas such as the Mountain Lion and South Penn deposits proximal to it east of Swamp Creek". The downdropped block of the graben is bounded on the west by Cretaceous granodiorite and on the east by Cretaceous/Tertiary diorite. A portion of Muessig's map pertaining to the Republic mining district is shown in Appendix H.

Within the graben, basement rocks are metamorphosed Permian and Triassic lava flows and sedimentary rocks. Overlying these rocks are, from oldest to youngest, sedimentary and volcanic rocks of the O'Brien Creek Formation (53 Ma), the Sanpoil Volcanics (51 Ma), and the Klondike Mountain Formation (46 Ma), all of Eocene age. The O'Brien Creek Formation consists of reworked tuffaceous sandstones, shales, and conglomerates. It is distinguished from other rocks in the area by detrital quartz, bedding planes, and a distinctive white color. Conglomerates in the formation contain granodiorite and high-grade metamorphic rocks, but no clasts of volcanic origin. Diamond drilling by Hecla has demonstrated that the contact between the O'Brien Creek Formation and the overlying Sanpoil Volcanics is gradational over an interval of at least 100 feet (Tschauder, 1989).

The Sanpoil Volcanics are a thick sequence of andesite, rhyodacite, and quartz-latite lava flows and breccias in the lower and middle sections, and an upper unit of poorly sorted pyroclastic breccias and lithic tuffs. Colors of the flows range from "drab shades of brown, green and purple to black" (Staatz and Pearson, 1990). This upper unit is interpreted as proximal fall-back deposits derived from unidentified vents (Braun, 1989). Although the exact demarcation between the Sanpoil Volcanics and the Klondike Mountain Formation is probably gradational, an angular unconformity of high relief found within the confines of the Republic district has been recognized as a convenient marker representing the upper erosional surface of the Sanpoil Volcanics (Muessig, 1967). In areas where drill holes penetrate the unconformity, silicification and primary gold-silver values are observed to be relatively high compared to background levels at the unconformity and to progressively fade out upward. This data indicates that the unconformity was at or near the paleosurface in the waning stages of mineralization; the onset of debris flows and lake sediments essentially capped existing hydrothermal vents, marking a temporary cessation of regional volcanism (Tschauder, 1989).

Overall, the Klondike Mountain Formation strata consist of a generally coarsening-upward succession of epiclastic sediments overlain by lava flows. Muessig (1967) divided it into three units: the lower Tom Thumb Tuff member consists of basal tuffaceous lake bed sediments and debris flows of chaotic mud-rich matrix-supported conglomerate (the "rubble zone" of Full and Grantham, 1968); the middle member consists of coarse-grained volcanic breccia and volcanic conglomerate, tuffaceous sandstone, and mudstone; the upper member consists of andesite and basalt flows. Sanpoil Volcanic detritus including epithermal vein fragments was found in drill core from the debris flow facies. Mineralizing epithermal solutions penetrated only a few tens of feet into the lowermost Tom Thumb Tuff materials and are not found in any of the middle or upper Klondike Mountain units (Braun, 1989).

The model shown in Figure 2 represents an epithermal precious-metal system of the type found at Republic. This model has many of the features described by earlier studies (Lindgren and Bancroft, 1914; Schmitt, 1950; Eimon, 1979; Hayba and others, 1985). In the model, geometric ore controls vary from a ". . . near-paleosurface disseminated environment consisting of sinter and highly altered silicified rock underlain by a circular to elliptical breccia zone grading downward into a stockwork of chalcedonic veinlets. The area in which the stockwork veins ultimately coalesce is the throttle zone where major gold deposition occurred. This zone produced the highest grade ore of the

system commonly exceeding 1.0 opt gold. Proceeding downward, a large [tightly confined] vein of massive quartz is formed that gradually decreases in width" (Tschauder, 1989). Note: Different investigators have used other terminology for Tschauder's *throttle* zone, most commonly the *bonanza* zone and *boiling* zone. We have chosen to use Tschauder's term for consistency in this report.

"The veins fill steep normal faults. In detail, the highest grade veins exhibit numerous states of filling, fracturing and brecciation, showing that the structures were active at the time of mineralization, and that the mineralization was episodic. Evidence for vein sealing and overpressuring indicate that the upwelling thermal fluids flashed intermittently in open space structures, resulting in metal precipitation" (Braun, 1989).

The Knob Hill, Golden Promise, and Gold Dollar deposits are examples of intact epithermal systems reflecting most, if not all, of the attributes of the model. However, Quaternary glaciation has truncated vein outcrops at the other mines in the district to a greater or lesser extent and that, in addition to the effects of post-mineral faulting, makes it difficult to determine their present placement within the model. By comparing silver:gold ratios, tenor, and other characteristics versus the model, Braun (1989) placed mineralization at the Republic mine at about the mid to lower throttle zone where values decreased to sub-economic grades in massive quartz veining about 550 feet below the discovery glory hole. "Other mines where the vein was exposed to this zone include the Ben Hur, San Poil, Pearl and Surprise. The high-grade Bailey orebody [part of the Knob Hill] is a special case where erosion exposed the vein to the throttle zone, but the deposit was covered by stream and glacial deposits until its discovery in 1984. The Quilp and Last Chance mines were exposed to the stockwork zone and had relatively long histories of production, extending to good depth. The Knob Hill and Mountain Lion deposits were exposed at the sinter level" (Braun, 1989).

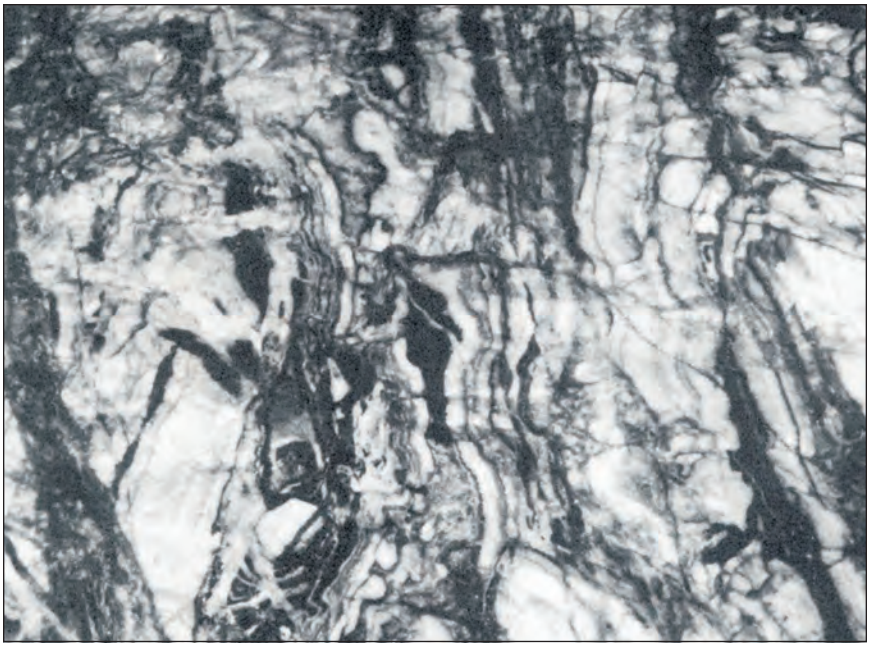

Figure 16. Colloform-banded chalcedonic veining in the Golden Promise mine. Dark bands contain most of the gold mineralization and metal sulfides. Area shown is 2 feet by 4 feet. (Reprinted from Derkey, 1996.)

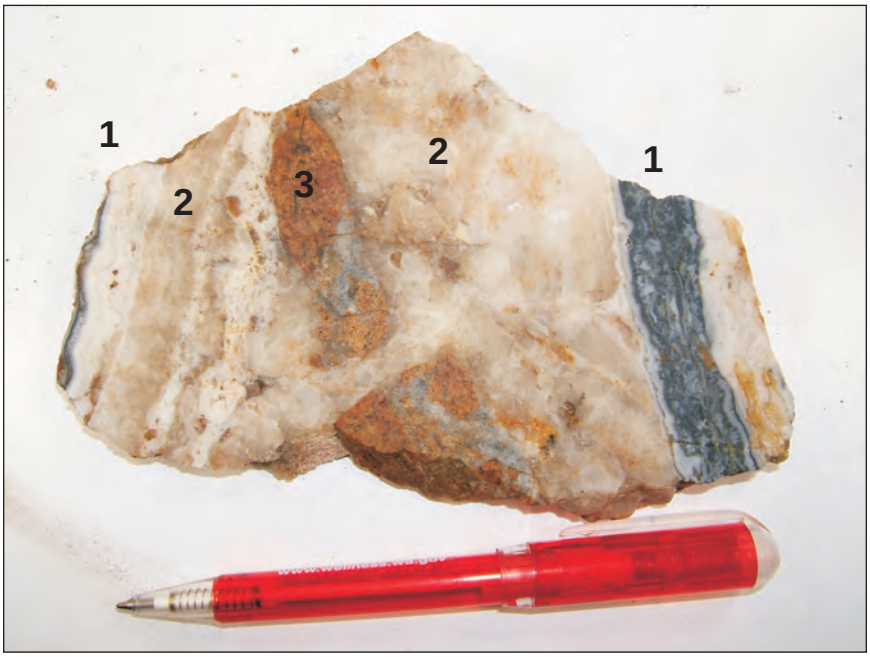

Figure 17. A portion of the Ben Hur outcrop showing colloform banding (1), calcite infusion (2), and host rock inclusions (3).

Mineralogy

When the Republic mining district is viewed as a whole, ore grade mineralization occurred from the lake bed sequence at the base of the Klondike Mountain Formation to a maximum depth of about 1600 feet on the Gold Dollar claim, however most ore bodies in the district exhibit a more restricted vertical range. Braun (1989) reported that major veins persist below this depth but values fall below 0.25 opt gold. Vein filling with colloform black and white chalcedonic banding is ubiquitous throughout the district (Fig. 16). It commonly displays tightly recumbent folding, host rock inclusions, and varying degrees of calcite infusion (Fig. 17).

The black-banded chalcedony has been attributed in some investigations to masses of intermixed sulfides and precious metals, usually an indicator of high grade ore. This is universally true within the model's throttle zone, however similar coloration can be found elsewhere in the district above and below the throttle zone where sulfides and precious metals are substantially absent. We believe the banding in this latter instance is caused by light scattering of microscopic porosity that appears black under ordinary light (J. Dragovich, DGER, oral commun., 2009). George Mustoe's (Western Wash. Univ., written com-

mun., 2009) examination of the black banding shown in Figure 17 found that silica was the overwhelming phase present.

Chalcedony, quartz, and calcite are the major gangue minerals. The ores are selenium-rich and tellurium-deficient. Scanning Electron Microprobe (SEM) and ore microscopy analyses have identified the following ore minerals listed in approximately decreasing order of abundance: pyrite (FeS_2), naumannite (Ag_2Se), chalcopyrite ($CuFeS_2$), galena (PbS), clausthalite (PbSe), sphalerite (ZnS), electrum–native gold (Au–Ag), argentian tetrahedrite ($(Ag,Cu,Fe,Zn)_{12}Sb_4S_{13}$), seleniferous stephanite ($Ag_5Sb[S,Se]_4$), proustite–pyragyrite (Ag_3AsS_3–As_3SbS_3), calaverite ($AuTe_2$), and native silver (Ag) (Taylor, 1968).

The ore minerals occur as micron-sized disseminations and, alternatively, as massive agglomerations of sulfides co-deposited with native gold and electrum, depending on vertical placement in the epithermal system. SEM photographs of both types are shown in Appendix G (Mustoe, written commun., 2009).

Structure

The Eureka fault is the primary mine-related structural feature in the district (Fig. 1). It is one of several northwest-striking, northeast-dipping steep normal faults that . . . "host many of the major veins of the district, including the No. 3 and Alpine [Knob Hill], San Poil, Ben-Hur, Black Tail, Surprise, and Quilp. The veins exhibit a complex history of faulting and re-sealing. Most veins exhibit post-mineral shearing" (Braun, 1989). To the north, the Eureka fault ends on the Gold Dollar claim, where it makes a right-angle intersection with the Knob Hill No. 3 vein at a depth of 800 feet. Diamond drilling and surface mapping by Hecla failed to disclose a continuation of the Eureka fault to the north.

The south end of the continuously mineralized Eureka fault occurs at the Quilp mine, where it is terminated by a strong northeast-trending shear zone, the Hermes fault. Braun (1989) stated, "The Hermes [in the Quilp vicinity] . . . has both pre- and post-mineral displacement and acted to either displace or terminate the mineralization." This fault is buried under alluvium immediately south of the mine, but another major fault, Muessig's "Republic Fault", is observed crossing Granite Creek several hundred feet east of the Republic mine and may represent the southern extension of the Eureka fault (Fig. 1 and Appendix H).

"Northeast-striking, southeast-dipping faults provided production from the Last Chance, Lone Pine, and Golden Promise veins, however not all northeast-striking faults are mineralized indicating they are both pre- and post-mineral. The faults are normal and of small displacement. In the Republic mining district they displace the Eureka fault in places and are prevalent up to 800 feet east of it at the Golden Promise mine" (Braun, 1989).

Zoning

Trace element zoning is common in epithermal precious metal systems, in particular the silver:gold ratio as a function of depth. Martin's (1988) thesis on the geochemistry of wall rocks and veins in the Republic mining district presents a good discussion of this phenomenon, specifically with regard to the manner in which changes in pH, brought on by rapid pressure release and subsequent boiling, determines the relative placement of metals and sulfides in hydrothermal fluids (Martin, 1988, p. 76-80).

Braun (1989) examined 100 samples taken at varying depths from veins across the district at a time when access was still possible and from numerous production assays within the Knob Hill mine. The purpose of the sampling was to determine what, if any, conclusions might be drawn regarding the effect of vertical zoning on: (1) gold tenor (2) silver:gold ratios, and (3) trace elements, as indicators of vertical placement within an intact hot-springs system. The results were analyzed using standard statistical methods for analysis of variance (ANOVA). A compilation of the sampling program results is shown in Table 1 with regard to the epithermal model.

The sampling data exhibit good agreement with the model as erratic values within the stockwork veins grade downward and reach a peak in the throttle zone; silver:gold ratios decrease with depth away from the throttle zone and values reach cutoff grade as a massive white quartz vein forms at a depth of approximately 1500 feet.

Braun (1989) studied trace elements to determine if they exhibit strong vertical gradients as do silver and gold. Each of the above samples were analyzed for gold, silver, copper, molybdenum, zinc, fluorine, arsenic, tellurium, thallium, selenium antimony, barium, and tungsten. The data found that molybdenum, and to a lesser degree, copper and tellurium increase with depth in the district. Molybdenum in particular showed a strong consistent increase of about 3X from 900 to 1500 feet. Arsenic and antimony exhibited consistent and well-defined decrease with depth, making them good predictors of vertical depth in the vein system at any one point. None of the trace elements showed correlation with increased gold mineralization. Braun concluded that within the Republic district, the best elemental indicator for gold was gold and compared to other epithermal deposits, such as at Bodie (California) and Sleeper (Nevada)—even though the mineral suites are almost identical—trace element zoning failed to follow the same increasing or decreasing patterns with depth.

Table 1. Vertical zoning of gold and silver in Republic district mines (modified from Braun, 1989).

Depth	Epithermal model zone	Ore characteristics	Gold tenor (opt)	Ag:Au ratio
0	sinter (paleosurface)	stratiform; disseminated mineralization in gray chalcedonic breccias and tuffaceous lake bed sediments, and highly altered volcanics	0.03–0.20	low
300	stockwork veins	numerous veinlets; banded chalcedony; minor silica wall-rock replacements	erratic	erratic
600	upper throttle zone	gray and white banded chalcedony; moderate-grade vein deposits	0.30–0.50	9–14
900	throttle zone	dark gray to black banded chalcedony, mixed with black sulfide banding; visible electrum and native gold	>1.0	5–8
1200	lower throttle zone	weak colloform banding; lower-grade vein deposits	0.30–0.50	2–5
1500–1600	main vein	massive; white quartz; strong silica replacement of wall rocks	<0.25	<2

OPENINGS

All the mines in the Republic mining district present significant physical hazards of one kind or another ranging from near-vertical open stopes to concealed openings, some of which are indicated by surface subsidence. All locations should be considered private property. The GPS locations of those openings found during DGER site characterizations are shown in Table 3 below.

MATERIALS AND STRUCTURES

Essentially all of the historic infrastructure—steam plants, hoists, mills, headframes, trestles, and rail line across and through Eureka Gulch—has been salvaged or burned. At Knob Hill, only a few shop buildings and the mill foundations remain (Fig. 18). The cage used at the circular Golden Promise men-and-materials shaft lies on an access road northeast of the mine (Fig. 19).

Figure 18. Hecla's Knob Hill mine site 2001, showing mill foundations (1), shop buildings (2), circa-1920 adits on Knob Hill (3). View is to the north.

Figure 19. Men and materials cage and equipment used in the Golden Promise vertical shaft, 1986–1995.

WATER

Historic data and recent observations indicate that all the mines discussed are flooded to some degree (Patty, 1921). Pumping by Hecla from the Golden Promise has kept the water level at an elevation approximately 135 feet above the 11-level (P. Hallinan, DOE, oral commun., 2009).

None of the mine openings discharged water at the time of DGER site characterizations. Raforth and others (2000) took water samples during high and low flow seasons in three streams proximal to the Republic mining district: Swamp Creek (North Fork Granite Creek) at a point 2 miles north of its crossing of SR 20; Eureka Creek, a tributary to Granite Creek, at a point near the north Republic city limits; Granite Creek main stem (Fig. 20). In this study, the Swamp Creek station was ". . . considered a representative site for background or upstream water quality, and the concentrations of most general chemistry parameters decrease downstream to the site on Granite Creek. By contrast . . . higher levels of most constituents occur in Eureka Creek. The nitrate/nitrite result for Eureka Creek during high flow, 1.6 mg/L, was the highest detected in any stream during the project . . . . Cyanide was not detected in any samples. Zinc, arsenic, copper and mercury were substantially higher in Eureka Creek." Although the level of arsenic concentration in Eureka Creek of 14 to 15 µg/L was below the chronic standard for effects to aquatic life in surface water (WAC 173-201A) (see Table 7), the level does exceed the new standard for ground water established in 2006 (WAC 246-290). None of the other metal analytes exceeded Washington State standards at the three locations sampled.

Water quality in Eureka Creek is unquestionably impacted by the numerous mines and mineralization along its course upgradient from Republic. In July 1941, a curtain of tailings slurry inundated Eureka Gulch to a depth of several feet after a 1200 x 50-foot section of the Knob Hill impoundment No. 1 dam failed. The material plugged a culvert on SR 20, overflowed the highway, and continued down Granite Creek into the Sanpoil River (*Spokesman Review*, 7/12/1941). Most of the present Eureka Creek flood plain was deposited in this event, bringing with it residual blasting agents that may have contributed to the high nitrate content observed in Eureka Creek.

MILLING OPERATIONS

Circa-1900s cyanide-based concentrating mills in the Republic district were mostly unsuccessful, with recoveries of 40 to 50 percent of assay values commonplace. Most had failed by 1915. Twenty-two years later, after advancements in mineral dressing of disseminated ores had come to fruition—in particular, the combination of flotation used in conjunction with cyanidation and grinding to -150 mesh—the Knob Hill mill achieved recoveries of 85 percent and above. A key factor limiting the early mills' output was the fine particle size of the gold/silver and sulfide fractions in Republic ores. Sulfide and precious metal particles in the range 0.5 to 25 microns in diameter are commonplace (Mustoe, written commun., 2009). (See Appendix G, Fig. G2.) Liberation of these particles largely exceeded the capability of circa-1900 grinding equipment. "Research on refractory gold ores in many parts of the world has shown that submicroscopic gold is one of the main factors in low recovery, which may be the case in the Republic/Eureka Gulch deposit" (Vaughan, 2004). "While submicroscopic gold is the most common cause of refractory behavior in ores, it is not the only cause. Gold ores that contain even moderate levels of tellurium and selenium . . . or very fine grained inclusions of native gold in sulfides, are often refractory" (Nekrasov, 1996). "These two elements are common constituents of epithermal gold deposits, often forming reaction rims around naumannite (Ag_2Se) and calaverite ($AuTe_2$) as thin as 4–6 microns that fail to dissolve in cyanide solutions" (Vaughan, 2004).

Additionally, these early mills relied on steam power out of necessity, a fact which not only obviated the use of evolving and efficient electrical equipment, but required construction of flues, smokestacks, boilers, and at the Republic mine, a cordwood supply flume 5 miles long (Umpleby, 1910). Battien (1998) reported that the first reliable hydroelectric power for the Republic area didn't arrive until 1937 when the Republic Power and Light Co. Inc. constructed 40 miles of transmission line from Tonasket to serve the new Knob Hill mill.

To a great extent, milling as a means of achieving profitable returns on non-bonanza-grade ore was largely eclipsed in 1902 with the arrival of two railways, the Republic and Kettle River line (a branch of the Canadian Pacific Railway) and the Great Northern Railway. This change enabled direct shipment of mine output to base-metal smelters for the gold-bearing high-silica flux required at Trail and Granby, B.C., and Tacoma. This turn of events helped but did not solve the underlying problem of low mill recovery, since the smelter's demand for Republic silica flux waxed and waned depending on the tonnage of lead, zinc, or copper ore to be processed. However, this capability eliminated the circuitous, often impassable, 80-mile overland trail route to the railhead at Marcus, Wash., and became a prime mover in the years leading up to and including World War II.

Patsy Clark mill

The Republic mine hosted three mills at various points in time, all of which were situated on the west bank of Granite Creek. Republic Gold Mining and Milling Co., Inc. constructed the first in 1897 (Appendix F, Fig. F1). The cyanide-based Pelatan-Clerici process used in the mill recovered less than half the gold/silver content. The tailings were deposited in Granite Creek and on its flood plain. The mill's capacity of 30 tpd was overwhelmed by the mine's production at the time of about 100 tpd, leading to its replacement the following year with the "Red" mill funded by the mine's new owners, Republic Consolidated Gold Mining Co., Inc. (Umpleby, 1910).

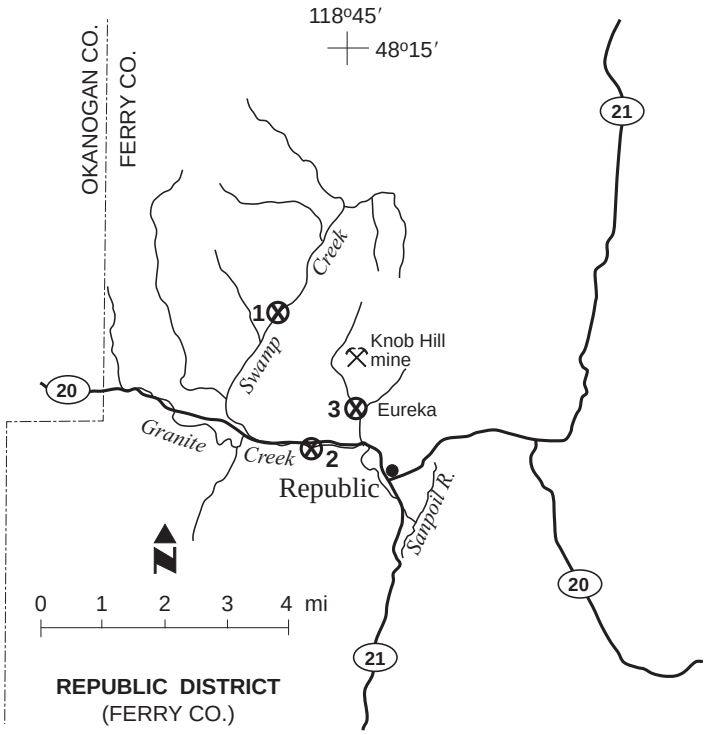

Figure 20. Location of water and sediment samples collected in Swamp, Granite, and Eureka Creeks. (Reprinted from Raforth and others, 2000.)

Red mill

D. C. Jackling designed the Republic mine's second mill—a $350,000, seven-level structure with an added roasting floor to render sulfides more amenable to cyanidation. The massive building stood directly above the Clark mill (Appendix F, Fig. F2). It had a targeted capacity of 200 tpd—100 tpd from the mine and 100 tpd of custom ore. The mill's crushers were located about 65 feet above the main haulage tunnel (level 4), an awkward situation that necessitated transferring ore from a sampling/assay building at the adit via an inclined 400-foot skip-tram to the mill. Power for the mill was generated by six 5- by 16-foot boilers of 500 horsepower capacity. A small refinery on the lowest level cast 90 percent gold/10 percent silver bars.

The Red mill's only throughput until 1937 was about 37,000 tons—lasting only nine months from October 1900 through July 1901. Poor recovery followed the new mill's process as well, hastening its failure, which was accelerated by a significant decline in the mine's ore reserves and the fact that the anticipated supply of custom ore never materialized. Ferry County held a forced sale on the property for unpaid taxes soon after the property failed. The New Republic Co., Inc., reinstated operations for two years starting in 1909, after which the mine again passed into receivership (Bancroft, 1914; Norman, 1918).

The record indicates that the Red mill last operated during the period that Eureka Mining milled an unknown quantity of

ore from the Quilp mine in early 1937. A trade journal article reports that the mill was used only a few months in 1938 (*Mining Journal*, 10/30/1938). Nothing remains on the site except the foundations (Fig. 21).

Figure 21. Part of the Red mill foundation at the Republic mine site. Notebook in lower right for scale. View is to the east.

Rathfon Reduction Co. mill

A local resident, D. W. Rathfon, took the Republic mine and mill out of receivership in 1913 and continued a limited 50 tpd production from the mine and re-processed the Clark mill tailings using a batch, straight-leach cyanide process. The exact location of this mill is unknown—it was possibly housed in the Red mill's sampling building. The operation reported shipments valued at $8000 in 1917 (Norman, 1918).

Knob Hill mill

The 400 tpd cyanide mill erected by Knob Hill Mines in 1937 operated continuously until closure in 1995 (Appendix F, Fig. F4). Addition of the flotation circuitry in 1940 increased recovery to 90 percent through the capture of gold- and silver-bearing sulfides (*Mining Journal*, Nov. 1941). Other additions and improvements to the mill were made by Knob Hill Mines, Day Mines, and Hecla (DGER mine file). Hecla dismantled the mill in 1996.

North Washington Power and Reduction mill

The New Republic Mining Company, Inc., built this mill in 1911 in conjunction with an unidentified early power company. The business plan was based on milling 250 tpd of ore via two modules of 125 tpd capacity each. Power for the mill was to be supplied by an electrical transmission line from a dam on the Similkameen River, but the power company failed to build the line and the mill reverted to steam. It was historically known as the 'White' mill. The single 125 tpd module activated during operations in 1911 and 1912 met with only limited success, and the mill passed into the hands of a receiver in 1913. The total amount of ore milled is unknown, but small. The mill was located on a spur of the Great Northern Railway upland from the west bank of Granite Creek, about a quarter mile northwest of the Red mill (*Mining and Engineering World*, 7/6/1912). From observations on aerial photographs, we believe the site is located at the GPS coordinates shown in Table 3. (See also Appendix C, Fig. C1).

Mountain Lion mill

The flow sheet for this 100 tpd mill utilized amalgamation plates to capture free gold, followed by straight cyanide leaching. It was located on a west-facing slope near Swamp Creek, about 400 feet below the shaft (Appendix F, Fig. F5). One of the first steam-fired 3-phase electrical generators powered the hoist, mill pumps, and lighting. The stamp-mill primary crushers in use achieved a -30 mesh (0.023 inch opening), which ultimately proved to be several orders of magnitude too coarse for liberation of the ore's finely divided precious metals. The mill operated for eight months in 1900, achieving only 55 percent recovery on a throughput of about 12,000 tons of ore. Attempts in 1903 and later to improve recovery with finer grinding met with limited success (P. Woodhouse, Northwest Underground Explorers, written commun., 2008). The mill fell into disuse in 1908.

San Poil mill

San Poil Consolidated Mining Co. erected a 125 tpd cyanide plant in June 1912. In contrast to the experience of other early mills in the district, a trade journal reported that at the San Poil mill's first production run " . . . everything was found to be in perfect alignment and worked smoothly" (*Mining and Engineering World*, 7/6/1912). The mill was located opposite the mine's main haulageway (Appendix F, Fig. F3). A bond holder's syndicate operated the mill successfully from 1913 through 1915, achieving 85 percent precious metals recovery by grinding to 94 percent -200 mesh screens and using a strong (7%) cyanide solution (Morse, 1914). The San Poil mill custom-milled all the pre-1915 Ben Hur and Knob Hill mines' production of milling grade ore. It appears that ore reserves and grade were insufficient to maintain production, and the receivers abandoned the property in 1916. Total throughput treated at the mill cannot be determined from available sources because production at all the source mines was split between direct-ship and milling-grade ore, but the low tonnage produced by the San Poil mine itself indicates that custom ore accounted for most of the mill's throughput. Aurum records indicate that leasers reworked some San Poil waste rock dumps and/or tailings in the late 1930s (Aurum Mining Co, 1916–1953).

Reconstruction in Eureka Gulch transposed the Knob Hill Road from the east side of Eureka Creek to the west side, an operation that removed all the infrastructure, stockpiled ore, waste rock and tailings shown in front of the mill in Figure F3. Today the San Poil mill foundations lie immediately above the shoulder of the Knob Hill Road at the intersection of the Knob Hill East road (Fig. 22).

TAILINGS AND WASTE ROCK DUMPS

Below the Red mill, tailings form a 15-foot cut bank on the west side of Granite Creek. Yellow, blue, and pink tailings (youngest to oldest) appear to represent different states of oxidation resulting from changes in ownership and changes in milling processes (Figs. 23 and 24). The blue fraction is a thin (2-inch) seam that does not appear to represent any significant volume of material. DGER analyzed these three materials for arsenic, copper, iron, lead, and zinc. Arsenic levels in all samples exceeded Washington State standards for unrestricted use (see Tables 4 and 5), by many levels of magnitude, and one sample exceeded the zinc standard.

At the Knob Hill Mine, Hecla has filled and revegetated tailings impoundments No. 1 and No. 2. The third impoundment, Aspen Pond, covers approximately 38 acres to a depth of 70 feet and is situated about 1500 feet north of the mill site. It was used from the early 1950s until 1995. The tailings ponds are currently undergoing reclamation by Hecla, with oversight by the Environmental Protection Agency (EPA) and Washington Department of Ecology (DOE). Altogether the Knob Hill mill tailings comprise approximately 2.2 million tons. Monitoring wells indicate that "seepage from the Aspen Pond tailings are not impacting groundwater quality" (Ecology and Environment, 2001).

Tailings from the circa-1900 mill runs at the Mountain Lion mine are very coarse, highly oxidized, and occupy a west-facing dump site a few tens of feet below the mill foundations (Fig. 25). Analyses of arsenic, chromium, and selenium in a grab sample of this material taken by DGER exceeded Washington State Model Toxic Control Act (MTCA) standards for unrestricted use (Tables 4 and 5). The silver content in this sample equates to 0.05 opt. Tailings from the post-1902 mill runs are spread out across the flood plain of Swamp Creek, forming a dense bramble-covered bog (Fig. 26). They consist of bleached, sand-sized particles admixed with chips of vein material and development waste rock from the water-level main adit shown in Appendix F, Figure F5. Analyses of antimony, arsenic, and selenium in a grab sample of this material taken by DGER exceeded Washington State MTCA standards for unrestricted land use (see Tables 4 and 5). The silver content in this sample equates to 1.1 opt. Some Mountain Lion tailings, averaging 0.10 opt gold and 1.34 opt silver, were excavated and trucked to the Knob Hill mill in 1938 (Aurum Mining Co, 1916–1953). It is impossible to estimate the volume of tailings due to their reworked and scattered nature. Based on the reported mine production of 12,000 tons, the present tailings volume could be as much as 9000 cubic yards, depending on the amount reclaimed.

Figure 22. San Poil mill location. Geologist (in red) stands on lower floor. View is to the west.

Figure 23. Overview of mill tailings at the Republic mine site. Granite Creek flows top right to bottom. Cropped detail shown in Figure 24 is outlined in black. View is to the northwest.

Samples of waste rock dumps taken by Weston Solutions, Inc. (2003), at the Quilp and Ben Hur mines showed levels of arsenic and selenium that exceeded Washington State standards for unrestricted land use by several orders of magnitude (Tables 4 and 5).

GENERAL INFORMATION

Alternate Names: Republic: Blaine-Republic, Quilp: Imperator, Eureka

MAS/MILS sequence number: see Table 2

Figure 24. Tailings on Granite Creek flood plain sample site: (1) yellow fraction (youngest), (2) blue fraction seam, not visible in photo, (3) pink fraction (oldest).

Figure 25. Coarse mill tailings at the Mountain Lion mill sample site. View is to the west.

Access: two-wheel drive

Status of mining activity: none; potential exploration work

Claim status: All the claims shown in Appendix D are patented. Contact the Ferry County Assessor for mineral survey numbers and current ownership. Hecla Mining Co., Coeur d'Alene, Idaho, and Vaagen Bros. Logging Co., Colville, Wash., are the major landholders.

Surrounding land status: Bureau of Land Management and private

Location and map information: All mines in the Republic mining district are located in Ferry County, in the Republic 1:100,000 quadrangle, and either the Republic or Storm King Mountain 1:24,000 quadrangle.

Directions: 34 airline miles west of Northport, Wash., on State Route 20

MINE OPERATIONS DATA

Type of mine: underground, surface

Commodities mined: gold, silver; minor lead, zinc, copper

Geologic setting: epithermal quartz fissure veins, mineralized pyroclastic rocks and tuffaceous lakebed sediments; O'Brien Creek Formation, Sanpoil Volcanics, Klondike Mountain Formation, all of Eocene age (Muessig, 1967)

Ore minerals: auriferous pyrite (FeS_2), naumannite (Ag_2Se), chalcopyrite ($CuFeS_2$), galena (PbS), clausthalite (PbSe), sphalerite (ZnS), electrum (Au–Ag), native gold (Au), argentian tetrahedrite ($\{Ag,Cu,Fe,Zn\}_{12}Sb_4S_{13}$), seleniferous stephanite ($Ag_5Sb[S,Se]_4$), proustite-pyragyrite (Ag_3AsS_3–As_3SbS_3), calaverite ($AuTe_2$), and native silver (Ag) (Taylor, 1968)

Non-ore minerals: quartz, calcite, pyrite

Host rocks: andesite, latite porphyry, tuff, debris flows, breccia, pyroclastic conglomerate

Period of production: varying periods per mine; the Republic mining district, 1896–1995 (Appendix E)

Development: >50,000 feet

Production: see Appendix E

Mill data: see above discussion

PHYSICAL ATTRIBUTES

Features: see Table 3

Materials: scrap metal

Machinery: shaft cage (Golden Promise); roasting kiln (South Penn)

Structures: accessory buildings at Knob Hill Mine

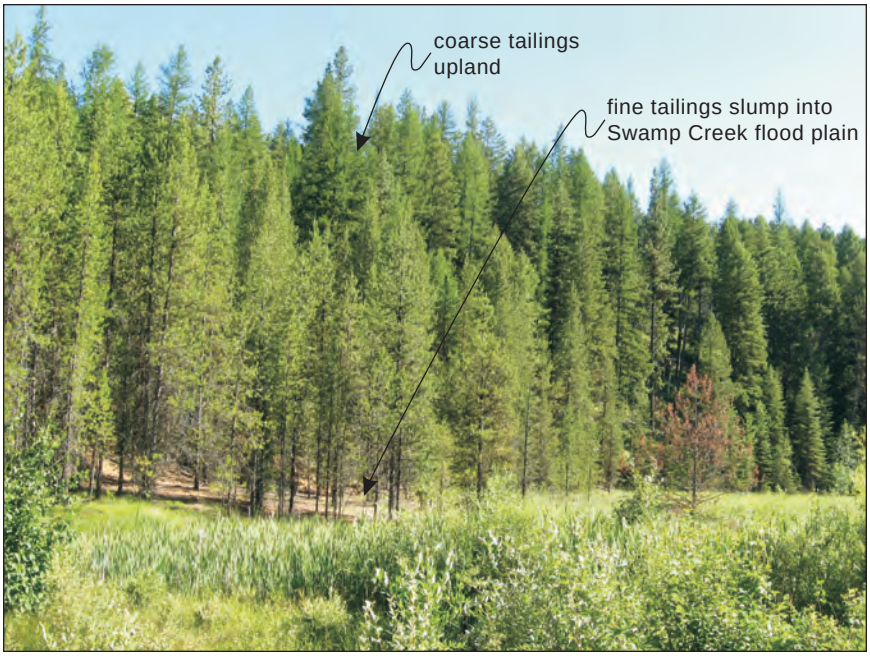

Figure 26. Fine tailings slumping into bog at Swamp Creek, Mountain Lion sample site. View is to the east.

Table 2. MAS/MILS sequence number. – – –, no data.

Republic	– – –	South Penn	0530-190109
Quilp	0530-650297	Knob Hill	0530-190084
Lone Pine	0530-470057	Golden Promise	0530-190471
Surprise	0530-190112	Tom Thumb	0530-190113
Last Chance	0530-190085	Mountain Lion	0530-190090
San Poil	0530-190103	Ben Hur	0530-190059

Waste rock dumps, tailings impoundments, highwalls, or pit walls: see discussion above

Analysis of waste rock dumps: none

Waste rock, tailings, or dumps in excess of 500 cubic yards: all except Tom Thumb, and San Poil

Reclamation activity: some open stopes covered, fenced, or dozed shut; natural revegetation; most pre-1940 tailings and dumps have been reworked

Soil Analysis: see Table 4

VEGETATION

Noxious Weeds: skeleton leaf toadgrass, diffuse and spotted knapweed, puncture vine, toadflax, Canada thistle.

Wildflowers: penstemon, Nootka rose, lupine, aster, black-eyed susan.

Trees: lodgepole pine, Douglas fir, larch.

WILDLIFE

Coyote, bull snake.

WATER QUALITY

Surface waters observed: Granite Creek, Eureka Creek, Swamp Creek (North Fork Granite Creek)

Proximity to surface waters: zero to several hundred feet

Domestic use: grazing

Acid mine drainage: none

Water field data: see Table 6

Surface water migration: runoff from the Republic mine property enters Granite Creek; runoff from the Tom Thumb, Mountain Lion, and South Penn properties enters Swamp Creek; all other mines named above drain into Eureka Creek.

Surface Water Analysis: see Table 7

ACKNOWLEDGMENTS

The authors thank our editor Jari Roloff for helpful suggestions on the layout and content of this report and Lee Walkling, DGER librarian, for research assistance. Additional appreciation goes to George Mustoe, Western Wash. Univ. Geology Department, for specific contributions to the mineralogy of the Republic ores and to Bob Raforth, Washington Department of Ecology, for comments on the water quality and sampling as described above. Lane Griffin, consulting geologist, donated an important sample of ore from the Knob Hill Mine. Julie Monroe at the University of Idaho Special Collections library provided important information from the Aurum Mining Co. (Day Mines Inc.) manuscript files. Tom Salzer, Technical Services Manager at the Washington State Conservation Commission, contributed valuable material regarding the geology of the Golden Promise and Knob Hill mines.

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Table 3. Mine features. – – –, no data; N/A, not applicable; *, combined area of all tailings ~2 acres, unknown thickness.

Mine	Description	Fenced	Length (feet)	Width (feet)	Height/depth (feet)	True bearing	Elev. (feet)	Decimal latitude	Decimal longitude
Republic	yellow tailings	no	*	*	*	N/A	2320	48.63748	118.73409
	blue tailings	no	*	*	*	N/A	2320	48.63781	118.73528
	pink tailings	no	*	*	*	N/A	2320	48.63796	118.73685
	adit	caved	– – –	– – –	– – –	– – –	2800	48.63839	118.74431
	adit	caved	– – –	– – –	– – –	– – –	2840	48.63605	118.74672
	adit	caved	– – –	– – –	– – –	– – –	2880	48.63783	118.74711
	mineral survey 364 cor 1	N/A	N/A	N/A	N/A	N/A	2836	48.63569	118.74506
	mineral survey 418 cor 4	N/A	N/A	N/A	N/A	N/A	2842	48.63594	118.74504
	open stope/outcrop	no	50	35	>200	N35E	2920	48.63653	118.74636
	glory hole with subsidence	no	200	100	10	N/A	2990	48.63796	118.74621
	Red mill	no	300	300	65	N/A	2500	48.63651	118.73694
	Clark mill	razed	N/A	N/A	N/A	N/A	2304	48.6369	118.7326
	White mill	razed	N/A	N/A	N/A	N/A	2304	48.6403	118.7397
Quilp	mine site	no	– – –	– – –	– – –	N/A	2800	48.65929	118.74833
	historic openings	closed	– – –	– – –	– – –	– – –	2800	48.65920	118.74719
Lone Pine/Black Tail	open stope	yes	– – –	– – –	– – –	– – –	2880	48.66451	118.74875
	shaft, caved	no	– – –	– – –	– – –	N/A	3050	48.66591	118.75003
Surprise	concrete foundation and shaft	no	– – –	– – –	– – –	N/A	2800	48.66063	118.74991
	adit, caved	closed	– – –	– – –	– – –	N/A	2840	48.66328	118.74982
Pearl	footings					N/A	2800	48.66222	118.74972
San Poil	adit reclaimed	closed	– – –	– – –	– – –		3130	48.66512	118.75656
	mill site foundation	no	– – –	– – –	– – –	N/A	2870	48.66628	118.75350
Ben Hur	concrete pad and hoist foundation	no	300	200	N/A	N/A	3080	48.66793	118.75849
	adit	open	>200	5	7	S38E	3010	48.66597	118.75578
Golden Promise	decline site	closed	13*	11*	1300*	N/A	2844	48.65929	118.74833
Knob Hill	mine and mill site	shaft(s) closed, mill razed	– – –	– – –	– – –	N/A	2970	48.67140	118.75357
	aspen tailings pond	yes	1650	930	– – –	N/A	3113	48.67564	118.75523
South Penn	open pit entrance	no	200	200	– – –	N/A	2965	48.67822	118.77126
	piezometer	no	– – –	– – –	– – –	N/A	2837	48.69965	118.75285
Mountain Lion	shaft	caved	16*	8*	700*	N/A	3080	48.67974	118.76711
	mill site	razed	N/A	N/A	N/A	N/A	2908	48.68034	118.77056
	adit	caved	1260*	6*	8*	S40E	2878	48.68087	118.77056
	upland tailings/dump	no	N/A	N/A	N/A	N/A	2839	48.68111	118.77072
	Swamp Creek tailings	no	N/A	N/A	N/A	N/A	2820	48.68106	118.77072
Tom Thumb	three caved shafts	no	5*	5*	≤365*	N/A	3060	48.70005	118.75241

Table 4. Soil Analysis. Metal concentrations are mg/kg. – – –, no data; *, data from Hart Crowser, 2006a,b; **; safe concentration limits have not been established. Analyses in bold indicate levels that exceed one or more standards shown in Table 5.

Metal	Republic yellow	Republic blue	Republic pink	Ben Hur dump* WR1-S1	Quilp dump* WR1-S2	Mountain Lion coarse upland	Mountain Lion Swamp Creek flood plain
Sb**: Antimony	– – –	– – –	– – –	3.81	4.28	14	88
As+3: Arsenic	**130**	**330**	**110**	**361**	**993**	**370**	**440**
Be: Beryllium	– – –	– – –	– – –	0.22	0.77	1.2	0.32
Cd: Cadmium	– – –	– – –	– – –	0.05	0.43	0.34	0.19
Cr: Chromium	– – –	– – –	– – –	32.9	22.4	**54**	37
Cu: Copper	18	51	8.8	19.1	62.1	19	21
Fe**: Iron	16,000	37,000	7,000	– – –	– – –	– – –	– – –
Hg: Mercury	– – –	– – –	– – –	0.147	0.53	0.13	1.1
Pb: Lead	29	27	18	14.2	30.5	23	21
Ni: Nickel	– – –	– – –	– – –	3.63	22.7	16	7.2
Se: Selenium	– – –	– – –	– – –	**6.3**	**11.3**	**2.0**	**10**
Ag**: Silver	– – –	– – –	– – –	13.4	64.9	1.2	37
Tl**: Thallium	– – –	– – –	– – –	1.25	0.38	0.25	1.2
Zn: Zinc	24	**760**	200	15.8	108	100	36

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Table 5. Soil quality standards for unrestricted land use. WAC 173-340-900, Model Toxics Control Act, Table 749-2, Priority contaminants of ecological concern for sites that qualify for the simplified terrestrial ecological evaluation procedure (partial data). Concentrations are mg/kg. *, inorganic; **, safe concentrations have not been established.

Metals/Land Use	As^{+3}	Be	Cd	Cr	Cu	Hg*	Pb	Ni	Se	Zn
Unrestricted land use	20	25	25	42	100	9	220	100	0.8	270
Industrial or commercial use	20	**	36	135	500	9	220	1850	0.8	570

Table 6. Surface water field data (Raforth and others, 2000).

Description	Flow (cfs)	Conductivity (μS/cm)	$NO_3 + NO_2$ (mg/L)	pH	Hardness	Temp. (°C)
Swamp Creek site (high flow)	7.2	149	0.28	6.9	64	11.0
Swamp Creek site (low flow)	0.26	388	– – –	7.4	178	8.7
Granite Creek site (high flow)	51	162	0.34	7.5	67	9.5
Granite Creek site (low flow)	6.3	263	– – –	7.9	115	5.9
Eureka Creek site (high flow)	1.2	908	1.6	7.2	390	10.2
Eureka Creek site (low flow)	0.2	1208	– – –	7.8	568	8.2

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Table 7. Surface water analysis. Metal concentrations are in micrograms/liter (μg/L); hardness is in milligrams/liter (mg/L). USEPA, U.S. Environmental Protection Agency; – – –, no data; *, standards for these metals are hardness dependent; ≤, indicates metal was not detected—the number following is the practical quantitation limit above which results are accurate for the particular analysis method—the metal could be present in any concentration up to that limit and not be detected. Conversion formulae are shown in http://www.ecy.wa.gov/pubs/wac173201a.pdf. Standards calculated for hardness values specific to Part 1 below are shown in Appendix B.

PART 1: ANALYSIS BY USEPA METHOD 6020, INDUCTIVELY COUPLED PLASMA/MASS SPECTROMETRY

Sample location	Arsenic	Cadmium*	Copper*	Iron	Lead*	Mercury	Zinc*	Hardness
Swamp Creek site (high flow)	1.5	0.11	1.7	894	0.11	0.0053	2.8	64
Swamp Creek site (low flow)	3.5	≤0.02	1.1	– – –	0.023	0.0028	4.9	178
Granite Creek site (high flow)	2.4	0.01	1.9	520	0.12	0.0054	3.3	67
Granite Creek site (low flow)	2.0	≤0.02	0.82	– – –	0.32	0.0020	1.6	115
Eureka Creek site (high flow)	14.0	≤0.10	4.6	242	0.14	0.0091	18.0	390
Eureka Creek site (low flow)	15.0	≤0.02	2.6	– – –	≤0.02	0.0033	7.8	568

PART 2: APPLICABLE WASHINGTON STATE WATER QUALITY STANDARDS

Type of standards (applicable Washington Administrative Code)	Arsenic	Cadmium	Copper	Iron	Lead	Mercury	Zinc	Hardness
Surface water standards (WAC 173-201A, Standard for aquatic life in surface freshwater, chronic level maximums at 100 mg/L hardness)	190	*	*	none	*	0.012	*	100
Ground water standards (WAC 246-290, Washington State Department of Health, standards for ground water, domestic consumption)	50.0	none	1300	300 (cosmetic only)	15	2.0	5000	– – –

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Appendix A. Methods and Field Equipment

METHODS

We recorded observations and measurements in the field. Longitude and latitude were recorded with a global positioning system (GPS) unit in NAD83 decimal degree format. Literature research provided data on underground development, which was verified in the field when possible.

Soil samples from dumps or tailings were taken from subsurface material and double bagged in polyethylene. Chain of custody was maintained.

Soil samples were analyzed for the metals listed in this report by inductively coupled plasma/mass spectrometry (ICP/MS) following USEPA (U.S. Environmental Protection Agency) Method 6010. Holding times for the metals of interest were observed.

Instrument calibration was performed before each analytical run and checked by standards and blanks. Matrix spike and matrix spike duplicates were performed with each set.

FIELD EQUIPMENT

barometric altimeter
binoculars
digital camera
flashlight
Garmin GPS III+, handheld GPS unit
Oakton digital pH meter
Oakton digital electrical conductivity meter
Taylor model 9841 digital thermometer

Appendix B. Water Quality Standards for Hardness-Dependent Metals

Conversion formulae are given in WAC 173-201A at http://www.ecy.wa.gov/pubs/wac173201a.pdf.
Chronic standard in micrograms/liter (μg/L)

Sample location	**Hardness (mg/L)**	Cd (µg/L)	Cu (µg/L)	Pb (µg/L)	Zn (µg/L)
Swamp Creek site (high flow)	64	0.7	7.8	1.5	71.6
Swamp Creek site (low flow)	178	1.6	18.6	4.7	170.3
Granite Creek site (high flow)	67	0.7	8.1	1.6	74.4
Granite Creek site (low flow)	115	1.1	12.8	2.9	117.6
Eureka Creek site (high flow)	390	2.8	36.3	10.7	331.1
Eureka Creek site (low flow)	568	3.7	50.1	15.6	455.3

Appendix C. Aerial Photos of the Republic Mining District

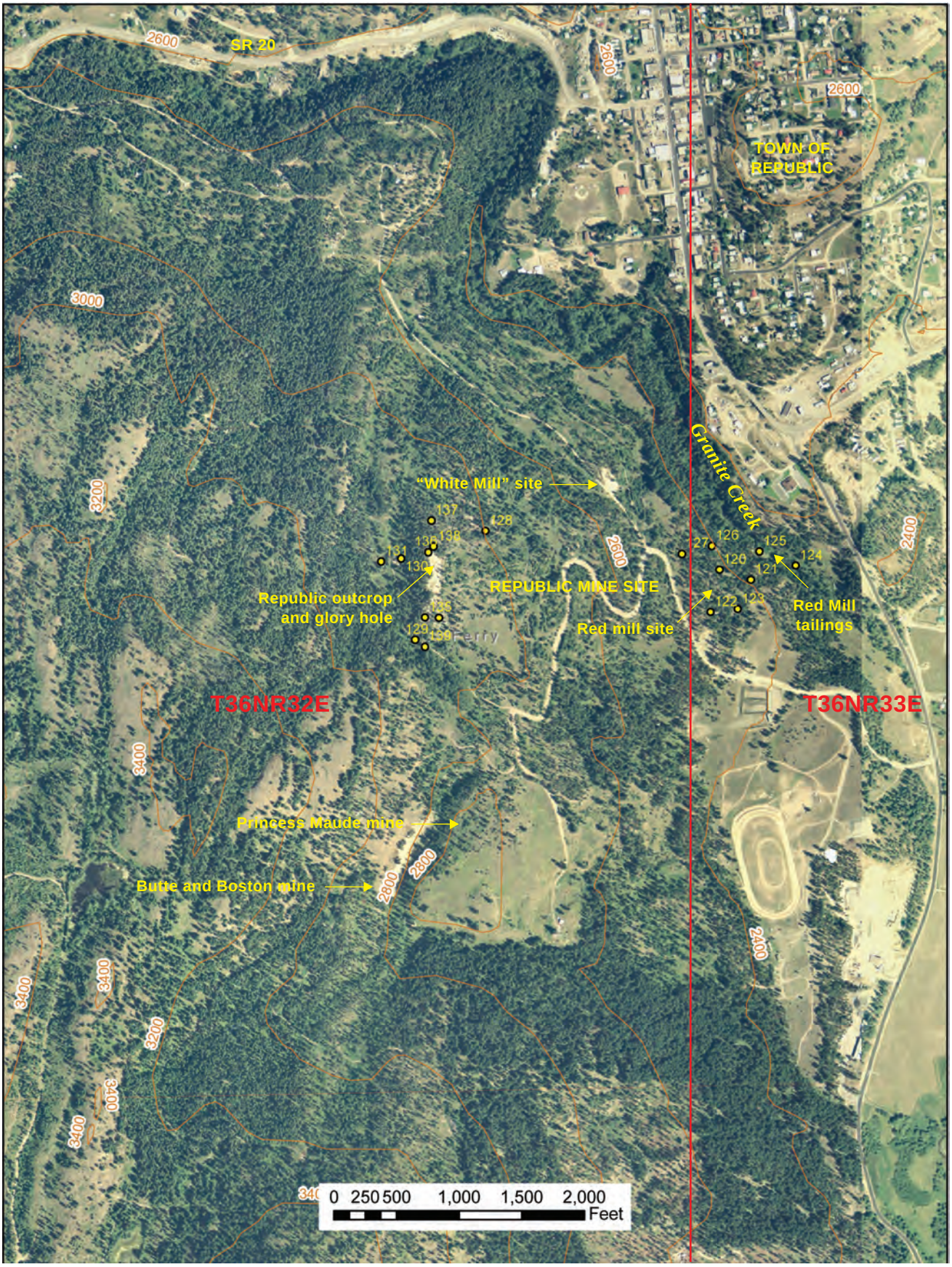


Figure C1. South Republic district mine sites: Republic, Butte and Boston, and Princess Maude. Numbered circles are field waypoints.

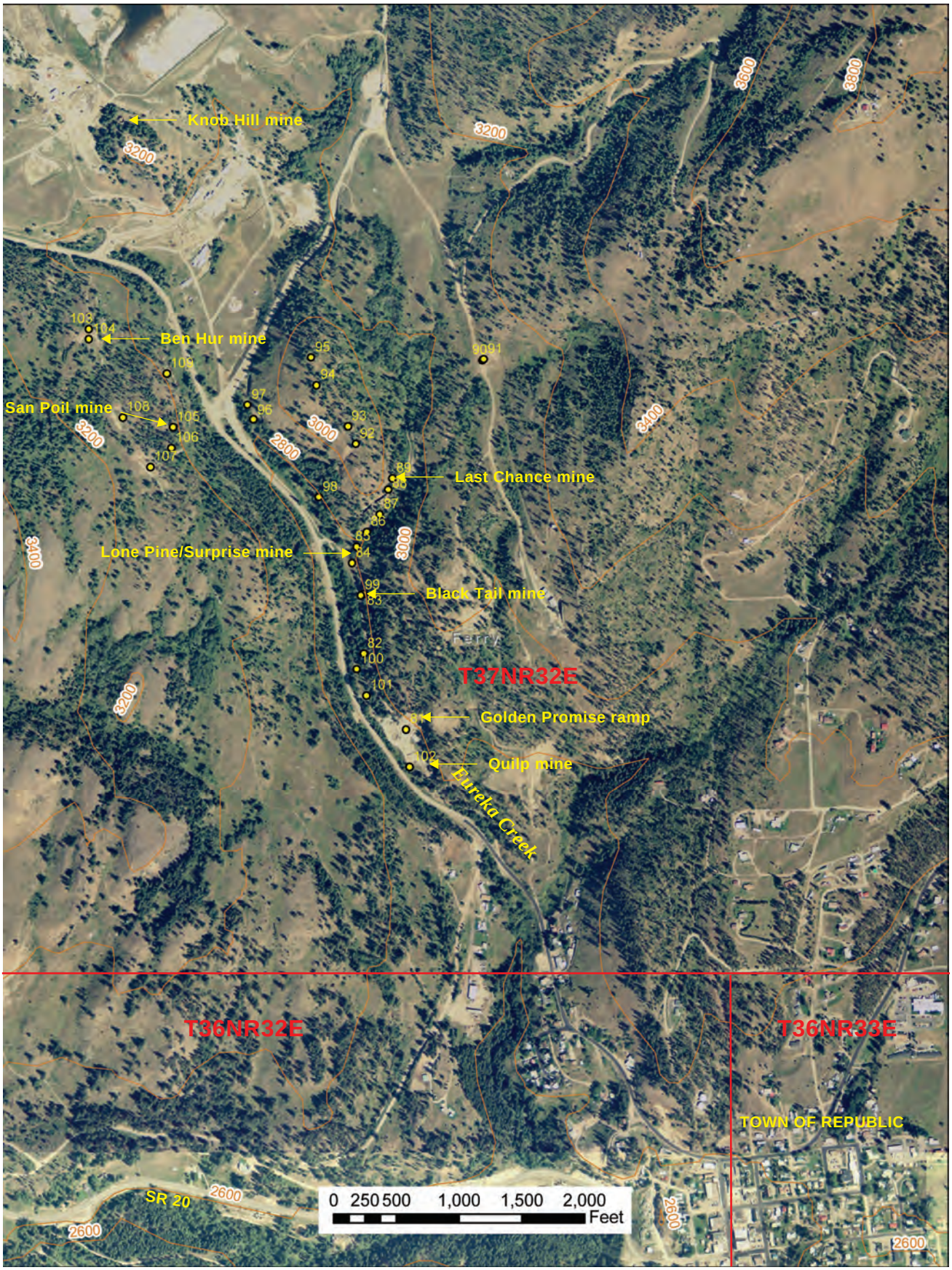


Figure C2. Central Eureka Gulch mine sites: Golden Promise, Knob Hill, Ben Hur, Lone Pine-Surprise, Quilp, Black Tail, Last Chance, and San Poil.

Figure C3. Mud Lake area mine sites: Ben Hur, Knob Hill, Mountain Lion, and South Penn.

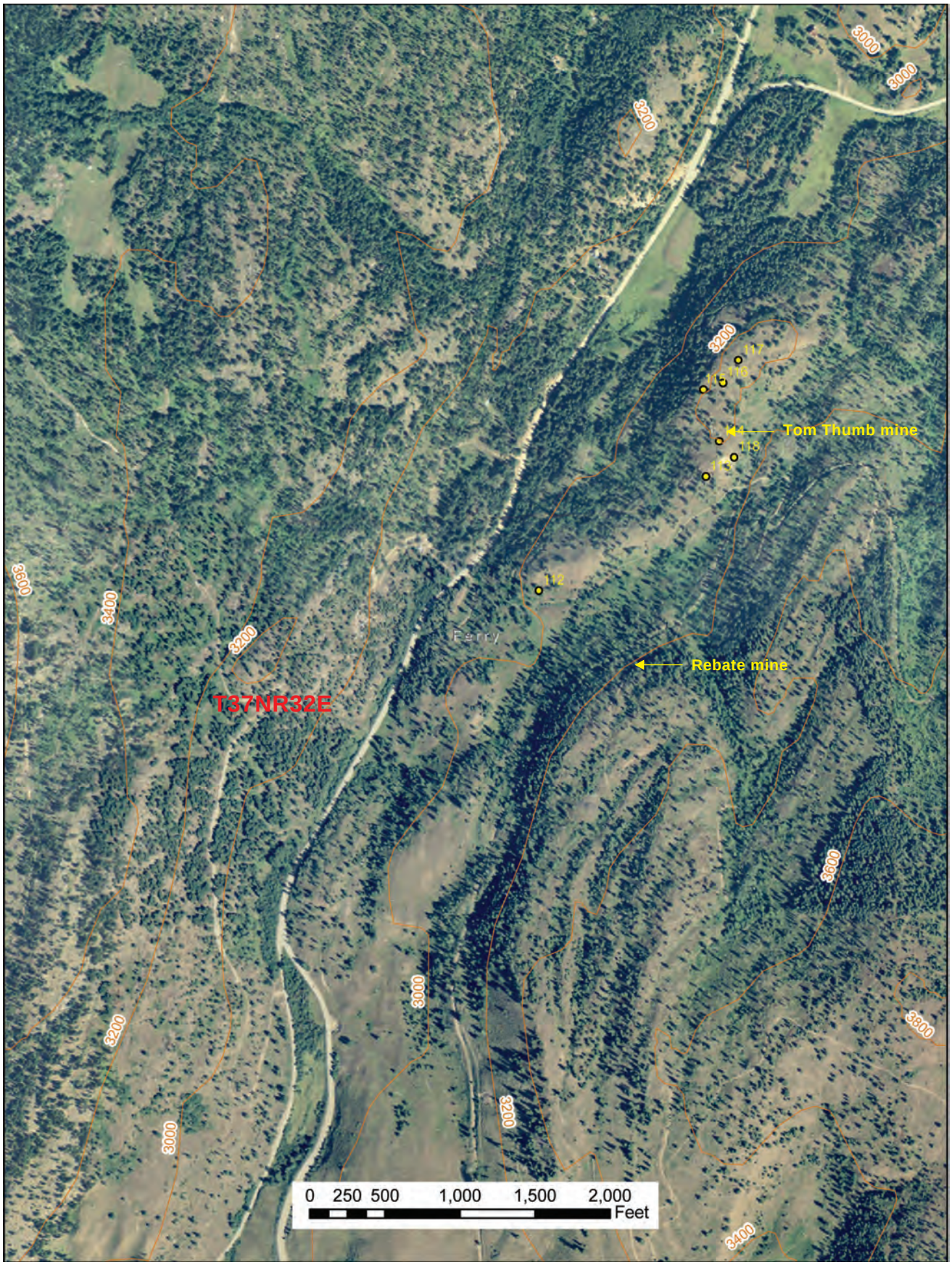


Figure C4. North Republic district mine sites: Tom Thumb and Rebate.

Appendix D. Patented Claim Map

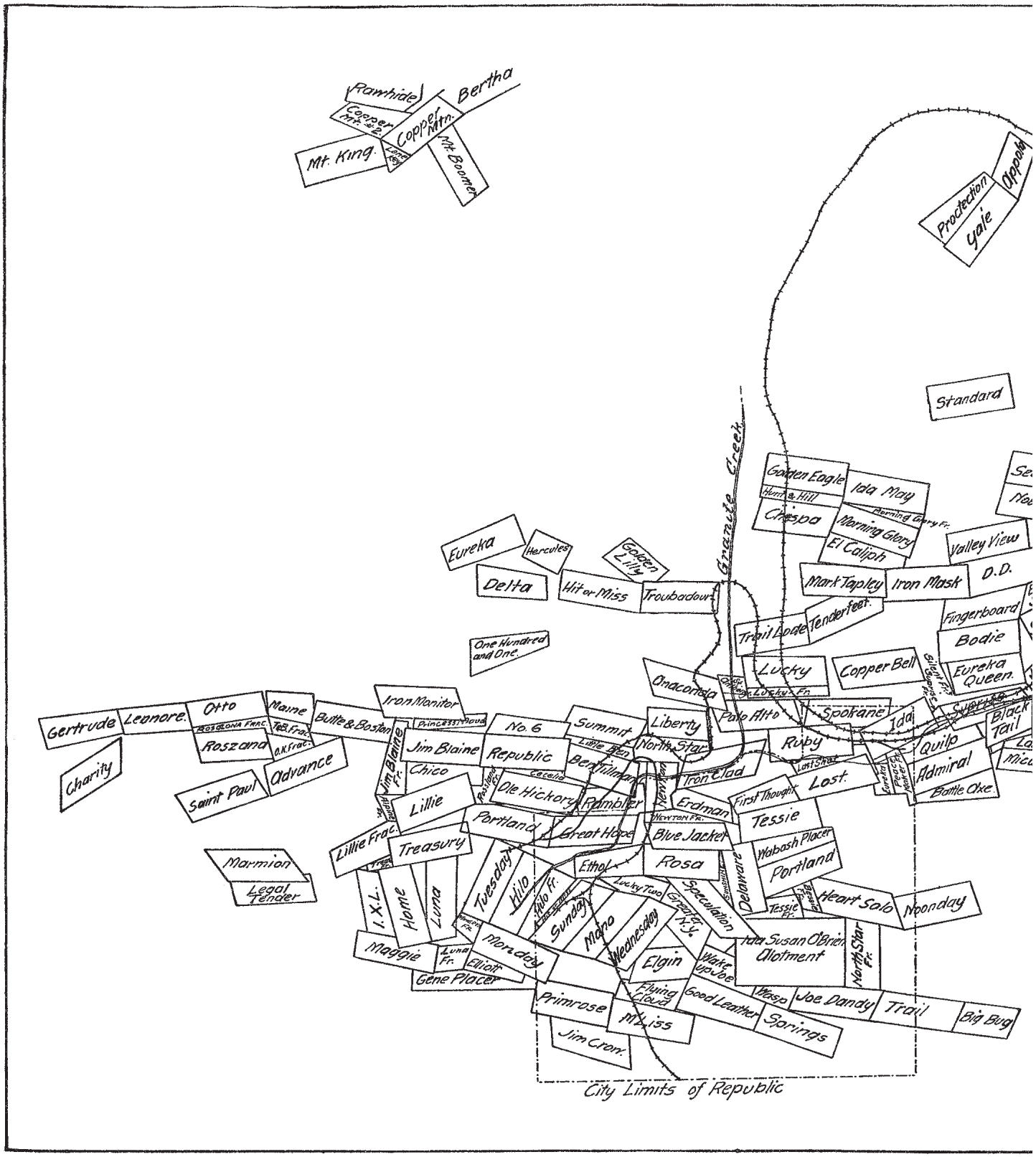
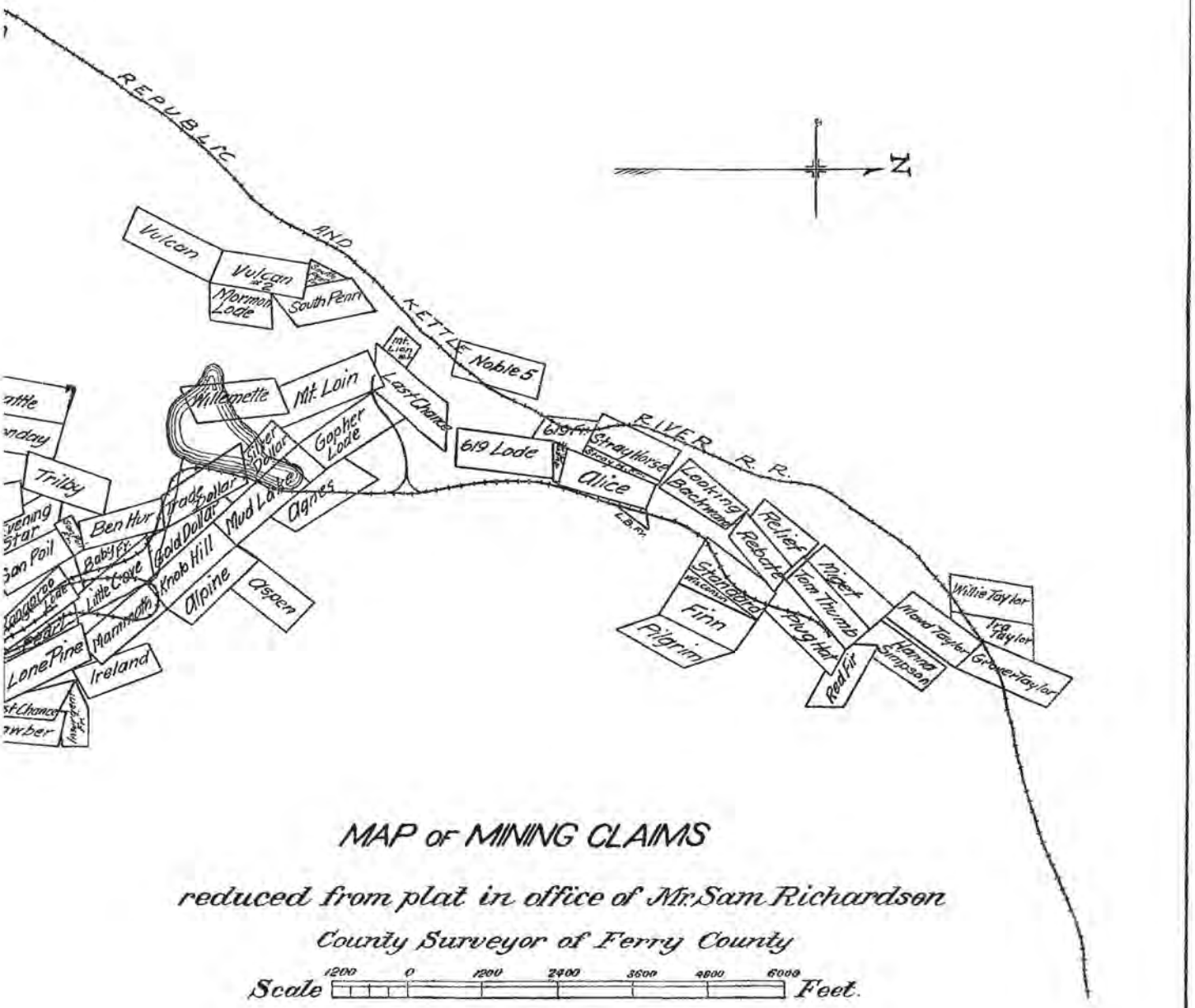


PLATE No. IX



MAP OF MINING CLAIMS

reduced from plat in office of Mr. Sam Richardson

County Surveyor of Ferry County

Scale 1200 0 1200 2400 3600 4800 6000 Feet.

Appendix E. Republic Mining District Production through 1994

Table E1. Republic mining district production. Production through 1985 in black; production from 1986 through 1994 in red. Compilation by Full (1972); revised by Crosby (1972–1981), Braun and Jehn (1982–1985), Braun (1989), and Wolff (2009).

			GRADE		TOTAL		VALUE	
MINE	PERIOD	TONS	Au (oz/T)	Ag (oz/T)	Au (oz)	Ag (oz)	Per ton	Total
Tom Thumb	1902–1917	7,857	0.462	2.50	3,631.9	19,656	$ 11.06	$ 86,864
	1934–1949	17,550	0.277	1. 21	4,861.4	21,236	$ 10.56	$ 185,248
		25,407	0.334	1. 61	8,493.3	40,892	$ 10.71	$ 272,112
Rebate	1941&1950	804	0.270	0.58	216.8	468	$ 9.85	$ 7,922
Mountain Lion								
Underground	To 1914[1]	20,000	0.242	2.00	4,840.0	40,000	$ 6.20	$ 124,043
	1939–1940	57,600	0.201		11,548.8		$ 7.02	$ 404,208
		77,600	0.211		16,388.8		$ 6.81	$ 528,251
Open Pit	1941–1945[2]	30,145	0.116	0.23	3,505.4	6,841	$ 4.23	$ 127,553
		107,745	0.185	0.43	19,894.2	46,841	$ 6.09	$ 655,804
Trevitt & Pierce	1941–1942[3]	28,707	0.121	0.13	3,485.9	3,665	$ 4.34	$ 124,612
	1941–1947	16,293	0.122	0.53	1,987.7	8,652	$ 4.65	$ 75,721
		45,000	0.122	0.27	5,473.6	12,317	$ 4.45	$ 200,333
Knob Hill Mines								
No. 1 Mine	1902–1937[4]	81,000	1. 519	4.47	123,039.0	362,070	$ 34.08	$ 2,760,458
No. 2 Mine	1941–1985[5,10]	2,681,386	0.664	3.85	1,780,354.9	10,323,597	$ 51.90	$139,300,000
Open Pit	1937–1941[6]	499,067	0.097	0.85	48,623.4	424,738	$ 4.02	$ 2,003,798
		3,261,453	0.599	3.41	1,952,017.3	11,110,405	$ 44.10	$144,000,000
Ben Hur	1905–1933	70,102	0.391	2.63	27,409.9	184,368	$ 9.66	$ 677.183
	1938–1950	19,922	0.320	1.74	6,375.0	34,664	$ 12.44	247,771
		90,024	0.375	2.43	33,784.9	219,032	$ 10.27	$ 924,954
Trade Dollar	1903–1915[7]	1,382	0.323	3.34	446.4	4,616	$ 8.68	$ 11,997
	1938–1948	17,886	0.290	1. 48	5,186.9	26,471	$ 11.20	$ 200,362
		19,268	0.292	1. 61	5,633.3	31,087	$ 11.02	$ 212,359
San Poil	1902–1933	71,399	0.349	1.43	24,918.3	102,101	$ 8.07	$ 576,322
	1934–1945	29,494	0.190	1.00	5,603.9	29,494	$ 7.36	$ 217,107
		100,893	0.303	1.30	30,522.2	131,595	$ 7.86	$ 793,429
Pearl Cove								
Pearl	1928[8]	2,321	0.33	1. 37	765.9	3,180	$ 7.64	$ 17,739
	1938–1943	4,480	0.21	0.81	940.8	3,629	$ 7.93	$ 35,508
		6,801	0.25	1.00	1,706.7	6,809	$ 7.83	$ 53,247
Little Cove	1939–1942	23,291	0.204	1.14	4,751.4	26,552	$ 7.95	$ 185,177
Old Cove	1910	145	0.73	4.16	105.9	603	$ 17.59	$ 2,551
	1934	88	0.253	1.2	22.3	106	$ 9.65	$ 849
		233	0.550	3.04	128.2	709	$ 14.59	$ 3,400
		30,325	0.217	1.12	6,586.3	34,070	$ 7.97	$ 241,824
Surprise	To 1910	2,400	0.96	5.08	2,304.0	12,192	$ 22.89	$ 54,939
	1910–1914	62,317	0.97	4.71	60,447.5	293,513	$ 22.88	$ 1,425,558
	1916–1928	73,960	0.225	2.42	16,641.0	178,983	$ 6.10	$ 451,359
	1934–1950	34,185	0.209	1.82	7,144.7	62,217	$ 8.61	$ 294,301
		172,862	0.501	3.17	86,537.2	546,905	$ 12.89	$ 2,226,157
Qui1p	1901–1928	110,862	0.474	3.12	52,548.6	345,889	$ 11.67	$ 1,293,713
	1936–1940	50,393	0.186	1.14	9,373.1	57,448	$ 7.32	$ 368,904
		161,255	0.384	2.50	61,921.7	403,337	$ 10.31	$ 1,662,617

MINE	PERIOD	TONS	GRADE Au (oz/T)	GRADE Ag (oz/T)	TOTAL Au (oz)	TOTAL Ag (oz)	VALUE Per ton	VALUE Total
Lone Pine–Last Chance								
Lone Pine	To 1910	8,924	0.609	3.39	5,434.7	30,252	$ 14.62	$ 130,486
	1910–1913	16,105	0.44	2.85	7,086.2	45,899	$ 10.80	$ 174,011
	1927–1928	2,866	0.400	3.55	1,146.4	10,174	$ 11.10	$ 31,800
	1934–1947	34,317	0.239	1.58	8,201.8	54,221	$ 9.49	$ 325,614
		62,212	0.352	2.26	21,869.1	140,546	$ 10.64	$ 661,911
Last Chance	To 1934	61,987	0.420	3.94	26,034.5	244,229	$ 11.05	$ 684,671
	1934–1942	24,803	0.198	1.68	4,911.0	41,669	$ 8.12	$ 201,511
		86,790	0.357	3.29	30,945.5	285,898	$ 10.21	$ 886,182
Insurgent & Fraction	1907–1928	22,675	0.745	5.43	16,892.9	123,125	$ 18.66	$ 423.051
		171,677	0.406	3.20	69,707.5	549,569	$ 11.48	$ 1,971.144
Black Tail	1902–1918	7,520	0.368	3.96	2,767.4	29,779	$ 9.98	$ 75,070
	1934–1945	6,091	0.19	2.00	1,157.3	12,182	$ 8.07	$ 49,167
		13,611	0.288	3.08	3,924.7	41,961	$ 9.13	$ 124,237
Republic	To 1902[9]	57,000	0.871	4.02	49,647.0	229,140	$ 20.42	$ 1,163,687
	1908–1933	40,607	0.834	3.77	33,866.2	153,088	$ 19.50	$ 791,867
	1934–1949	42,442	0.214	1.11	9,082.6	47,111	$ 8.28	$ 351,387
		140,049	0.661	3.07	92,595.8	429,339	$ 16.47	$ 2,306,941
District Total thru 1985		4,340,373	0.557	3.23	2,377,308.8	13,597,810	$ 35.80	$155,630,000
Golden Promise	1987–1994[11,12]	599,913	0.78	3.73	437,089.0	2,239,904	$367.26	$220,358,788
District Total thru 1994		4,940,286	0.57	3.21	2,814,398.8	15,837,714	$ 76.11	$375,988,179

Note: Gold Value based on $20.67 prior to 1934; increase to $35 per ounce 1934 to July 73; market value after 1 July 73. Silver Value based on 60¢ per ounce prior to 1928; market value after 1928.

1. Early production for Mountain Lion not of record, reported to be $200,000 with shipments in 1904 and 1905 averaging $5 in gold and 2 ounces of silver per ton.
2. A small tonnage may have been included in Knob Hill open pit figures prior to 1941.
3. Total tons reported to have been 45,000 between 1941 and 1947 with some shipments direct to Tacoma and Trail that averaged 0.122 oz Au and 0.531 oz Ag.
4. Tonnage and value figures found in Knob Hill files in longhand notes, grades based on 1910–1911 production.
5. Value as shown on Ore Production Reports.
6. Probably includes small unidentified tonnages of Mountain Lion ore and tailings.
7. Production for 1911, 1912, and 1913 included with tonnage for San Poil mine, probably not large.
8. Production has been credited to the Pearl mine by the U.S. Bureau of Mines for 1903, 1905, 1909, 1912, 1913, 1914, 1915, 1917, 1918, 1919, 1921, 1922, 1927 and 1928, but the tonnage has been combined with production from other mines and cannot be accurately separated on the basis of existing data. However, the total uncredited tonnage included in the U.S. Bureau of Mines data is not large and the total unidentified production from the Pearl mine is probably small.
9. Tonnage from Lindgren, grade based on 1908–1915 production.
10. Includes minor tonnage from old dumps of other mines from time to time.
11. Production figures are based on published data in Hecla annual reports; Minerals Yearbook, v. II, for 1987, 1988, 1992; Washington Geology, v. 1, 1989–1991, 1993, 1994.
12. Dollar value based on yearly median price per ounce for gold and silver as published in Kitco.com.

Appendix F. Historic Photos

Figure F1. Patsy Clark mill at the Republic mine, 1898. The bridge at lower left crosses Granite Creek, which is flowing right to left. View is to the south. Photo courtesy of Ferry County Historical Society.

Figure F2. Republic Consolidated Mining Company's 'Red' mill at the Republic mine, probably circa 1915–1920 after the property was in receivership. The boiler smokestacks and the surface tramway that carried ore from the sampling mill at the lower right to the crusher building at top right have been torn down. Patsy Clark mill ruins are out of the photo to the left. The various stacks of white material in the center of the photo are waste rock and mill tailings deposited on the west bank of Granite Creek, which flows from right to left. The brush and road in the foreground lie on the east bank. The discovery site of the Republic vein and prospect trenches are out of the photo at the top right. View is to the southwest. Photo courtesy of Ferry County Historical Society.

Figure F3. Overview of the San Poil mill and mine site circa-1916. The main haulage tunnel is located at the center left at the terminus of the surface tram running upslope to the crusher building. Note the rock dump overflowing the rail tracks next to the loading bin, left center. Ben Hur mine is off photo at right. Eureka Creek and Knob Hill mine road is at the bottom. View is to the west. Photo courtesy of Ferry County Historical Society.

Figure F4. Knob Hill mill circa-1949. Original mine adits are located on the hillside above and to the left of the mill. The Knob Hill mine No. 2 inclined shaft is located over the ridge at the far left. View is to the north. Photo courtesy of Ferry County Historical Society.

Figure F5. Overview of the Mountain Lion mill and mine site circa-1900. A covered tramway runs from the vertical shaft head frame (top right) to the mill. The 1260-foot southeast-bearing adit is located adjacent to the dry house and compressor buildings at the far left bottom. Note the mill tailings spreading out on the flood plain of Swamp Creek, which flows from left to right. View is to the east. Photo courtesy of Ferry County Historical Society.

Figure F6. Quilp mine, the tramway, Great Northern trestle, and probably the first cabin in Eureka Camp. View is to the northwest. Photo courtesy of Ferry County Historical Society.

Appendix G. SEM and Edax Photos

Figure G1. Polished Ben Hur vein outcrop sample showing black colloform chalcedony and quartz with minor calcite. Portion of insert pane is shown in SEM image below. Sample size is about 1.5 x 2 inches. Photo courtesy of G. Mustoe, 2009.

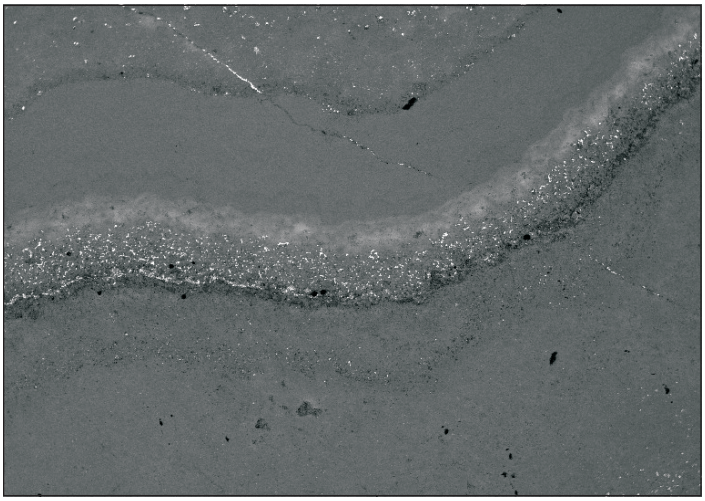


Figure G2. SEM (backscattered electron detector) image at 56x magnification. The sample area is predominantly quartz; the white specks represent sulfide particles 0.5 to 2 microns in diameter. The white particles are either proustite (silver/arsenic/sulfur) or argentite (silver sulfide), as determined by energy-dispersive x-ray fluorescence (EDAX) scans. Photo courtesy of G. Mustoe, 2009.

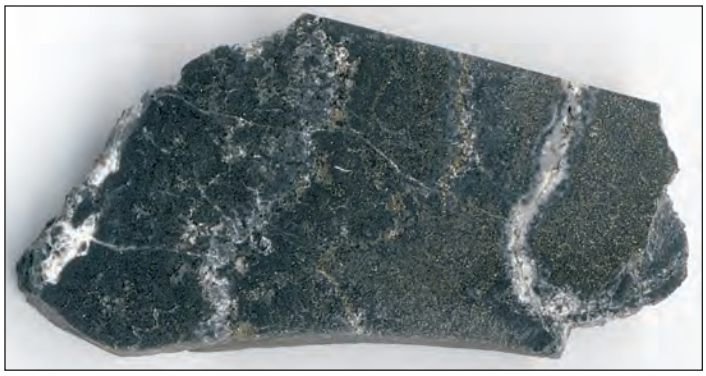


Figure G3. High-grade vein sample from the Knob Hill mine. SEM photograph below was taken in approximate center of the sample. Original size: 1 x 2 inches. Photo courtesy of G. Mustoe, 2009.

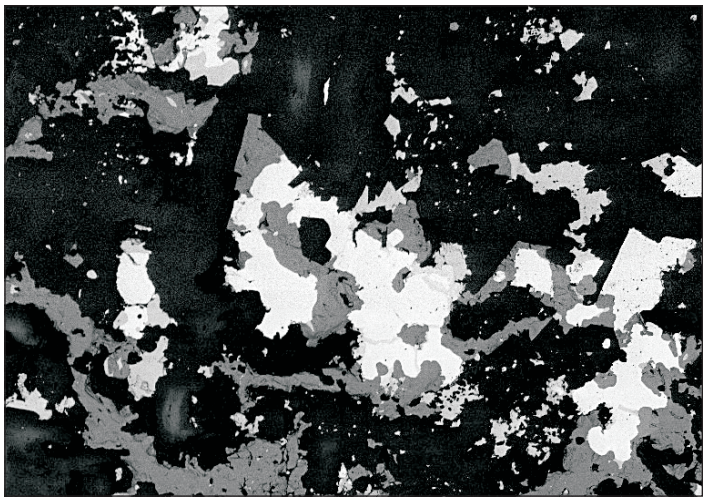


Figure G4. SEM image at 185x magnification of Knob Hill vein ore. Gold is white, quartz is black, chalcopyrite is light gray, naumannite is dark gray. The gold content over a wide field of view could not be estimated, but the silver content is approximately 13% by weight. Data and photo courtesy of G. Mustoe, 2009.

Appendix H. Geologic Map

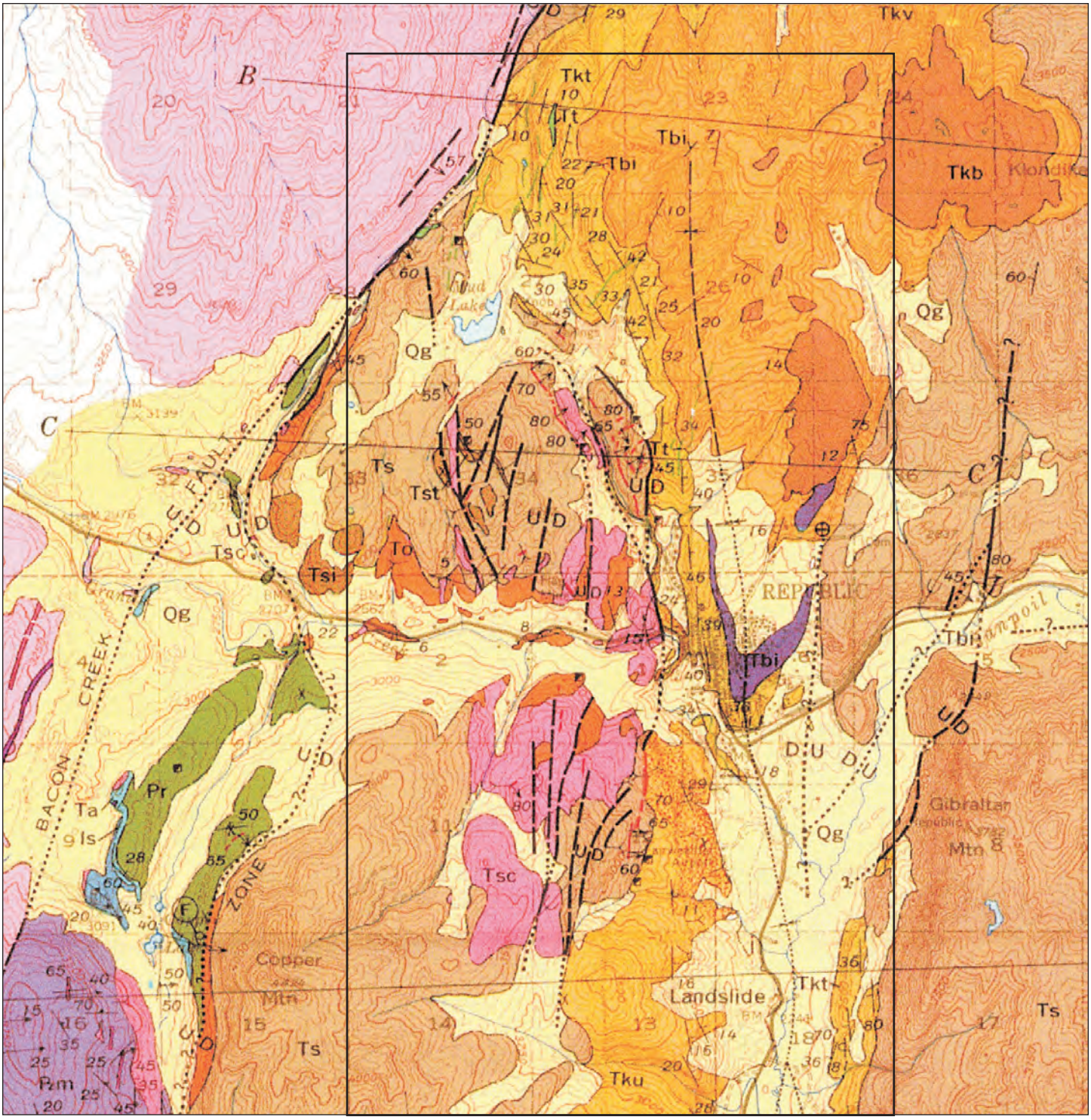


Figure H1. Map with Republic mining district (inside black rectangle), scale 1:3800. (Reprinted from Muessig, 1967.)

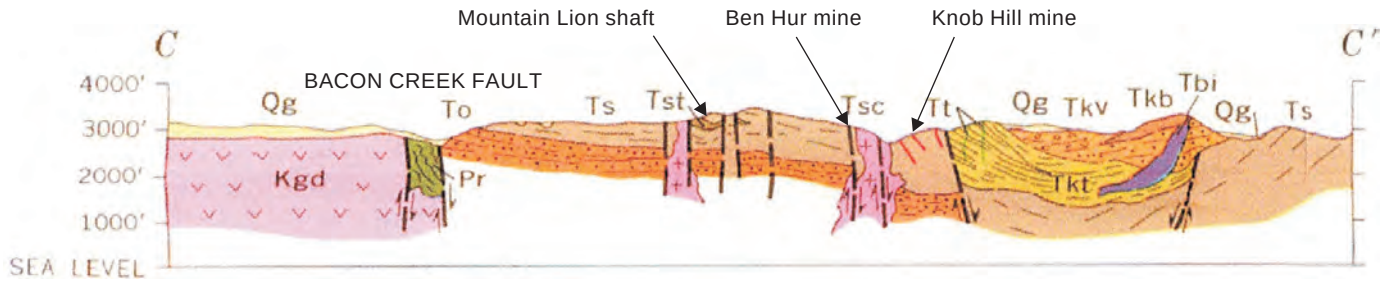
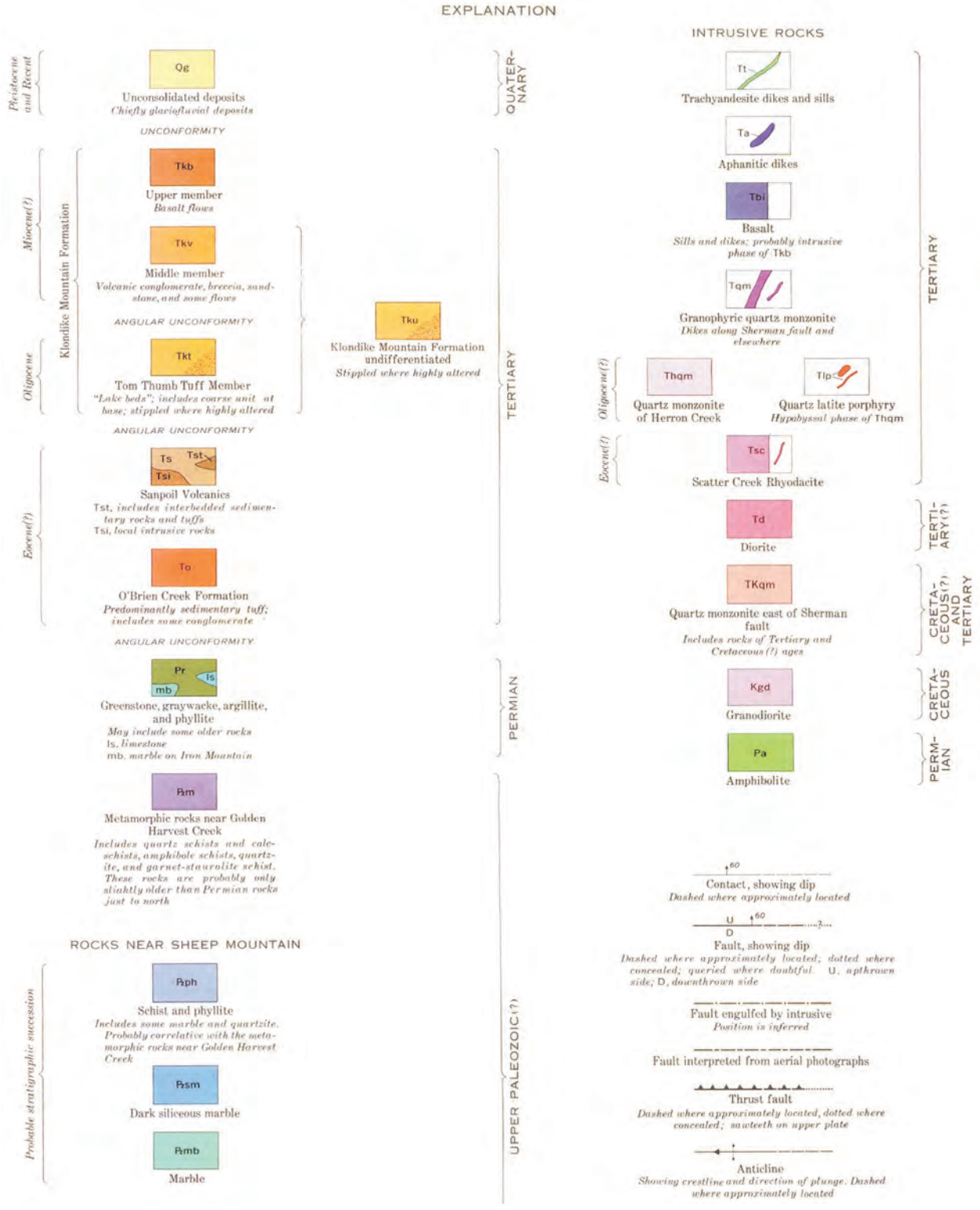
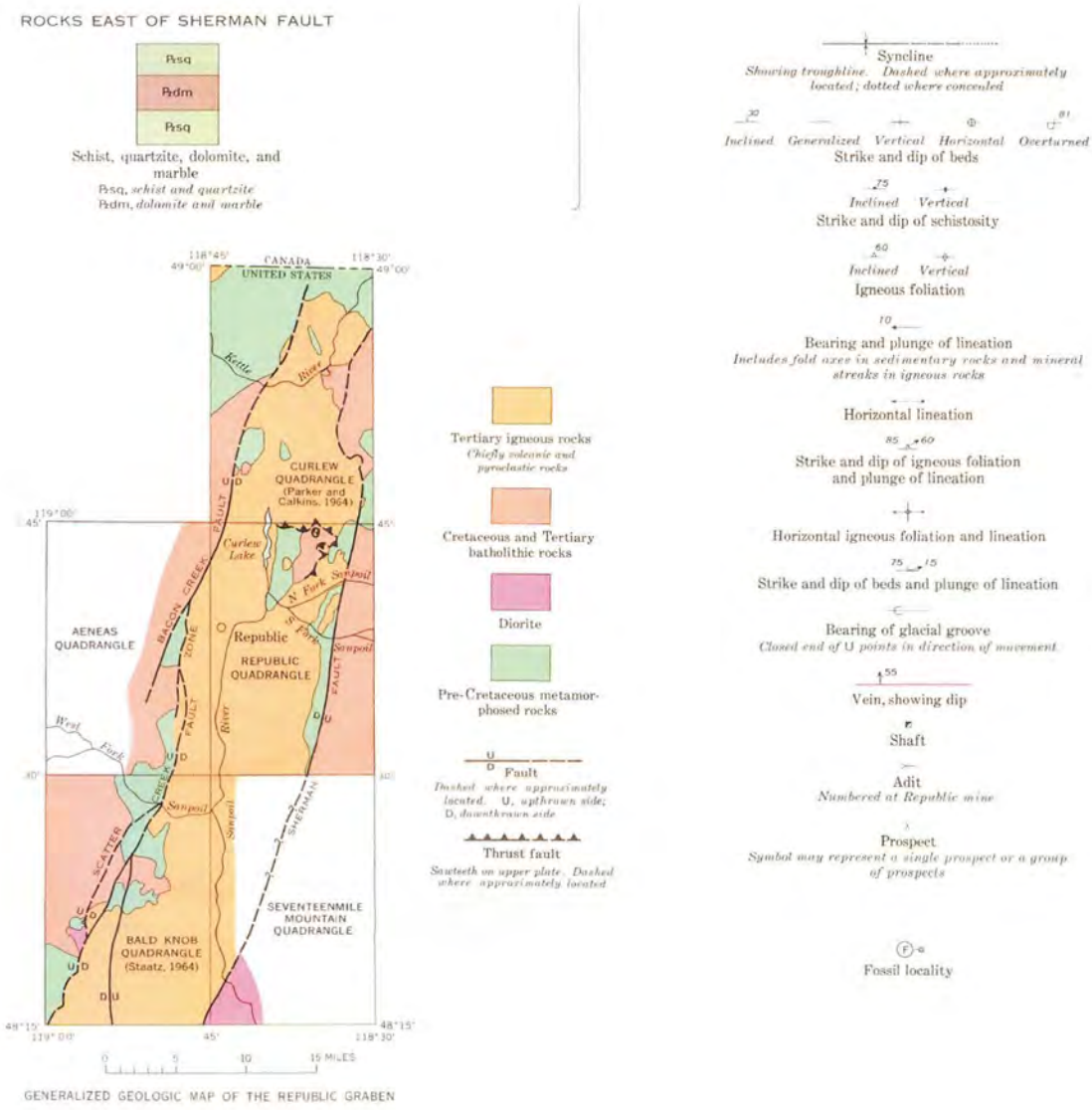


Figure H2. *(above)* Geologic cross section C–C′, scale 1:3800. (Adapted from Muessig, 1967.)

Figure H3. *(below and left)* Key to units. Not all units are present in the Republic mining district. (Reprinted from Muessig, 1967.)




ROCKS EAST OF SHERMAN FAULT
Psq
Pdm
Psq
Schist, quartzite, dolomite, and marble
Psq, schist and quartzite
Pdm, dolomite and marble
CANADA
UNITED STATES
Kettle River
CURLEW QUADRANGLE (Parker and Calkins, 1964)
Curlew Lake
N Fork Sanpoil
S Fork Sanpoil
AENEAS QUADRANGLE
BACON CREEK ZONE FAULT
Republic
REPUBLIC QUADRANGLE
West Fork Sanpoil River
SHERMAN FAULT
SCATTER CREEK FAULT
SEVENTEENMILE MOUNTAIN QUADRANGLE
BALD KNOB QUADRANGLE (Staatz, 1964)
0 5 10 15 MILES
GENERALIZED GEOLOGIC MAP OF THE REPUBLIC GRABEN
Tertiary igneous rocks
Chiefly volcanic and pyroclastic rocks
Cretaceous and Tertiary batholithic rocks
Diorite
Pre-Cretaceous metamorphosed rocks
Fault
Dashed where approximately located. U, upthrown side; D, downthrown side
Thrust fault
Sawteeth on upper plate. Dashed where approximately located
Syncline
Showing troughline. Dashed where approximately located; dotted where concealed
Inclined Generalized Vertical Horizontal Overturned
Strike and dip of beds
Inclined Vertical
Strike and dip of schistosity
Inclined Vertical
Igneous foliation
Bearing and plunge of lineation
Includes fold axes in sedimentary rocks and mineral streaks in igneous rocks
Horizontal lineation
Strike and dip of igneous foliation and plunge of lineation
Horizontal igneous foliation and lineation
Strike and dip of beds and plunge of lineation
Bearing of glacial groove
Closed end of U points in direction of movement
Vein, showing dip
Shaft
Adit
Numbered at Republic mine
Prospect
Symbol may represent a single prospect or a group of prospects
Fossil locality