NATURAL RESOURCES

INACTIVE AND ABANDONED MINE LANDS—
Boundary Red Mountain Mine, Mt. Baker Mining District, Whatcom County, Washington

by Fritz E. Wolff,
Matthew I. Brookshier,
and David K. Norman

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Information Circular 99
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site
location

WASHINGTON STATE DEPARTMENT OF
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Errata: The photo (Fig. 7) shown in the earlier edition of this IC as the Boundary Red Mountain mine mill was actually of the Lone Jack stamp mill shortly after it was built in 1900. The photo was mislabeled in the collection from which it was taken. New photos of the Boundary Red Mountain mine mill have been added to this edition. The correction is based on photos that appeared in an article in *The Olympian* on Dec. 2, 1979: “Searching the Lone Jack for Gold and Ghosts,” by Mary Ellen Benson. Verification of the photo location was based on on a site investigation by a DGER geologist in 2003.

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Inactive and Abandoned Mine Lands— Boundary Red Mountain Mine, Mt. Baker Mining District, Whatcom County, Washington

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INTRODUCTION

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

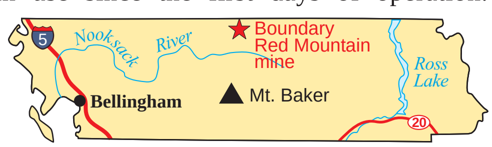
More than 3800 mineral properties have been located in the state during the last 100 years (Huntting, 1956). Many are undeveloped prospects of little economic importance. Therefore, in considering the population to include in the Inactive and Abandoned Mine Lands (IAML) inventory, we have identified 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 reopen 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. The IAML database may be viewed with assistance from DGER personnel. IAML reports are posted online at http://www.dnr.wa.gov/geology/pubs/.

SUMMARY

Four adits of the Boundary Red Mountain (BRMt) mine lie on the north slope of a group of 7000-foot peaks identified as the Pleiades (Fig. 1). Notation on the Mt. Larrabee USGS 7.5-minute quadrangle refers to the property as the Red Mountain Mine, an unfortunate coincidence since a mine of the same name is located at Trinity near Lake Wenatchee. In order to avoid confusion, we have adopted the name Boundary Red Mountain mine, which has been in use since the first days of operation. (Mt. Larrabee was formerly named Red Mountain.) The property is situated in secs. 3



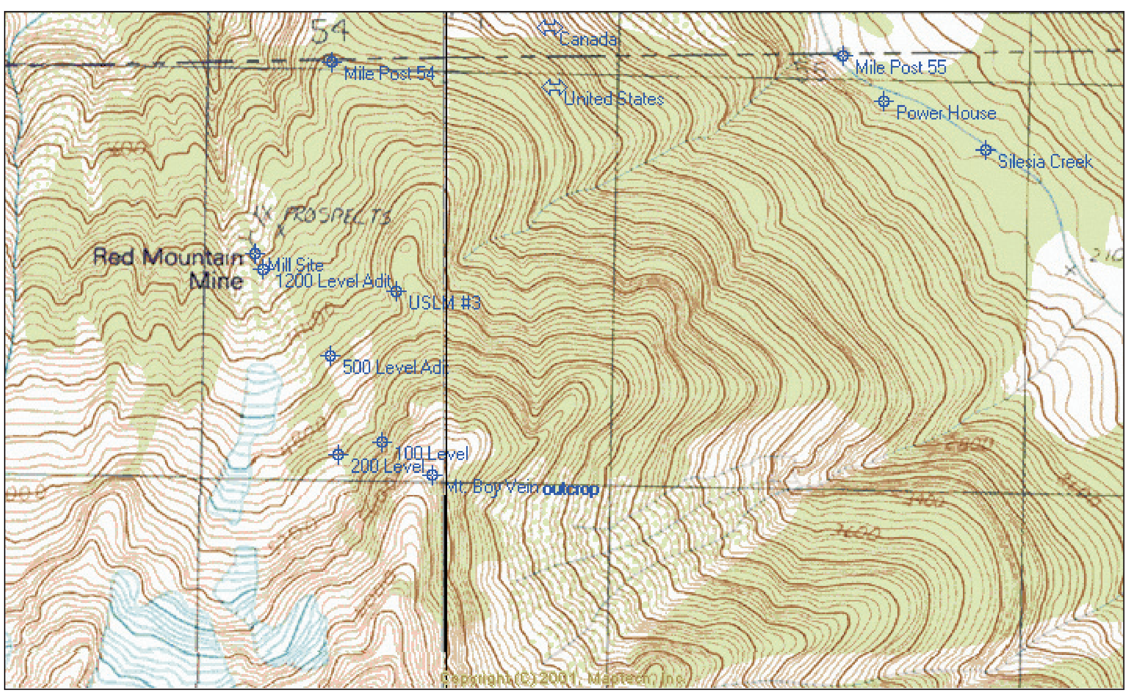


Figure 1. Map showing the location of the Boundary Red Mountain mine in Whatcom County (top) and a more detailed map of the mine site (bottom). Section lines are 1 mile apart.

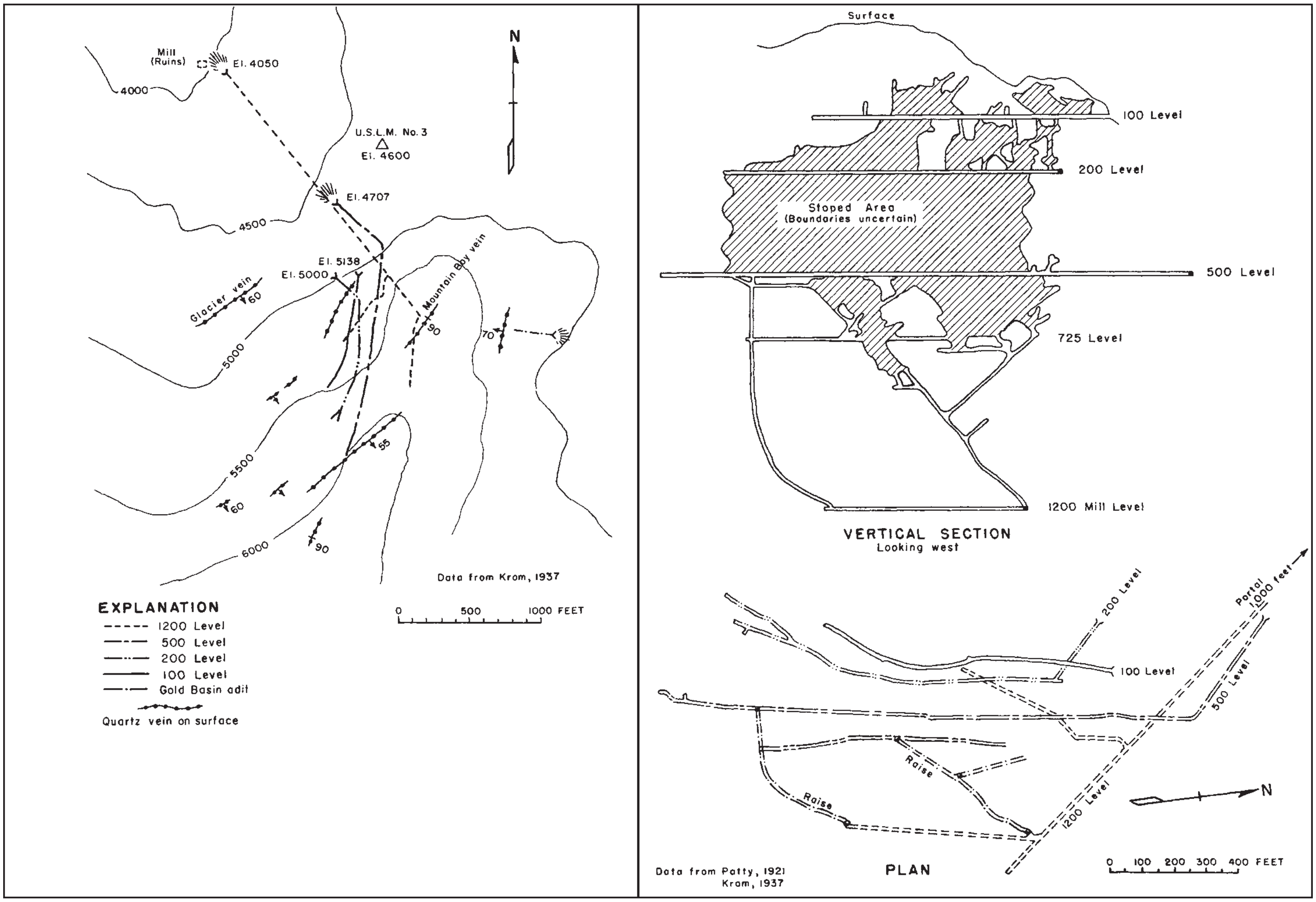


Figure 2. Site map of the Boundary Red Mountain mine workings and veins (after Moen, 1969).

and 4, T40N R9E, and sec. 34, T41N R10E. The northernmost corner of the property lies approximately 1385 feet south of milepost 54 on the U.S.–Canada border.

The property consists of six contiguous patented lode claims surrounded by the Mt. Baker Wilderness Area, which is administered by the U.S. Forest Service. Title to the patented claims is privately held. As described below, access to the property is not easy. The overland approach from Canada is no longer an option due to changes in border security, and the USFS trail from Skagway Pass/Twin Lakes to Silesia Creek, which has not been maintained, stops short of the border by 1 mile. When snow free, dumps at the mine's 1200 and 500 Levels can accommodate a small helicopter. Elevations of former infrastructure and development range from 2000 feet on Silesia Creek to stopes at the 100 Level at over 5000 feet. Aside from a few years of standby status occasioned by fires and snow slides, the mine was in continuous production from 1913 to 1942. Grant (1987) estimates the total production at 80,000 tons with an average mill-head grade of 0.6 ounce per ton gold. The reported total dollar value at the historic price of gold was $947,579 (Moen, 1969).

Ore occurs in five quartz fissure veins—the Red Mountain vein was the only one actually mined. On the 1200 Level, about 950 feet below the outcrop, this vein pinches down to a narrow stringer and the gold values are low (Krom, 1937). The other veins may be faulted segments of the Red Mountain vein or separate entities. The highly metamorphosed host rocks, a fine-grained diorite and carbonaceous amphibole schist, occur in a structural block of Devonian Yellow Aster Complex (Chaney, 1992). The veins strike fundamentally south into the cliff bands and talus beneath multiple peaks of the Pleiades edifice. Dip ranges from 50 degrees east to vertical.

During its production years, the mine had a power plant on Silesia Creek, thousands of feet of phone and power transmission lines, several bunkhouses, an office, a stamp mill, and an aerial tramway. No structures remain standing, as was the case in 1969 (Moen). Most of the mill equipment lies where it fell when the mill burned circa 1940 (DGER mine file). Water discharges from the 1200 Level haulage tunnel at 500 gallons/minute in the summer months. It infiltrates the waste rock dump a few feet from the portal (see Table 5). Mill tailings, invisible from the mill site, were discharged over an embankment, falling ~800 feet toward a stream-fed ravine. DGER personnel visited the site in September 2003.

ACCESS

Historically, the easiest approach to the mine was from Chilliwack, B.C., by following logging roads leading south along Slesse Creek (Silesia Creek in U.S.) to milepost 54. From the milepost, an overgrown trail ascends a cleaver between two avalanche chutes to the mine. Several problems have arisen that make this approach currently unworkable. Both sides of the "Chilliwack–Slesse Creek" road(s) are impassable (Chilliwack Search and Rescue, written commun., 2004), and the trail to the mine from milepost 54 switchbacks across the border several times. The border has alarms and is monitored by the U.S. Border Patrol. Attempts to obtain permission (from U.S. Customs at Blaine, Wash.) for DGER personnel to use the approach from Canada were unsuccessful. From the U.S. side of the border, the mine can be reached by following a foot trail from Skagway Pass near Twin Lakes, descending Winchester Creek to Silesia Creek, proceeding north to a point near milepost 55 and ascending 2000 feet through forest to the mine. The trail has not been maintained (USFS Glacier Station Ranger, oral commun., 2003). It is overgrown with brush and numerous windfalls. For access by air, waste rock dumps at 4050- and 4707-foot elevations can accommodate a small helicopter.

Figure 3. Outcrop and adit (arrow) of the Mountain Boy vein. View to the west.

OWNERSHIP

The property consists of six patented lode claims: Klondike, Rocky Draw, Mountain Boy, Glacier, Climax, and Climax Extension No. 1. The claims were located between August 1898 and July 1900. They were surveyed for patent as Mineral Survey 699 in October 1902. The patent number for the block of 139 acres is 39545. The estate of John Wiatrak, Olympia, Wash., owns the patented claim group (Whatcom Co. Assessor, written commun., 2003). Figure 1 indicates the approximate location of U.S. Land Monument No. 3, 600 feet N39°E of the 500 Level adit (DGER mine file).

HISTORY

C. W. Both and associates discovered the Red Mountain vein in 1897 and staked it the following year. Elmon Scott, a Washington State Supreme Court justice, took an interest in the mine and organized the Red Mountain Gold Mining Co., which acquired title to the claims and started work in 1902. In 1907, the Boundary Red Mountain Mining Co. assumed title to the property. A five-stamp mercury amalgamation mill was constructed in October of 1914. The following year, George Wingfield and associates of Goldfield Consolidated Mining Co. leased the mine and upgraded the mill to 60 tons/day with ten stamps, installed a water-driven Hendy-Francis turbine power plant on Silesia Creek, and generally improved the infrastructure. World War I interrupted the flow of men and materials, but mining continued at a slower pace. Work continued in stopes above the 500 Level until 1923, at which time a crosscut known as the 1200 Level was begun from the mill site. Krom (1937) reported, "In March, 1925 . . . the [Red Mountain] vein was struck 2200 feet from the portal. It proved to be merely a narrow stringer, two inches to eight inches wide. An inclined raise was carried southward in the plane of the vein to the 500 Level. After many delays the 500 Level was reached, with commercial ore showing some 200 feet below this level."

After the collapse of the Wingfield interests in 1927, the mine was placed in receivership at the Reno National Bank, Reno, Nevada. A. H. Westall, a former superintendent at the mine, leased the property and continued operations with a crew of seven until 1935. At this time International Gold Mines Ltd., a Canadian company, was organized for the purpose of acquiring the BRMt mine and equipment. International Gold Mines Ltd. declared bankruptcy in 1938. W. W. Wagner and Tom Bourn of Bellingham purchased the mine from the receivership for $12,000 in 1939. In the 1950s, Bourn willed the patented land to John P. Wiatrak, a geologist who had formerly worked with him at the mine.

Solo International Resources Ltd. of Vancouver, B.C., entered into a lease and option agreement based on an examination done by A. R. Grant in 1987 (DGER mine file). Grant later issued an amended report after spending the 1988 summer season at the mine. Grant's examination appears to be the last comprehensive sampling and estimate of remaining ore reserves. Grant and Beach (1989) traced the Red Mountain vein 1500 feet south of a point directly above the southernmost 500 Level heading. "Here, . . . it disappears under a small hanging glacier at the 6940 foot elevation." A 15-foot chip sample taken at this point assayed 1.066 ounces per ton gold. Grant stated, "The potential ore blocks above and to the south of the present mine workings (down to the 500 Level only) total 308,000 tons. Salvage and potential ore blocks within the mine range from 29,000 tons to 42,000 tons. It is anticipated the target grade for the potential ore in the Red Mountain vein system will remain in the 0.5 ounce per ton Au range. The northerly projection of the vein structure was traced by air [~3000 feet] into the Silesia Creek drainage." It is not apparent if further exploration or development work was carried out after 1988.

Mining at the BRMt was not for the timid or faint hearted. Meltwater from snowfields and glaciers above the mine poured through production stopes and raises 2 to 3 feet wide at a rate of 500 gallons per minute during the summer months (Krom, 1937). During winter months, avalanches shot by on both sides of the camp quarters. Labor turnover was as high as 96 percent in September 1921. Krom (1937) reported the following observation: "Labor turnover was so rapid that it required the proverbial three crews—one coming, one working, and one leaving—to keep the mine in operation. Not uncommonly, men arrived and departed without having worked one full shift." Aside from the isolation and difficult conditions, moving equipment and supplies purchased in the U.S. through Canadian customs provided an additional layer of complexity, and immigration laws prevented local Canadian labor from entering the U.S.

GEOLOGIC SETTING

The veins of the BRMt group occur as five disconnected quartz fissure veins in the metamorphic Yellow Aster Complex of Devonian age. The host rocks consist of amphibole schist and a fine-grained metadiorite containing hornblende. Disseminations of pyrite occurs in both units. Moen (1969) reported that the gold-bearing veins ". . . appear to have been formed during two stages of mineralization. During the initial stage, fractures in the rock were filled with quartz containing small amounts of iron sulfides, and chalcopyrite. Later, recurrent movement along the veins produced microbrecciation of the quartz permitting hydrothermal solutions containing pyrite, pyrrhotite, chalcopyrite, free gold and tellurobismuthite to infiltrate partings in the quartz fissure." The main ore mineral is native gold alloyed with minor amounts of silver. This is the same mineral assemblage and paragenesis found at the nearby Lone Jack mine. The brecciated zones contain distinctive wavy brown bands of iron oxide in otherwise vitreous milky quartz. Most of the gold is so fine-grained as to be invisible to the unaided eye. However, Krom (1937) reported gold occurring in sheets as much as 1 inch square by approximately 1 micron thick, filling thin fractures in the quartz.

Five veins were discovered on or near the BRMt claims. They are the Red Mountain vein, Gold Basin vein, Mountain Boy vein, and the Glacier vein (Krom, 1937). The entire production of the mine thus far has come from the Red Mountain vein. It can be traced along strike, insofar as topography permits, for more than 1500 feet. It strikes northeast, with dips ranging from 58 to 70 degrees southeast. Chaney (1992) reported, "The quartz veins occupy a series of en echelon tensional gashes within the brittle metadiorite. The veins have an orientation of N30E to N50E with near vertical dips and a pinch and swell character. Some of the veins are terminated by faults, others die out in breccia zones and still others pinch out in the country rock." It should be noted that thickness varies from a thin shear at points to 10 feet in width in the space of a few feet along strike. The pinching and swelling of the fissure veins underground corroborates what is seen on the surface.

The relationship of the veins to each other and to various levels is shown in Figure 2. The quartz fissure vein cropping out on the southeast skyline above the 500 Level portal is probably the Mountain Boy vein (Fig. 3) described by Krom (1937). It is at the approximate location of his point EE1 on plate 3 (DGER mine file). A short drift was driven on this outcrop and a 3-foot deep by 200-foot long trench extends to the east before disappearing in a cliff.

Figure 4. 500 Level portal with circa-1989 ladders and timbers.

Figure 5. View to the southwest from the 500 Level landing. Arrow points to a trail leading to 100 and 200 Level portals.

OPENINGS

Slopes on the north face of the Pleiades range from 55 degrees to vertical. This topography enabled development adits to intercept the Red Mountain vein at distances ranging from 300 to 2200 feet from portal. They are designated: the 100 Level at 5138 feet elevation, the 200 Level at 5000 feet elevation, the 500 Level at 4707 feet elevation, and the 1200 Level at 4050 feet elevation (Krom, 1937).

Standing near the 500 Level landing, we observed traces of the 100 and 200 Level adits through binoculars. The 100 Level entrance appears to be on a bench in a cliff face. Grant (1989) reported the 100 level caved near the entrance, but "Access has been gained via an open stope on the hillside ca. 100′ above the level. Overall though, its condition is badly deteriorated." The

200 Level was caved 115 feet along the vein/adit intersection (Grant, 1987). Total development at the mine cannot be calculated precisely. The combined four main levels exceed 7000 feet in length. Sublevels, stopes, and raises drive the development figure upward to ~10,000 feet. Grant's report (1987) gives detailed explanations of stope development, assays along the vein, and widths. The highest grades encountered, approximately 1.13 ounces per ton gold over an approximate 3-foot mining width, were above the 500 Level. Moen's vertical cross section in Figure 2 is the best representation of the estimated development to date. Detailed maps also appear in Krom (1937).

The 500 Level portal is located on a relatively level bench. The aerial tramway used for lowering ore to the mill began at this point. The tram terminal foundation and a crushed tram bucket are still in place. The entrance is open, but shows sloughing a short distance inside. The overall condition is unknown as of September 2003; however, according to Grant, it was in good condition and open to the face 1987. A few replacement ladders and dimensional timbers are stored at the entrance (Fig. 4). A sparse trail proceeds uphill from this area to the 200 and 100 Level adits (Fig. 5).

Figure 6. Water discharging from 1200 Level portal. Miscellaneous piping and mill equipment in foreground. View to the south.

The 1200 Level, the lowest and longest level in the mine, was started in 1923. "In March 1924, the 10- by 10-foot crosscut encountered the vein 2200 feet from the portal; however the vein proved to be only 2 to 8 inches wide with gold values of less than 0.1 ounce per ton. The vein was drifted upon an additional 500 feet to the south in hopes that it would increase in width, but only thin discontinuous quartz veins were found in the fault zone" (Krom, 1937).

The floor of the 1200 Level is essentially a streambed 6 to 8 inches deep. The portal is open, but the overall internal condition is unknown (Fig. 6). Grant reported it open to the face in 1987. The vertical extent of the mined area from stopes in the 100 Level to the 1200 Level haulage tunnel is approximately 950 feet (Moen, 1969).

MATERIALS AND STRUCTURES

The original bunkhouse, office, blacksmith shop, power plant, and mill have been destroyed by fire or snow slides.

WATER

Water discharged from the 1200 Level portal in September of 2002 at 500 gallons/minute. The pH measured 8.5 and conductivity reading was 90 μS/cm. Analyses for arsenic and copper were below the Washington State requirements shown in Table 5 for domestic consumption (WAC 246-290). At a measured hardness of 43 mg/L, the copper content exceeds the calculated standard for chronic effects on aquatic life specified in Table 5 (WAC 173-201A). The water was clear; the bed natural color. Water temperature was 39°F.

MILLING OPERATIONS

In 1913, a five-stamp mill was constructed at 4000 feet elevation near the company's offices and crew quarters. The mill was supplied with power from a 75 KVA Hendy-Francis generator on Silesia Creek via a 1.5-mile-long transmission line. Ore originally dropped from storage bins at the 500 Level to the mill by aerial tramway. By 1920, five additional stamps had been installed, raising the capacity to "about 60 tons per day, with a recovery of 89 percent" (DGER mine file). Mercury amalgamation plates outside the mill were used to recover the gold. After 1924, all production dropped to the 1200 Level for tramming directly to the mill. The mill was perched on a narrow isthmus of forested land between two avalanche chutes (Fig. 7). Miscellaneous mill equipment and timbers are scattered over a 30 x 75-foot area. The mill processed about 80,000 tons of ore before being destroyed by fire in 1942 (DGER mine file). Tailings and slimes were discharged over an 800-foot embankment, eventually collecting near an underlying glacial stream. Moen reported that the tailings were reworked in 1946 producing $1800 in gold. We could not access this material for sampling, but vestiges of siliceous-appearing material can be seen on color aerial photographs (DNR flight NW-C-01).

WASTE ROCK DUMPS

The waste rock dump adjacent to the mill falls off at an approximate 60-degree angle. It is almost entirely unmineralized metadiorite. A small grab sample of quartz vein material from this location analyzed equal parts bismuth and tellurium and 0.35 ounce per ton gold. The 500 Level dump is similar.

GENERAL INFORMATION

Names: Boundary Red Mountain, Red Mountain

MAS/MILS sequence number: 0530730155

Access: four-wheel drive, hike, helicopter

Status of mining activity: none

Claim status:

Patented claims are: Klondike, Rocky Draw, Mountain Boy, Glacier, Climax, and Climax Extension No. 1. The claims were located between August 1898 and July 1900. They were surveyed for patent as Mineral Survey 699 in October 1902. The patent number for the 139-acre block is 39545. All unpatented claims in the land described in the Summary were closed in 1988.

Current ownership: Muriel Wiatrak, Olympia, Wash.

Surrounding land status: Mt. Baker–Snoqualmie National Forest, Mt. Baker Wilderness Area

Location and map information: see Table 1

Directions: The Boundary Red Mountain Mine is located ¼ mile south of milepost 54 on the U.S.–Canada border. Follow Mt. Baker Highway (SR 542) to a turnoff on a gravel road 11 miles east of Glacier, Wash. Follow FR 3065 up the Swamp Creek drainage a distance of about 3 miles. Four-wheel drive is required just prior to reaching Twin Lakes. At Twin Lakes, follow a dozer road south toward the Lone Jack mine property. This road intersects a pack trail at elevation 4800 feet heading northeast along Winchester Creek past West Fork Silesia Creek to Silesia Creek at elevation 2400 feet. From this point an unmaintained trail follows Silesia Creek north 1.7 miles toward border milepost 55. A person with good climbing skills can reach the mine at elevation 4000 feet by ascending the slope south and west of the milepost. Alternatively, the dumps at the mine's 500 and 1200 levels are sufficiently large and level to allow landing by a small helicopter.

MINE OPERATIONS DATA

Type of mine: underground

Commodities mined: gold, minor silver

Geologic setting: quartz fissure veins in metasedimentary and dioritic rocks of the Devonian Yellow Aster Complex (Moen, 1969)

Ore minerals: gold, tellurobismuthite (Bi_2Te_3), minor silver and chalcopyrite

Non-ore minerals: quartz, calcite

Host rock: argillaceous schist and metadiorite

Period of production: 1913–1942

Development: 7000 feet of adits; total development, including stopes, raises, and sublevels, is ~10,000 feet (DGER mine file)

Production: $947,579

Mill data: ten-stamp mercury amalgamation mill

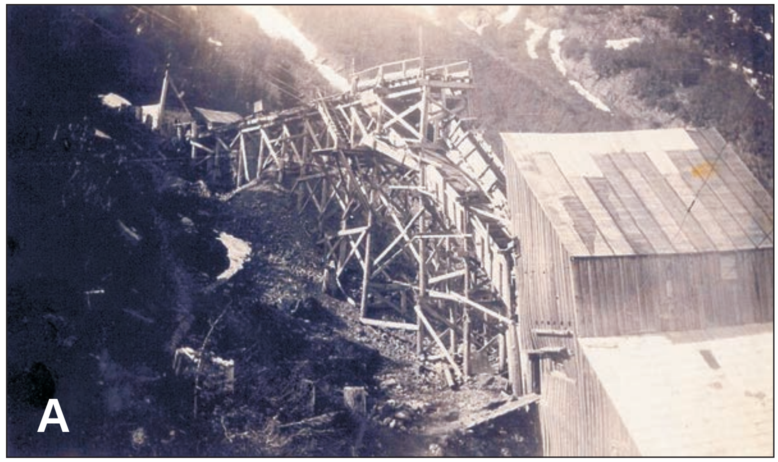


Figure 7. A. The Boundary Red Mountain camp site and mill. View is to the west. **B.** The mill itself opposite the 1200 Level portal. View is to the south. Both photos taken circa-1930. Courtesy of Mike Impero, Bellingham, Wash.

PHYSICAL ATTRIBUTES

Features: see Table 2

Materials: steel mine rail, aluminum ladders, scrap metal

Machinery: scrap metal

Table 1. Location and map information

Mine property	County	Location	Decimal latitude	Decimal longitude	1:24,000 quad.	1:100,000 quad.
Boundary Red Mountain	Whatcom	sec. 3, T40N R9E, sec. 34, T41N R9E	48.99556	121.63187	Mt. Larrabee	Mt. Baker

Table 2. Mine features. – – –, no data; **, data from DGER mine map file

Description	Condition	Fenced (yes/no)	Length (feet)	Width (feet)	Height/depth (feet)	True bearing	Elev. (feet)	Decimal latitude	Decimal longitude
mill site	ruins	no	75	30			4020	48.99556	121.63187
1200 Level adit	open, stable	no	2480**	10	10	S35E	4050	48.99522	121.63169
500 Level adit	open, stable	no	2280**	5	7	S40E	4707	48.99240	121.62878
200 Level adit	– – –	– – –	1360**	– – –	– – –	S35E**	5000	– – –	– – –
100 Level adit	– – –	– – –	1000**	– – –	– – –	S5W**	5138	– – –	– – –
Mountain Boy vein outcrop	caved adit, trench	no	– – –	5	7	W	5640	48.98979	121.62654
power plant	– – –	– – –	– – –	– – –	– – –	– – –	2040**	48.9980**	121.6103**

Structures: none

Waste rock dumps, tailings impoundments, highwalls, or pit walls: tailings are inaccessible; waste rock dumps are opposite portals

Analysis of waste rock dumps: quartz grab sample analyzed 26.3 mg/kg bismuth, 30.6 mg/kg tellurium, 12.3 mg/kg gold

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

Reclamation activity: none

VEGETATION

Cascade alpine zone grasses, wildflowers, shrubs, and alpine fir observed.

WILDLIFE

See Table 3 for bat habitat information.

WATER QUALITY

Surface waters observed: Silesia Creek

Proximity to surface waters: 4000 feet

Domestic use: none

Acid mine drainage or staining: none

Water field data: see Table 4

Surface water migration: none

Table 3. Bat habitat information

Opening	Aspect	Air temp. (°F) at portal	Air flow: exhaust	Air flow: intake	Multiple interconnected openings	Bats or bat evidence
1200 Level adit	NW	50	yes	no	yes	no
500 Level adit	NW	45	yes	no	yes	no

Table 4. Surface water field data

Description	Flow (gpm)	Conductivity (μS/cm)	pH	Bed color	Temp. (°F)
1200 Level discharge	500	90	8.5	natural	39

ACKNOWLEDGMENTS

The authors thank our editors Jari Roloff and Karen Meyers for helpful suggestions on the layout and content of this report. Additional appreciation goes to USFS Region 6 personnel Bob Fujimoto and Dick Sawaya. Phillip Wiatrak contributed valuable historic information from personal files.

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Table 5. Surface water analysis. Metal concentrations are in micrograms/liter (μg/L); hardness is in milligrams/liter (mg/L); USEPA, U.S. Environmental Protection Agency; ≤ 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; **, standards for these metals are hardness dependent. 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	Bismuth	Tellurium	Arsenic	Cadmium**	Copper**	Iron	Lead**	Mercury	Zinc**	Hardness
1200 Level adit	≤50	≤50	≤10	– – –	13.1	≤ 100	– – –	– – –	– – –	43

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	– – –

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
Hanna Instruments DiST WP-3 digital conductivity meter and calibration solution
litmus paper, range 0–14, and 4–7
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)
1200 Level discharge	43	– – –	5.51	– – –	– – –