NATURAL RESOURCES

INACTIVE AND ABANDONED MINE LANDS— Lone Jack Mine, Mount Baker Mining District, Whatcom County, Washington

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

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Information Circular 98
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site location

WASHINGTON STATE DEPARTMENT OF
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Published in the United States of America

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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).

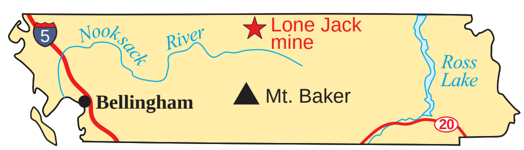
More than 3800 mineral properties have been located in the state during the last 100 years (Huntting, 1956). Many are undeveloped prospects of little economic importance. Therefore, in considering the population to include in the Inactive and Abandoned Mine Lands (IAML) inventory, we have identified 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

The three adits of the Lone Jack mine lie on the northeast and southeast slopes of a 6440-foot peak, known locally as Bear Mountain, inside the Mt. Baker Wilderness Area (Fig. 1). The property consists of five patented claims currently owned by John Bullene, with various operating agreements made to Diversified Development Co. of Bellingham. The mine can be reached from Shuksan on State Route (SR) 542, by following USFS road 3065 (unmaintained) to Twin Lakes, then by dozer trail approximately 1.5 miles to the site (Fig. 2). U.S. Mint receipts report 9463 ounces of gold and 1900 ounces of silver from the Lone Jack mine from discovery through 1969. An additional



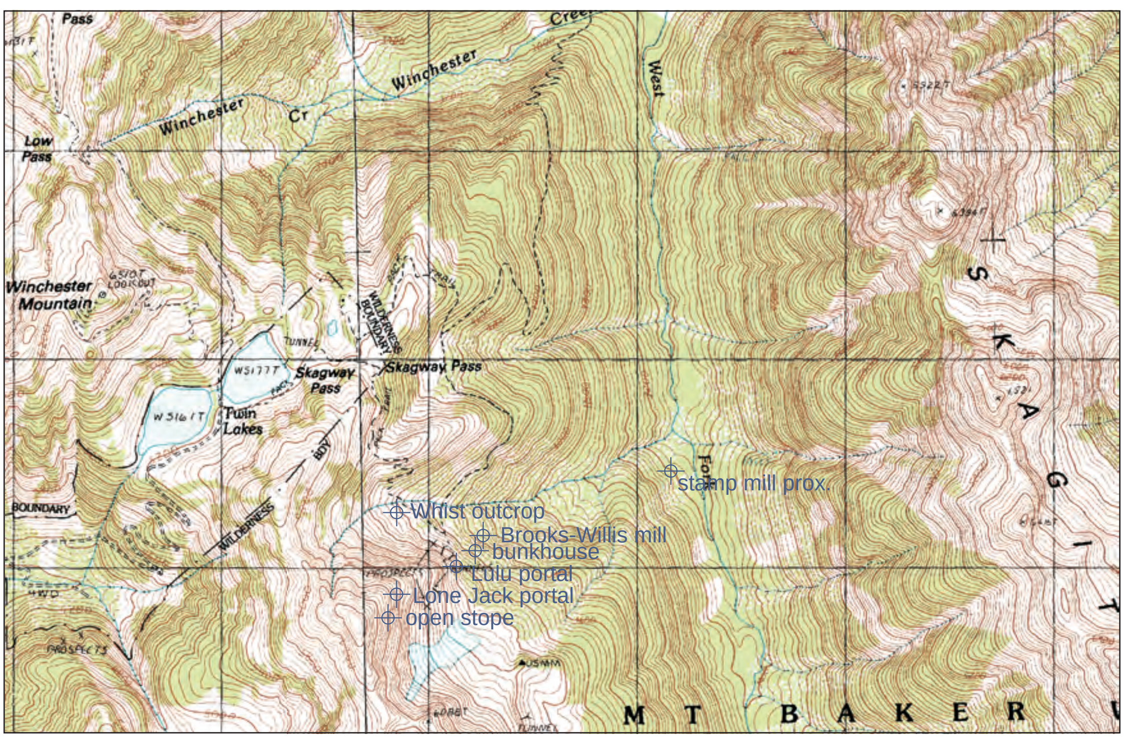


Figure 1. Map showing the location of the Lone Jack mine in Whatcom County (top) and a more detailed map of the mine site (bottom). Section lines are 1 mile apart.

900 ounces gold were produced circa 1992. The total dollar value at the historic price of $20 per ounce would have been approximately $192,000, including a small amount of silver; total value in today's precious metals market would exceed $4 million. Using these data as the only reliable data of record, and an approximate 10 to 15 thousand tons mined, the grade from all operations is in the range of 0.63 to 0.94 ounces per ton gold.

Three widely separated quartz fissure veins, containing free gold, tellurobismuthite, and iron sulfides, are visible on cliffs above the mine adits. Argillaceous Darrington Phyllite shot through with exsolved quartz stringers is pervasive in the mine area. This material contains some sulfide mineralization, but is barren of gold content. The production veins are in massive quartz bodies that pinch and swell, ranging in thickness from 3 to 9 feet (Moen, 1969).

The mine has seen four discontinuous periods of operation. The Mount Baker Mining Co. mined the Lone Jack lode from 1898 through 1907, at which time the stamp mill burned, the aerial tramway collapsed, and operations ceased. Most of the mine's precious metal output occurred during this period. Boundary Gold Co. developed the Lulu lode in 1915 under lease. Operations ceased in 1917. The Brooks-Willis Metals Co. leased the mine in 1917 and exercised their option to purchase it in 1920. They erected a flotation mill, bunkhouse, sawmill, flume, and power plant (Lindstrom, 1941). The company mined ore from the Lulu lode in 1923. Evidence indicates that avalanches destroyed the flotation mill in the winter of 1924/1925, after which operations ceased (DGER mine files). In the early 1990s, Diversified Development Co. drove development on the Whist vein for the first time. The mine has been idle since 1997 (Chris Secrist, Diversified Development Co., written commun., 2001). Angles from the horizontal at the mine range from 30 to 90 degrees, and snow accumulations of 10 to 20 feet are normal. The operations window has been limited to mid-August through mid-October, depending on yearly snow accumulations at this altitude.

DGER personnel acquired field data at the site on August 8, 2002, and September 29, 2004. The location is secs. 22 and 23, T40N R9E. The five patented claims were located from U.S. Land Monument No. 1, established in 1899 in conjunction with Mineral Survey 534.

Figure 2. Lone Jack mine site overview. 1, trail to Lone Jack portal; 2, flotation mill site, next to talus; 3, Lulu portal; 4, Whist vein outcrop; 5, Lulu vein outcrop. View to the south.

Figure 3. Exsolved quartz stringers in Darrington Phyllite talus beneath Lone Jack portal. Pack for scale.

OWNERSHIP

The Lulu, Sidney, Whist, Jennie, and Lone Jack patented claims were acquired by Harry Bullene circa 1940 as agent to the estate of Philip Brooks. Current owner is John Bullene, Kamiah, Idaho, with various operating agreements transferred to Diversified Development Co., Bellingham, Wash., in conjunction with permits and agreements with the U.S. Forest Service.

HISTORY

The property was discovered in 1897 by R. Lambert, J. Post, and L. Van Valkenburg, and originally known as the Post-Lambert mine. The following year H. Hahn and L. Friede of Portland, Oregon, purchased the property for $50,000 and formed the Mt. Baker Mining Co. The company winched a 10-stamp mill up to Skagway Pass and Twin Lakes using horses and a skid-mounted steam engine. The mill was lowered down a switchback trail to an area near West Fork Silesia Creek thought to be free of snowslides. An aerial tramway erected in 1901 transported ore from the mine to the mill until 1907 when the mill burned (Lindstrom, 1941).

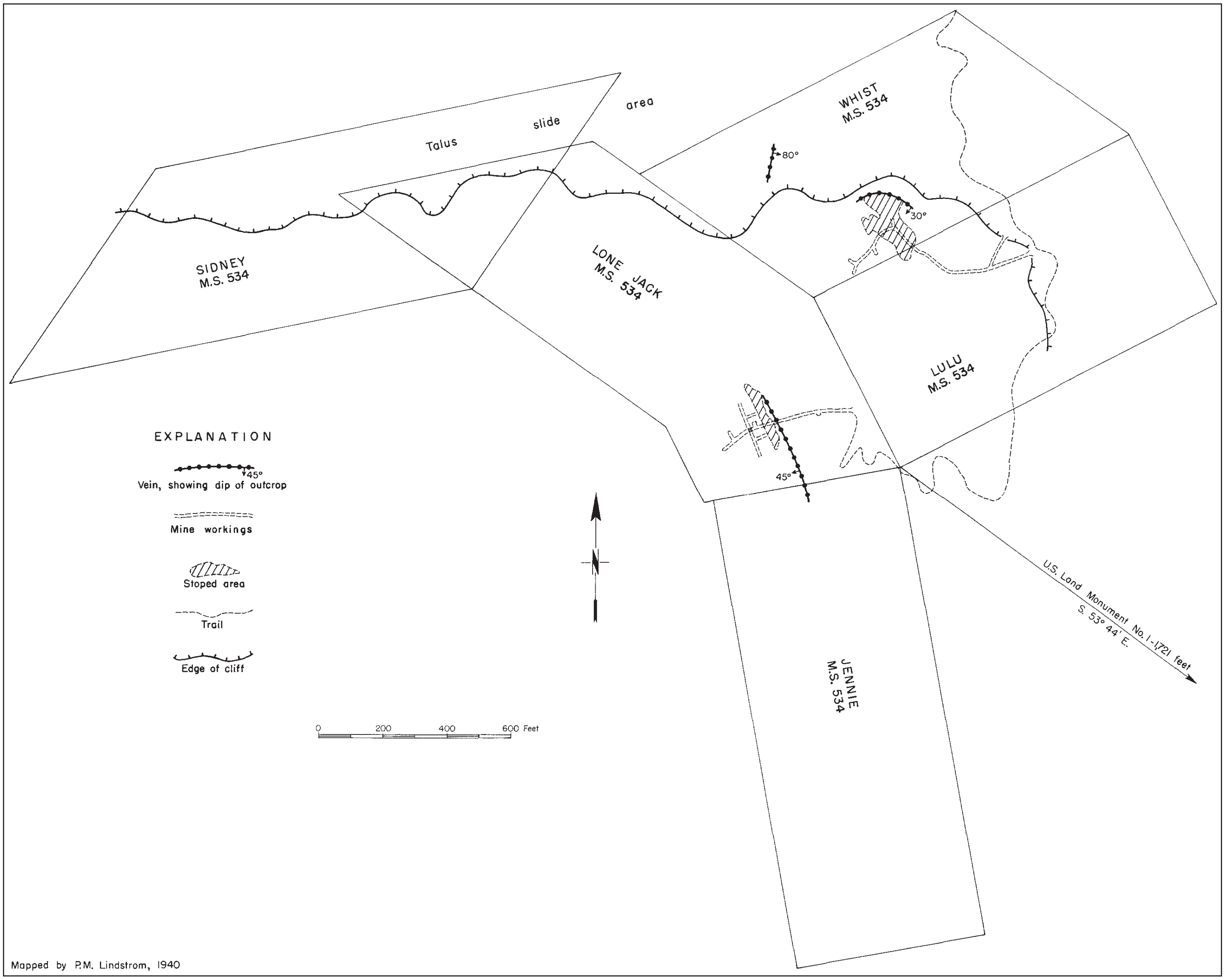


Figure 4. Patented claims, veins, and mine workings (after Moen, 1969).

The mine lay idle until 1915 when the property was leased by the Boundary Gold Co., which mined a few hundred tons of ore from the Lulu vein. In 1917, the Brooks-Willis Metals Co. purchased the property, continued mining, and built a 30-ton-per-day flotation mill on a slope immediately below the Lulu portal. This mill, which also served as a boardinghouse, was supplied with power from a diversion flume and hydroelectric plant several thousand feet below the mine on West Fork Silesia Creek. A snow slide in the winter of 1924/25 destroyed the mill and operations ceased. Harry Bullene, agent to the estate of Philip Brooks, acquired title to the property after Brooks' death in July 1940. Between 1925 and 1941, general improvements were made to the mine, focused mainly on building a road from Skagway Pass to the mine, a distance of about 1.5 miles. Robert J. Cole leased the property from the Brooks estate in 1941 and performed annual assessment work on the surrounding 15 unpatented claims until about 1970 (Garrett, 1967).

In August 1964, an Army demolition team and U.S. Forest Service personnel detonated 300 cases of dynamite stored inside the Lulu portal. Significant quantities of nitroglycerin had infiltrated the powder magazine's floor. The explosion shot a ball of fire 200 feet in the air but did little damage to the interior of the opening (DGER mine file).

From the inception of operations by Diversified Development Co. in 1992 until 1996, approximately 800 tons of ore per season were shipped to the Asarco smelter in East Helena, Montana. A crosscut driven in 1995 intercepted the Whist vein for the first time. Three hundred feet of drifting on the vein the following season met with limited success. Since 1997, road and safety maintenance have been carried out (Chris Secrist, written commun., 2001).

GEOLOGIC SETTING

The veins of the Lone Jack group occur as three disconnected quartz fissure veins in pre-Jurassic black phyllitic schist, known as the Darrington Phyllite. The schist contains numerous stringers and lenses of exsolved quartz that formed during metamorphism of the schist (Fig. 3). Except for small amounts of fine-grained pyrite, the exsolved quartz is barren. The gold-bearing vein quartz (see Fig. 9) is younger than the exsolved quartz and is probably related to Tertiary granodioritic intrusives in the Lone Jack cirque (Christenson, 1986). Lindstrom (1941) identi-

Figure 5. *(top right)* Lone Jack portal area, south side of Bear Mountain. 1, Lone Jack vein portal (hidden); 2, waste rock dump; 3, access trail. View to the north.

Figure 6. *(bottom right)* Lone Jack vein portal.

fied two distinct generations of quartz in the mineralized veins. The older quartz is white, coarse-grained, and allotriomorphic. Movement along the vein microbrecciated this material which was later recemented by an infusion of fine-grained second generation quartz containing free gold and tellurobismuthite. The gold and tellurobismuthite are mostly invisible to the unaided eye; however, some parts of the vein contain pinhead-size specks of gold and platy flakes of tellurobismuthite up to 1/8 inch in diameter.

The three veins at the Lone Jack mine may be faulted segments of the same vein or separate and distinct entities emplaced under similar conditions. However, the mineral paragenesis is identical: pyrite→pyrrhotite→chalcopyrite→tellurobismuthite and gold (probably simultaneously). Christenson (1986) describes the Lone Jack vein as lying in a "relatively coherent block of Darrington Phyllite between two [high-angle] shear zones, parallel to local planes of foliation." Christenson's map indicates that the Whist vein lies "within the fault which truncates the eastern margin of the Lone Jack vein. The Whist appears to pinch out upwards into this fault." The relatively flat-lying Lulu vein has been juxtaposed during faulting, but also appears to have been emplaced parallel to local foliation (Christenson, 1986).

The mineralogy, paragenesis, gold content, and data from fluid inclusion studies at the Lone Jack mine and the Boundary Red Mountain mine are virtually identical (Chaney, 1992). The Boundary Red Mountain mine is located 3 miles north of the Lone Jack mine adjacent to the high-angle Shuksan fault.

OPENINGS

The relationship of the three veins to each other and the claim boundaries is shown in Figure 4. The Lone Jack portal is the southernmost opening. It is perched on the south side of Bear Mountain and intersects a massive quartz vein approximately 3 feet thick, 300 feet from the portal (Figs. 5 and 6). The vein strikes N10°W and dips 45 degrees to the west. From 1900 to 1907, the Mount Baker Mining Co. operated stopes in this adit, dropping ore 2200 vertical feet to the aforementioned stamp mill via an aerial tramway. No further mining of any extent occurred in this opening after 1907. Grant (1985) felt that most of what was minable from this vein had been extracted. His report indicates that the vein appears to pinch out at the south end and is truncated 500 feet north at a fault where the stope opens onto a vertical cliff. An exploratory drift angles 250 feet to the northwest from this termination. It is largely in barren talc schist. The gold content in Grant's 35 samples, taken from the stope, range from 0.01 ounce per ton to 2.41 ounces per ton (Christenson, 1986). The Lone Jack adit can only be reached from the Lulu portal by following a steep, barely recognizable trail leading southerly through the avalanche chute and notch shown in the upper center of Figure 7. The stope is open to the surface 300 feet southwest of the adit at 5600 feet elevation. A large blue arrow spray-painted above the opening is visible above the trail. Safety at this point requires technical rock climbing equipment and skills.

The Lulu vein crops out on the north side of Bear Mountain in a cliff. It strikes generally east and dips 8 to 60 degrees south, varying in width from several inches to 9 feet. The portal is open and appears stable (Fig. 8). The portal is Y-shaped with a pillar in the center. A bit-sharpening forge and blacksmith shop were located at this point. A clear stream discharged approximately 10 gallons per minute from the portal in August of 2003.

The 190 pounds of ore Lindstrom (1941) took from the Lulu workings for laboratory flotation tests averaged 0.33 ounce of gold per ton. A map in Grant's 1985 report notes that samples taken from the south extension of the stope are 50 percent phyllite and 50 percent quartz, which indicates that the Lulu vein begins to lose structural integrity or disseminate at this point.

The Whist vein had no development done on it prior to a new portal driven by Diversified Development Co. beginning around 1992 (DGER mine file). This vein crops out 800 feet northwest of the Lulu portal, several hundred feet higher in elevation. A dozer road connects the two openings. The Whist vein stands close to vertical and strikes S10°W. It is the mine's northernmost geologic structure. It is exposed on the surface for 80 feet and then disappears under talus and vertical cliffs. In 1995 the company intersected the vein from a new adit below the outcrop. Some success was achieved in terms of gold values in 300 feet of drifting along the vein. A snowfield obscured the Whist portal on August 8, 2002. Mining has exposed the outcrop to the surface for a distance of approximately 40 feet. Efforts have been made to close the opening to public entry by covering it with chain link fencing and a collection of boards and timbers (Fig. 9). Crossland (1923) reported assay values of 0.8 to 1.3 ounces per ton gold taken at this point.

An overall view of 80 samples taken by Grant in 1985 corroborates precisely with the experience of previous operations: namely, that the gold is very rich in localized areas and impoverished in others separated by only a few feet. The gold is found in the free state, often accompanied by concentrations of tellurobismuthite. Pyrite and pyrrhotite are also present in the vein(s) but do not appear to contain dissolved gold. Samples from the Lone Jack stope showed values ranging from 0.01 to 2.41 ounces gold per ton; from the Lulu stope, values of 0.02 to 1.3 ounces per ton.

Figure 7. Trail to Lone Jack portal, taken from Lulu portal. View to the south.

Figure 8. Lulu portal entrance.

MATERIALS AND STRUCTURES

Two steel containers, possibly for storing tools and/or powder, are present. Several hundred feet of 4-inch aluminum pipe were cached near the Lulu portal. A rock retaining wall indicates a building site of unknown provenance adjacent to the access road at elevation 4520 feet (Fig. 10).

Crossland's report (1923) indicates the Brooks-Willis operation constructed a combination bunkhouse/flotation mill (Fig. 11) on the steep slope below the Lulu portal and a sawmill and power plant on West Fork Silesia Creek. His report verifies that these structures were standing and in good condition in November of that year. A photo taken some years later (exact date unknown) shows the mill destroyed by avalanche and the relocated bunkhouse intact (Fig. 12).

Lindstrom (1941) identified the location of the stamp mill, flotation mill, and bunkhouse in a photograph taken from point 6521 in the Skagit Range immediately east of the mine. The approximate locations are shown in Figures 1 and 2. Remains of the bunkhouse were still observable in 1941 (Lindstrom) and 1965 (Garrett, 1967), but no trace of any structures were observed by us or by Christenson in 1985.

WATER

Water discharged from the Lulu portal at approximately 10 gallons per minute in August of 2002. The pH measured 5 and the conductivity reading was 35 μS/cm. Analyses for arsenic, copper, lead, and zinc were below the Washington State requirements (see Table 5). A trickle of water was present in the Lone Jack portal in September of 2004. The pH was 9.4 and the conductivity 160 μS/cm. The water at both locations was clear.

MILLING OPERATIONS

Lindstrom (1941) reported that two mills were built at the Lone Jack mine. The first, a 10-stamp mill that was later enlarged to 15, was located on a bench near West Fork Silesia Creek, 4000 feet distant from the mine and 2800 feet lower in elevation. This mill was built in 1900 and fed by a 50-ton aerial tramway from the Lone Jack portal. It was destroyed by fire in 1907. Records indicate that a 10-foot Lane grinding mill replaced the stamps in 1915, probably at the same location. Mercury amalgamation was used to recover free-milling gold. Brooks-Willis Metals Co. constructed the second mill in 1922/23. It contained primary and secondary crushers rated at 30 tons/day, flotation cells, and amalgamation plates (Katz, 1927). No mill tailings can be observed on color aerial photographs. Tailings from the stamp mill were probably discharged into West Fork Silesia Creek and have long since disappeared. Records indicate that the flotation mill may have operated only during the summer of 1924, the last year of mining by Brooks-Willis (DGER mine files). If so, the volume of tailings generated would have been very small. Lindstrom (1941) reported “The mine has not been operated since 1924.…After operations ceased, the mill built by Brooks and Willis was destroyed by a snow slide.”

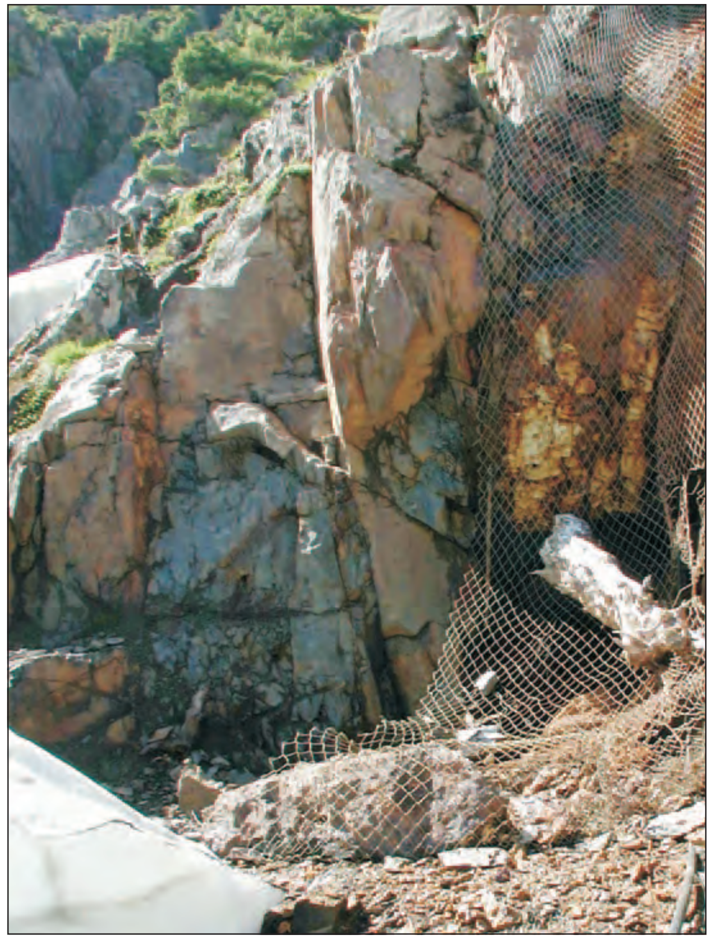


Figure 9. Whist vein outcrop and open stope.

WASTE ROCK DUMPS

Waste rock dumps of approximately 500 cubic yards lie near the Whist portal and outcrop. A hand-picked sample of quartz containing major pyrrhotite was obtained near the Whist outcrop. It analyzed equal amounts of bismuth and tellurium; gold was not detected above the analyses’ practical quantitation limit of 9.9 milligrams/kilogram (0.29 ounce/ton). Waste rock below the Lone Jack portal is predominantly unmineralized development rock with slight iron staining. Waste rock from the Lulu workings has slid down a 50-degree slope and is covered with slide alder and brush.

Figure 10. Historic building site.

GENERAL INFORMATION

Names: Lone Jack; Post-Lambert

MAS/MILS sequence number: 0530730073

Access: four-wheel drive vehicle and hike

Status of mining activity: none

Claim status:

The property consists of five patented claims (Lone Jack, Whist, Lulu, Jennie, and Sidney)

Table 1. Location and map information

Mine property	County	Location	Decimal latitude	Decimal longitude	1:24,000 quad.	1:100,000 quad.
Lone Jack	Whatcom	sec. 22, T40N R9E unsurveyed	48.945092	121.61956	Mt. Sefrit	Mt. Baker

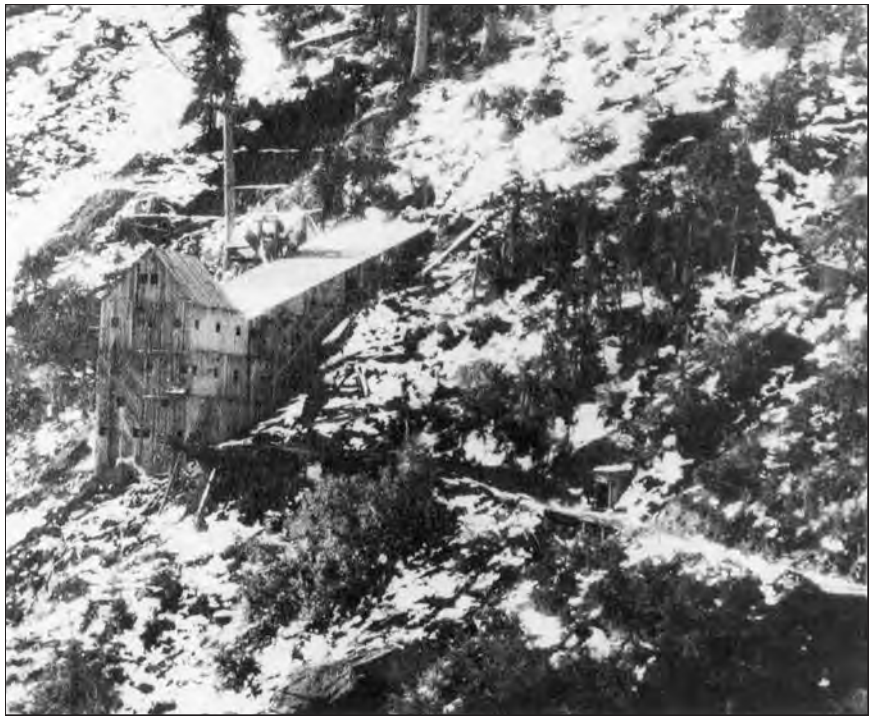


Figure 11. Combination bunkhouse/flotation mill constructed circa 1922 by Brooks-Willis Metals Co. Cutouts for (relocated) bunkhouse foundation in background. Photo courtesy of Whatcom County Museum, Bellingham, Wash.

surveyed in 1899 under Mineral Survey 534. U.S. Land Monument No. 1 is located approximately 1921 feet S54°E from the Lone Jack portal.

Current ownership: John Bullene, Kamiah, Idaho. Operating agreement(s) with Diversified Development Co., Bellingham, Wash., and the U.S. Forest Service.

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

Location and map information: see Table 1

Directions: Follow Mt. Baker Highway (SR 542) to a turnoff on a graveled road 11 miles east of Glacier, Wash. Follow USFS road 3065 up the Swamp Creek drainage a distance of about 3 miles, at which point four-wheel drive is required just prior to reaching Twin Lakes. Two hiking routes can be taken from Skagway Pass adjacent to the lakes: (1) a 10-foot-wide dozer trail proceeds northeasterly past a locked gate and contours around the mountain in a southerly direction, reaching an area near the Lulu portal at a distance of about 2 miles. This is the easiest route. (2) An obvious foot trail departs Skagway Pass heading south. The trail maintains an altitude of about 5000 feet for a distance of 1.5 miles before reaching a permanent snowfield adjacent to the Whist vein opening described above. The snowfield can be crossed with care. Crampons and ice axes may be required.

MINE OPERATIONS DATA

Type of mine: underground

Commodities mined: gold, minor silver

Geologic setting: quartz fissure veins in metasedimentary rocks of the Jurassic–Cretaceous Darrington Phyllite. The deposit is 2 miles east of the west boundary of the Chilliwack batholith (Moen, 1969).

Ore minerals: gold, tellurobismuthite (Bi_2Te_3); may contain dissolved precious metals

Non-ore minerals: pyrite, pyrrhotite

Host rock: Darrington Phyllite of the Shuksan Metamorphic Suite

Period of production: 1900–1907; 1916–1917; 1922–1924; 1991–1996 (approximate)

Development: in excess of 2300 feet of drifts and raises, plus stoping volumes (Moen, 1969)

Production: 10,370 ounces of gold and 2000 ounces of silver have been documented; actual production may be greater

Mill data: 10-stamp mill (increased to 15-stamp), burned 1907; 30 ton/day flotation mill destroyed by snowslides

PHYSICAL ATTRIBUTES

Features: see Table 2

Figure 12. Flotation mill (arrow) destroyed by avalanche in foreground, relocated bunkhouse in background. Approximate date post-1924. Note trace of tramway cables in center. Photo courtesy of P. Jeffcott Collection.

Table 2. Mine features. *, data from DGER mine map file; **, Chris Secrist, Diversified Development Co., written commun., 2001

Description	Condition	Fenced (yes/no)	Length (feet)	Width (feet)	Height/depth (feet)	True bearing	Elev. (feet)	Decimal latitude	Decimal longitude
Whist outcrop	open to the surface, precarious exposure, chain link fence being dragged down 60 degree face	no	300**	3	7	N10E	4880	48.94587	121.62304
Lulu portal	open, stable appearance	no	680*	6	7	N45E	4680	48.94516	121.62009
Lone Jack portal	open, stable appearance; stope partly caved and open to surface at two locations	no	300*	5	7	N10W	5520	48.94345	121.6229

Materials: several hundred feet of 12-pound steel mine rail, >200 feet 4-inch aluminum air pipe

Machinery: none

Structures: two steel storage containers

Waste rock dumps, tailings impoundments, highwalls, or pit walls: no tailings; minimal waste rock dumps opposite portals

Analysis of waste rock dumps: quartz grab sample containing pyrrhotite analyzed 50.4 milligrams/kilogram (mg/kg) bismuth, 48.2 mg/kg tellurium; gold not detected above 9.9 mg/kg, the practical quantitation limit of the method used

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

Reclamation activity: none

VEGETATION

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

WILDLIFE

The mine is located within a suspected spotted owl management area, but insufficient data is available for designation as an established territory (WDFW, 2004). See Table 3 for bat habitat information.

WATER QUALITY

Surface waters observed: West Fork Silesia Creek

Proximity to surface waters: 4000 feet

Domestic use: none

Acid mine drainage or staining: none

Water field data: see Tables 4 and 5

Surface water migration: none

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. Darrell Jacobson and Phil Woodhouse of Northwest Underground Explorations contributed historic photos.

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
Lulu Portal	NE	70	yes	no	yes	no
Lone Jack portal	E	55	yes	no	yes	no

Table 4. Surface water field data. *, taken at lowest flow time of year

Description	Flow (gpm)	Conductivity (μS/cm)	pH	Bed color	Temp (°F)
Lulu portal discharge	~10	35	5	natural	51
Lone Jack portal discharge	~2*	160	9.4	natural	44

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; – – –, 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	Arsenic	Cadmium**	Copper**	Iron	Lead**	Mercury	Zinc**	Hardness
Lulu portal	<1.5	– – –	1.6	– – –	<0.5	– – –	6.4	11

PART 2: APPLICABLE WASHINGTON STATE WATER QUALITY STANDARDS

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

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Appendix A. Methods and field equipment

METHODS

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

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

Soil samples were analyzed for the metals listed in this report by inductively coupled plasma/mass spectrometry (ICP/MS) following USEPA (U.S. Environmental Protection Agency) Method 6010. Holding times for the metals of interest were observed. Instrument calibration was performed before each analytical run and checked by standards and blanks. Matrix spike and matrix spike duplicates were performed with each set.

FIELD EQUIPMENT

barometric altimeter
binoculars
digital camera
flashlight
Garmin GPS III+, handheld GPS unit
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)
Lulu portal discharge	11	0.20	1.72	0.21	16.10