NATURAL RESOURCES

INACTIVE AND ABANDONED MINE LANDS— Ruby Hill Mining District, Okanogan County, Washington

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

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Information Circular 112
August 2011

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location

WASHINGTON STATE DEPARTMENT OF
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WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES

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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 and published a series of corresponding Open File Reports and Information Circulars. Site characterization field work 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 were the U.S. Bureau of Land Management (BLM), the U.S. Environmental Protection Agency (EPA), and the Washington Department of Ecology (DOE).

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.

IAML site characterizations focus 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. The IAML database captures this information in database format (Microsoft Access). Reports such as this one provide documentation on mines or groups of mines within specific mining districts or counties. 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). 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.

Figure 1. Location of the Ruby Hill mining district in Okanogan County.

SUMMARY

The Ruby Hill mining district (Fig. 1) is located in T34 and 35N, R25E, 11 airline miles northwest of the town of Okanogan (App. C, Fig. C1). Exceptional silver assays from the district garnered entrepreneurial attention in 1886 when the north half of the Colville Reservation was opened to mineral exploration. It ranks along with the Republic mining district as one of the earliest major metalliferous discoveries in the state.

The mines discussed in this report have had four abbreviated and widely separated periods of production between 1889 and 1967, during which time the price of silver fluctuated between $0.70 and $1.00 per ounce. The total combined net smelter return was about $284,000. Profitability of operations at Ruby Hill have been hampered by two conditions: (a) its remote location from smelters, resulting in exceptionally high shipping costs, and (b) the spotty nature of high grade intercepts separated by stretches of lower grade silver mineralization not considered ore at the time of operation. A good overall description of the district from a mineral deposit point of view is that it is only partly developed and minimally explored.

The ore deposits occur in a series of hydrothermal fissure veins striking north to northwest subparallel to lineation trends in the Salmon Creek Schists and Gneisses of pre-Jurassic age. The veins' appearance suggests that they were formed by a late stage magmatic injection of massive quartz derived from the intrusive Conconully Granodiorite of Cretaceous age, which forms a steeply plunging contact with the Salmon Creek metamorphic series. The principal mines lie close to the contact or directly on it (App. C, Fig. C2). The quartz contains co-deposited

granular aggregates and intergrowths of base- and precious-metal sulfides and at least one telluride mineral. The persistence of any given vein along strike has not been determined, but it appears from outcrops on claims with common end lines that a few run for several thousand feet (Arlington group, Fourth of July and Keystone, First Thought, and Second Thought). The maximum explored depth in the district with ore grade mineralization in quartz is about 500 feet at the Arlington and Fourth of July mines. Oreshoots are generally disconnected in both strike and dip and separated by large gaps, identified as "barren quartz" by Milliken (1891) and Patty (1921), and zones of finely disseminated ore minerals. Vein widths vary across the district from a few inches to 90 feet.

The following minerals have been identified at most mines in the district: galena, sphalerite, chalcopyrite, tetrahedrite, cerargyrite, pyrargyrite, native silver, and pyrite. Pyrite is ubiquitous and may contain interstitial gold and silver values (Moen, 1973). The richest mineralization in the district assayed 200 to 300 ounces per ton (opt) silver, but shipments of hand-sorted ore averaged about 50 opt silver, 3.5 percent lead, 1.5 percent copper, and 0.02 opt gold. Silver content of mill concentrates falls in the range 150 to 300 opt. The first identification of the mineral hessite [silver telluride] was in a sample collected at the Fourth of July dump during DGER site characterization in June of 2010 (George Mustoe, Western Wash. Univ., written commun., 2010).

Adit portals at some mines are open; caving is likely however at unknown locations underground. Shafts at the Arlington, Fourth of July, Last Chance, and First Thought are caved.

Five adits discharged acid mine drainage that infiltrates before reaching known surface waters. All mines discussed in this circular are flooded to some degree, depending on specific site conditions. Discharge sampled either by Huchton (1995) or Raforth and others (2000) contained concentrations of metals that exceed one or more state standards for arsenic, cadmium, iron, copper, lead, selenium, and zinc. Levels of selenium and zinc in water were the highest encountered at any of the mines characterized in the IAML project (see Table 6). The toxicity levels for these metals present a health hazard since the mine lands are used for recreational activities and cattle grazing. Metal contaminants found in waste rock dumps and mill tailings generally reflect the water quality analyses regarding arsenic, lead, and selenium, with levels that exceed Model Toxics Control Act (MTCA) standards for unrestricted use and industrial/commercial use. The values reported in Table 2 are from soil grab samples only and may or may not represent the site as a whole. Sparse revegetation has occurred at each site, but no reclamation work is evident.

Three concentrating mills were built: a stamp mill at Ruby City (1892–1893) and flotation mills at the Arlington and Sonny Boy mines (1938–1940). Market conditions, combined with unreliable water sources and inadequate ore reserves, were major contributors to the mills' closing.

In light of the fact that precious metal prices have risen to all-time highs at the date of publication, the Ruby Hill district may see renewed activity in spite of an apparent absence of historic drilling data and district-scale geologic mapping. R. W. Phendler's (1974) geochemical soil traverse is the most recent technical exploration study in the DGER mine files. It identified five anomalous areas of mineralization >100 ppb silver and numerous float locations and quartz outcrops within a 1 mile radius of the First Thought mine.

ACCESS

From the town of Okanogan, follow the northwest-bearing Salmon Creek Road approximately 22 miles to the historic site of Ruby City. Using this site as a starting point, turn west on the Loup Loup Canyon Road and continue over the crest of Ruby Hill. Stay left on this road and turn south at the 1.5 mile point. At 2.0 miles, turn left on Buzzard Lake Road. A short spur heading south at the 2.6 mile point goes past the First Thought adit No. 3, partially hidden in woods a few feet uphill to the east, and leads to the Last Chance dumps 600 feet farther along. Both mine openings lie essentially under the immediate west shoulder of the Buzzard Lake Road. The Sonny Boy mine is located on a short spur about 1000 feet east of a switchback at the 3.8 mile point. The main haulage tunnel at the Arlington mine lies behind a log barrier at the 4.8 mile point. A series of switchbacks continuing uphill leads to the Fourth of July mine at the 6.3 mile point and 4500 feet elevation. Check with Bureau of Land Management (BLM) offices in Wenatchee or Okanogan for road conditions, as the Ruby Hill and Buzzard Lake roads are passable (2010) only with high-clearance four-wheel drive vehicles.

OWNERSHIP

Many of the lode claims in the district were patented at or near the time of discovery. Since that time a number of original patents reverted to Federal ownership administered by the BLM. The patents still in existence as of the date of publication are shown in Appendix D, Figure D8. Ownership of the five principal mines discussed below has changed hands many times since patent. As a result, several claims and (or) fractions thereof have divided ownership. The seven patents surrounding and including the Arlington mine are fractionally owned by private parties and Arlington Mine Last Chance, Elmira, Oregon. The Last Chance and First Thought claims and surrounding fractions are owned by a private party. The Fourth of July patent, including the adjacent Keystone and Climax claims are the property of AU Mines Inc., Calgary, Alberta. Three unpatented claims at the Sonny Boy property, held by possessory title in the late 1930s, are closed. In the immediate area of the principal mines (sec. 31, T35N R25E, or secs. 5 and 6, T34N R25E), there are no active unpatented claims at date of publication. Contact the Okanogan County Assessor for current specifics related to property in the Ruby Hill mining district.

DISTRICT HISTORY

The discovery in 1886 of massive quartz veins containing high-grade silver mineralization on Ruby Hill created a minor stampede to the district, leading to the founding of a town site on Salmon Creek known as Ruby City. Patents for at least 30 claims were granted. By 1891, a significant amount of development work had been carried out, but none of the properties were fully operational, due primarily to the tremendous difficulty and associated cost involved in shipping run-of-mine ore to smelter—40 miles of wagon road, transfer to river steamer, 85

miles, transfer to rail, and 175 miles to Tacoma. The freight cost burden underscored the necessity of a local milling facility being available, not only to recover silver from non-bonanza grade ore, but more importantly to drastically reduce the tonnage of material shipped.

To meet this need, Washington Reduction Company constructed a stamp mill at Ruby City in the fall of 1892 and transported ore via aerial tramway from the First Thought and Last Chance mines east over the crest of Ruby Hill to the mill. The concentrates from this mill, which operated for only six months, returned $66,000 in silver, with credits for copper and lead. The mill's closure was driven by a wave of investment speculation in railroads leading to a series of nationwide bank failures and market collapse in the spring of 1893. The price of silver dropped 30 percent to $0.70 per ounce. This event removed all the profitability from the remote district, and Ruby City was abandoned.

With the exception of the Fourth of July mine, the First Thought, Last Chance, and Arlington mines were capitalized or controlled by a syndicate formed by then U.S. Senator Jonathan Bourne of Portland, Oregon. The syndicate holdings, First Thought Silver Mining Co., Inc., (FTSM) and Washington Reduction Co., Inc., (WRC) were administratively dissolved in 1923 for nonpayment of fees.

A brief period of renewed mining at the Arlington and Sonny Boy mines took place during the late 1930s, followed by small shipments from the Fourth of July mine in the years 1958 to 1967. Excavations at the Last Chance and First Thought waste rock dumps probably date from the spike in silver prices in 1980. No other work appears to have been done in the district since that time (DGER mine file).

GEOLOGIC SETTING

The base metal–silver deposits in the district occur in hydrothermal quartz fissure veins proximal to a steeply plunging, northwest-striking contact between intrusive granodiorite of the Conconully batholith, and metamorphic rocks of the Salmon Creek Schists and Gneisses. The Last Chance, Arlington, and Sonny Boy mines cut the contact underground. The metamorphic rocks were derived from Paleozoic sediments and volcanics subjected to regional metamorphism during the Jurassic orogeny, and later invaded by granitic magma of probable late Cretaceous age (Gulick and Korosec, 1990). (See App. C, Fig. C2.)

The veins were formed during late-stage cooling of the intrusive magma when massive quartz containing aggregates of sulfide ore minerals was injected into open-space fissures. The crystallization temperatures of galena, tetrahedrite, chalcopyrite, bornite, and sphalerite found throughout the district indicate that the deposits crystallized at about 200°C; that is, at the lower range of mesothermal deposits and the upper range of epithermal deposits (Park and MacDiarmid, 1970).

The longest continuous exposure along strike of a quartz vein in the district is 1100 feet at the First Thought mine, and the maximum continuity down dip is approximately 500 feet at the Arlington and Fourth of July mines. Vein widths vary from a few inches up to a body 90 to 100 feet wide at the First Thought. The veins strike generally N10W with dips ranging from 25 to 90 degrees both east and west; most dips exceed 65 degrees. Jones (1917) reported that the Last Chance vein "near the portal dips 50W, but toward the caved part of the drift [at 400 feet] is overturned and dips 60E."

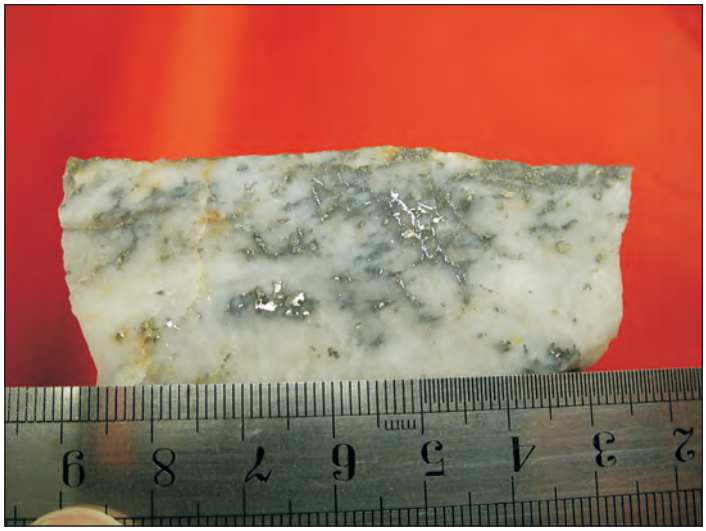

Figure 2. Disseminated hessite and sulfide mineralization in quartz from a dump sample.

The reported mineral assemblage in the district is similar from mine to mine, but identification of the primary silver-bearing mineral(s) appears more complex than previously reported. Tetrahedrite, an antimony-rich copper sulfide, is generally credited as the source mineral for Ruby Hill silver ore. However it is one end member of a continuous solid solution series with tennantite, an arsenic-rich copper sulfide, as the other end member. Silver in the published composition of pure tetrahedrite is negligible, whereas in tennantite it ranges up to 14 percent (Anthony and others, 1990). Other silver-rich minerals in the series are argentotennantite (34%) and freibergite (34–50%). These mineral phases also contain sufficient arsenic and antimony to account for the high values found in water and soil analyses. Argentiferous galena and pyrite also contributed to the silver content. We can't say for sure without a thorough study of the ore minerals by scanning electron microscope (SEM), but silver in the district more than likely occurs in one or more of the above named sulfide phases in conjunction with a silver telluride mineral, hessite, identified during DGER site characterization (see below). Native silver, pyrargyrite, and cyrargyrite have been reported (Derkey and others, 1990).

DGER obtained two hand specimens of massive quartz and a ten-pound bulk sample from the Fourth of July adit waste dump. One specimen shows a significant concentration of hessite, Ag_2Te, a relatively rare telluride mineral (Fig. 2). The hessite is intimately associated with an unidentified mineral similar to tennantite but containing twice the antimony content: 7%As, 25%S, 23%Sb, 3%Fe, 42%Cu (Fig. 3). The identification was made with EDAX/SEM technology (G. Mustoe, written commun., 2010). The only previously reported occurrence of hessite in the state was at the L-D mine in Wenatchee (Cannon, 1975). The grain shown in Figure 4, found in the second hand-specimen, is principally galena containing intergrowths of tetrahedrite, pyrite, and sphalerite, which suggests that the sulfides were codeposited and probably crystallized after the

quartz (J. Price, Nevada Bureau of Mines and Geology, written commun., 2010). The bulk sample assayed 0.3 opt silver.

Secondary enrichment is virtually nonexistent because the primary ore minerals extend to the surface. Near-surface parts of the veins tend to be rich in silver; lead, zinc, and copper sulfides predominate respectively with increasing depth (Moen, 1973).

PRINCIPAL MINES

The First Thought and Last Chance mines are located on separate but parallel southeast-striking quartz fissure veins about 600 feet apart. The First Thought claim lies adjacent to the east sideline of the Last Chance claim (App. D, Fig. D8).

First Thought Mine

The First Thought vein was opened by three adits separated by 280 feet from highest to lowest (App. C, Fig. C3). The estimated total development is 5000 feet. Milliken (1891) made the following comment after examining the mine on behalf of the Northern Pacific Railroad: "The property has been well opened in an intelligent manner; the quartz has been well sampled and assayed, and all that should have been done, has been." (Milliken's cross section and plan maps are shown in App. D, Figs. D1 and D2.) Milliken estimated proven ore reserves at between 24,000 and 35,000 tons. The tonnage actually mined in the following two years until the market collapse in the spring of 1893 is unreported. By 1917 the stopes were inaccessible (Jones, 1917).

FTSM numbered the levels in the reverse order in which they were driven (Hodges, 1897; Milliken, 1891). The first and lowest adit was shown on historic maps as No. 3, the second or middle adit as No. 2, and the last and highest as No. 1. Some reports show the reverse numbering based on elevation. The principal vein mined at the First Thought strikes N15W and dips 70E.

Level No. 3 (elevation 2780 feet) bears S80E, essentially perpendicular to the vein's strike. At a distance of 650 feet, a ventilation raise was driven to the surface. The drift then turns due east and cuts the downdip extension of the vein, where a small stope was mined. It continues in barren ground past the stope to the heading at 880 feet from the portal. Bright-orange acidic water discharges from the portal at ~2 gallons/minute. The pH measured 5.0, and the conductivity reading of 1950 μS/cm is the highest reading at any of DGER's IAML sites, indicating a significant concentration of sulfate ion (Fig. 5). The ventilation raise may act as a conduit for descending groundwater from the upper levels. The discharge water seasonally floods most of the waste rock dump surface and infiltrates by sheet flow within 100 feet of the portal (Fig. 6). The water contains levels of arsenic, cadmium, iron, and zinc that exceed state standards for surface water shown in Table 6 (Raforth and others, 2000; Huchton, 1995). Huchton (1995) sampled the No. 3 adit waste rock dump and found arsenic levels that exceeded state standards by a factor of 50X, along with elevated copper, lead, and selenium content. The silver content in Huchton's dump sample was 1.4 opt.

Level No. 2 begins with an east-bearing crosscut for ~50 feet until it intersects the vein and turns S15E (Fig. 7). Here it splits

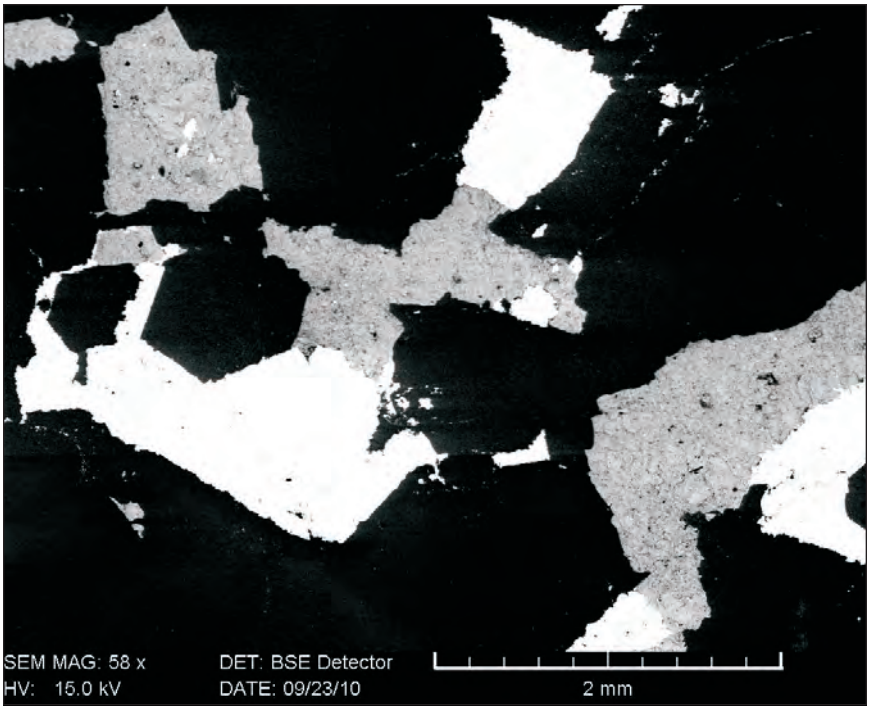

Figure 3. Scanning electron microscope (SEM) photo showing codeposited hessite (white) and an unidentified Cu/As/Sb sulfide mineral (dark gray) in a matrix of older euhedral quartz crystals (black). (Photo courtesy of George Mustoe, 2010.)

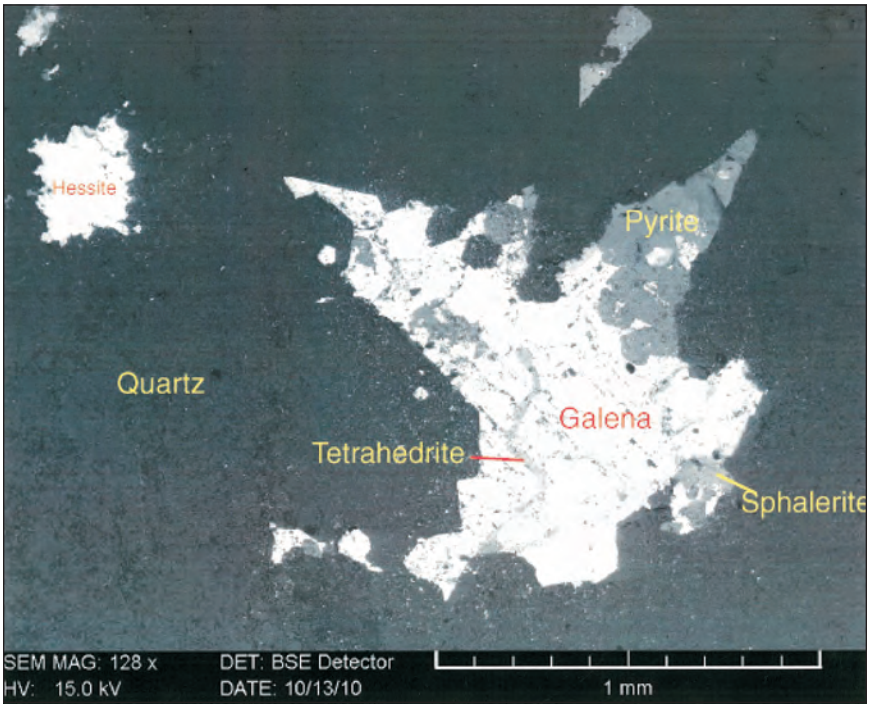

Figure 4. SEM photo showing galena grain with intergrowths of pyrite, sphalerite, and tetrahedrite. The sulfides crystallized after the quartz phase. (Photo courtesy of George Mustoe, 2010.)

into hanging wall and foot wall drifts about 500 feet in length, which are caved. Measured horizontally, the vein on this level is about 90 feet wide. Seasonal water, having approximately the same composition and metal exceedances described above, emanates from the adit (Huchton, 1995).

Level No. 1 was driven on the outcrop with drifts along the foot and hanging walls. The portal is open for a few tens of feet, but caved. The quartz vein on this level is approximately 50 feet wide; the two drifts are 900 feet long with eight interconnecting crosscuts (Milliken, 1891).

Comments made by Milliken (1891) when drifts were open and assays available are the best on-site indication of the discontinuous nature of the mineralization, not only at the First Thought mine, but probably applicable to the Ruby Hill mines in general: "Although the total width of the massive quartz vein on this level [No. 1] is approximately 50 feet, ore-grade mineralization is localized in narrow streaks along the hanging wall and footwall. From the portal to crosscut No. 5 [~400 feet] a streak of ore on the hanging wall is found which averages 4½ ft. in width with an average value of 23 oz. silver. From cross cut No. 5 [south] to the present face the quartz is barren. Along the foot wall, starting at crosscut No. 3 there is about 50 ft. the width of the drift [~5 ft] that will assay 20 oz. but from this point [south] to the present face [~450 ft] the quartz is practically barren."

"In adit No. 2 along the foot wall drift, bunches of rich ore, assaying from 100 to 300 ozs. and from one to three ft. of medium grade ore averaging 15 to 40 ozs. have been found, but from this point 246 ft. from the portal to the present face the vein is practically barren . . . since the continuation of these drifts in No. 2 to the south under No. 1 show practically barren quartz, it also shows that the ore bodies found in No. 1 directly above, do not go down, or in other words there is no continuity as to depth of ore bodies found above. For this reason it is difficult to estimate, if one estimates at all, the amount of ore in sight shown by the various crosscuts and levels. However, the total number of tons in round numbers is 34,000 . . . and allowing for bad spots obtain about 24,000 tons."

Figure 5. Acid mine drainage at the First Thought lower adit (No. 3), June 2010. Water is 4 feet deep. View is to the East.

Figure 6. First Thought lower adit discharge, August 2001. Note the iron staining on the rocks. View is to the west.

Last Chance Mine

Development at the Last Chance includes a 320-foot vertical shaft and a southeast-bearing 650-foot adit on the vein. The shaft is collared in schist of the Conconully metamorphic complex, and cuts the steeply plunging granodiorite contact at a depth of about 200 feet. Two levels of limited extent were driven off the shaft at depths of 100 and 220 feet. At the bottom of the shaft, a third level, 1300 feet long, was driven east toward and past the First Thought vein, cutting a wide zone of 'quartz stringers" about 1300 feet from the portal (App. D, Fig. D3). There is no indication of mining from this level (DGER mine files).

At the time of DGER geologist Ernest Patty's 1920 field work (Patty, 1921), the adit was accessible but caved 500 feet from the portal. About 50 feet from the portal, Patty observed a 2- to 4-foot band of galena, chalcopyrite, and tetrahedrite (in decreasing order of abundance), surrounded by massive quartz. The sulfide band extended along the drift approximately 200 feet. The last known production from the Last Chance was from this drift between 1920 and 1921, when a lessee shipped a few carloads totaling less than 100 tons of hand-sorted ore assaying 30 opt silver, 17 percent lead, and 4 percent copper (Patty,

1921). The shaft site lies a few feet above the caved adit shown in Figure 8, but it has been obliterated by sloughing.

The waste rock dump occurs on two levels superimposed on one another; the lower dump is adjacent in elevation to the adit portal; the upper dump is adjacent to the shaft location. The upper dump is 100 feet long x 80 feet wide with a crest to toe distance of 80 feet. It contains an estimated minimum of 4000 cubic yards.

Although the shaft and underground workings are more than likely flooded because of the high water table on Ruby Hill, we observed no direct discharge or drainage pathways. The pond shown in Figure 9 is formed by snowmelt and precipitation. The circa-1980 pond excavation would have allowed a new adit to be driven on the massive quartz cropping out below the historic adit and shaft (Fig. 9). The aquatic plants in the pond are *Hippuris vulgaris* a species native to Washington, but on the endangered species list in other states (G. Shoemaker, DNR Aquatic Resources Division, oral commun., 2010). The pond contains elevated levels of cadmium, copper, lead, and zinc (see Table 6).

Figure 7. First Thought No. 2 level adit. The drift crosscuts the vein's hanging wall 50 feet from the portal. It is caved after that point. View is to the east.

Figure 8. Overview of the initial surface development at the Last Chance mine. The depression at center is the excavation shown in Figure 9. View is to the southeast.

Sonny Boy Mine

Early work on this property was minimal, probably little more than shallow surface excavations. In 1935, after 43 years of inactivity, Ruby Mountain Mining Co. Inc. staked three unpatented lode claims and drove an upper and lower adit on the vein, 65 and 600 feet long respectively (App. C, Fig. C4). Subsequently a surface stope about 60 feet long and 30 feet deep was opened on the footwall (Fig. 10). Two separate near-vertical raises were driven that connected the upper adit and the surface stope to the lower adit which served as a haulageway. The upper adit (Fig. 11) is open to the heading, at which point an unmarked near-vertical raise descends to the haulageway.

In the four years the company operated the mine, a workmanlike camp was established, including a 25 ton/day flotation mill, and produced ore in the range of 3400 to 4400 tons, depending on actual stope volumes, which are unknown (Fig. 12). Hand-sorted ore assayed about 30 opt silver and 0.02 opt gold; after the mill came on line in 1939, shipments of concentrate returned 150 to 240 opt silver (DGER mine file). Shipments were made to smelters at Tacoma, Washington, and Kellogg, Idaho. It appears the company was unable to develop ore reserves of sufficient quantity to continue and ceased active operations in 1940. The corporation was administratively dissolved in 1947 for nonpayment of fees. The claims, which were never patented, are closed.

The Sonny Boy outcrop strikes N10W and dips 50W to vertical. Mineralization at the Sonny Boy differs somewhat from that reported at other mines in the district in that the primary ore mineral reported by the company was "silver and gold bearing pyrite, although galena and sphalerite can be identified" (DGER mine file). Huntting (1956) described two veins at the Sonny Boy from 6 inches to 6 feet in width. The lower level exhibits a high degree of geologic complexity. One vein ends abruptly 180 feet from the portal, and the vein on which most of the stoping was done is picked up 20 feet to the east by a crosscut at the heading. The vein then splits again, encounters a major steeply dipping cross fault, and continues through a shear zone to the end. The mine appears to sit right on the contact between granodiorite, which hosts the mineralization throughout most of

Figure 9. Circa-1980 excavation accessing the Last Chance vein outcrop dipping steeply west. Water exceeds state standards for cadmium, copper, lead, and zinc. View is to the south.

Figure 10. Open stope at the Sonny Boy mine is approximately 30 feet deep at top left by 7 feet wide. View is along strike to the southeast.

the lower adit, and quartz monzonite gneiss exposed in the final 60 feet of the adit (App. D, Fig. D4).

The Sonny Boy vein may be an extension of the Arlington vein discussed below, providing the respective strikes of the two systems remain relatively constant. If so, the overall length of the fissure exceeds 4500 feet.

Colluvium has formed a dam at the lower adit portal, inundating most of the drift (Fig. 13). The pH of the impounded water measured 5.5. The iron-stained water is used by grazing cattle. No water analyses are available. The waste rock dump contains an estimated 2600 cubic yards. The only circa-1937 infrastructure still visible are the millfeed ore bin ruins (Fig. 14) and an empty concrete powder magazine. The mill foundations were found, but seasonal runoff appears to have dissipated the tailings to such an extent that a sample could not be obtained.

Arlington Mine

Huntting (1956) reported the dollar value of production at the Arlington mine from inception through 1940 at $144,650 (approximately 115,000 ounces silver) from 8300 tons. Total underground development is approximately 4500 feet (App. C, Fig. C5).

This property was located in 1887, one year after the Last Chance and First Thought mines. The initial work consisted of a 200-foot near-vertical shaft sunk on the steeply dipping 'Arlington' vein. Jones (1917) stated that the Arlington vein on the upper adit level "differs greatly in character at different points. Its maximum width is 10 feet, but it pinches out in the fissure near the north and south ends of the drifts." Drifts ran approximately 350 feet north and south from the shaft bottom, some stopes were broken, and by the summer of 1893, 1000 tons of ore had been mined with a net smelter return of $25,000. The mine was abandoned soon afterward because of the bank failures and financial collapse across the country.

The mine saw a resurgence of activity after the turn of the 20th century. In 1905, a newly organized corporation, Arlington Mining Co., Inc., purchased the property and drove the upper adit bearing N80E, which crosscuts the principal or 'Arlington' vein at the shaft bottom 400 feet from the portal and a smaller vein dipping east at 440 feet from the portal. Patty (1921) reported that the secondary vein was explored for 350 feet along strike but "contains little ore." Exploration of this second structure is not discussed in later reports.

The shaft was abandoned in 1910, after the company drove the No. 2 or lower adit 230 feet lower in elevation. It bears almost due east and served as the main haulageway (App. D, Fig. D5). It was originally 1290 feet long, cutting the Arlington vein 972 feet from the portal. Today, the portal has been obliterated by surface excavations or collapse of the overlying mass of granitic colluvium and is considered caved. Iron-stained acid mine drainage flowing from the toe of the highwall shown in Figure

15 marks the portal location below which the mine has historically been flooded. Fir, larch, pine, and cottonwood trees up to 4 inches in diameter have begun to establish a foothold on the dump. The upper adit, which was open to the shaft intersection in 2004, is reached by a steep spur road descending from a switchback on the Buzzard Lake Road, east of and above the lower adit (D. Jacobsen, Northwest Underground Explorers, written commun., 2010). Three waste rock dumps totaling approximately 9800 cubic yards are located opposite the portal. The dumps were partially scavenged during a 1980 spike in the price of silver.

The company re-incorporated as the Arlington Silver Mining Co., Inc., in 1918, with head offices in Spokane. At this time, the lower and upper levels were connected by two raises. Between 1918 and 1921, 39 carloads of hand-sorted ore totaling 1570 tons were shipped to the American Smelting and Refining Co., Inc., smelter at Tacoma. The shipments averaged 70 opt silver, 0.02 opt gold, and 1.2 percent copper (Patty, 1921). From the shaft collar to the bottom of the winze gives an overall depth of known mineralization on the Arlington vein of 540 feet.

The two mineralized veins lie essentially on the contact between foliated hornblende mica-schist of the Salmon Creek metamorphic complex and the Conconully granodiorite; in places the quartz fissure is found in one or the other host rock. Jones (1917) identified tetrahedrite as the predominant ore mineral, but in places the vein contained "abundant chalcopyrite and smaller amounts of galena and sphalerite."

The mine was on standby until Arlington Mines Inc. purchased the patented claims and existing equipment in 1937, reopened the adits, and constructed a 50-tpd stamp and gravity concentrating mill. At this time, a 100-foot winze was sunk on the vein from the lower adit level, and at least one sublevel and several stopes were developed (App. D, Fig. D6). Huntting (1956) reported that a sample taken at the bottom of the winze in 1947 assayed 18 opt silver over a 2½-foot width. The mill was augmented with ball mill and flotation equipment the following year. Huchton (1995) reported the mill was destroyed by fire in 1958. The mill ruins (Fig. 16) lie downslope at the opposite (west) end of the flat shown in Figure 15. During 1938 and 1939, Arlington Mines milled a total of 5700 tons of ore returning $71,683. We estimate the grade to be in the range of 16 to 20 opt silver, based on the average price of silver at the time of $0.80 per ounce. The company ceased operations in 1940 and was dissolved in 1945 for nonpayment of fees.

Acid rock drainage from the lower adit is well documented. In December 1920, the president of Arlington Silver Mines described a situation existing on one of the sublevels below the lower adit: "We were much interested in our discoveries with reference to acid solutions . . . . These solutions cut away our pipes and rails. They were found to contain a large percent of iron, and copper sulphate. An analysis of the disintegrated iron indicated 8 to 20 percent copper, about .02 gold [opt], and ½ ounce [opt] silver in every instance." (DGER mine file). DGER estimated the seepage from the highwall at 5 gpm in June 2010; Huchton's estimate in May 1995 was 15 to 20 gpm. Analyses for cadmium and zinc taken at that time exceed state standards for aquatic life shown in Table 6. Raforth and others' (2000) sample at the same point exceeded this standard for cadmium and zinc. Mill tailings of approximately 4200 cubic yards lie in a swampy draw immediately downgradient from the mill site and support a thick stand of brush and trees (Fig. 17). The sample taken at this site exceeds state standards for arsenic, copper, and lead (see Tables 2 and 3), and the silver content is 1.1 opt.

There appears to have been no attempt to delineate the lateral or vertical extent of the Arlington vein by core drilling. As it stands, only about one-half the length of the Arlington claim has

Figure 11. Portal of the upper adit of the Sonny Boy mine. The adit is open 65 feet to the heading, at which point an unmarked raise drops to the haulage level. View is to the southeast.

Figure 12. Overview of the Sonny Boy mine camp, 1939. View is to the southwest. (Photo courtesy of Karen Turner LaFontaine, 2010; George Turner estate.)

been explored by development. The last note of interest regarding the Arlington mine in DGER files is a 1976 article describing a planned reopening of the property by Nesco Mining Co., later Nesco Resources, Inc. There is no record of the nature of the work performed, if any (*Wallace Miner*, 6/11/76).

Fourth of July Mine

This property, which produced some of the richest ore in the district, assaying 1000 opt silver, is located on the crest of Ruby Hill at 4500 feet elevation (App. C, Fig. C6). One of the first smelter shipments of ore from the Ruby Hill district came from the Fourth of July mine's 200-foot inclined shaft sunk on the vein. By 1890, shaft levels at 30, 70, 120, and 200 feet had been developed. That year, a Montana syndicate, encouraged by the results of the earlier shipment, acquired the property and sank a double-compartment vertical shaft to a depth of 200 feet, with production levels at 100 and 200 feet below the ground surface. The shaft was later deepened to 500 feet with a 300-foot level (Patty, 1921). All of this development work, including a total of about 850 feet of drifts, was accomplished in the three years leading up to the economic collapse of 1893, at which time the mine was shut down. Total net return at this time was $36,000.

There is no record of the mine operating again until 1958, when it was reopened by then owner, Cecil Murray, who operated the property and shipped a small quantity [unreported] of hand-sorted ore assaying 50 to 80 opt silver; a lessor made small shipments in 1967 (Moen, 1973). The tonnage produced at this latter day is unknown and is the last known production from the district (DGER mine file). AU Mines Inc., Calgary, Alberta, acquired the Fourth of July, Keystone, and Climax patents from the Murray estate in 1974 (Lucas, 1975).

The discovery outcrop is still much in evidence a few feet below the Buzzard Lake Road (Fig. 18). Viewed along strike (N) from the discovery site, the first feature encountered is the inclined shaft, which is caved about 10 feet below the collar (Fig. 19); the unfenced vertical shaft lies 70 additional feet northwest (Fig. 20). It is caved about 50 feet below the surface. Milliken's 1891 map shows production stopes in "ore" on levels at 70 and 120 feet, but even though the quartz fissure is persistent 140 feet south and 160 feet north of the shaft, the cross section shows no indication of ore-grade mineralization. "On the [120] level, nothing but white quartz is to be seen." The two shafts were joined by interconnecting drifts at the 120 and 200 foot levels (App. D, Fig. D7).

An east-bearing adit lies downslope and about 300 feet northwest of the shafts. It discharges water in the spring months and is flooded below the portal elevation of 4390 feet (Figs. 21 and 22). The adit does not appear on Milliken's 1891 map and may have been driven by the current owner, AU Mines, Inc., in 1975. It is a moderate decline to a point about 40 feet from the portal, where it dips steeply to the east and is flooded. Twenty feet below the water surface, it is filled with gravel and cobblestones. At a point 25 feet inside the portal, a drift turns to the south. In May 2010, scuba divers swam approximately 250 feet along this drift in extreme visibility conditions, did not reach the heading, and found

Figure 13. Haulageway portal, lower adit site, at the Sonny Boy mine. Water ~2 feet deep is impounded behind the colluvium dam (notebook for scale). View is to the southeast.

Figure 14. The mill-feed ore bin ruins at the Sonny Boy mine. Mill site is downhill at the bottom left. View is to the east.

nothing of historical importance (D. Jacobsen, written commun., 2010). The adit discharged flowing water at the time of Huchton's site visit in May 1995 and was partly flooded in June 2010 at the time of the DGER site visit. Huchton's water sample showed levels of cadmium, copper, and zinc that exceeded state standards shown in Table 6 by several levels of magnitude. The discharge infiltrated a few feet from the opening. Huchton's soil sample of the dump exceeds state standards for arsenic, lead, and selenium (see Tables 2 and 3).

The host rock is biotite gneiss (Gulick and Korosec, 1990). The vein is 4 feet wide at the surface, expanding to 20 feet between walls on the 200 level. The vein averages about 6 feet overall. It dips 65E and strikes N to N20W. The metallic ore minerals are tetrahedrite, galena, sphalerite, and hessite—a silver telluride mineral previously unreported in the Ruby Hill district (see below). Lenticular paystreaks ranging in thickness from 18 to 24 inches were encountered near the hanging wall (Moen, 1973). We found disseminated grains of galena and hessite as small as 0.05 mm in massive quartz.

Hodges (1897) reported specimens of native silver observed at the mine. Parts of the vein are highly sheared by strike-slip faults paralleling the vein walls. DGER has not located any historic sampling data regarding the continuity of ore-grade mineralization at depth or along strike. Lucas (1975) estimated 129,000 tons remained in the vein within the boundaries of the Fourth of July claim at 50 percent probability, assuming an average width of 6 feet to the depth of the double-compartment shaft. Additionally, "the Fourth of July vein or one closely related to it is believed to also be present within the southeastern or undeveloped portion of both the Fourth of July claim and the adjoining Keystone claim (8-foot vein with up to 50 opt silver, developed with a 150-foot shaft."

Figure 15. Overview of the Arlington site. Acid mine drainage emanates from the lower adit at the foot of the highwall. View is to the east. The mill site lies 100 feet behind the photographer's position.

OPENINGS

The shafts at the Fourth-of-July mine are caved and unfenced. The Last Chance and Arlington shafts are caved or filled to the surface. Some portals are still intact at the Arlington, First Thought, Sonny Boy, and Fourth of July mines, but the adits may be caved at various points and potentially impound water. All openings in the district are considered hazardous. See Table 1.

MATERIALS AND STRUCTURES

No materials were located during DGER site characterization. Structures observed were the empty powder magazine and ore bin at the Sonny Boy, a dilapidated headframe at the Fourth of July, and the Arlington mill ruins.

Figure 16. Arlington mill ruins. View is to the west.

WATER

Acid mine drainage occurs at all the mines discussed in this report and infiltrates near adit portals. Those sampled by Huchton (1995) and Raforth and others (2000) contained concentrations of metals that exceed one or more state standards for arsenic, cadmium, iron, copper, lead, selenium, and zinc. Levels of selenium and zinc in water were the highest encountered at any of the mines thus far characterized in the IAML project. The toxicity levels shown in Table 6 should be taken into account, given the land use by humans and grazing cattle.

MILLING OPERATIONS

As discussed above, the Bourne syndicate stamp mill at Ruby City operated about six months, and the Arlington and Sonny Boy flotation mills at most only two years, ceasing operation in 1940. Metal prices led to closure of the Bourne mill, and either the near term outbreak of WWII or the inability to develop viable ore reserves led to closure of the others. Most of the district's smelter shipments were hand-sorted, mine-run ore. DGER personnel looked for, but did not find, the location of the Washington Reduction Company's stamp mill at Ruby City.

Regardless of market conditions, the bulk of Ruby Hill district experience suggests that even high-grade ore must be concentrated to offset freight costs and that stringent assay control of quartz broken in the normal course of development must be done to separate truly 'barren' material from that containing cutoff grade silver and higher. The particles of disseminated grains discussed above (Figs. 20 and 21) are probably representative of those found in low-grade material in the district generally and suggest that recovery of these values by flotation or cyanidation, or a combination thereof, requires grinding to pass screens in the range of 80 to 100 mesh.

Figure 17. Arlington tailings sample site and coauthor Mac McKay.

TAILINGS AND WASTE ROCK DUMPS

Four of the 12 waste rock dumps in the district have been sampled: Last Chance, First Thought, Arlington, and Fourth of July mines. The analyses for arsenic, lead, and selenium exceed state standards for unrestricted use and industrial/commercial use listed in WAC 173-340-900, Model Toxics Control Act (MTCA) (see Tables 2 and 3). Of the two flotation mill tailings known to exist, only the Arlington material was found in sufficient quantities to be sampled. Arsenic, copper, and lead content in this sample exceeded MTCA standards.

GENERAL INFORMATION

Names: First Thought, Last Chance, Sonny Boy, Arlington, Fourth of July

MAS/MILS sequence number: First Thought, 053470298; Last Chance, 0530470299; Sonny Boy, 0530470300; Arlington, 0530470314; Fourth of July, 0530470315

Access: Four-wheel drive from the town of Okanogan via Salmon Creek Road and Buzzard Lake Road; or from Highway 20 and Loup Loup Canyon Road

Status of mining activity: none

Claim status: patented claims of mixed ownership; no unpatented claims at time of publication

Current ownership: see above and contact Okanogan Co. Assessor's Office

Surrounding land status: Bureau of Land Management

Map information: Ruby Hill 1:24,000 scale; Omak 1:100,000 scale

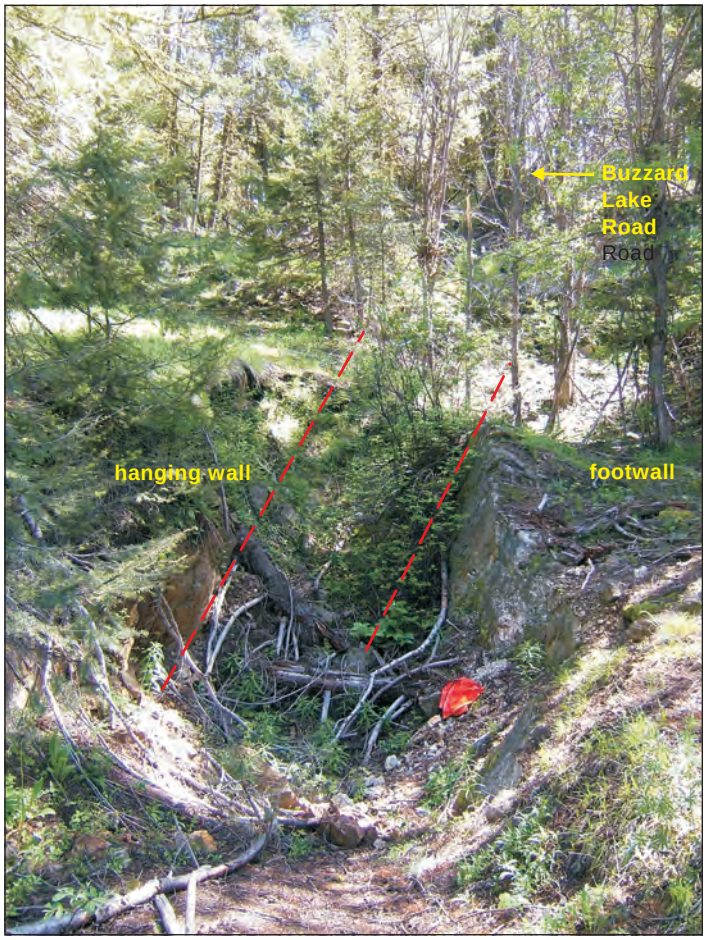

Figure 18. Fourth of July mine discovery outcrop. View is to the south.

MINE OPERATIONS DATA

Type of mine: underground and surface open stopes

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

Figure 19. Inclined shaft at the Fourth of July mine, caved 10 feet below surface. Vein dips 65E.

Figure 20. Site of the double compartment vertical shaft at the Fourth of July mine, caved 50 feet below the surface. View is to the east.

Geologic setting: predominantly pre-Jurassic Salmon Creek Schists and Gneisses (also known as the Conconully metamorphic complex) on or near the contact with granodiorite of the Similkameen batholith (late Cretaceous)

Ore minerals: tetrahedrite; var. freibergite and tennantite; hessite, chalcopyrite, sphalerite, galena; possible cyrargyrite, argentite, pyrargyrite; pyrite was reported as carrying silver

Non-ore minerals: quartz, pyrite

Host rock: gneiss and schist, granodiorite

District period of production: 1886–1893, 1901–1924 intermittent, 1937–1940, 1958–1967

Development: exceeds 13,000 feet total

Production: exceeds the recorded figure of $244,000

Mill data: flotation mills at Arlington and Sonny Boy, stamp mill at Ruby City.

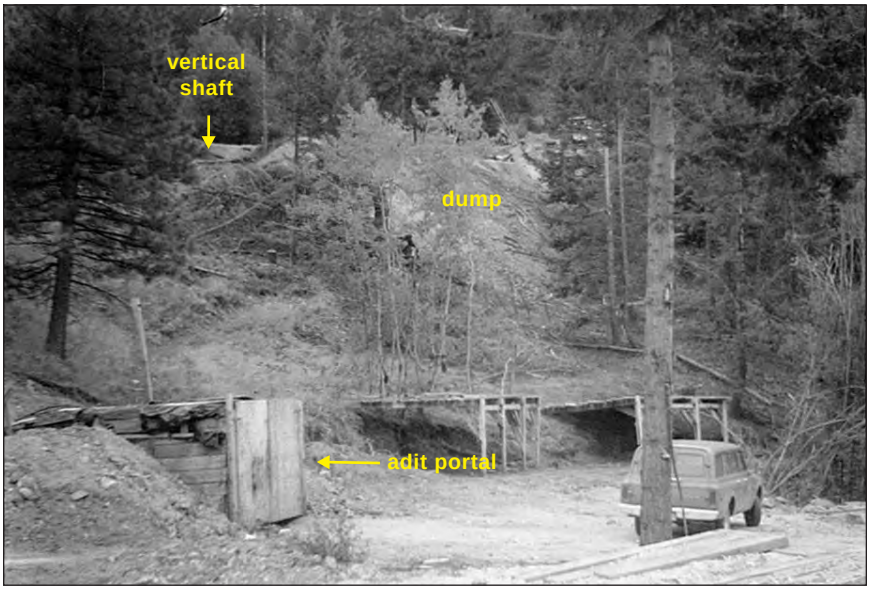

Figure 21. Overview of the Fourth of July site. View is to the southeast. (1978 photo by Wayne Moen.)

PHYSICAL ATTRIBUTES

Features: Table 1

Materials: none

Machinery: Arlington mine: ball mill, stamp mill cam and scrap

Table 1. Mine features. – – –, no data; **, data from DGER mine file; N/A, not applicable.

Description	Condition	Length along bearing (feet)**	Width (feet)**	Height/depth (feet)**	True bearing	Elev. (feet)	Decimal latitude	Decimal longitude
First Thought adit No. 3	portal open, caved unknown distance	880	5	7	S70E	2800	48.49286	119.74001
First Thought adit No. 2	portal open, caved unknown distance	100 ft; perpendicular to vein, thence hanging wall and footwall drifts ~400 ft	5	7	S73E thence S10E	2980	48.4922	119.73816
First Thought adit No. 1	portal open, caved unknown distance	hanging wall and footwall drifts ~940 ft	5	7	S15E	3080	48.4917	119.73782
Last Chance adit	portal caved	650	5	7	S20E	3100	48.49151	119.74101
Last Chance vertical shaft	caved at surface	320	– – –	– – –	N/A	3100	48.49122	119.74016
Sonny Boy lower adit	portal open, caved unknown distance	530	5	7	S	3600	48.48331	119.73902
Sonny Boy upper adit	open	60	5	7	S	3760	48.48298	119.73886
Sonny Boy millsite	burned	N/A	N/A	N/A	N/A	3650	48.48346	119.73920
Sonny Boy open stope	open/ unprotected	70	7	30	S	3794	48.48275	119.73870
Sonny Boy trench	open	N/A	N/A	5	S	3845	48.48236	119.73854
Arlington upper adit	portal open, caved unknown distance	450	5	7	S75E	4325	48.47087	119.73421
Arlington lower adit	excised by excavation	1290	5	7	S80E	4090	48.47175	119.73655
Arlington millsite	burned ruins with machinery	N/A	N/A	N/A	N/A	4025	48.47208	119.73781
Arlington tailings	buried under brush	N/A	N/A	N/A	N/A	4015	48.47225	119.73809
Arlington shaft	caved/obscure/location calculated	– – –	– – –	200	N/A	4550	48.47088	119.73134
Fourth of July adit	portal open, caved and flooded below invert	– – –	6	10	N	4390	48.47759	119.72983
Fourth of July inclined shaft	collar open, caved at 10 feet	200	3	5	S10E	4480	48.47668	119.72937

Structures: Sonny Boy mine: powder magazine block building, ore bin

Waste rock dumps, tailings impoundments, highwalls, or pit walls: twelve waste rock dumps, two tailings impoundments, one highwall >50 ft

Analysis of waste rock dumps and tailings: Tables 2 and 3

Waste rock, tailings, or dumps in excess of 500 cubic yards: eight

Reclamation activity: none

VEGETATION

Some Douglas fir regeneration to 10 inches in diameter; larch; stressed ponderosa pine and aspen; sparse weeds and grasses.

Figure 22. Overburden collapse at the adit portal, June 2010.

Table 2. Soil analysis. Analyses in bold indicate levels that exceed one or more of the standards shown in Table 3. Metal concentrations are mg/kg; ≤ 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; – – –, no data; *, data from Huchton (1995), two samples; **; safe concentration limits have not been established by WAC173-340-900, shown in Table 3 below; WRD, waste rock dump.

Metals	Antimony (Sb)**	Arsenic III (As+3)	Beryllium (Be)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Lead (Pb)	Nickel (Ni)	Selenium (Se)	Silver (Ag)**	Thallium (Tl)**	Zinc (Zn)
First Thought WRD*	0.00–0.11	**865–1110**	0.003–0.007	≤0.1	17.1–26.2	39.3–**152**	0.27–0.47	**514–1160**	6.77–9.29	**3.44–11.1**	≤0.03–45.2	– – –	124–173
Arlington tailings	63	**51**	0.091	7.8	5.4	**240**	1.3	**490**	5.2	≤4.1	36	≤4.1	210
Fourth of July WRD	6.9	**450**	0.002	0.64	9.5	27	0.043	210	2.0	≤4.1	9.7	≤4.9	37

Table 3. 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 milligrams/kilogram. Levels for antimony, silver, and thallium have not been established.

Metals	Antimony (Sb)	Arsenic III (As+3)	Beryllium (Be)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Lead (Pb)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Thallium (Tl)	Zinc (Zn)
Unrestricted land use	no std.	20	25	25	42	100	9 (inorganic)	220	100	0.8	no std.	no std.	270
Industrial or commercial use	no std.	20	no std.	36	135	550	9 (inorganic)	220	1850	0.8	no std.	no std.	570

WILDLIFE

Ruby Hill is documented habitat for the Western rattlesnake, *Crotalus viridis*. They are found at all elevations and locations in the district. Caution is advised for visitors traveling off-road. See Table 4 for bat habitat information.

WATER QUALITY

Surface waters observed: intermittent streams at Arlington and Sonny Boy mines

Proximity to surface waters: ~100 ft

Domestic use: cattle grazing, shooting, other recreational activities

Acid mine drainage or staining: First Thought, Fourth of July, Sonny Boy, and Arlington mines

Water field data: Tables 5 and 6

Surface water migration: Adit discharges infiltrate within 100 feet at the Last Chance and First Thought portals. The Arlington lower adit discharge flows across the alluvium floor to a 500 gallon stock-watering tank and infiltrates approximately 200 feet downgradient. The Fourth of July adit collects water that overflows in wet years.

Table 4. Bat habitat information. – – –, no data

Opening	Aspect	Air temp. (°F) at portal	Air flow: exhaust	Air flow: intake	Multiple interconnected openings	Bats or bat evidence
First Thought adit No. 3	NW	70	no	no	yes	no
First thought adit No. 2	W	70	no	no	yes	no
First thought adit No. 1	NW	– – –	– – –	– – –	yes	– – –
Sonny Boy lower adit	NNW	50	yes	no	yes	no
Arlington upper adit	W	43	no	no	yes	no
Fourth of July adit	W	– – –	no	no	no	no

Table 5. Surface water field data. *, data from Huchton (May 1995); **; data from Raforth and others (June 2000); – – –, no data.

Description	Flow (gpm)	Conductivity (μS/cm)	pH	Bed color	Temp. (°F)
First Thought adit No. 3	2, 20*	1600*, 1750, 1950**	5.0, 6.0, 6.64**	dark orange	50
First Thought adit No. 2	2, 4*	– – –	4.0, 5.0*	reddish-orange*	– – –
First Thought adit No. 1	1, 2*	– – –	5.0, 6.0*	reddish-orange*	– – –
Last Chance adit pond	none	1020, 1320*	8.0, 7.0*	reddish-orange*	72
Sonny Boy lower adit	none	690	5.5	orange	46
Arlington lower adit	5, 20*, 67**	600, 725**	6.0, 6.98**	orange	– – –

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The authors thank Ginger Shoemaker of the DNR Aquatics Resources Division for identifying aquatic plants at the Last Chance mine, and Douglas Hale of the Okanogan Health District for supplying Huchton's reports of soil and water analyses for the mines on Ruby Hill. Daryl Jacobsen, Vic Pisoni, and Phil Woodhouse of Northwest Underground Explorers shared photographs and valuable information from their investigations in the Ruby Hill area. DGER librarian Lee Walkling provided research assistance in locating primary source material. Karen LaFontaine contributed photos taken by her family in 1938 at the height of

Table 6. 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; (1), data from Raforth (2000); (2), data from Huchton (1995). Values in bold exceed one or more state standards shown in Part 2. 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	Selenium	Zinc*	Hardness
Arlington mine lower adit (1)	1.6	**4.0**	0.79	**331**	1.4	≤0.002	– – –	**371**	355
Arlington mine lower adit (2)	5.1	**6.6**	≤20.0	– – –	≤	≤	– – –	**432**	– – –
First Thought mine No. 3 lower adit (1)	**69**	33	2.9	**48300**	≤0.2	≤0.002	– – –	**8230**	1120
First Thought mine No. 3 lower adit (2)	8.2	**14**	≤20.0	– – –	2.0	≤0.3	**6**	3140	– – –
First Thought mine No. 2 middle adit (2)	**1480**	**739**	7610	– – –	52.3	≤0.3	**8.4**	38000	– – –
Last Chance pond (2)	4.3	**30**	**135**	– – –	**26.9**	≤0.3	– – –	**1690**	452
4th of July adit (2)	4.3	**17.9**	356	– – –	1.6	≤0.3	**6**	1040	– – –

PART 2: APPLICABLE WASHINGTON STATE WATER QUALITY STANDARDS

Type of standards (applicable Washington Administrative Code)	Arsenic	Cadmium	Copper	Iron	Lead	Mercury	Selenium	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	5.0	*	100
Ground water standards (WAC 246-290, Washington State Department of Health, standards for ground water, domestic consumption)	10.0	5	1300	300 (cosmetic only)	15	2.0	50	5000	– – –

the Sonny Boy mine's operation (IAML mine file). Jonathan G. Price, State Geologist and Director of the Nevada Bureau of Mines and Geology, provided valuable observations regarding ore paragenesis at the Fourth of July mine. We also thank our editors Jari Roloff and Karen Meyers for helpful suggestions on the layout and content of this report.

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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 and water samples collected by Huchton (1995) and used in this report were analyzed by White Earth Analytical, Inc., Ephrata Wash.

Except for mercury, soil and water samples were analyzed for the metals listed in this report by inductively coupled plasma (ICP) in accord with USEPA (U.S. Environmental Protection Agency) Method 6010B. The water sample DGER collected was 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. Mercury was analyzed in accord with USEPA method 7471A (CVAA). 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

Field equipment used by investigators other than DGER is shown in the respective citations. DGER used the following equipment for measurements and photos:

digital camera
Garmin handheld GPS unit
Oakton digital pH meter
Oakton digital electrical conductivity meter
Taylor model 9841 digital thermometer

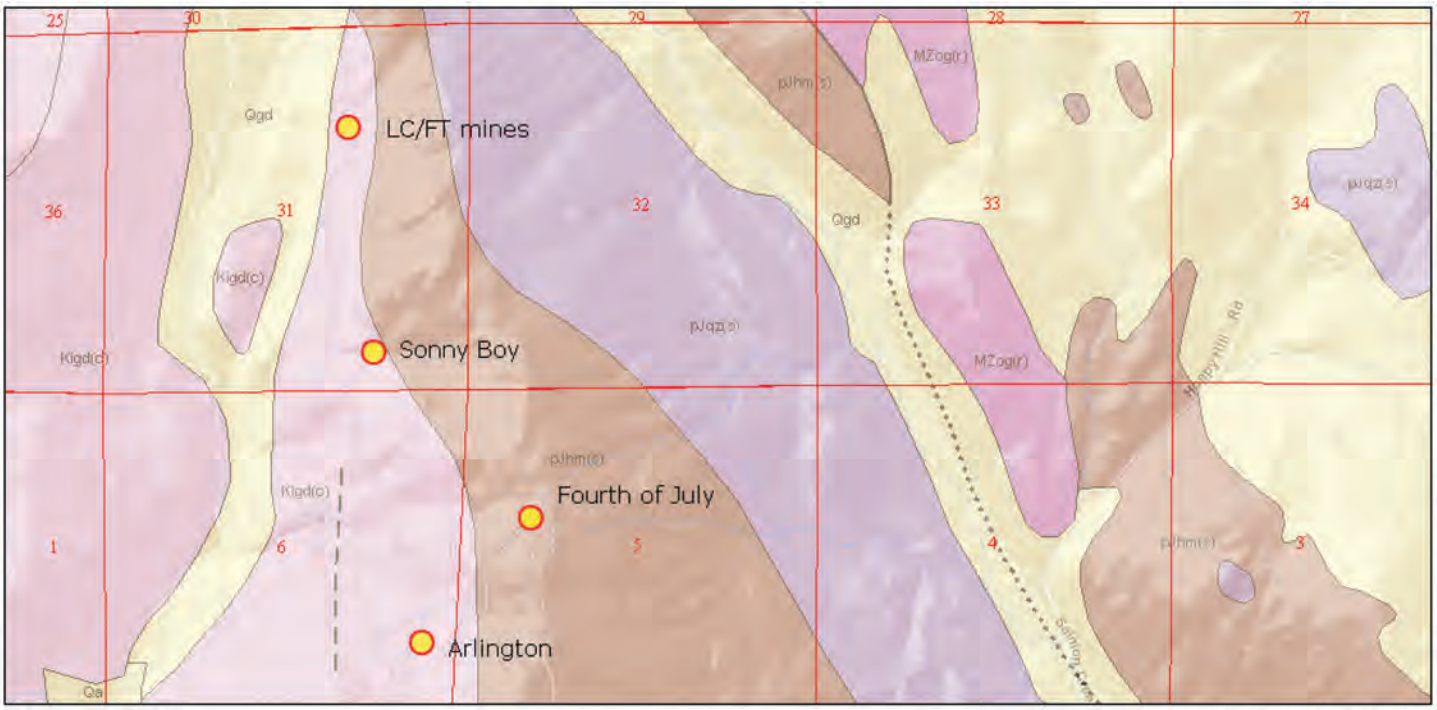
Appendix B. Water quality standards for hardness dependent metals

Chronic standard in micrograms/liter (μg/L). Hardness data from Raforth and others (2000).

Sample location	Hardness (mg/L)	Cd (μg/L)	Cu (μg/L)	Pb (μg/L)	Zn (μg/L)
Arlington mine lower adit	355	2.63	33.43	9.65	305.01
First Thought mine lower adit (No. 3)	1155	6.25	91.83	31.14	830.76
Last Chance pond	452	3.14	70.49	12.40	375.19

Appendix C. The Ruby Hill mining district

Figure C1. Aerial photo of the Ruby Hill mining district.



Map Scale 1:35487

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Geologic Units (1:100,000 scale)

Unconsolidated Sediments

Qa	Quaternary alluvium, dune sand, loess, and artificial fill
Qgd	Glacial drift, undivided—Pleistocene continental glacial, glaciolacustrine, and outburst flood deposits, Fraser-age

Intrusive Igneous Rocks

Kigd(c)	Tertiary–Cretaceous and Cretaceous intrusive igneous rocks (Conconnully Granodiorite)

Metamorphic Rocks (Amphibolite Facies and Higher)

pJhm(s)	pre-Jurassic–Permian metamorphic rocks (Salmon Creek Schists and Gneisses)
MZoz(r)	Mesozoic orthogneisses and migmatites
pJqz(s)	Mesozoic and older metamorphic rocks (Salmon Creek Schists and Gneisses, quartzite)

Contacts (1:100,000 scale)

———	Contact - Identity and existence certain, location accurate

Faults (1:100,000 scale)

———	Fault, unknown offset - Identity and existence certain, location accurate
– – –	Fault, unknown offset - Identity and existence certain, location approximate
·····	Fault, unknown offset - Identity and existence certain, location concealed

Figure C2. Geologic map of the Ruby Hill area (after Gulick and Korosec, 1990).

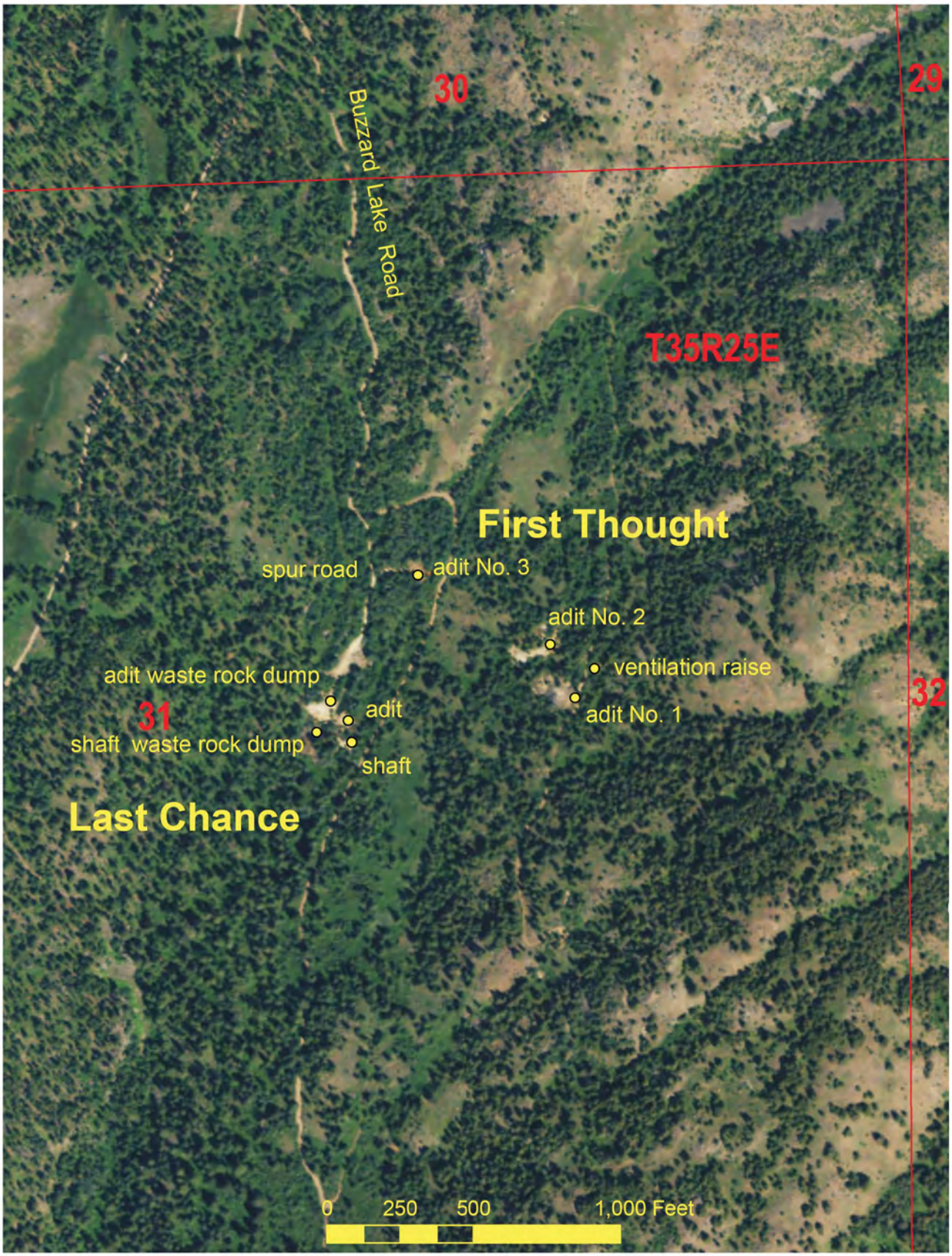


Figure C3. Aerial photo showing features at the First Thought and Last Chance mines.

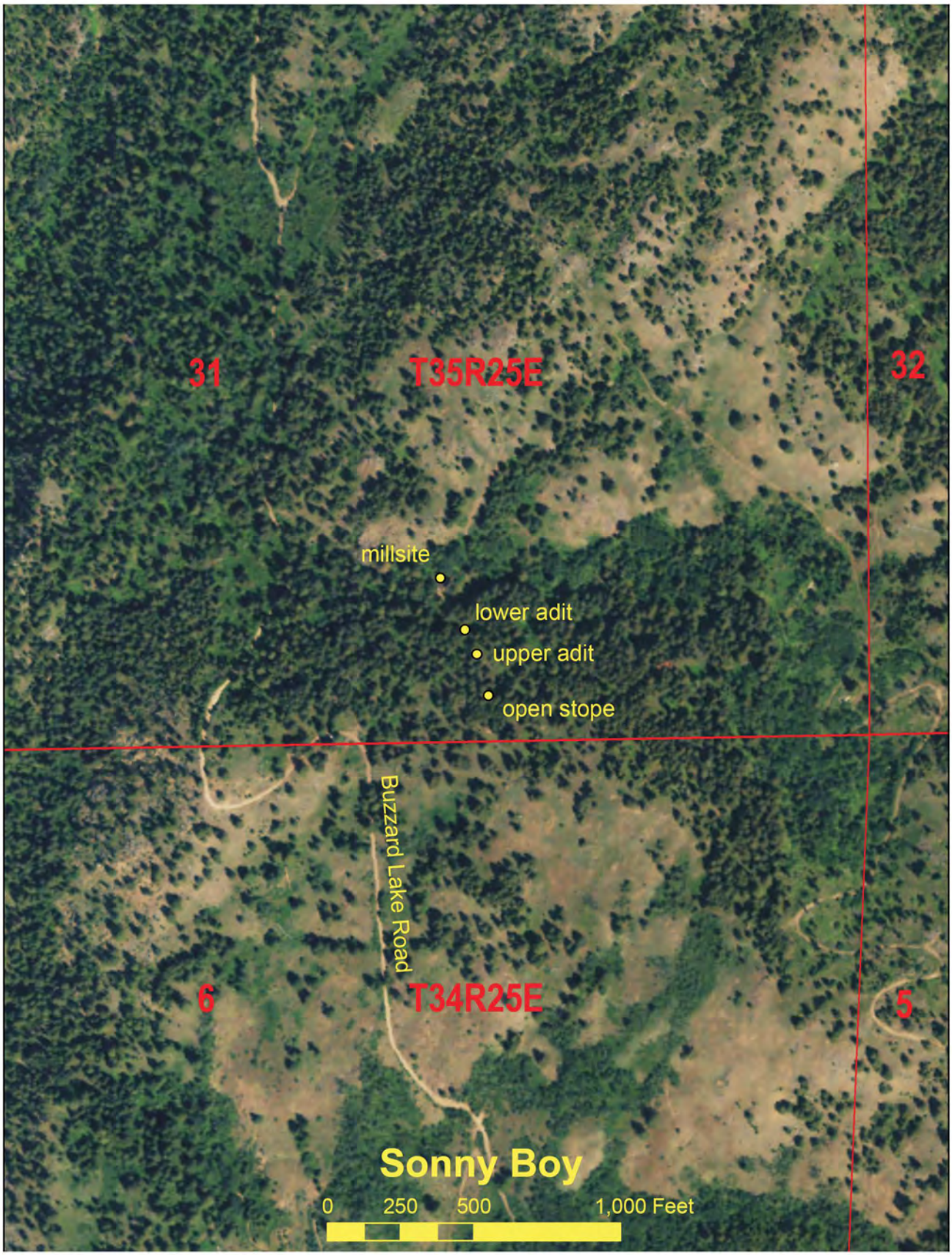


Figure C4. Aerial photo showing features at the Sonny Boy mine.

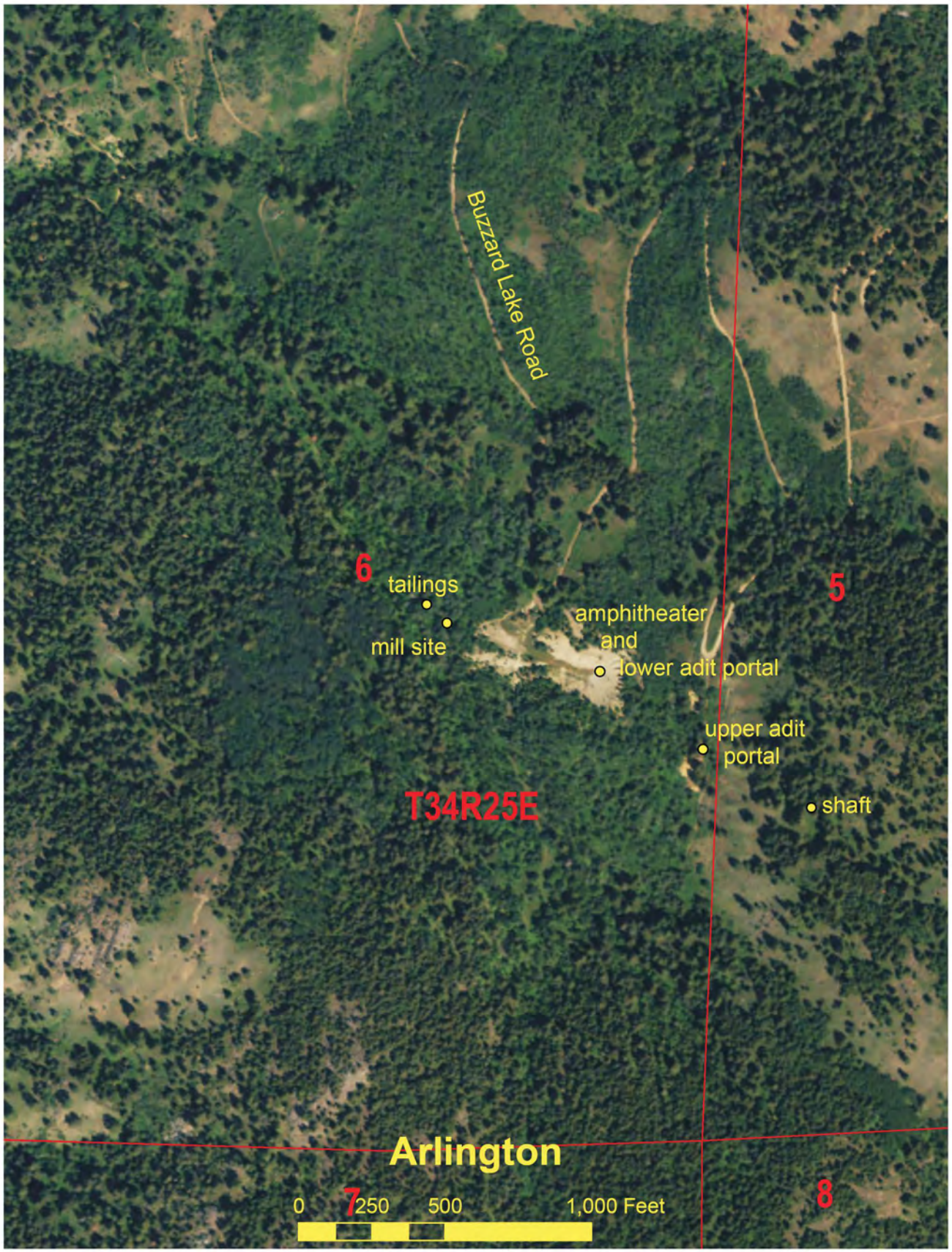


Figure C5. Aerial photo showing features at the Arlington mine.

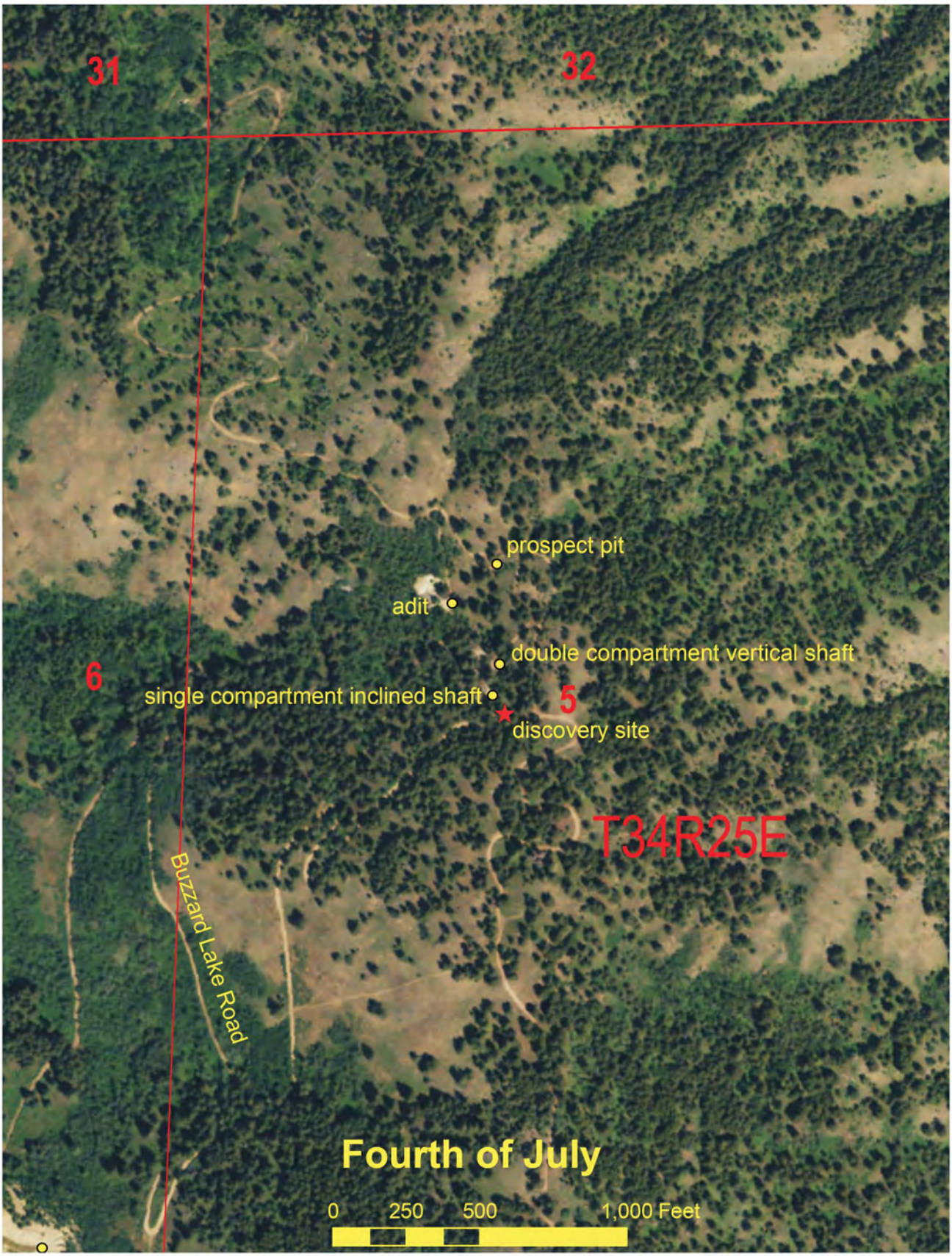


Figure C6. Aerial photo showing features at the Fourth of July mine.

Appendix D. Mine drawings and claim locations

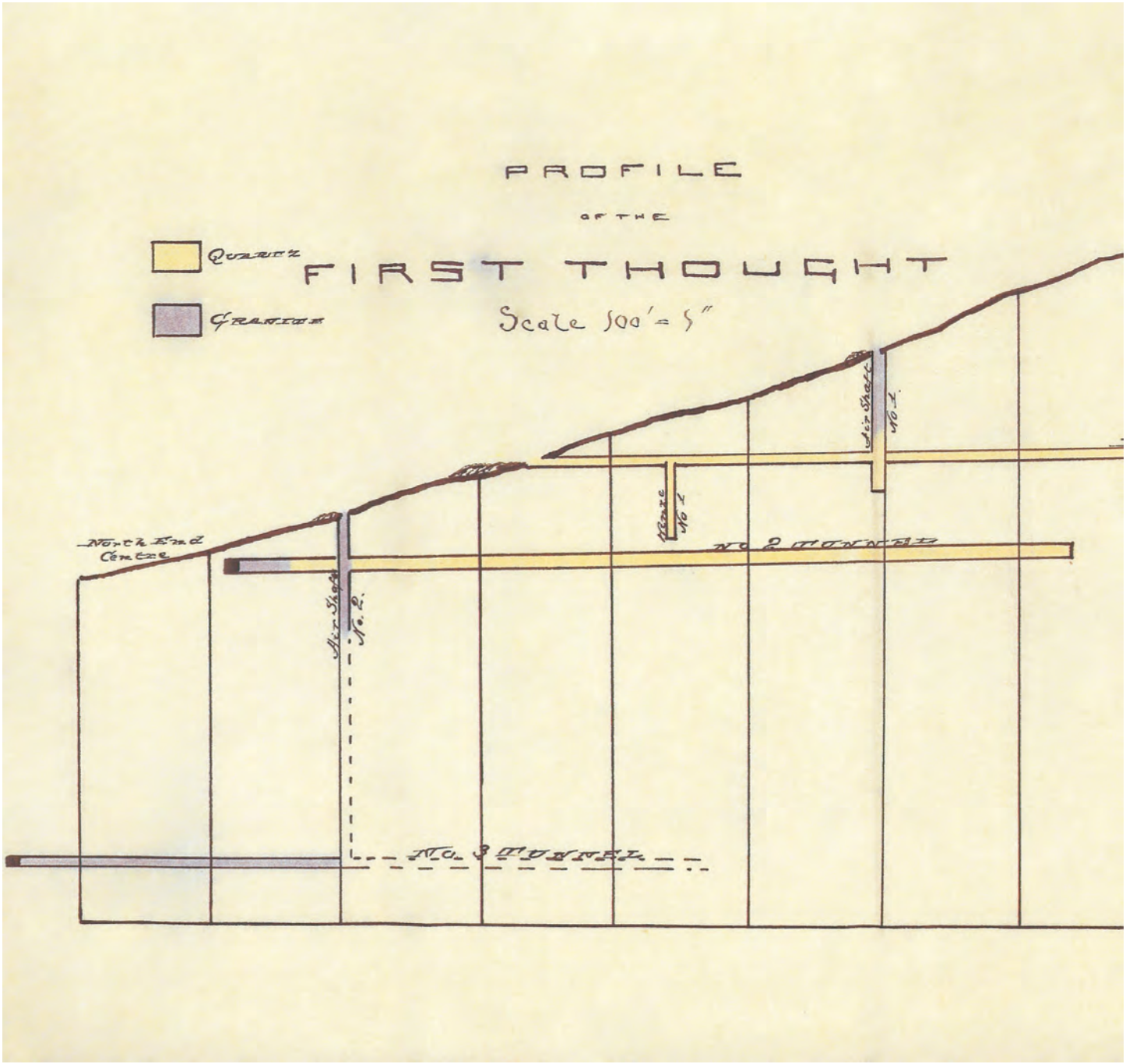


Figure D1. Cross section of the First Thought mine (left half). (Reprinted from Milliken, 1891.)

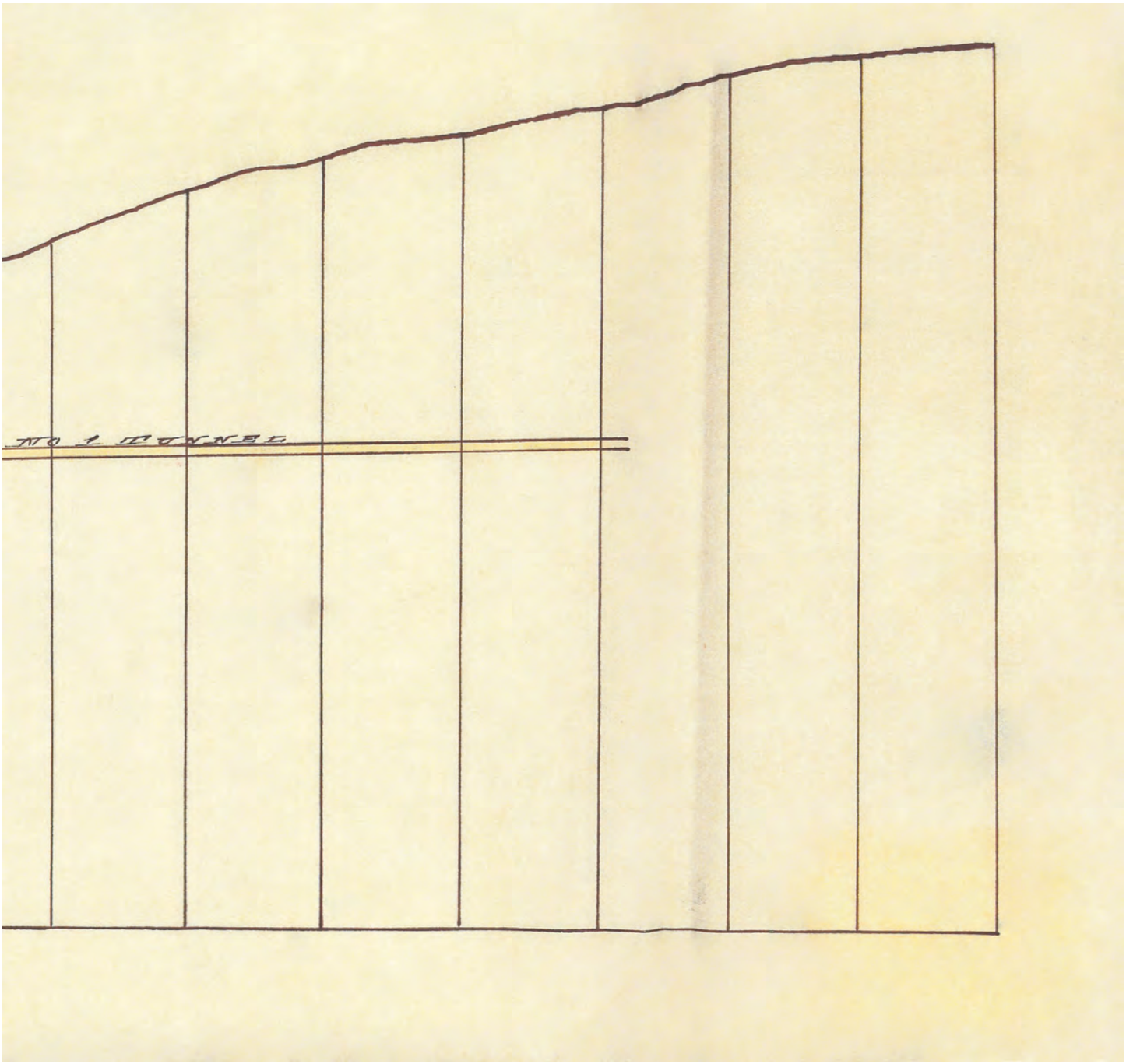


Figure D1. *(Continued)* Cross section of the First Thought mine (right half). (Reprinted from Milliken, 1891.)

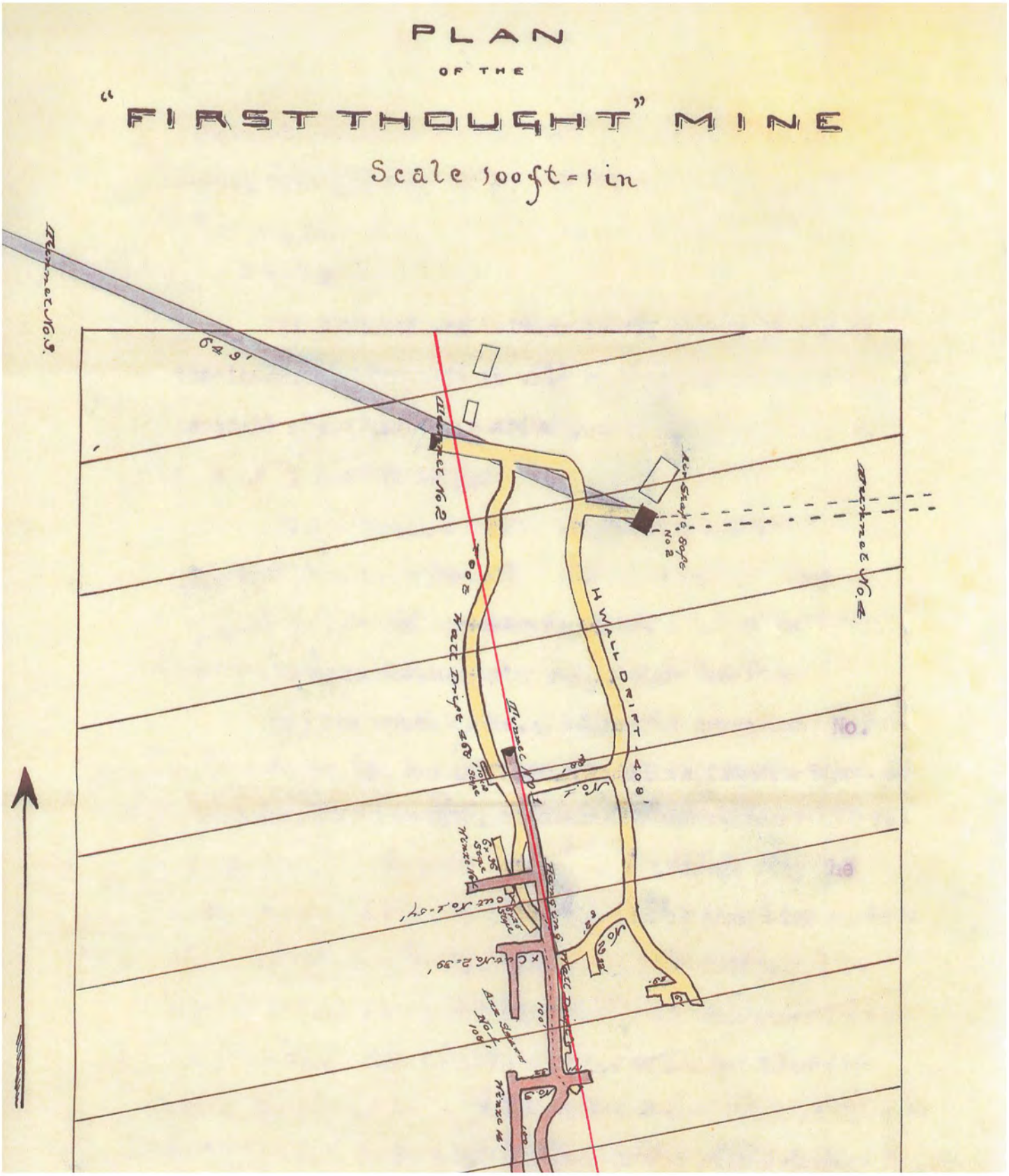


Figure D2. Plan view of First Thought underground development (top half). (Reprinted from Milliken, 1891.)

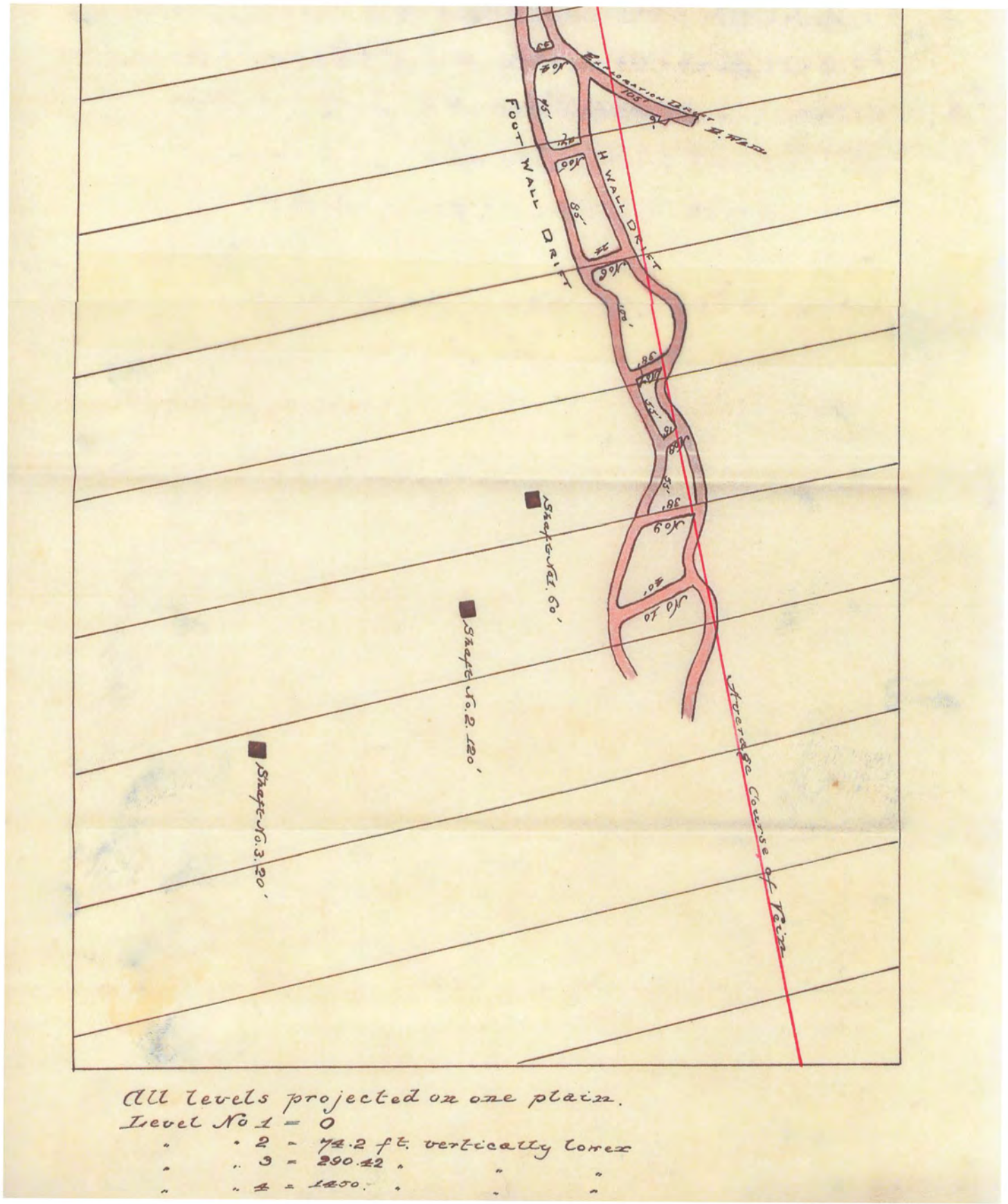


Figure D2. *(Continued)* Plan view of First Thought underground development (top half). (Reprinted from Milliken, 1891.)

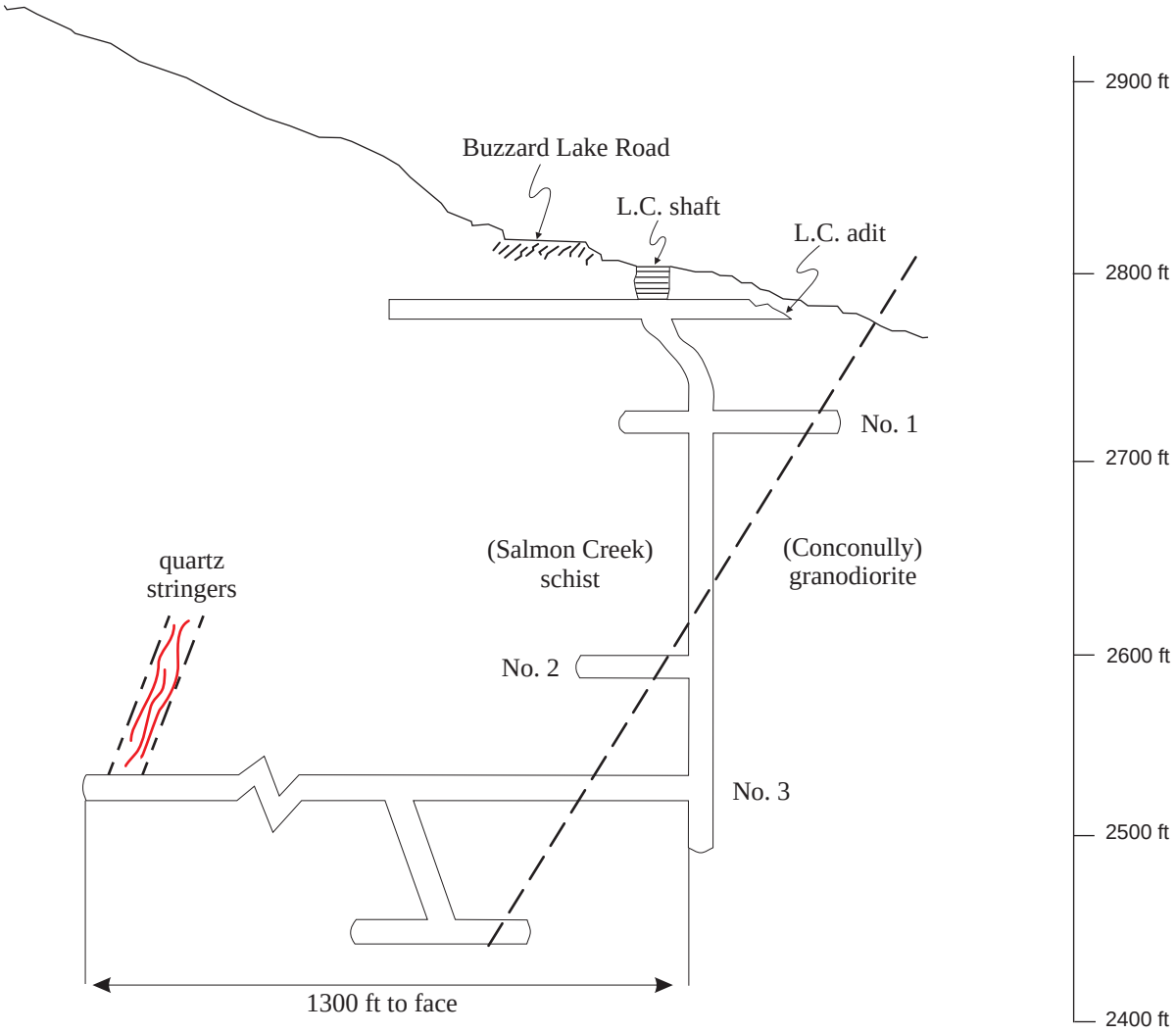


Figure D3. Cross section of the Last Chance mine development. Vertical scale: 1 inch = 100 feet; no horizontal scale. View is to the south. (Adapted from a sketch by J. S. Wyatt, 1917, DGER mine files.)

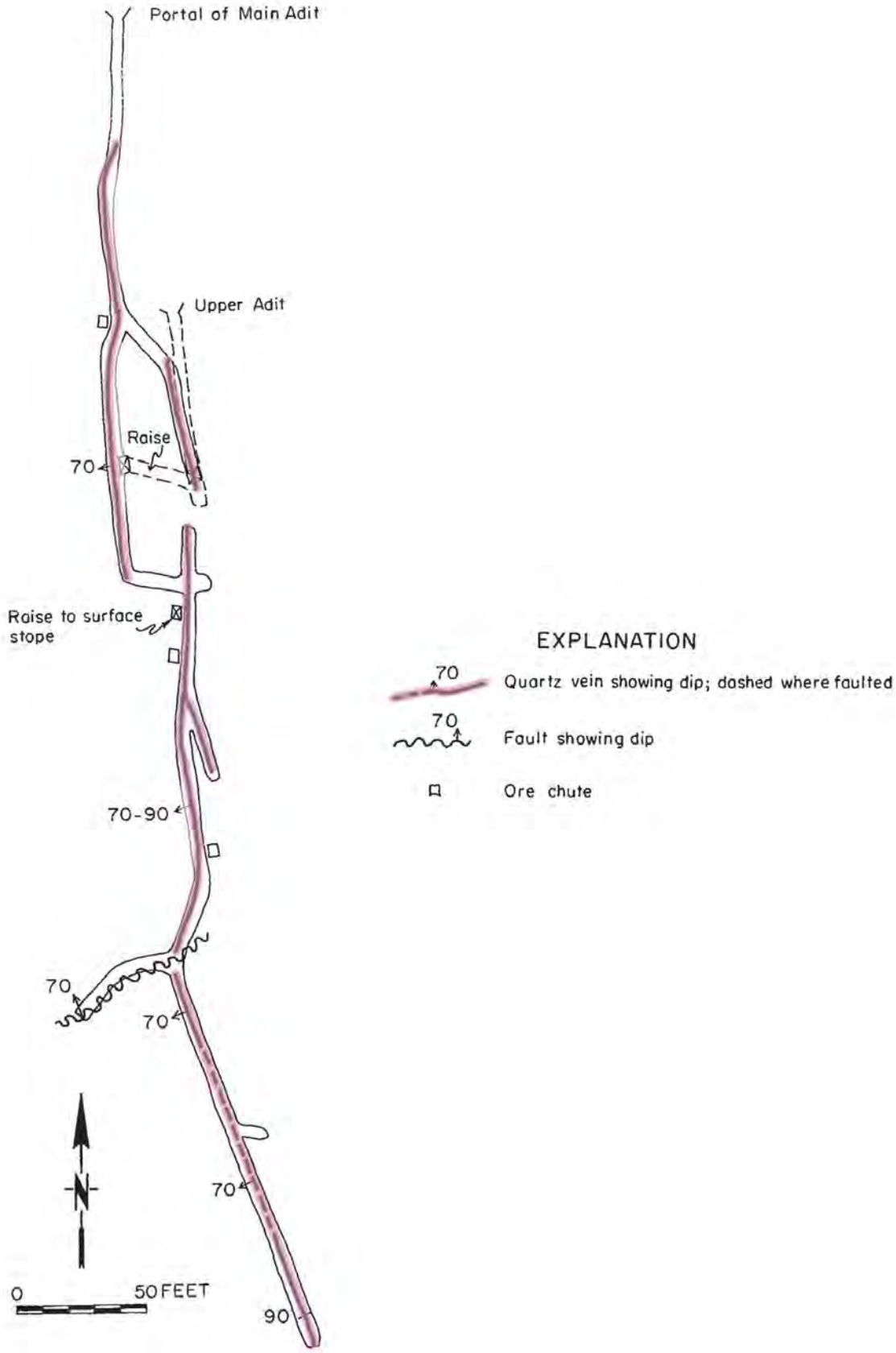
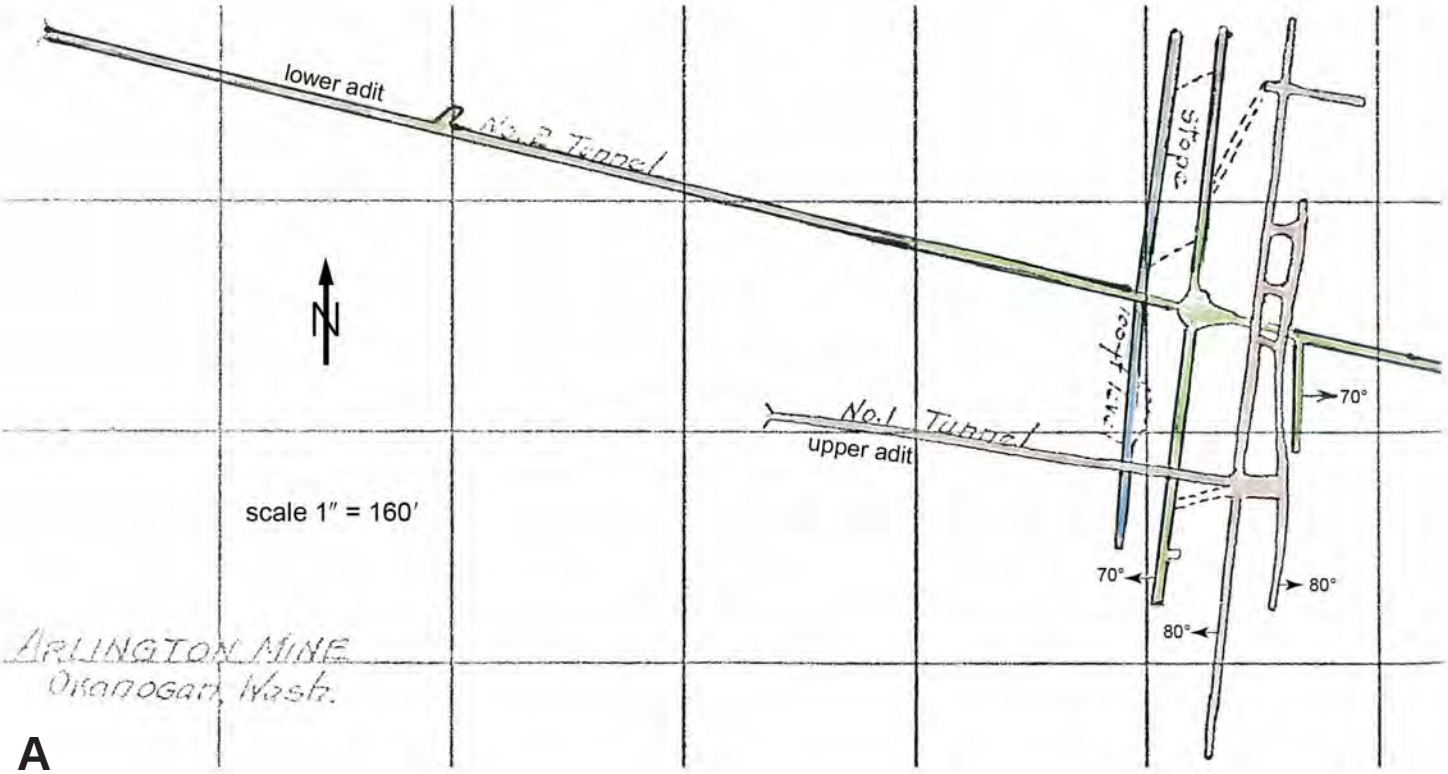


Figure D4. Plan view of the Sonny Boy mine development. (Reprinted from Moen, 1973.)



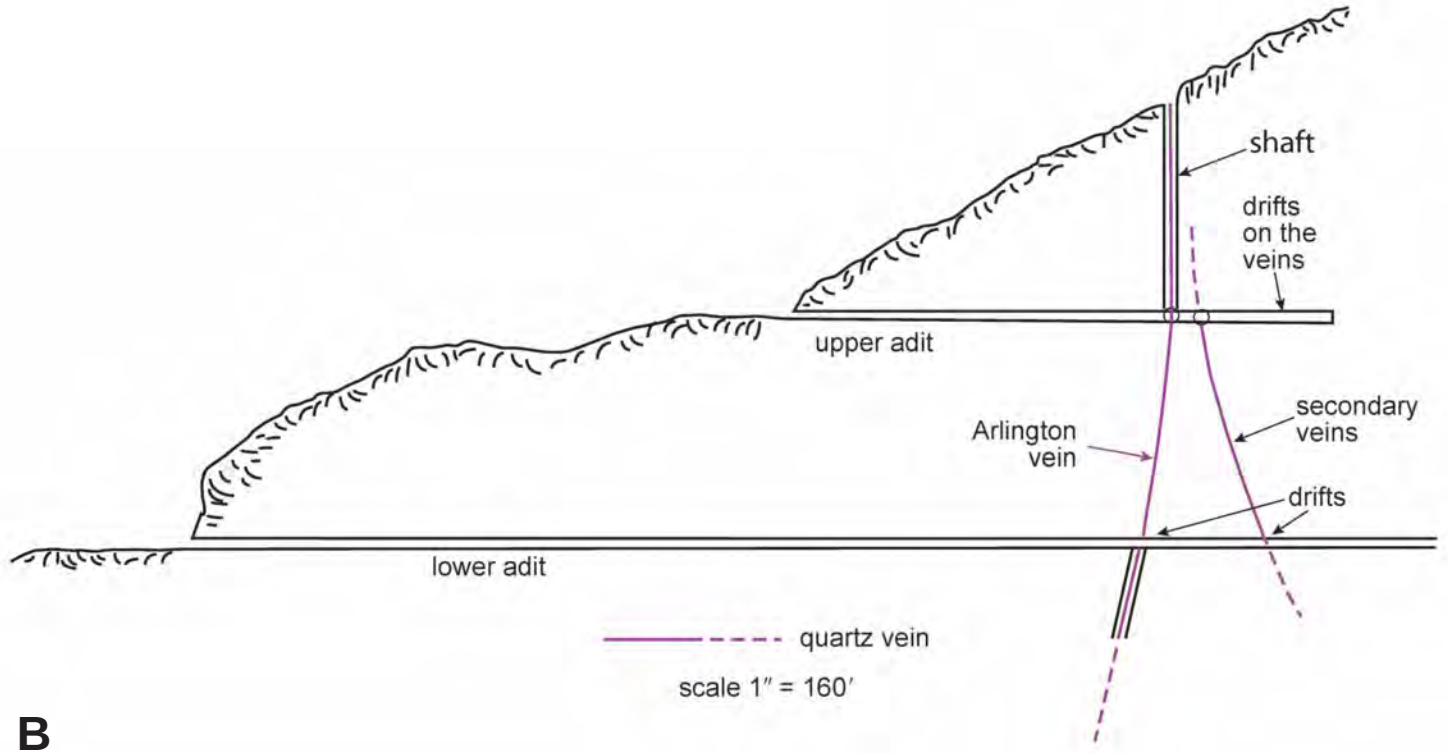


Figure D5. **A.** Plan view map of the Arlington mine. The upper adit is superimposed on the lower adit. **B.** Cross-section sketch of subsurface vein morphology. View is to the north. (Reprinted from map and sketch by Clarke, 1947, DGER mine files.)

Figure D6. Cross section of the Arlington mine between the upper and lower adits along the plane of the Arlington vein (adapted froma sketch by Clarke, 1947, DGER mine files). View is to the east.

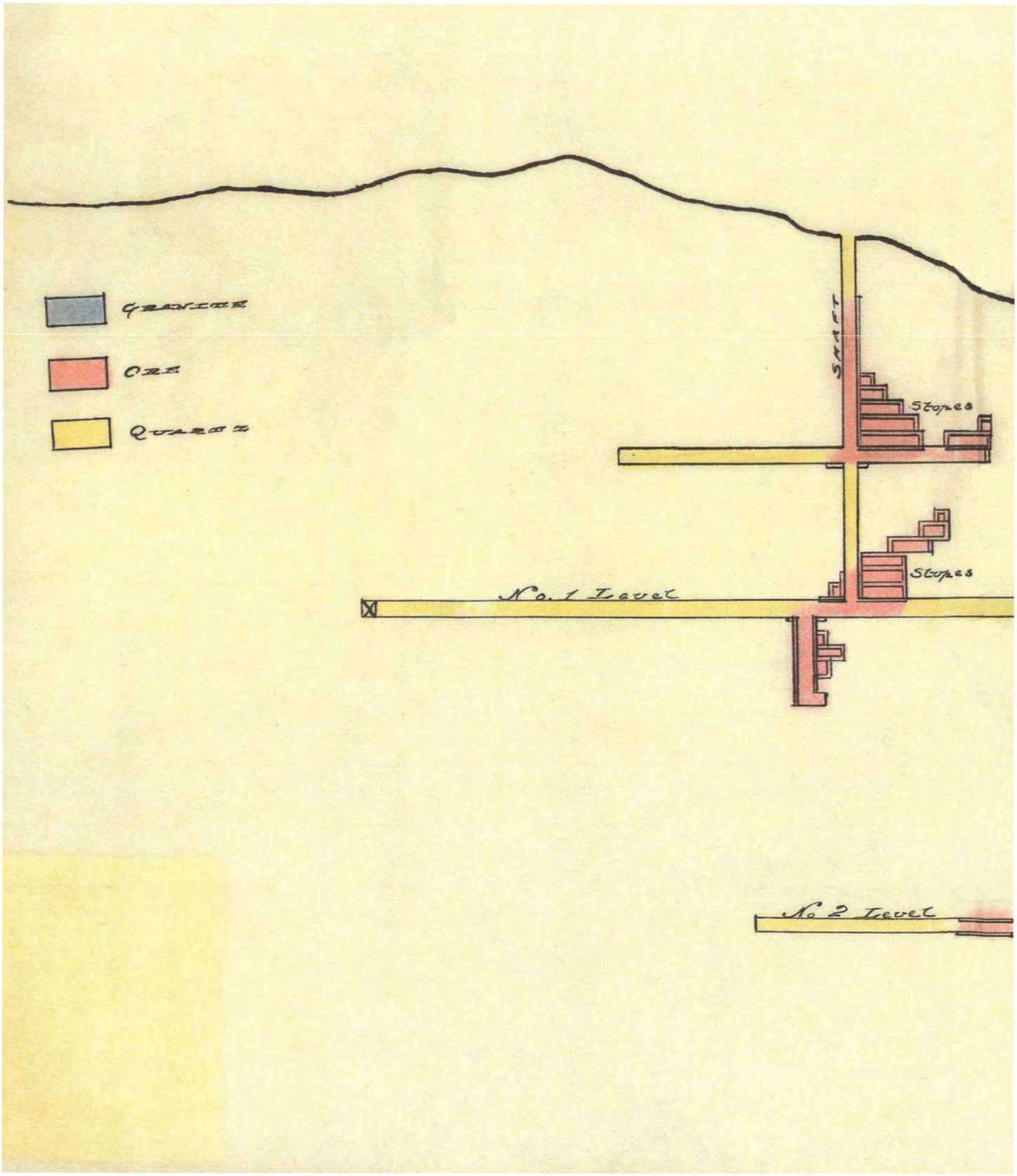


Figure D7. Cross section of the Fourth of July mine in 1890 (left half). (Reprinted from Milliken, 1891.) The vertical shaft was later deepened to 500 feet. The superimposed circa-1975 adit location is calculated. Milliken's "granite" notation is biotite gneiss. The inclined shaft lies in the plane of the vein dipping east. View is to the west.

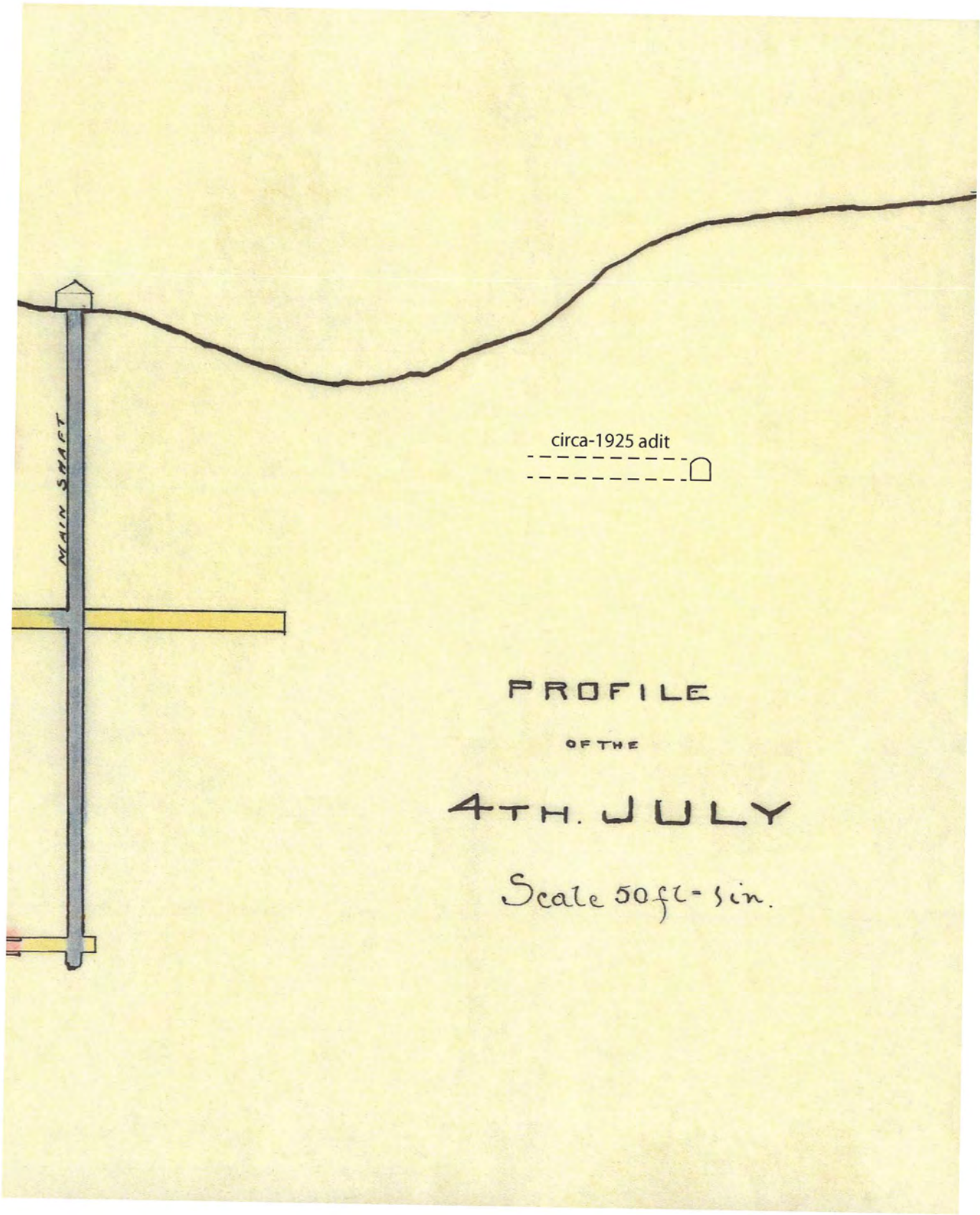


Figure D7. *(Continued)* Cross section of the Fourth of July mine in 1890 (right half). (Reprinted from Milliken, 1891.)

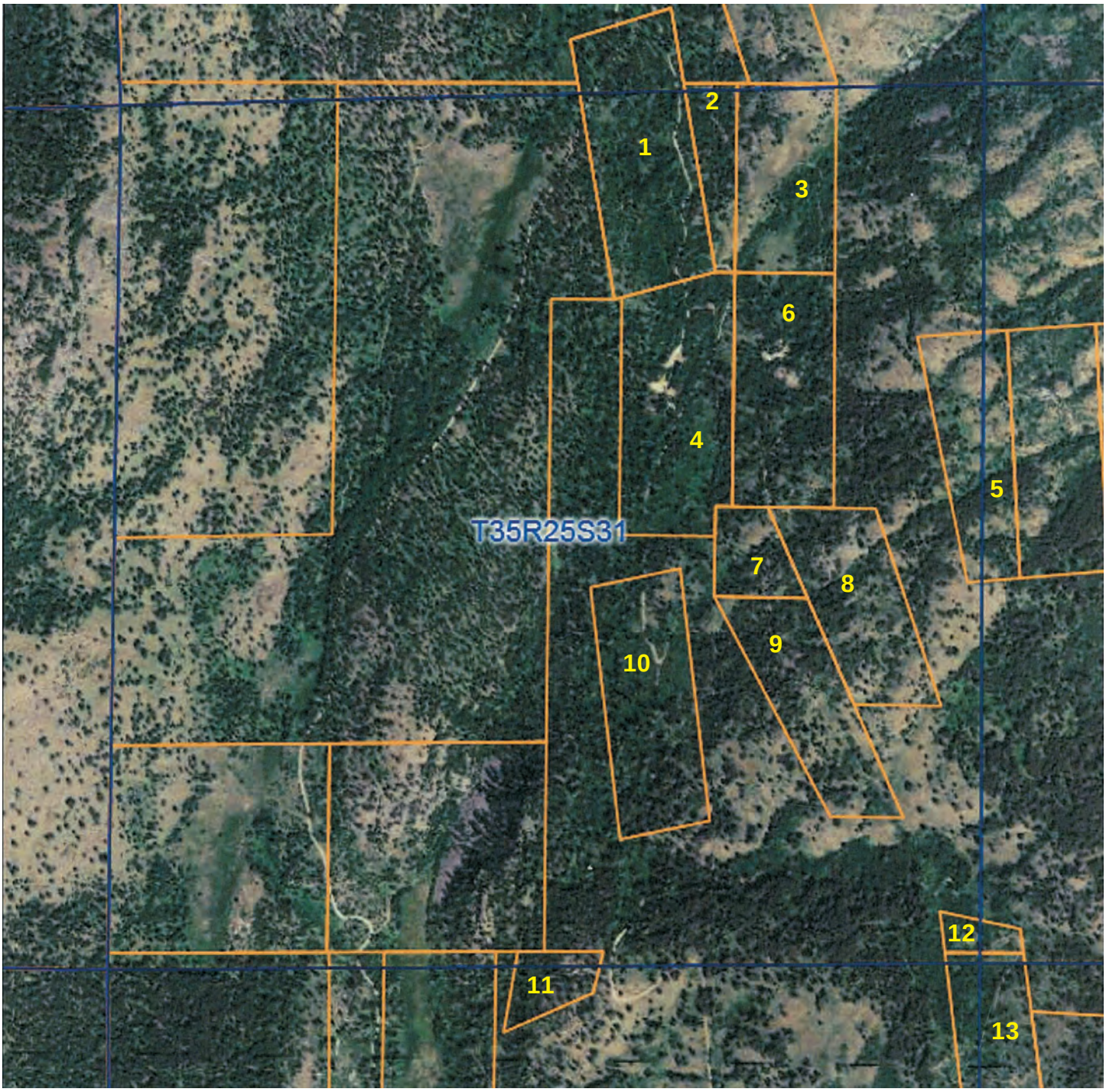


Figure D8. Patented claims in sec. 31, T35N R25E (northern claims).

Map no.	Name and Mineral Survey no.	Okanogan Co. parcel no.	Ownership
1	Kitty, no. 229	993525/3120	private
2	Last Chance fraction, no. 746	/3120	private
3	Silver, no. 736	/3013	USA
4	Last Chance, no. 746	/3119	private
5	Bryn Mawr, no. 107	/3012	USA
6	First Thought, no. 80	/3119	private
7	Second Thought fraction, no. 150	/3121	USA

Map no.	Name and Mineral Survey no.	Okanogan Co. parcel no.	Ownership
8	Second Thought, no. 150	/3121	USA
9	Delta, no. 149	/3121	USA
10	Buckeye, no. 75	/3121	USA
11	May, no. 102	/3013	USA
12	Unknown fraction	/3013	USA
13	Bay Horse, no. 68	/3013	USA

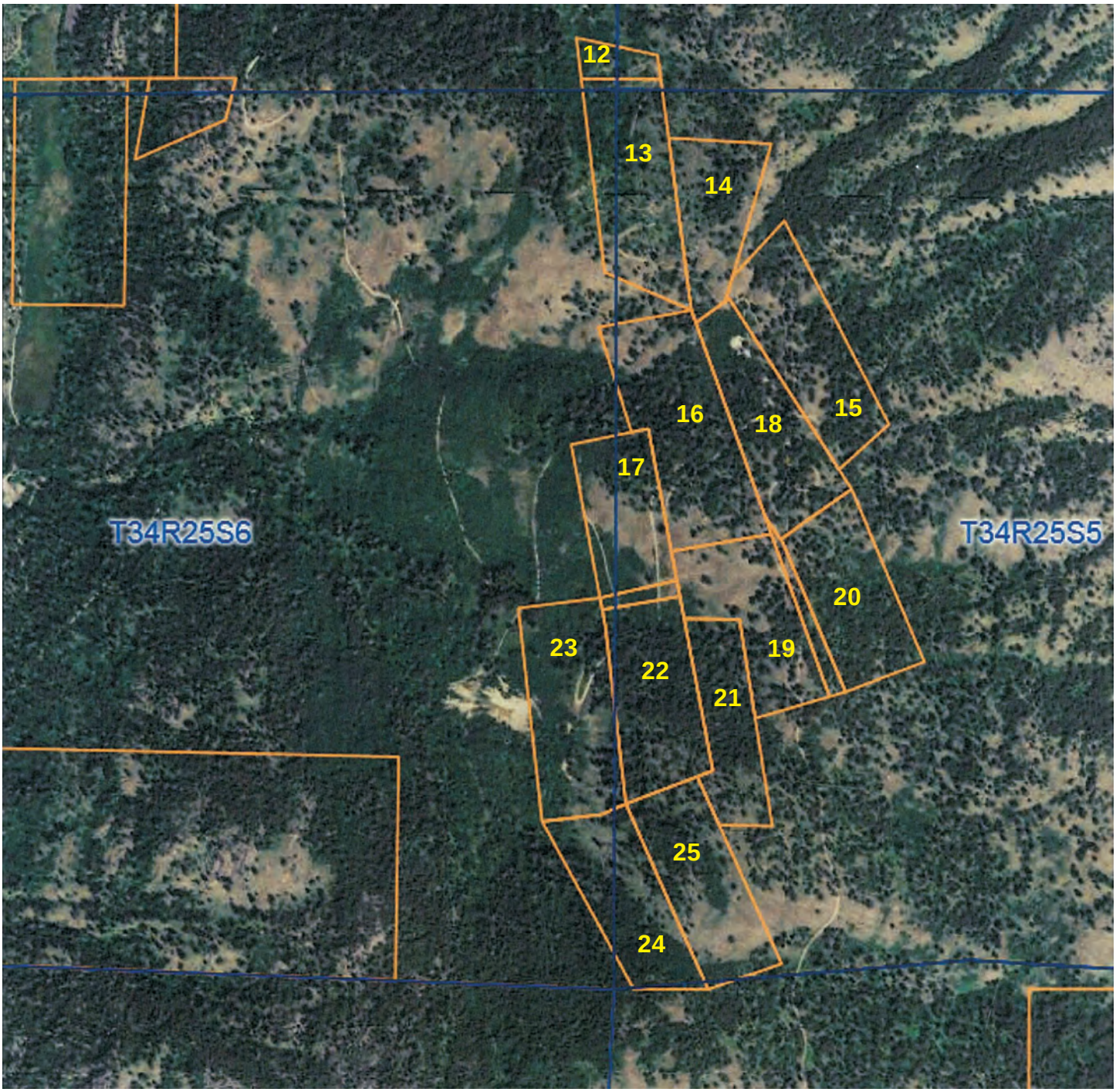


Figure D9. Patented claims in secs. 5 and 6, T34N R25E (southern claims).

Map no.	Name and Mineral Survey no.	Okanogan Co. parcel no.	Ownership
12	Unknown fraction	993525/3013	USA
13	Bay Horse, no. 68	/3013	USA
14	Monitor, no. 72	993425/0514	private
15	Antler, no. 128	/0506	private
16	Arizona, no. 74	/0511	private
17	1806 Lode, nos. 1032A&B	/0508	private
18	Fourth of July, no. 37	/0515	private
19	Climax, no. 99	/0515	private

Map no.	Name and Mineral Survey no.	Okanogan Co. parcel no.	Ownership
20	Keystone, no. 71	/0515	private
21	Minnesota, nos. 1032A&B	/0511	private
22	Arlington, no. 38A	/0508	private
23	Princess, nos. 1032A&B	/0511	private
24	Wisconsin, no. 417	/0514	private
25	Pomeroy, no. 76	/0509	private
26	Arlington Fraction	/0512	private