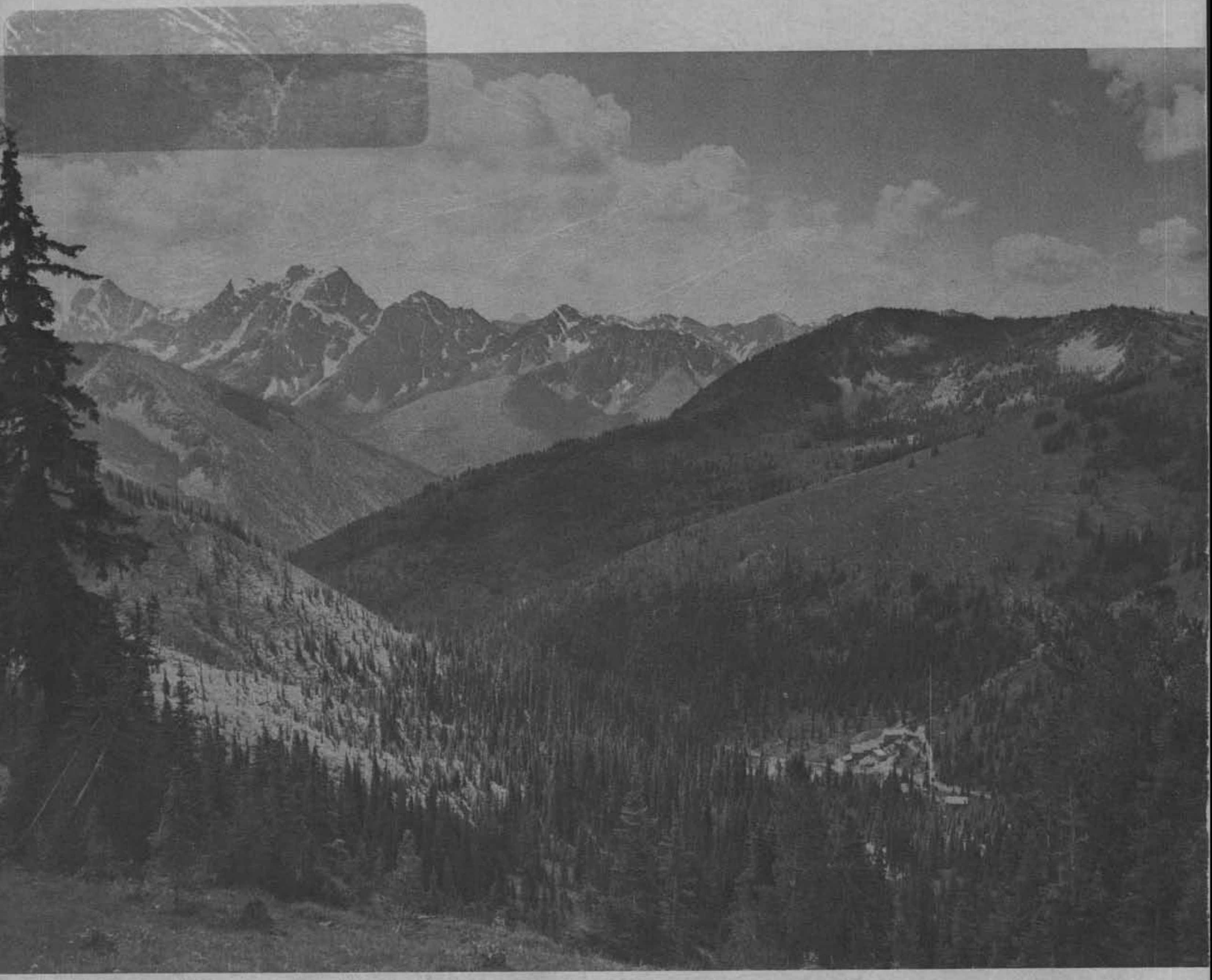
MINES AND MINERAL DEPOSITS of WHATCOM COUNTY, WASHINGTON



By WAYNE S. MOEN

Washington Department of Natural Resources
Division of Mines & Geology

Bulletin No. 57

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COVER PHOTO

Slate Creek mining district. Looking south from Windy Pass.
New Light mill in lower right, Mount Ballard and Azurite Peak in upper left.
(Photo courtesy of Washington Department of Commerce and Economic Development)

State of Washington

Department of Natural Resources

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DIVISION OF MINES AND GEOLOGY

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Mount Baker. Bagley Lakes near center, Highwood and Picture Lakes at bottom of photo.
(Photo courtesy of U.S. Forest Service.)

MINES AND MINERAL DEPOSITS
OF
WHATCOM COUNTY, WASHINGTON

By Wayne S. Moen

ABSTRACT

Whatcom County, in the northwestern part of Washington, is composed of approximately 66 percent Federal lands, 6 percent State lands, and 28 percent privately owned lands. About 85 percent of the land area of the county is mountainous, and most areas in this percentage are poorly accessible. The mountainous region is part of the North Cascade Mountains, whereas the western lowland region, known as Whatcom Basin, is part of the Puget Lowlands. Within the two mining districts of the county—the Mount Baker and the Slate Creek—less than 15 percent of the area is within a mile of existing roads. Because of the relative inaccessibility of the area, as well as adverse weather conditions, the development of the county's mineral resources in the remote mountainous areas has been hampered.

About 32 percent of the county is within the North Cascade Primitive Area.[1] This area is geologically favorable for the occurrence of mineral deposits; however, it has never been adequately evaluated for its mineral potential. Although the Primitive Area is open to prospecting and mining until 1983, it is doubtful that any mineral deposits will be developed there, as U.S. Forest Service regulations prohibit the building of roads in that area. The proposed North Cascade National Park would include the greater part of the North Cascade Primitive Area that is in Whatcom County and would prohibit in the Area any kind of mineral development.

The total mineral (excluding sand, gravel, and building stone) production of the county from 1900 to 1965 is in the neighborhood of \$46 million; \$43½ million is credited to nonmetallic minerals, and \$2½ million to metallic minerals. The production of metallic minerals has been from 32 mines and mainly as gold, which amounted to 98 percent of total production. Silver, copper, lead, and zinc, in order of decreasing value, made up only 2 percent of the total metallic mineral production. The past production of nonmetallic minerals consisted of coal, limestone, sand and gravel, clay, peat, building stone, quartz, and olivine, in order of decreasing value. Currently (1966), no metal mine is producing and the county's mineral production is mainly limestone, sand and gravel, olivine, and stone. Ranked with the rest of the counties of the State, Whatcom County was second in the production of nonmetallic minerals for 1965. This is because cement is included in the U.S. Bureau of Mines mineral production figures and the

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[1] This report was written in 1966. In October 1968 the President signed Senate Bill 1321 into law (Public Law 90-544), thereby creating the 503,500-acre North Cascade National Park, the 105,000-acre Ross Lake National Recreation Area, the 62,000-acre Chelan National Recreational Area, the 520,000-acre Pasayten Wilderness, and adding 10,000 acres to the Glacier Peak Wilderness.

Most of that part of the former North Cascade Primitive Area that was east of Ross Lake is now in the Pasayten Wilderness, and presumably the area is legally open to prospecting and claim staking until 1983 as provided by the Wilderness Act, but these activities may be effectively prohibited through strict regulations. That part of the former North Cascade Primitive Area that was adjacent to both sides of Ross Lake and the upper Skagit River now comprises most of the Ross Lake Recreation Area, and new mineral discoveries there may be leased from the National Park Service, if mining operations "would not have significant adverse effects on the administration of the recreation areas." The law states that the administration shall be in a manner which will best provide for (1) public outdoor recreation benefits; (2) conservation of scenic, scientific, historic, and other values contributing to public enjoyment; and (3) such management, utilization, and disposal of renewable natural resources and the continuation of such existing uses and developments as will promote or are compatible with, or do not significantly impair, public recreation and conservation of the scenic, scientific, historic, or other values contributing to public enjoyment.

Most of that part of the former North Cascade Primitive Area west of Ross Lake, plus some additional area, are now in the northern part of the new North Cascade National Park, so this area is closed to prospecting and the staking of mining claims. However, the establishment of the park and recreational and wilderness areas did not affect the validity of any valid mining claims existing in those areas at the time the areas were established.

county is the State's largest producer of cement. In this report, cement is not included in production figures.

Since 1900, 75 wells have been drilled for gas and oil, but as yet no oil production has resulted. In spite of this unsuccessful drilling, sporadic exploration for oil still continues in Whatcom Basin.

The reserves of coal, limestone, sand and gravel, building stone, quartz, and clay are moderate. The deposits are mainly in the western part of the county and are accessible for development. The olivine reserves are the largest in the United States and offer a tremendous potential for mineral development in the county. The reserves of gold are moderate, and those of silver, copper, lead, and zinc are small. The development of the gold properties depends largely on a possible rise in the price of gold, whereas lack of access hinders the development of the other minerals. The county contains deposits of iron, chromium, molybdenum, nickel, and tellurium, but the deposits are not considered to be of commercial value under present economic conditions.

The rocks of the county range from Recent to Devonian in age. The Recent Pleistocene rocks serve as sources for sand and gravel and common clay. The lower Tertiary sedimentary rocks, which consist mainly of the Chuckanut Formation, contain coal measures and beds of building stone and fire clays. Green andesite has been quarried for use as building stone from Cretaceous rocks, which also contain beds of iron. The limestone deposits range in age from Permian to Devonian and are found mostly in rocks of the Chilliwack Group. The olivine is confined mainly to Twin Sisters Mountain and is of early Tertiary age. Most of the deposits of gold, silver, copper, lead, and zinc occur as hydrothermal quartz fissure veins that are related to granodiorite and quartz diorite intrusions of early Tertiary age.

In the western part of the county the significant metallic mineral deposits are concentrated in the Twin Lakes-Mount Larrabee area north of Shuksan. In the eastern part of the county the significant metallic deposits occur east of Granite Creek and south of Canyon Creek; the greatest concentration of deposits is on the Bonita Creek drainage.

INTRODUCTION

Whatcom County, in the northwestern part of Washington, is 100 miles long from east to west and 25 miles wide. It is bounded on the north by British Columbia, Canada; on the east by Okanogan County; on the south by Skagit County; and on the west by waters of the Strait of Georgia. Its northern boundary is latitude 49°00′, and longitude 122°00′ is near the center of the county. The eastern two-thirds of the county is within the Mount Baker National Forest.

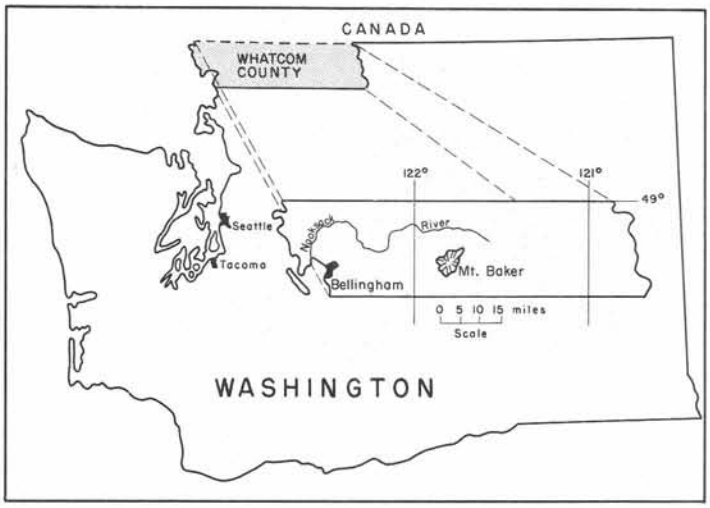

FIGURE 1.—Location map of Whatcom County.

On the western edge of the county two parcels of land are separated from the mainland by water. Lummi Island, which has an area of 9 square miles, is about 1 mile southwest of Gooseberry Point. Point Roberts, which is 5 square miles in area, is 12.5 miles west of Blaine and is part of the mainland of British Columbia that extends southward across the International Boundary into Whatcom County. Access to Point Roberts by car from Blaine is by way of 22 miles of road in British Columbia. Ferry service makes Lummi Island accessible from Gooseberry Point.

The land area of Whatcom County is 2,082 square miles. The population of the county in 1964 was 72,000, making it the eighth most populous county in Washington. Bellingham is the largest city and the county seat of Whatcom County. It has a population of 35,200, which makes it the sixth largest city in the State. Other incorporated communities include Lynden (2,650), Blaine (1,735), Ferndale (1,525), Nooksack (334), Sumas (655), and Everson (450).

The western part of Whatcom County supports fishing, dairy farming, and other types of agriculture. In the mountainous regions lumbering is the most important industry, although in the past the value of mineral production has exceeded that of logging. At present (1966), mining is confined to limestone, clay, sand and gravel, building stone, and olivine. The principal areas that contain economically valuable metallic minerals are the Mount Baker mining district in the central part of the county and the Slate Creek mining district in the eastern part.

PHYSIOGRAPHY AND CLIMATE

Whatcom County is in the northern part of the Puget Lowlands and Cascade Mountains physiographic provinces of Washington. About 85 percent of the county is mountainous. In the southern part of the county the mountains rise steeply from Bellingham Bay on Puget Sound and in less than 2 miles reach altitudes of 2,385 feet (on Chuckanut Mountain). Northeast of Bellingham four mountains—Squalicum, Anderson, Sumas, and Vedder—form the western front of the Cascade Mountains. Sumas Mountain is the highest of these four and rises to a height of 3,400 feet above Whatcom Basin. Eastward from Whatcom Basin the relief increases and the terrain becomes extremely rugged, and for the most part the area is roadless. The crest of the Cascades forms the eastern boundary of the county, and altitudes there range from 5,000 to 8,000 feet. However, the greatest altitudes are not along the Cascade crest but are on Mount Baker (10,778 feet) and Mount Shuksan (9,127 feet), near the central part of the county. Mount Baker, with its snowcapped peak, dominates the topography of northwestern Washington (see Frontispiece). East of Mount Baker and Mount Shuksan, serrated rocky ridges and slender rocky pinnacles form an impressive alpine type of topography that dominates the landscape. Much of the terrain is above 6,000 feet, which is the general timberline for the area. Above 7,000 feet, snowfields and glaciers can be found throughout the year on Bacon Peak, Hogan Mountain, Mount Terror, Whatcom Peak, and Mount Redoubt. Also above timberline, many small lakes occupy glacial cirques and on rocky ridges glacial tarns are common.

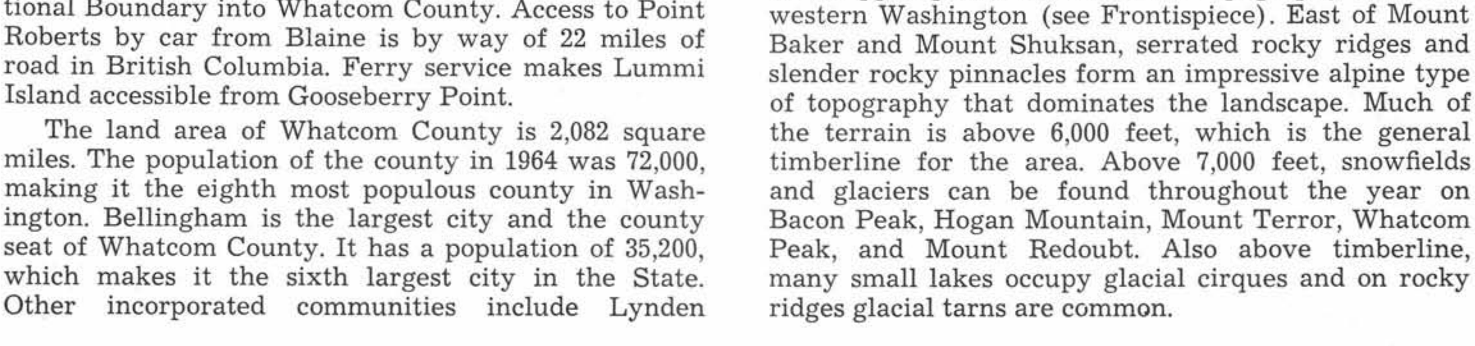

FIGURE 2.—Relief map of Whatcom County. (Photo of part of Relief Map of State of Washington, 1964, U.S. Geological Survey.)

FIGURE 3.—Whatcom Basin. Looking west from Sumas Mountain. Nooksack River is in center of photo.

Whatcom Basin, the nonmountainous part of Whatcom County, has an area of about 380 square miles. It is an area of low relief, and more than one-half of the basin is below the 140-foot contour line. Areas of greater relief include the hills east of Blaine, which rise to 500 feet; the hills west of Ferndale, which rise to 380 feet; and the hills north of Bellingham, which rise to 320 feet. These upland areas, which consist mainly of glacial till, have hummocky glacial moraine topography; in some areas the terrain becomes nearly level and has only gentle swells and swales. The topography of the basin probably reflects the general terrain of the underlying bedrock, which crops out at several places in the basin.

The major rivers of Whatcom County are the Nooksack, in the western part; Baker, in the central part; and Skagit, in the eastern part of the county. These rivers and their numerous tributaries form dendritic drainage patterns. Whatcom, Baker, Diablo, and Ross Lakes are the largest lakes of the county and occupy several of the lower valleys.

Much of the lowland area of the county has been cleared of the original heavy timber and is utilized for agriculture and for dairy pasture. The mountainous areas, especially in the western part of the county, contain thick stands of Douglas fir, western hemlock, and western red cedar. Because of heavy rainfall on the western slopes of the northern Cascades, the region contains dense undergrowth of alder, willow, maple, salmonberry, blackberry, ferns, and devils club. Above timberline, forests give way to typical alpine vegetation that consists of groves of mountain hemlock and alpine fir surrounded by meadows of heather, huckleberry, and blueberry. In many meadows wildflowers grow in abundance, and on the highest peaks only heather, lichen, and a few wildflowers grow.

Because of westerly to southwesterly prevailing winds from the Pacific Ocean, Whatcom County has a modified oceanic climate. The mean annual temperature is near 50°. In summer the temperature seldom reaches 80°, and in winter it seldom falls below 20°. In general, summers are cool and winters comparatively mild. Precipitation is heavy in the area. In Whatcom Basin the mean annual rainfall is 35 inches. At Mount Baker Lodge, 30 miles east of Bellingham, the mean is 132 inches; at Newhalem, in the eastern part of the county, the mean annual rainfall is about 70 inches. In the Whatcom Basin most of the precipitation falls in the form of rain; however, from November until March there is a possibility of some snowfall. At altitudes above 2,500 feet, snow falls usually from November through April, and at 4,000 feet the snow reaches a depth of 15 to 20 feet by the last of March. In general, about 75 percent of the precipitation falls between September and May.

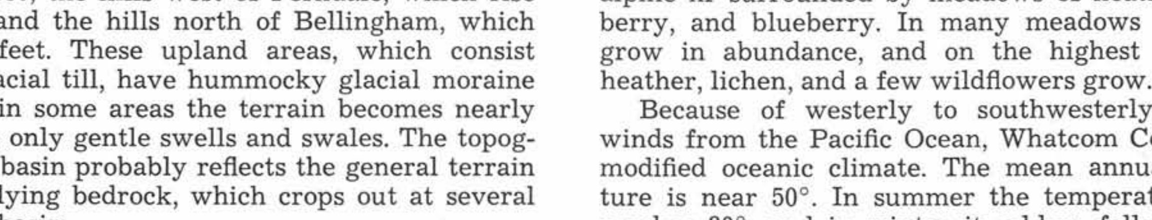

FIGURE 4.—Mean annual precipitation in Whatcom County.

ACCESS

Along the west coast of Whatcom County the seaports of Bellingham and Blaine provide access to seagoing vessels. At the western end of the mainland, Interstate Highway 5 provides a vehicle route through the county and affords direct access to Vancouver, British Columbia. From Bellingham, State Highway 542 provides access to the Mount Baker mining district and terminates near Mount Baker Lodge. Many miles of excellent county roads exist in the lowland areas of western Whatcom County; the mountainous areas are accessible mainly by logging and forest access roads. Access to the Skagit River area in the southeastern part of the county is by way of State Highway 20 from Sedro Woolley, in Skagit County. East of Ross Lake, work is still in progress on the North Cross State Highway to Winthrop, in Okanogan County. In the extreme southeastern part of the county the Slate Creek mining district is accessible from Winthrop on the east by State Highway 20 to Mazama and by county and forest access roads from Mazama to Canyon Creek. The western part of Whatcom County is served by the Great Northern, the Northern Pacific, and the Chicago, Milwaukee, St. Paul and Pacific railroads. Maple Falls, which is 20 miles northeast of Bellingham, is the nearest railroad shipping point to the west half of the Mount Baker mining district. For the east half of the district, railroad loading facilities are at Concrete, in Skagit County. The nearest railroad shipping point for the extreme eastern part of Whatcom County is Pateros, which is in Okanogan County and is 75 miles by road southeast of the Slate Creek mining district.

LAND STATUS

The development of mineral resources depends to a large extent upon the availability of land open to exploration and mining. The land area of Whatcom County is 1,332,480 acres, or 2,082 square miles. More than half of the land is owned by the Federal Government, mainly as national forest, and the remainder is private, state, and county lands in decreasing order of total acreage. A breakdown of the major classes of land ownership in the county is as follows:

Land Ownership of Whatcom County

Type	*Area (acres)*	*Percentage*
Private (includes minor county land and public domain)	380,946	28.5
State forest land	73,500	5.5
Federal:		
Indian reservations	12,800	1
National forest	865,234	65
Total	1,332,480	100

All metallic mineral deposits of the county that have a record of significant production, as well as almost all known occurrences of metallic minerals, are within the Mount Baker National Forest (Pl. 2). With the exception of several established campgrounds and administrative sites, most of this national forest is open to prospecting and mining. The North Cascade Primitive Area comprises about one-half of the Mount Baker National Forest. However, the creation of the North Cascades National Park, which is presently (1966) under consideration, will, for all practical purposes, prohibit mineral development in the primitive area (see footnote on p. 1).

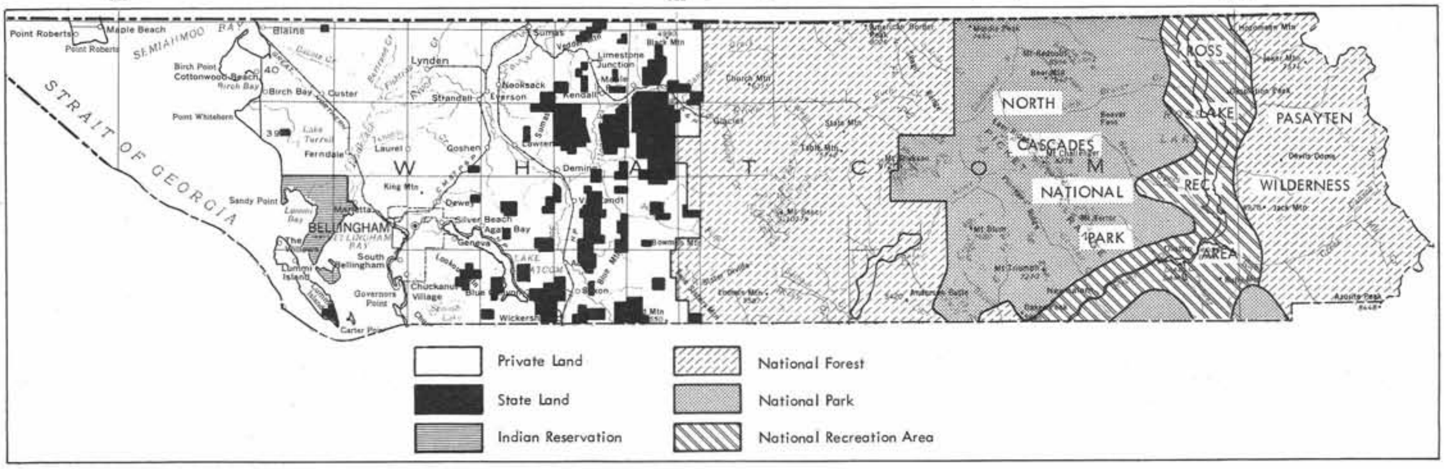

FIGURE 5.—Land ownership map of Whatcom County.

SOURCES OF INFORMATION

Much information exists on the mineral deposits of Whatcom County, but it is by many authors and in widely scattered reports. Most of the information contained herein was obtained from the references cited in the text and listed under "References" at the end of the report. In order to supplement this information, the months of August and September in 1964 and 1965 were devoted to field work. During this time the locations of most mineral deposits were verified or established and examinations were undertaken on deposits that could be of economic value, now or in the future. Very little information was obtained by examining mines, as many mine workings are inaccessible because of caved portals.

ACKNOWLEDGMENTS

In compiling this report the writer depended much on the findings of earlier workers who studied the geology and mineral deposits of Whatcom County; their work is acknowledged individually throughout the report. Special thanks go to mine owners who volunteered information on their mines. The writer is especially grateful to A. J. Kauffman, Jr., Chief, Albany Office of the U.S. Bureau of Mines, for mineral production figures; to Harry Kramer, President, Western Gold Mining, Inc., for claim maps of the Slate Creek mining district; to Russell F. Martini, former director of Whatcom County Industrial Development Council, for use of his mines files; and to Keith Whiting, Chief Geologist, Northwest Exploration, American Smelting and Refining Co., for mine maps of the Azurite mine. To Marshall T. Huntting, Supervisor, Washington Division of Mines and Geology, for his help and cooperation, and to the Division staff for assistance in typing, drafting, and editing of the manuscript, I herewith express my thanks.

PREVIOUS WORK

The earliest account of the mines of Whatcom County is given by L. K. Hodges in a report prepared for the Seattle Post-Intelligencer in 1897. This publication, "Mining in the Pacific Northwest," briefly describes the mines in the Slate Creek area of eastern Whatcom County, as well as several mines on the Ruth Creek drainage, in the western part of the county. In 1902, in Washington Geological Survey Annual Report for 1901, Henry Landes and others reported on the mines of the Mount Baker and Slate Creek mining districts. That report discusses the mines that were in operation as well as prospects that appeared to be promising. In 1921 Ernest N. Patty reported on the Lone Jack and the Boundary Red Mountain mines of the Mount Baker mining district. Patty's report appeared as part of Washington Geological Survey Bulletin No. 23, "The Metal Mines of Washington." A historical account of the mines of the Mount Baker mining district is given by P. R. Jeffcott (1963) in "Chechaco and Sourdough, or the Mount Baker Gold Rush." Other reports have been written about the various mineral occurrences of the county, and mineral investigations have been made by consulting mining engineers and geologists on specific properties. These reports are included in the list of references on pages 132 to 134 of this report.

The first report on the geology of parts of Whatcom County was made by Russell (1899) in his report on the "Geology of the Cascade Mountains in Northern Washington." In the summers of 1897 and 1898, Russell made a cursory survey across the Cascades by way of the upper Skagit River, Ruby and Slate Creeks, and the Methow River, and reported on the major rock units of the region. In 1904 Smith and Calkins reported on "A Geological Reconnaissance across the Cascade Range near the Forty-Ninth Parallel." The reconnaissance was essentially topographic, beginning at Osoyoos Lake in Okanogan County and terminating at the Strait of Georgia in western Whatcom County. However, a considerable amount of geologic information was gained during the traverse. The "Geology of the North American Cordillera at the Forty-Ninth Parallel" reports on the work of Daly (1912), who named several major rock units of the county; however, most of his work was on the Canadian side of the International Boundary. In 1930 Crickmay reported on his studies between the Coast Range of British Columbia and the Cascade Range of Washington. This report covers parts of the foothills of western Whatcom County. Coombs (1939) was the first to report on the geology of Mount Baker, and Ragan (1963) reported on the emplacement of the Twin Sisters Mountain dunite. The most complete geologic study of the Northern Cascade Mountains has been in progress since 1949 by Peter Misch, of the University of Washington. A nontechnical description of the geology is given by Misch (1952) in the "Mountaineer." His most recent work is the "Tectonic Evolution of the Northern Cascades of Washington State" (Misch, 1966). On the extreme eastern edge of the county the rocks have been studied by Barksdale since 1948 (see Barksdale, 1960). In Bellingham Basin, Newcomb and others (1949) reported on the surficial geology of western Whatcom County, and the water resources of the Nooksack River basin have been described by the Washington Division of Water Resources (1960). In 1962 the writer reported on the geology and mineral deposits of the north half of the Van Zandt quadrangle. This area is southeast of Sumas and adjacent to the Canadian border. In 1963 Miller and Misch reported on an angular unconformity on the west slope of Sumas Mountain. Recent work by Danner (1966) covers the limestone deposits of the county. The geologic mapping done prior to 1961 by Misch accounts for most of the geology that appears on the geologic map of Whatcom County (Pl. 1) accompanying this report. Mapping by other individuals is shown on the source map of geologic mapping that appears on Plate 1.

GENERAL GEOLOGY

The rocks of Whatcom County range in age from Devonian to Recent, but not all geologic time units in this span are present. The youngest rocks, for the most part, are in Whatcom Basin and in the bottoms of the largest valleys. The older rocks crop out mainly in the mountainous areas of the county.

The rocks of Whatcom Basin consist of Pleistocene till, stratified drift, and outwash sand and gravel that were deposited in thicknesses of as much as 600 feet by Pleistocene continental glaciers during their advances and retreats in Whatcom County. Upon this surface of glacial debris the Nooksack River, as well as shifting streams of postglacial times, left deposits of Recent sand, gravel, and silt. Similar deposits left by glacial and Recent streams are also in Columbia Valley (near Kendall) and along the Nooksack River and its largest tributaries. In the eastern part of the county the valleys of the largest streams also contain deposits of Recent alluvium.

Pleistocene deposits in Whatcom Basin are underlain by early Tertiary (early Eocene to early Oligocene) and Late Cretaceous continental sedimentary rocks that consist of arkose, conglomerate, siltstone, and coal-bearing shale. These rocks, which consist mainly of the Chuckanut Formation, crop out as a northeastward-trending belt that extends from Chuckanut Mountain, south of Bellingham, to Church Mountain, north of Glacier. Other outcrops of the Chuckanut Formation are on the western slope of Sumas Mountain, and an isolated outcrop is east of Baker Lake. In Whatcom Basin the Chuckanut Formation is overlain by late Eocene-early Oligocene continental sedimentary rocks that have been correlated with the Huntingdon Formation of southwestern British Columbia. Palynology studies by Hopkins (1966) indicate that the upper part of the Tertiary sequence may be Miocene.

Marine sedimentary rocks of Mesozoic age form extensive outcrops in eastern Whatcom County from Ross Lake to the Okanogan County line. The rocks consist mainly of arkose, quartzite, argillite, and conglomerate and correspond to the Dewdney Creek Group of British Columbia and Smith and Calkins' Pasayten Formation. In the western part of the county, Mesozoic sedimentary rocks consisting of grit, argillite, tuffaceous sandstone, and conglomerate crop out from Mount Baker to the Canadian border. Small outcrops of these rocks are also on Sumas Mountain and Lummi Island.

The oldest marine sedimentary rocks have been mapped as the Chilliwack Group in western Whatcom County and as the Hozomeen Group in the eastern part of the county. These rocks are essentially of Carboniferous-Permian age, although in western Whatcom County some Devonian limestones are present. The rocks of the Chilliwack Group consist chiefly of graywacke, argillite, chert, and limestone and crop out mainly north of the Nooksack River from Sumas Mountain on the west to Swamp Creek on the east. Rocks similar to those of the Chilliwack Group crop out in the area surrounding Baker Lake. The rocks of the Hozomeen Group, which are cherty quartzite, limestone, and andesite, crop out west of Ross Lake near the Canadian border.

The extrusive igneous rocks of the county occur as scattered outcrops from Sumas Mountain, in the western part of the county, to Ross Lake, on the east. However, the extrusive rocks are not as extensive as the sedimentary rocks. The youngest and largest mass of extrusive rock is the Quaternary andesitic volcanic mass that makes up Mount Baker. This dominant volcano rises to an altitude of 10,750 feet and covers an area of about 80 square miles. On the northern slopes of Mount Baker the volcanic rocks are underlain by Tertiary andesite. Other Tertiary volcanic rocks crop out in the vicinity of Ruth Mountain, along Silesia Creek near the Canadian border, and near Glacier Peak, west of the north end of Ross Lake. These rocks, of Oligocene age, consist mainly of dacite and andesite breccias and tuffs that contain interbeds of tuffaceous sandstone.

The largest body of Mesozoic volcanic rocks crops out on the North Fork of the Nooksack River at the confluence of Wells Creek. These rocks consist of massive green andesite flows of Jurassic age.

The oldest volcanic rocks in Whatcom County are of Carboniferous-Permian age. In the western part of the county these rocks are part of the Chilliwack Group, and in eastern Whatcom County they are part of the Hozomeen Group. The Chilliwack volcanics consist chiefly of andesitic lithic tuffs, augite andesite, and spilite, which crop out mainly on the northwestern slope of Church Mountain and to the northeast of Mount Baker. The Carboniferous-Permian volcanics of the Hozomeen Group in eastern Whatcom County consist mainly of greenstone, cherty andesite, and spilite that form extensive outcrops from the Canadian border southward to within 5 miles of the Skagit County line. This mass of volcanic rocks, which forms extensive outcrops east of Ross Lake, is 5 miles wide and 24 miles long.

The intrusive igneous rocks of the county occur mainly between Mount Shuksan and Ross Lake as a northward-trending belt. Smaller, isolated bodies of intrusive rocks occur in the extreme northeastern corner of the county near Castle Peak and in the southeastern part of the county near Azurite Peak. In the western part of the county, intrusive rocks make up the main mass of Twin Sisters Mountain, and other intrusive rocks crop out on Sumas Mountain. The main mass of intrusive igneous rocks consists of Oligocene granodiorite and quartz diorite of the Chilliwack Batholith. Bordering the batholith, and probably related to it, are stocks and bosses of granodiorite, quartz diorite, and diorite. Not all intrusive rocks are granitic; the Twin Sisters Mountain intrusion is dunite, and the predominant intrusive rock on Sumas Mountain is serpentinite.

Rocks of metamorphic origin are extensive in eastern Whatcom County. The largest mass of metamorphic rock consists of pre-Jurassic gneiss that extends from the Skagit County line, where it is more than 15 miles wide, northward to the Canadian border, where it narrows to 5 miles in width. Small bodies of pre-Jurassic schist occur in the gneiss and form larger bodies to the east and west of the gneiss. The main body of schist is greenschist, which makes up Mount Shuksan and extends southward from the mountain into Skagit County. Another belt of pre-Jurassic schist roughly parallels the eastern border of the gneiss for about 20 miles. Low-grade metamorphic rocks consisting of pre-Jurassic phyllite crop out from Mount Shuksan northward to Swamp Creek. Phyllite also forms a narrow band on the western border of the greenschist. In the western part of the county pre-Tertiary graphitic schist and pre-Jurassic phyllite crop out for about 22 miles, from Samish Lake eastward to Twin Sisters Mountain. To the north these rocks are overlain by sedimentary rocks of the Chuckanut Formation.

The oldest metamorphic rocks of the county are pre-Carboniferous crystalline rocks that form isolated fault slices along the western slopes of the northern Cascades. Meta-quartz diorite, metadiorite, amphibolite, and gneiss are the predominant rocks. The largest body of these rocks occurs southwest of Mount Baker. Smaller outcrops are on Yellow Aster Butte north-northeast of Mount Baker and on Church, Red, and Vedder Mountains to the northwest of Mount Baker and near the Canadian border.

The distribution of the major rock units of Whatcom County is shown on Plate 1, and the geologic map units are shown in Table 1.

TABLE 1.—*Rock units of Whatcom County*

SEDIMENTARY ROCKS

Rock unit	Map symbol	Age and lithology
	Qa	Recent alluvium: Silt, sand, and gravel along streambeds.
	Qg	Pleistocene glacial drift undivided: Glacial and glaciofluvial sand, gravel, and till; includes alpine glacier outwash and till.
	Qg_1t	Pleistocene till: Hard, blue-gray to gray concrete-like mixture of clay, silt, sand, and gravel deposited as terminal or recessional moraine.
	Qg_1o	Pleistocene advance and recessional outwash, stratified drift, and associated deposits: Principally silt, sand, and gravel; some clay. Includes some alluvium.
	Qs	Recent landslide deposits: Predominantly landslide debris.
Huntingdon Formation	Tc	Tertiary nonmarine rocks: Massive conglomerate, sandstone, siltstone, and refractory and ferruginous shale.
Chuckanut Formation	TKc	Paleocene-Cretaceous nonmarine rocks: Brown-gray to light-gray, medium- to coarse-grained massive cross-bedded arkose with interbedded conglomerate and siltstone. Contains shale and coal seams.
Dewdney Creek Group and Pasayten Formation	Kl	Lower Cretaceous marine rocks: Black shale and siltstone, light- to medium-gray arkose and quartzite. Also some conglomerate and phyllite.
Nooksack Group	JKs	Upper Jurassic-Lower Cretaceous marine rocks: Graywacke, argillite, and siltstone; some slate and phyllite. Includes graywacke breccias and ribbon chert and minor local limestone lenses and basalt flows.
Cultus Formation(?)	J	Lower and Middle Jurassic marine rocks: Dark-gray, massive to thick-bedded, siliceous argillite, siltstone, and shale; includes minor graywacke and limestone.
Bald Mountain Formation	TRJ	Upper Triassic and (or) Lower Jurassic marine rocks: Conglomerate, gritstone, graywacke, and carbonaceous argillite.
Chilliwack Group	CPm	Carboniferous-Permian marine sedimentary and volcanic rocks, undivided: Cherty and slaty argillite, siltstone, graywacke, chert, greenstone, tuff, andesite, and spilitic volcanic rocks.
	CPms	Carboniferous-Permian marine sedimentary rocks: Predominantly graywacke, argillite, and slate. Includes minor limestone, siltstone, arkose, conglomerate, ribbon chert, and minor volcanic rocks. Some Devonian rocks near Sumas Mountain.

EXTRUSIVE IGNEOUS ROCKS

Rock unit	Map symbol	Age and lithology
Mount Baker Volcanics	Qv	Pleistocene-Recent volcanic rocks: Predominantly light-gray porphyritic andesite, tuff, and agglomerate.
Hannegan Volcanics	Mv	Miocene volcanic rocks: Acidic and intermediate rocks. Includes some andesite, breccia, and tuff.
	Tv	Tertiary volcanic rocks, undivided: Includes andesite, basalt, rhyolite, and associated pyroclastic rocks.

TABLE 1.—*Rock units of Whatcom County*—Continued

Rock Unit	Map Symbol	Age and lithology
Wells Creek Volcanics	Jv	Middle Jurassic volcanic rocks: Andesite, dacite, and minor basalt; slate and graywacke interbeds.
Hozomeen Group (eastern Whatcom County) Chilliwack Group (western Whatcom County)	CPmv	Carboniferous-Permian volcanic rocks: Predominantly altered andesite, basalt, and diabase with interbedded chert and argillite. Includes some tuff, greenstone, and spilitic volcanic rocks.
INTRUSIVE IGNEOUS ROCKS		
Chilliwack Batholith	Tg	Tertiary granitic rocks: Predominantly granodiorite and quartz diorite. Includes minor diorite and gabbro.
Twin Sisters Dunite	Td	Tertiary dunite: Dunite and saxonite, partly serpentinized.
Black Peak Batholith	TKg	Tertiary-Cretaceous granitic rocks: Granite, granodiorite, trondhjemite, and quartz diorite.
Sumas Mountain Serpentinite	pTb	Pre-Tertiary ultrabasic rocks: Serpentinite and saxonite of Sumas Mountain.
	bi	Basic intrusive rocks of undetermined age: Predominantly gabbro. Includes some serpentine.
	Ti	Tertiary dikes, sills, and small intrusive bodies.
METAMORPHIC ROCKS		
	pT	Pre-Tertiary sedimentary and metasedimentary rocks undivided: Phyllite, graphitic schist, argillite, graywacke, chert, and talc; some faulted-in blocks of serpentinite and greenstone.
Skagit Gneiss	pJgn	Pre-Upper Jurassic gneiss: Biotite, quartz diorite, trondhjemite, and hornblende gneisses, many of which are migmatitic. Includes small granitic bodies locally.
Elijah Ridge Schist	pJsc	Pre-Upper Jurassic metamorphic rocks of the medium- and high-grade zones: Schist, amphibolite, and minor lime-silicate rocks, marble, quartzite, and metaconglomerate.
Darrington Phyllite	pJph	Pre-Upper Jurassic metamorphic rocks of the low-grade zone: Predominantly phyllite and slate. Includes some limestone, quartzose phyllite, schistose metaconglomerate, breccia, and basic igneous rocks.
Shuksan Greenschist	pJgs	Pre-Upper Jurassic greenschist.
Yellow Aster Complex	pCm	Pre-Carboniferous crystalline complex: Metahornblendite, amphibolite, gneiss, metadiorite, meta-quartz diorite, and trondhjemite.

GLACIATION

Most of Whatcom County was covered by a thickness of several thousand feet of ice during the Wisconsin Stage of Pleistocene glaciation. Had it not been for glaciation, the greater part of Whatcom Basin might still be covered by the waters of Puget Sound. Also, glaciation made significant contributions to the mineral wealth of the county in the form of sand and gravel deposits and ground and surface water reservoirs.

The continental glaciers that covered the county as well as large areas to the south were part of the late Pleistocene sequence of the Cordilleran glacier complex. In the past this glaciation has been referred to as the Vashon Glaciation, but recent work (Armstrong and others, 1965) restricts the use of the name "Vashon" to a stade (a period of glacial advance) and defines the last major glaciation as the Fraser Glaciation. Before the Fraser Glaciation, at least three other periods of continental glaciation occurred in western Washington (Crandell and others, 1958).

Before the advance of the ice that marked the beginning of the Fraser Glaciation, western Whatcom County probably consisted of a lowland of shallow lakes, swamps, and flood plains in the drainages of the ancestral Fraser and Nooksack Rivers. Originating in the mountains of British Columbia, the glaciers advanced southward into the Strait of Georgia, the Fraser Lowland, and into the Puget Lowland and formed the Puget ice lobe that extended as far south as Tenino, in Thurston County. Glacial erratics on the higher peaks of the northern Cascade Mountains indicate that the ice was as much as 6,000 feet thick in the northern parts of Whatcom County but decreased in thickness southward toward the terminus of the glacier. Radiocarbon dating indicates that the last major glacier advance of the Vashon Stade began about 25,000 years B.P. (before present) and reached its maximum about 14,500 years B.P. (Armstrong and others, 1965).

As the ice of the Vashon Stade melted, a mantle of ground moraine was left over most of the area that had been covered by ice. One such moraine deposit blocked a major valley east of Bellingham and formed a dam that impounded the waters of Lake Whatcom. Elsewhere in western Whatcom County, melt waters from the receding glacier reworked parts of the ground moraine and deposited the material as outwash sand and gravel in the largest valleys.

At the close of the Vashon Stade (13,500 years B.P.), coastal lowlands of northwestern Washington and southwestern British Columbia were invaded by the sea in an episode of glacial history known as the Everson Interstade. At this time the relative position of the sea was 600 feet or more above the present sea level. Radiocarbon dating indicates that the sea covered Whatcom Basin for about 1,500 years and southwestern British Columbia for 2,000 years. As the glacier melted northward, a general uplift of the land and a consequent lowering of sea level caused the sea to withdraw to its present location. During the uplift of the land the Fraser River flowed through Sumas Valley and joined the Nooksack River near Everson. The combined rivers then flowed westward into the Strait of Georgia. As the uplift continued, the Fraser River abandoned its Sumas Valley drainage and returned to its original and present course. About this time the Nooksack River flowed across the lowland into Lummi Bay, but later it changed its course and flowed into Bellingham Bay. After establishing its present course, the Nooksack River reworked much of the glacial debris in its valley and produced broad flood plains of Recent alluvium.

The economic significance of the Fraser Glaciation is that the outwash and recessional sands and gravels are important aquifers and the principal deep source of ground water in western Whatcom County. The clays of the outwash deposits have supplied one of the basic raw materials for the manufacture of cement, as well as common brick and drainage tile. The outwash sands and gravels supply excellent aggregate for concrete. Along flood plains of the Nooksack River, silt plains provide excellent soils for pasture and crops.

MINING HISTORY

The first discovery of minerals in Whatcom County was made by Indians prior to 1852—the year that Captain Henry Roeder and Russel V. Peabody arrived in Bellingham Bay and built a sawmill on the banks of Whatcom Creek. At this time Captain Pattle, who was cutting timber in the San Juan Islands, was informed by Indians that coal existed on Bellingham Bay (Jenkins, 1923). He and two men named Morgan and Thomas located three claims in parts of Bellingham, which then consisted of the settlements of Whatcom, Sehome, and Fairhaven. In 1853 another seam of coal was discovered at Sehome by two men named Hewitt and Brown, and under the direction of Edmund C. Fitzhugh a company was formed that marked the beginning of the Bellingham Bay Coal Co. Shortly thereafter, mining was begun at the intersection of Railroad Avenue and Myrtle Street on a seam of coal that dipped northward under Bellingham.

In 1858 the settlements on Bellingham Bay, whose basic industries were logging and mining, became crowded with prospectors and miners. Because of the discovery of gold on the Fraser River to the north in British Columbia, prospectors and miners from as far away as California flocked to the area, confident that this new gold discovery would rival the great California gold rush. Mills in Whatcom and Sehome were shut down as workers joined the rush to the Fraser River. In order to attract miners to the settlements on Bellingham Bay and receive the business of outfitting them, Whatcom took measures to build a trail north to connect with the Hudson's Bay Company's Brigade Trail up the Fraser River (Trimble, 1914). While waiting for this trail to be completed, some of the more impatient men prospected the area east of Bellingham and along the Nooksack River. The first discovery of gold in Whatcom County was made at this time, when on July 24, 1858, William Young arrived in Whatcom with two coarse gold nuggets that he had found 11 miles northeast of the mouth of the Nooksack River. When the Whatcom trail to the Fraser and Thompson River areas of British Columbia was finished, most prospectors joined the Fraser River stampede. However, prospecting continued in the county, and in 1860 a party of prospectors from Whatcom found encouraging amounts of placer gold on the South Fork of the Nooksack River.

In the late 1870's, placer gold was discovered in the eastern part of the county, on Ruby Creek, by a man named Rowley. Several hundred prospectors, many from the goldfields of British Columbia, converged on the area, and over $100,000 in placer gold was reportedly mined from stream gravels. Because of the inaccessibility of the area and the limited amount of placer ground, this gold rush was short lived. Access to the Ruby Creek area at that time was mainly from Fort Hope, in British Columbia, down the Sumallo River to its junction with the Skagit River, from which point an Indian trail was followed to the mouth of Ruby Creek. In 1879, parties in Whatcom and Sehome expressed concern over a more direct route to the Ruby Creek workings. Cursory surveys were undertaken, but no start was made on the actual building of a wagon road from Bellingham Bay across the mountains to the Ruby Creek trail.

By 1885 the South Fork of the Nooksack River was the scene of many small-scale placer mining operations, and near the mouth of Skookum Creek a townsite called Livewood was established. Hundreds of prospectors gathered there, and all the ground along the river was staked. However, bedrock was deep, and few pans yielded more than a few cents to the pan.

In 1893, residents of Whatcom and Sehome were still concerned over a road to Ruby Creek, in the eastern part of the county. At that time, Banning Austin and R. M. Lyle surveyed a route eastward from Glacier to Whatcom Pass, a distance of about 30 miles. However, in 1894 the Ruby Creek road project was abandoned because of steep grades and high altitudes.

By 1895 a wagon road from Whatcom extended as far east as Cornell Creek, near Glacier. Beyond Cornell Creek a trail known as the Cascade State Trail extended 20 miles farther east, to within 2 miles of Hannegan Pass. Mileposts were established along the trail and for years served as reference points for the many mining claims that were staked in the area. North of the 19 milepost, E. H. Thomas and J. W. Hulett in the summer of 1894 made several gold-silver discoveries that marked the beginning of claim staking in the Mount Baker mining district.

In 1896 the first significant discovery of lead, zinc, and silver was made in what was then known as the Shuksan or the Nooksack mining district of western Whatcom County. Near the 18 milepost on the Cascade State Trail, H. C. Wells discovered the Silver Tip vein. This discovery was followed by discoveries of gold-bearing quartz to the east along the Trail, as well as in the surrounding area. On August 23, 1897, the most important discovery of gold in the Mount Baker area was made by Jack Post, of Sumas. While prospecting with R. S. Lambert and L. G. VanVolkenberg, Post discovered the Lone Jack vein, on the southern slope of Bear Mountain above the West Fork of Silesia Creek. Gold-bearing quartz from the discovery assayed as high as $10,000 per ton, and, as would be expected, a gold rush followed; Sumas became the main outfitting town. In the Nooksack mining district, tent cities of miners sprang up almost overnight. Gold Hill was established at the present site of Shuksan; Trail City was 2 miles east, at Swamp Creek; Wilson's Townsite was at the confluence of Ruth Creek and the Nooksack River; Gold City was at the 18 milepost on the Cascade Trail; and Union City was at the headwaters of Swamp Creek (Fig. 24, on p. 62). In 1898, at a miners' meeting in Sumas, the Mount Baker mining district was established. At that time, claim staking in western Whatcom County was not confined to the upper reaches of the North Fork of the Nooksack River. In the vicinity of Baker Lake, prospectors roamed the hills, and many claims were recorded in New Whatcom. The most well known prospector of the Baker Lake area was Joseph Morovits, who staked many claims south of Mount Shuksan and east of Mount Baker and established a homestead north of Baker Lake.

In the Ruby Creek area of eastern Whatcom County, placer mining had been carried on since 1891—this being a revival of the earlier placer mining that had been undertaken in the early 1880's. Nuggets as large as an ounce in weight were found along Ruby and Slate Creeks. With such favorable showings of placer gold, it was only natural that a search for the "mother lode" was to follow. In September of 1891 the first lode claim, known as the Nellie Belle, was staked by Franklin Rives on Ruby Creek, and in July 1892, Henry Benke and partners discovered and staked the Anacortes claim near the headwaters of Canyon Creek. However, not until the Eureka lode was discovered by A. M. Barron in September 1893 did prospectors rush to the Slate Creek mining district. It was at the Eureka that free-milling gold was found in soil overlying a decomposed iron oxide-rich quartz vein. Trails were opened into the district from the Skagit River, on the west, and up the Methow River from Winthrop, in Okanogan County. By 1900 at least 3,000 lode and placer claims had been staked in the Slate Creek mining district, and the mining camp of Barron was established in Eureka gulch. With the discovery of the Lone Jack mine in 1897 in western Whatcom County and of the Eureka mine in 1893 in eastern Whatcom County, the mining of lode gold began in the county. The mining history of the Mount Baker and Slate Creek mining districts from 1900 to 1965 is discussed further under the descriptions of these mining districts on pages 62 and 96.

It is only natural that the nonmetallic mineral deposits of the county were developed as the country around Bellingham Bay was settled. South of Fairhaven, along Chuckanut Bay, deposits of sandstone were quarried on a part-time basis in the early 1870's. By 1900 these quarries were operating on a large scale and were supplying stone to coastal cities of Washington for use in the construction of governmental and business buildings. By 1920 the market for sandstone no longer existed and the quarries were closed. Because clay was abundant in western Whatcom County, brickyards utilized the clay for the manufacture of common brick. In the early 1900's several small brick companies were in operation in Bellingham, and near Sumas, fire clay was mined intermittently.

In 1878, after 25 years of operation, the Bellingham Coal Co. closed down following a mine fire. However, in 1892 coal was discovered by core drilling in the northwestern part of Bellingham, and in 1917 Bellingham No. 1 mine was opened. Mining of the coal seam continued until 1955, when operations ceased. Elsewhere in the county, coal was discovered at the southeastern end of Lake Whatcom in 1887; at Glacier in 1907; and near Anderson Creek, 5 miles northeast of Bellingham, in 1920. Small amounts of coal were produced from the deposits until 1937. Mining operations were started on other coal seams in the county, but the production of coal from these mines was insignificant.

As early as 1901, drilling for oil was undertaken in the Bellingham area, and in the years that followed most parts of the western lowland area of the county, as well as several of the foothills, were drilled. Between 1901 and 1965, a total of 75 wells were drilled for oil and gas, but no oil production resulted. However, several of the wells did tap pockets of natural gas that was used on a limited scale for local domestic purposes.

Around 1912, deposits of limestone in Columbia Valley, north of Kendall, were being quarried. Near the present site of the Columbia Cement Company's quarry on Red Mountain, the International Lime Co.

erected a plant for the manufacture of hydrated lime. Across the valley, on the east slope of Sumas Mountain, the Balfour Guthrie Co. operated quarries to supply limestone to The Olympic Portland Cement Company's plant at Bellingham. In 1926 the International Lime Company's quarries were acquired by The Olympic Portland Cement Co., and since that year quarry operations have been carried on at this site. To supply the limestone needs of the pulp industry in Bellingham, limestone quarries near Silver Lake and Maple Falls have been in operation since the 1920's.

Although olivine was discovered in the county in the early 1900's, it was not until 1963 that an attempt was made to develop it. At that time the Olivine Corporation of Bellingham began to quarry the olivine for use in the manufacture of foundry sand. However, olivine for this purpose has been quarried in Skagit County since 1958.

After the quarrying of sandstone on Chuckanut Bay ceased in the 1920's, little, if any, stone for building purposes was produced in the county. In the 1940's a green andesite deposit east of Glacier was found suitable for use as building stone and several small quarries were opened on a part-time basis. At present (1966), a limited amount of stone is being produced from these quarries.

Since the 1930's, peat has been mined in the western part of the county, mainly for local use. From 1935 to 1942 the Washington Peat Moss Co., of Deming, mined peat near Mosquito Lake to supply out-of-county markets.

At present (1966), mining in Whatcom County has declined to the point where no metals are being produced. The production of nonmetallic minerals consists of limestone, sand and gravel, olivine, building stone, and clay. Exploration for oil continues sporadically, mainly by others than major oil companies.

The preceding discussion is only a brief resumè of the development of the county's mineral resources. The history is covered in more detail under the heading of each mineral commodity, as well as in the discussions on the Slate Creek and Mount Baker mining districts.

MINERAL PRODUCTION

A conservative estimate of the mineral production of Whatcom County (excluding sand, gravel, and building stone) from 1900 to 1965 is about $46,000,000. This represents the production of coal, limestone, clay, peat, quartz, olivine, gold, silver, copper, lead, and zinc. Cement, which is normally included in mineral production figures, is not included in the above production figures, as confidential company data would be revealed. Sand and gravel and building stone are not included in this figure, as production figures for building stone are not available and only from 1935 through 1964 are any values published for sand and gravel; in those years, $9,525,570 in sand and gravel was produced.

Only an estimate of the total mineral production of the county can be given because: (1) the production of some minerals was never reported, (2) some figures are withheld to avoid what companies consider confidential data, and (3) the production figures for some years are missing.

For metallic minerals, production figures are fairly complete. From 1903 to 1958 the production of metallic minerals amounted to $2,395,612, of which 98 percent was gold. The yearly production figures for metals are given in Table 2.

For nonmetallic minerals the main production has been of coal and limestone. From 1917 to 1955, almost $26,000,000 in coal was produced. The dollar value of coal produced before 1917 is not available, as the production is reported in tons. However, from 1891 to 1916, a total of 517,786 tons of coal was mined in the county. The production of limestone from 1919 to 1958 was 2,500,000 tons, valued at about $4,800,000. The production of limestone after 1958 is confidential. The fire clay production from 1922 to 1949 was 53,418 tons, valued at $151,000. Although large amounts of common clay have been mined since 1912 for use in the manufacture of cement, the value of the clay is confidential. The production of peat has never been large; the value of peat produced from 1935 to 1942 was $41,907. Small amounts of peat have been produced sporadically since 1942, mainly on a noncommercial scale. Olivine represents one of the major nonmetallic minerals that is presently produced in the county; however, production figures for olivine are confidential.

TABLE 2.—*Gold, silver, copper, lead, and zinc produced in Whatcom County (1900-1965)* 1/

Year	No. of mines		Ore (short tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
	Lode	Placer							
2/ 1900	---	---	-------	------	------	-----	-----	---	---------
2/ 1901	---	---	-------	------	------	-----	-----	---	---------
2/ 1902	---	---	-------	------	------	-----	-----	---	---------
1903	3	---	-------	1,760	21,200	-----	-----	---	$48,418
1904	3	1	20,000	5,563	25,308	-----	-----	---	129,371
1905	2	1	18,000	3,772	22,111	-----	-----	---	91,338
1906	2	3	2,900	1,848	465	-----	-----	---	38,508
1907	2	5	2,620	1,391	244	-----	-----	---	28,920
1908	1	4	51	292	71	-----	-----	---	6,083
1909	1	---	50	27	6	-----	-----	---	562
1910	---	1	-------	1	------	-----	-----	---	26
1911	---	1	-------	9	1	-----	-----	---	190
1912	1	2	40	106	24	-----	-----	---	2,201
1913	3	1	480	266	95	-----	-----	---	5,549
1914	2	2	1,842	756	188	-----	-----	---	15,739
1915	2	2	995	606	50	-----	-----	---	12,545
1916	3	---	10,550	6,444	400	-----	-----	---	133,463
1917	5	---	10,897	6,646	2,500	-----	-----	---	139,442
1918	2	---	956	483	39	-----	-----	---	10,026
2/ 1919	---	---	-------	------	------	-----	-----	---	---------
1920	1	1	8	25	3	-----	-----	---	522
1921	1	---	2,875	1,666	91	-----	-----	---	34,534
1922	1	---	8,876	4,628	247	-----	-----	---	95,926
1923	1	---	5,628	2,903	164	-----	-----	---	60,146
1924	1	---	1,557	907	38	-----	-----	---	18,770
1925	2	---	6,456	4,392	244	-----	-----	---	90,969
1926	---	1	-------	3	------	-----	-----	---	58
1927	1	---	6,462	4,200	220	-----	-----	---	86,947
1928	1	---	4,750	3,503	182	-----	-----	---	72,510
1929	1	---	4,694	2,674	141	-----	-----	---	55,349
1930	2	---	7,106	3,471	173	84	-----	---	71,822
1931	1	---	1,779	603	35	-----	-----	---	12,475
1932	4	---	3,067	1,729	245	1,096	1,167	---	35,914
1933	2	2	104	113	23	454	-----	---	2,371
1934	4	---	84	29	116	-----	433	---	1,102
1935	3	1	1,124	537	210	205	1,925	---	19,054
1936	5	---	4,035	886	204	-----	-----	---	31,161
1937	5	---	28,525	13,197	1,161	-----	-----	---	462,793
1938	5	2	36,871	12,294	1,352	-----	-----	---	431,164
1939	7	5	6,489	3,179	629	67	213	---	111,709
1940	2	3	569	345	121	200	100	---	12,189
1941	5	2	781	378	180	800	400	---	13,475
1942	3	---	122	55	21	-----	-----	---	1,940
1943	1	---	23	1	83	400	-----	---	146
2/ 1944	---	---	-------	------	------	-----	-----	---	---------
2/ 1945	---	---	-------	------	------	-----	-----	---	---------
2/ 1946	---	---	-------	------	------	-----	-----	---	---------
1947	3	1	302	105	115	200	-----	---	3,821
1948	1	---	75	6	------	-----	-----	---	210
1949	1	---	143	23	21	-----	-----	---	824
2/ 1950	---	---	-------	------	------	-----	-----	---	---------
1951	2	---	14	16	41	400	100	100	729
1952	1	---	45	72	157	-----	400	250	2,768
1953	1	---	26	40	105	-----	-----	---	1,495
2/ 1954	---	---	-------	------	------	-----	-----	---	---------
2/ 1955	---	---	-------	------	------	-----	-----	---	---------
2/ 1956	---	---	-------	------	------	-----	-----	---	---------
2/ 1957	---	---	-------	------	------	-----	-----	---	---------
1958	1	---	85	9	13	-----	-----	---	327
1959	---	---	-------	------	------	-----	-----	---	---------
1960	---	---	-------	------	------	-----	-----	---	---------
1961	---	---	-------	------	------	-----	-----	---	---------
1962	---	---	-------	------	------	-----	-----	---	---------
1963	---	---	-------	------	------	-----	-----	---	---------
1964	---	---	-------	------	------	-----	-----	---	---------
1965	---	---	-------	------	------	-----	-----	---	---------
Total			202,056	91,959	79,959	3,906	4,738	350	$2,395,612

1/ Data furnished by U.S. Bureau of Mines, Albany, Oregon.

2/ No production data available.

NONMETALLIC MINERAL DEPOSITS

Whatcom County has deposits of coal, clay, limestone, sand and gravel, building stone, peat, olivine, quartz, and natural gas. Most of these deposits are within a 30-mile radius of Bellingham and are shown on Plate 2. All these materials have at one time or another been produced in the county; however, at present (1966) only clay, limestone, sand and gravel, building stone, and olivine are being mined. The nonmetallic mineral resources of the county offer the best possibilities for future development, as the deposits are mainly on private and State-owned land and are more accessible than the metallic mineral deposits. The development of mineral resources on national forest land will prove more difficult each year, as the policy of the U. S. Forest Service increasingly tends to discourage mineral development.

Coal

Coal was the first mineral of economic value discovered in Whatcom County; it has the greatest total value of all minerals mined to date (exceeding $26 million), and reserves of 327 million tons make coal one of the most abundant minerals in the county. From 1891 to 1955, the year production ceased, about 5.8 million tons of coal was mined (Beikman and others, 1961).

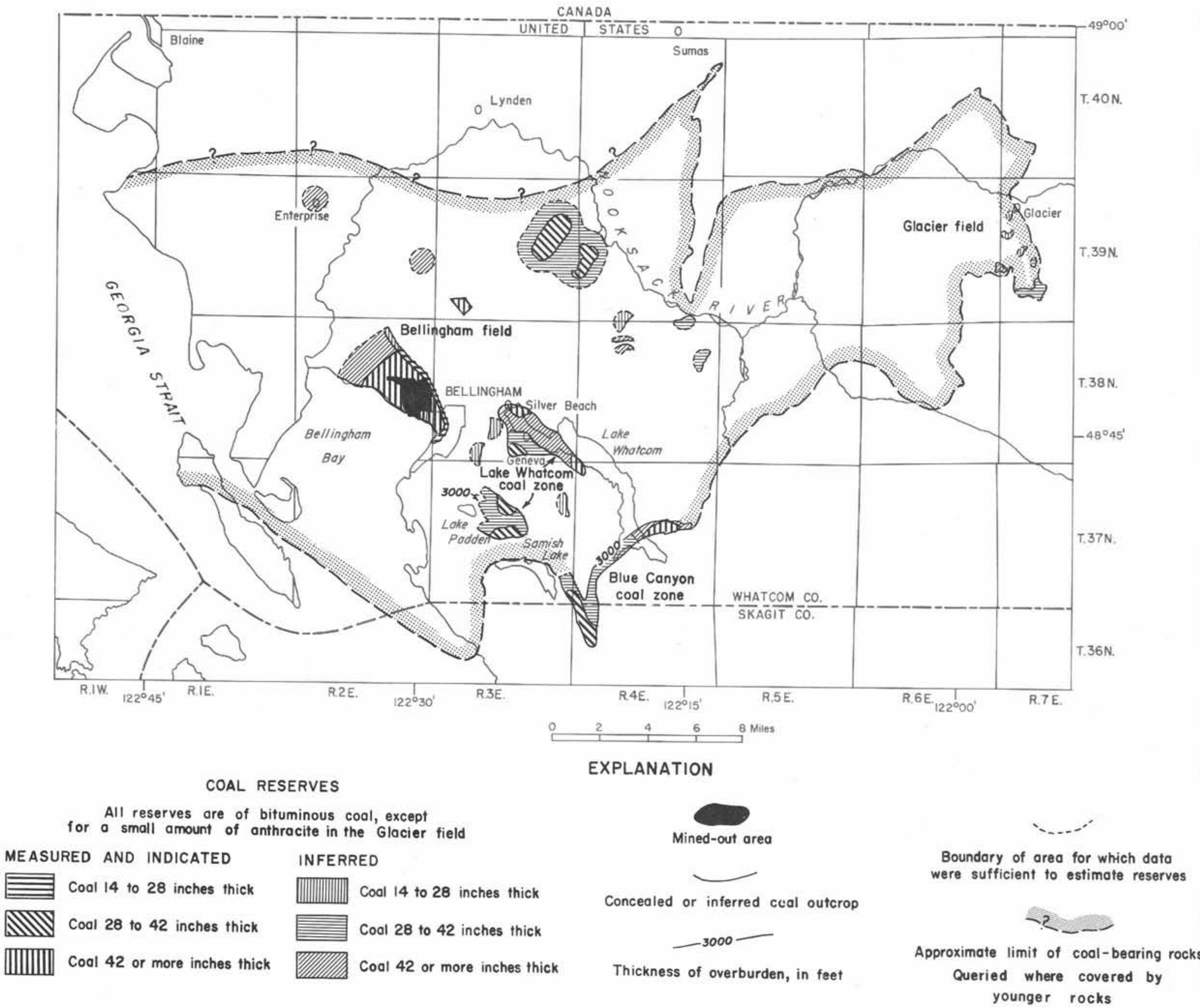

FIGURE 6.—Coalfields of Whatcom County.

Although coal mining in the county ceased in 1955, there is always a possibility that coal will be mined in the future. In 1959 and 1961 the Puget Sound Power & Light Co. undertook exploratory drilling to determine whether sufficient coal is present to operate a steam-electric plant. Five to ten miles north of Bellingham, eight core holes were drilled to depths of 1,992 feet to explore the northward extension of the Bellingham Bay seam. Several coal seams as much as 15.2 feet in thickness were encountered in the drill holes.

Geology of the Coalfields

The coal seams of Whatcom County are in the Chuckanut Formation of Late Cretaceous-early Tertiary age. The Chuckanut Formation underlies much of Whatcom Basin, but for the most part is concealed by a thick cover of glacial debris. South and east of Bellingham, rocks of the Chuckanut Formation form extensive outcrops in mountainous terrain that extends northeastward from Bellingham to Glacier, a distance of 30 miles (Pl. 1). This belt of Chuckanut rocks is about 10 miles wide.

The Chuckanut Formation consists of intercalated beds of conglomerate, arkose, siltstone, shale, and coal seams along Chuckanut Drive that have a total thickness of about 9,000 feet. About 12 miles east of Bellingham, near Van Zandt, outcrops of the Chuckanut Formation suggest a total thickness of more than 15,000 feet. The individual rock units vary considerably in thickness; conglomerates are as much as 80 feet thick, arkoses as much as 125 feet thick, and shales and siltstones are as much as 100 feet thick. The coal seams are found throughout the formation and are generally interbedded with shale and siltstone beds. The seams range in thickness from less than 1 foot to as much as 15.2 feet; however, the average coal seam is only about 2 feet wide. The two principal seams are stratigraphically more than 10,000 feet apart. The Blue Canyon seam is near the bottom of the Chuckanut Formation, and the Bellingham No. 1 seam is near the top.

Regional folding of the Chuckanut Formation has produced a general northwestward structural trend; however, this folding has been complicated by transverse folding that curved the main axis of the folds (Pl. 3). As a result of folding, the beds of the formation have been tilted from horizontal as much as 90° and in a few places overturned. However, most dips range from 20° to 60°. The folding was accompanied by minor faulting that has offset some coal seams. At the Blue Canyon mine, parts of the Blue Canyon seam have been thrust-faulted over basement schist; near the fault the coal is highly granulated.

The thickest coal seam that has been mined is in a syncline under Bellingham. This seam, about 14 feet thick and known as Bellingham No. 1, has partings of shale near its base, and only the upper 7 or 8 feet is minable. A 2-foot coal seam (Bellingham No. 2) is about 100 feet below the main seam; no mining has been undertaken on this seam. Both seams, which are in the upper part of the Chuckanut Formation, have a general northwest strike, dip 7° to 18° southwestward under Bellingham Bay, and are of subbituminous grade.

The King Mountain coal seam is the name given by Glaeser (1960, p. 8) to the northward extension of the Bellingham No. 1 seam. Core from a drill hole near the N. 1/4 cor. sec. 21, T. 39 N., R. 3 E., showed the seam to be 15.2 feet thick at 1,970.2 to 1,985.4 feet beneath the surface. The average strike of the seam is N. 15° E., and the dip is 4° westerly. Glaeser (1962, p. 5) gives the following stratigraphic section for the King Mountain coal seam:

	Stratigraphic thickness (feet)
Highly carbonaceous shale	0.5
Coal and bony coal	0.5
Slightly carbonaceous shale	0.7
Highly carbonaceous shale	0.1
Mainly coal and a little bony coal	5.1
Mainly bony coal and minor carbonaceous shale	1.1
Moderately carbonaceous shale and minor bone	1.5
Gray shale	1.9
Highly carbonaceous shale and minor coal and bone	2.3
Moderately carbonaceous shale	1.5
Total	15.2

Six and six-tenths feet of the seam contains 8,859 Btu per pound and 28.5 percent ash and is classed as subbituminous coal (Glaeser, 1962, p. 8). About 1½ miles east of the above core hole, the seam, at a depth of 1,462 feet, is only 1.7 feet thick. Near the center of the SW1/4 sec. 32, T. 39 N., R. 3 E., and at a depth of 1,684.8 to 1,692.3 feet, the King Mountain seam is 7.5 feet thick. Cores from the drill holes showed six other coal seams that range from 2.5 to 5.0 feet in thickness.

The Blue Canyon coal seam is near the base of the Chuckanut Formation and in most places is separated from the underlying schists by a thin conglomerate layer. In other places the coal was in direct fault contact with the schists (Jenkins, 1923, p. 31). The coal seam was as much as 12 feet thick and had an average thickness of about 7 feet. Three other seams, each about 2 feet thick, overlie the main coal seam. All the seams dip 50° to 60° to the northwest. The coal was considered to be a good quality bituminous coal but was badly broken and contained numerous cleavage planes, causing it to crumble easily. This fine-grained character of the coal made handling difficult, as the largest fragments were seldom over 7 inches in diameter (Jenkins, 1923, p. 103). The highly fractured nature of the coal, as well as its irregular thickness, appears to be the result of disharmonic folding, in which the lower part of the Chuckanut Formation was thrust over the underlying basement schists.

The coal seams of the Glen Echo mine are about 8,500 feet stratigraphically above the base of the Chuckanut Formation (Mullen, 1939, p. 17-A). The coal, about 5 feet thick, was mined from the lowest of four seams. The seams above the main seam are 3 to 4 feet thick and are separated from each other by 50 to 75 feet of sandstone. However, shale occurs in the three upper coal seams. Near the surface the coal seams dip from 50° to 75° northwest, but in the mine workings, several hundred feet from the portal, the dips are only 10° to 15° to the northwest.

The coal at the Glacier coalfield differs from that elsewhere in the county in that it is partly anthracite. Like the Blue Canyon coal seams, the

Glacier coal seams are near the base of the Chuckanut Formation and in sandstone and shale that rest on crystalline igneous rocks and phyllite. The seams in general dip 45° to 68° north and in places have been crushed and fractured and forced into abnormal shapes by intense folding. However, there appears to be only minor offsetting of the seams. According to Woodruff (1914, p. 393), the best grades of anthracite occur in the Discovery No. 1 and the No. 2 tunnels (Fig. 7); elsewhere, the coal is mainly bituminous. At the No. 2 tunnel the coal occurs in a lens that has a maximum thickness of 3 feet. At the Discovery No. 1 tunnel, which Woodruff believed to be the most promising prospect, the coal is lenticular and has a maximum thickness of about 7 feet. About a mile west, at the Smith tunnel the coal in the same stratigraphic horizon as the Discovery seam is but 6 inches thick. In general, the seams appear to vary considerably in thickness throughout the field.

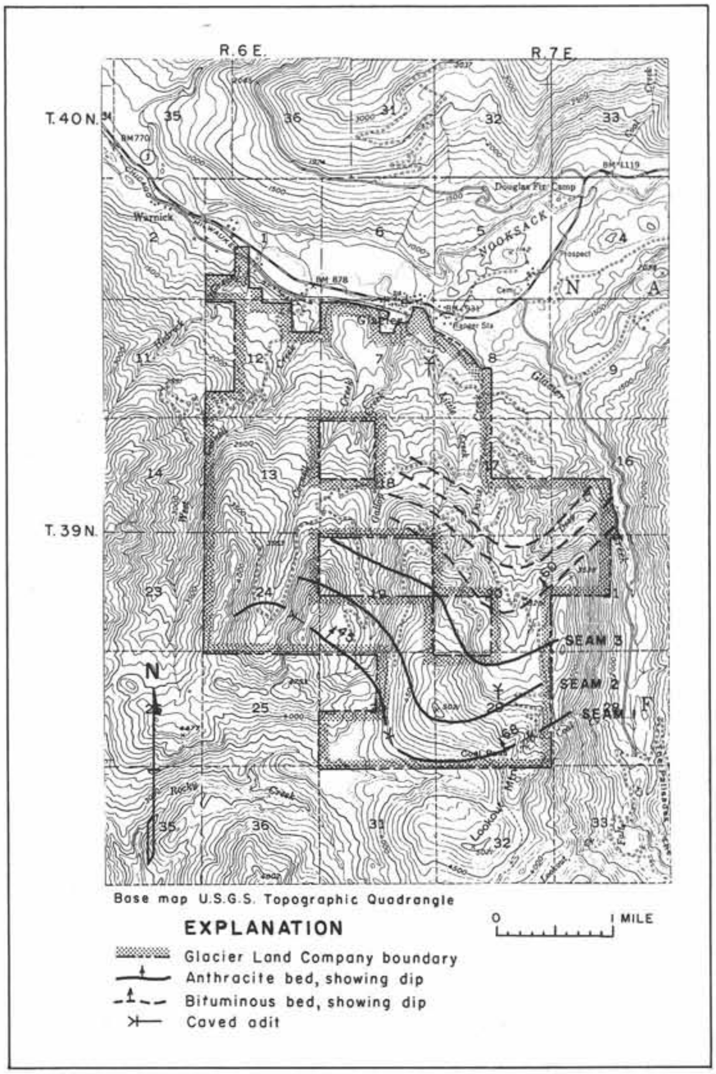

FIGURE 7.—Glacier anthracite coalfield.

Data from tunnels, outcrops, and drill holes indicate that the anthracite is contained mainly in three seams, which are designated as seams 1, 2, and 3 (Fig. 7). Seam 1 is a few feet above the underlying phyllite and schist and is about 8 feet thick. Seam 2, which is 6 to 10 feet thick, is about 1,200 feet stratigraphically above seam 1. Seam 3 is 1,100 feet above seam 2 and is about 6 feet thick. At least four other coal seams are above seam 3 in the Glacier field, but most of the seams are only several inches thick and consist of lignitic to bituminous coal.

Green (1943, p. 13) reports the following analyses by several workers on samples from the anthracite seams:

Moisture	1.42 to 2.70	percent
Volatiles	5.97 to 8.78	percent
Fixed carbon	83.88 to 89.52	percent
Sulfur	0.53 to 1.21	percent
Ash	1.67 to 5.87	percent
Specific gravity	1.441 to 1.478	
Btu	14,241 to 14,515	

Based on the above fixed carbon and ash contents, the coal is classed as semianthracite. According to Klemgard (1953, p. 12), the ash-forming constituents are mainly calcite, pyrite, kaolinite, and some prochlorite.

The anthracite for the most part appears to be confined to sec. 29, T. 39 N., R. 7 E. To the east the seams terminate against a fault that parallels Glacier Creek, and west of sec. 29, near Gallop Creek, the coal is bituminous. The transformation of bituminous coal into anthracite was no doubt due to increased temperature and pressure in part of the coalfield. However, there is some question as to whether the transformation was due wholly to dynamic metamorphism brought about by mountain building. Coal seams elsewhere in the county exhibit as much, and in some places more, folding and shearing but are not anthracitic. It is possible that there was an increase in temperature at the Glacier field that did not occur in the other coalfields. This increase in temperature could have been brought about by near-surface intrusive rocks related to Mount Baker, which is 6 miles southeast of the Glacier coalfield.

PHYSICAL AND CHEMICAL PROPERTIES

According to Beikman and others (1961, p. 13), Whatcom County coal has the following properties:

> Most of the coal in Whatcom County is of high-volatile C bituminous rank; however, the only known occurrence of anthracite in the State is in the Glacier field in the north-central part of the county. Only four analyses of the coal in the Glacier field were available, and these were all of coal that occurs very near the base of the coal-bearing sequence. Although all the coal in the field has been assumed to be anthracite, the coal higher in the sequence may be of bituminous rank.
>
> The Blue Canyon coal bed has low moisture, ash, and sulfur content, and according to Jenkins (1923, p. 105), is said to possess coking qualities. The Bellingham coalbed, because of its thickness and accessibility, is presently (1961) the most commercially significant coalbed in the county. It has a moisture content ranging from 6.9 to 8.4 percent and averaging 7.4 percent; an ash content ranging from 11.7 to 19.9 percent and averaging 15.1 percent; and a sulfur content ranging from 0.2 to 0.4 percent and averaging 0.3 percent.

Analyses of Whatcom County coals are given in Table 3.

TABLE 3.—*Analyses of Whatcom County coals*[1]

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units)

Location			Mine or prospect	Coalbed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
Sec.	T.	R.			M	VM	FC	Ash			
13	38 N.	2 E.	Bellingham	Bellingham No. 1	7.3	35.8	41.3	15.7	0.3	10,542	15
24	38 N.	2 E.	...do	Bellingham No. 2	5.5	40.0	43.4	11.2	...	11,048	1
15	37 N.	4 E.	Blue Canyon ..	Blue Canyon	1.6	41.3	55.0	2.2	1.1	11,919	1
34	38 N.	3 E.	Geneva	Unnamed	5.5	32.7	24.8	37.0	1.1	7,161	1
5	38 N.	4 E.	Glen Echo	...do	8.4	37.9	40.3	18.5	0.4	9,715	2
31	38 N.	4 E.	Rocky Ridge ...	...do	5.0	31.5	23.7	39.8	0.9	7,232	1
[2]32	39 N.	3 E.	Core hole	King Mountain ..	5.3	34.5	33.1	27.1	0.47	9,059	1
35	39 N.	4 E.	Deming	Unnamed	6.5	24.2	30.9	38.4	1.9	7,541	1
24	39 N.	6 E.	Prospect	...do	4.3	9.0	77.2	9.5	1.1	13,350	1
24	39 N.	6 E.	...do	...do	10.7	13.1	68.7	7.5	0.9	11,900	1
30	39 N.	7 E.	Discovery	...do	5.0	7.2	76.8	11.1	1.0	12,660	2

[1]Beikman and others, 1961, p. 13.
[2]Glaeser, 1960, p. 9.

Reserves

Beikman and others (1961, p. 16) have estimated the total coal reserves of Whatcom County as of January 1, 1960, at 325 million tons. Sixty-four percent of the reserves are classified as inferred, and 36 percent as measured and indicated. Of this total, more than 50 million tons is bituminous in the Bellingham coalbed and 5 percent, all inferred, is anthracite in the Glacier field. The coal reserves of the county as reported by the U.S. Geological Survey are shown in Table 4.

In addition to the reserves established by the U.S.G.S., core drilling by the Puget Sound Power & Light Co. in 1959 and 1961 revealed the existence of an additional 2.08 million tons of bituminous coal in the King Mountain coal seam (Glaeser, 1962, p. 8). The company did not calculate reserves for the six coal seams that lie above the King Mountain seam. These seams contain an additional 6.95 million tons of coal and are shown as Johnson No. 1 through No. 6 on Table 4.

Bellingham Coal Mines Company

The original mine of the Bellingham Coal Co. was at the intersection of Railroad Avenue and Myrtle Street. Mining was continued northward under Bellingham to an area beneath Holly Street and as far northwest as the intersection of Champion, Unity, and Dock Streets. The total amount of coal mined is not known, but over a period of 25 years the yearly production was as much as 20,000 tons. Much of the coal was shipped by boat to San Francisco. Mining ceased in 1878, after a mine fire and the flooding of the workings with water from Bellingham Bay.

In 1892 a mining engineer, R. B. Symington, was employed by the Bellingham Bay Improvement Co. to test drill for an extension of the coal area in the northwest part of Bellingham. After drilling six core holes, he encountered the main coal seam at 410 feet beneath the surface. Development of the seam was begun in 1917, and mining operations were begun in September 1918. The mine was operated almost continuously until 1951, and it had a daily production of 1,000 tons. Jenkins (1923, p. 97) reports that cement plants were the largest purchasers for the coal. In March 1952, under management of the Northwestern Improvement Co., the mine was brought back into production, using continuous mining machinery. Coal was mined until 1955, at which time the mine was permanently closed. During its operating years the mine was one of the State's largest coal producers; the total production from the mine was around 5¼ million tons.

The portal of the main slope of the Bellingham Coal mine is 1,200 feet northeast of the intersection of Northwest and Birchwood Avenues. Southwest of the portal, a shopping center now covers part of the area where mine buildings once stood.

The Bellingham No. 1 coal seam, which is overlain by 285 feet of sand, gravel, and clay, was reached by a 550-foot, 30° slope that heads S. 62° W. The seam averages 14 feet in thickness and in the upper levels of the mine dips 18° southwestward. In the lower levels the dip is as flat as 7°. Jenkins (1923, p. 91) gives the following stratigraphic section of the upper 9.5 feet of coal that was mined from the third level north:

	Stratigraphic thickness	
	ft	in
Roof	......	......
Bony coal	......	6
Brown shale	......	2
Coal	1	......
Shale	......	½ to 1
Coal	1	8
Coaly shale	......	½
Coal	......	6
Coaly shale	......	½
Coal	1	6
Coaly shale	......	½
Coal	......	6
Brown shale	......	2
Coal	1	6
Brownish yellow shale, coaly	......	2 to 4
Coal	1	4
Floor of mine	......	......

Mining was seldom carried on below the 2 to 4 inches of brownish yellow shale. This shale is persistent throughout the mine.

TABLE 4.—*Coal reserves of the major coal fields in Whatcom County* 1/

Coal bed or coal zone	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown: Measured and indicated: 14 to 28 inches	28 to 42 inches	42 or more inches	Total	Inferred: 14 to 28 inches	28 to 42 inches	42 or more inches	Total	All categories: 14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 36 N., R. 4 E.													
Blue Canyon ------	0-1,000	-----	2.43	-----	2.43	0.67	1.01	-----	1.68	0.67	3.44	-----	4.11
	1,000-2,000	-----	1.62	-----	1.62	.63	.94	-----	1.57	.63	2.56	-----	3.19
	2,000-3,000	-----	1.31	-----	1.31	.45	.67	-----	1.12	.45	1.98	-----	2.43
Bed total -------		-----	5.36	-----	5.36	1.75	2.62	-----	4.37	1.75	7.98	-----	9.73
T. 37 N., R. 3 E.													
Lake Whatcom ----	0-1,000	-----	2.82	1.03	3.85	0.48	2.57	0.34	3.39	0.48	5.39	1.37	7.24
	1,000-2,000	-----	2.19	-----	2.19	.26	3.06	-----	3.32	.26	5.25	-----	5.51
	2,000-3,000	-----	1.47	-----	1.47	-----	4.56	-----	4.56	-----	6.03	-----	6.03
Bed total -------		-----	6.48	1.03	7.51	0.74	10.19	0.34	11.27	0.74	16.67	1.37	18.78
Blue Canyon ------	0-1,000	-----	0.24	-----	0.24	-----	0.32	-----	0.32	-----	0.56	-----	0.56
	1,000-2,000	-----	.16	-----	.16	-----	.40	-----	.40	-----	.56	-----	.56
	2,000-3,000	-----	-----	-----	-----	-----	.20	-----	.20	-----	.20	-----	.20
Bed total -------		-----	0.40	-----	0.40	-----	0.92	-----	0.92	-----	1.32	-----	1.32
Township total ----		-----	6.88	1.03	7.91	0.74	11.11	0.34	12.19	0.74	17.99	1.37	20.10
T. 37 N., R. 4 E.													
Lake Whatcom ----	0-1,000	-----	0.90	3.10	4.00	-----	-----	-----	-----	-----	0.90	3.10	4.00
Blue Canyon ------	0-1,000	2.44	0.20	2.85	5.49	2.45	2.42	0.99	5.86	4.89	2.62	3.84	11.35
	1,000-2,000	2.82	.40	3.29	6.51	3.23	3.15	1.32	7.70	6.05	3.55	4.61	14.21
	2,000-3,000	1.50	.72	1.75	3.97	4.62	3.82	2.41	10.85	6.12	4.54	4.16	14.82
Bed total ------		6.76	1.32	7.89	15.97	10.30	9.39	4.72	24.41	17.06	10.71	12.61	40.38
Township total ----		6.76	2.22	10.99	19.97	10.30	9.39	4.72	24.41	17.06	11.61	15.71	44.38
T. 38 N., R. 2 E													
Bellingham No. 1 --	0-1,000	-----	-----	29.43	29.43	-----	-----	22.97	22.97	-----	-----	52.40	52.40
Bellingham No. 2 --	0-1,000	12.27	-----	-----	12.27	6.35	-----	-----	6.35	18.62	-----	-----	18.62
Township total ----		12.27	-----	29.43	41.70	6.35	-----	22.97	29.32	18.62	-----	52.40	71.02
T. 38 N., R. 3 E.													
Bellingham No. 1 --	0-1,000	-----	-----	4.53	4.53	-----	-----	-----	-----	-----	-----	4.53	4.53
Bellingham No. 2 --	0-1,000	1.86	-----	-----	1.86	-----	-----	-----	-----	1.86	-----	-----	1.86
Lake Whatcom -----	0-1,000	1.32	3.35	5.32	9.99	2.07	8.16	18.58	28.81	3.39	11.51	23.90	38.80
	1,000-2,000	.55	1.13	3.39	5.07	1.21	8.44	22.26	31.91	1.76	9.57	25.65	36.98
	2,000-3,000	.06	.09	.36	.51	.17	2.96	10.69	13.82	.23	3.05	11.05	14.33
Bed total ------		1.93	4.57	9.07	15.57	3.45	19.56	51.53	74.54	5.38	24.13	60.60	90.11
Township total ----		3.79	4.57	13.60	21.96	3.45	19.56	51.53	74.54	7.24	24.13	65.13	96.50
T. 38 N., R. 4 E.													
Unnamed ---------	0-1,000	0.44	1.16	1.64	3.24	0.74	2.22	1.09	4.05	1.18	3.38	2.73	7.29
	1,000-2,000	.44	1.16	1.64	3.24	.76	.90	1.09	2.75	1.20	2.06	2.73	5.99
	2,000-3,000	.44	1.16	1.64	3.24	.65	.90	1.09	2.64	1.09	2.06	2.73	5.88
Bed total ------		1.32	3.48	4.92	9.72	2.15	4.02	3.27	9.44	3.47	7.50	8.19	19.16
Lake Whatcom -----	0-1,000	-----	0.06	0.22	0.28	-----	-----	-----	-----	-----	0.06	0.22	0.28
Township total ----		1.32	3.54	5.14	10.00	2.15	4.02	3.27	9.44	3.47	7.56	8.41	19.44
T. 39 N., R. 2 E.													
Unnamed ---------	0-1,000	-----	-----	-----	-----	3.58	2.68	15.65	21.91	3.58	2.68	15.65	21.91
T. 39 N., R. 3 E.													
Unnamed ---------	0-1,000	-----	8.17	-----	8.17	-----	18.55	-----	18.55	-----	26.72	-----	26.72
2/ King Mountain --	1,700-2,000	-----	-----	2.08	2.08	-----	-----	-----	-----	-----	-----	2.08	2.08
3/ Johnson No. 1 --	478	-----	-----	1.58	1.58	-----	-----	-----	-----	-----	-----	1.58	1.58
3/ Johnson No. 2 --	908	-----	.79	-----	.79	-----	-----	-----	-----	-----	.79	-----	.79
3/ Johnson No. 3 --	955	-----	-----	1.17	1.17	-----	-----	-----	-----	-----	-----	1.17	1.17
3/ Johnson No. 4 --	1,206	-----	.79	-----	.79	-----	-----	-----	-----	-----	.79	-----	.79
3/ Johnson No. 5 --	1,295	-----	-----	1.42	1.42	-----	-----	-----	-----	-----	-----	1.42	1.42
3/ Johnson No. 6 --	1,684	-----	-----	1.20	1.20	-----	-----	-----	-----	-----	-----	1.20	1.20
Township total -----		-----	9.75	7.45	17.20	-----	18.55	-----	18.55	-----	28.30	7.45	35.75
T. 39 N., R. 4 E.													
Unnamed ---------	0-1,000	-----	2.93	-----	2.93	0.42	5.89	-----	6.31	0.42	8.82	-----	9.24
	1,000-2,000	-----	-----	-----	-----	.48	-----	-----	.48	.48	-----	-----	.48
	2,000-3,000	-----	-----	-----	-----	.55	-----	-----	.55	.55	-----	-----	.55
Bed total -------		-----	2.93	-----	2.93	1.45	5.89	-----	7.34	1.45	8.82	-----	10.27
T. 39 N., R. 7 E.													
Glacier----------- (anthracite)	0-1,000	-----	-----	-----	-----	0.67	1.81	0.50	2.98	0.67	1.81	0.50	2.98
	1,000-2,000	-----	-----	-----	-----	.33	1.49	-----	1.82	.33	1.49	-----	1.82
Bed total ------		-----	-----	-----	-----	1.00	3.30	0.50	4.80	1.00	3.30	0.50	4.80
Grand total -------		24.14	35.25	67.64	127.03	30.77	77.12	98.98	206.87	54.91	112.37	166.62	333.90

1/ Beikman and others, 1961, except as noted in footnotes 2 and 3, p. 16. 2/ Glaeser, 1962, p. 8. 3/ Washington Division of Mines and Geology, calculation from Glaeser, 1962.

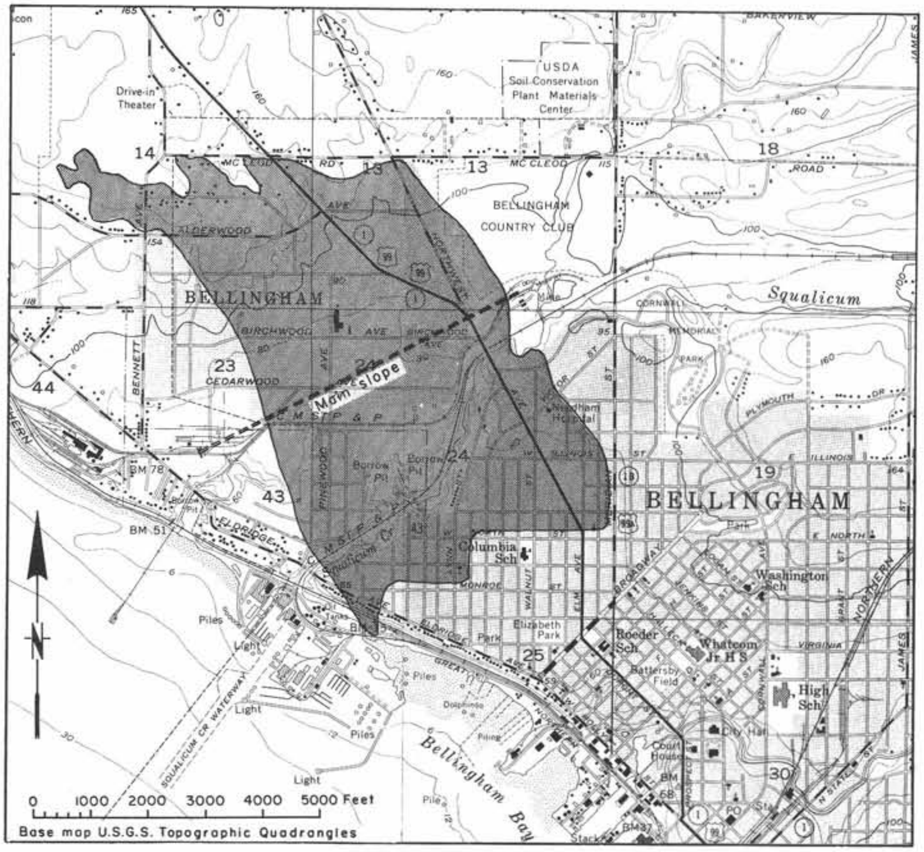

FIGURE 8.—Areal extent of Bellingham Mine No. 1 workings.

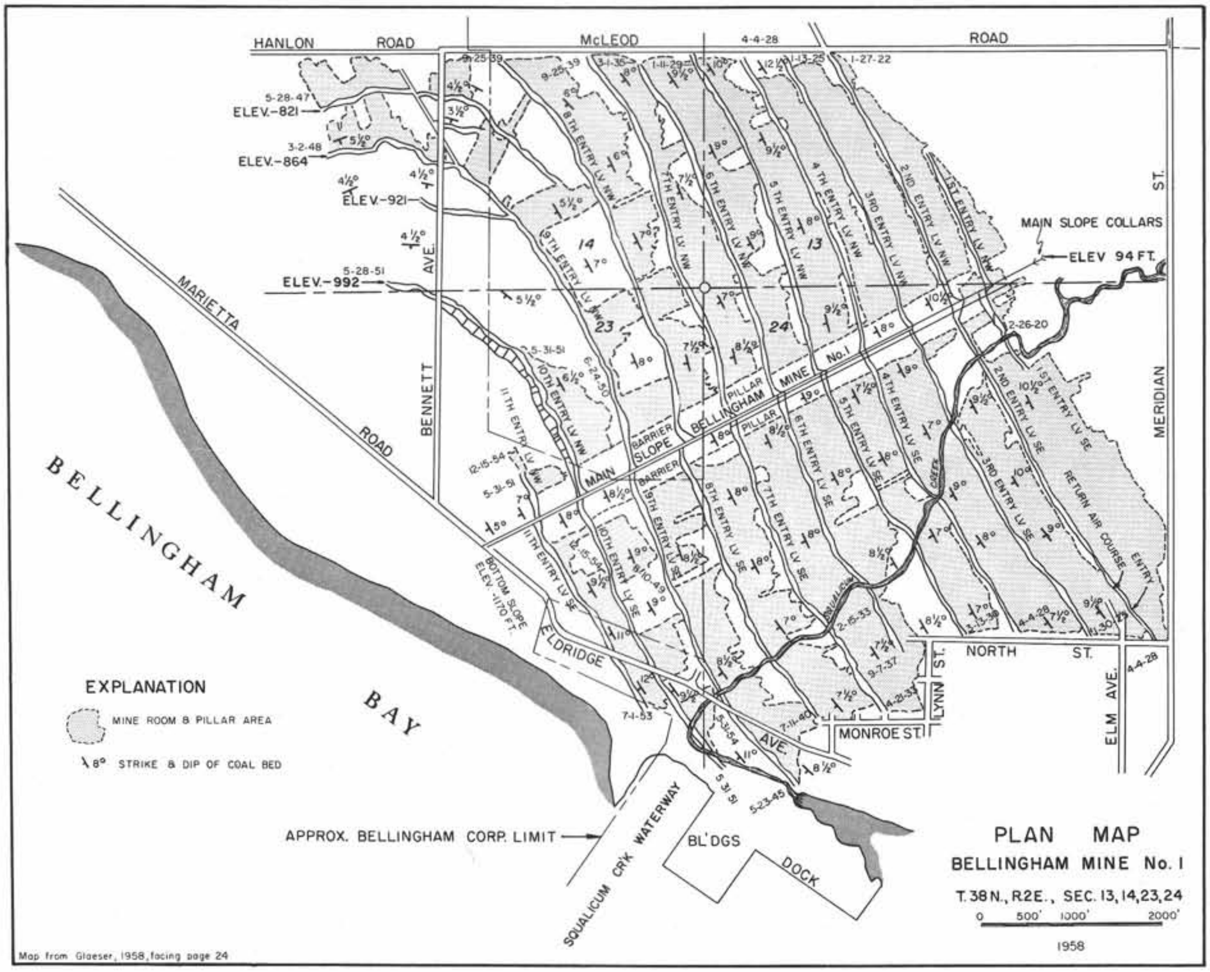

FIGURE 9.—Plan map, Bellingham Mine No. 1.

From the main slope, which is 6,800 feet long and follows the dip of the coal seam, entries were driven southeastward and northwestward at 500- to 700-foot intervals. From these entries the coal was mined in 20-foot rooms with 30-foot pillars between rooms. The second entry is 413 feet beneath the surface and is one of the longest entries in the mine. This level, which is directly beneath and parallel to Northwest Avenue, extends 3,000 feet northwest and 4,500 feet southeast from the main slope. The lowest entry, which is the tenth entry, is 1,023 feet beneath the surface and extends 1,100 feet southeast. The underground workings of the mine cover 1,340 acres; the area of Bellingham underlain by the workings is shown in Figure 8.

Although the coal seam averaged 14 feet in thickness, only the upper 7 or 8 feet was profitable to mine. However, when the Joy continuous miner was put into operation in 1952, the full thickness of the seam was mined. In the early years of the mining operation, horses and mules were used for underground haulage and a steam hoist pulled the mine cars to the surface. In the 1940's the animals were replaced with electric locomotives; however, the steam hoist operated until the mine closed in 1955.

The washing plant was near the portal of the main slope, and Green (1943, p. 26) describes the operation of the plant as follows:

> Cars are dumped through a rotary dump onto shaking screens, and the plus 4-inch size goes to the picking tables. The undersize is then screened through a revolving screen, and the nut and finer sizes go to separate washers. There are three Forrester jigs with a Foust jig for the pea size. The 5/16-inch and finer sizes go over a battery of 5 Deister Overstrom tables. Storage and shipping bunkers have a capacity of 1,000 tons. Yard storage is handled by 2 locomotive-type cranes.

Blue Canyon Coal Mining Company

The second largest coal mine in Whatcom County was operated on a coal seam that was discovered in 1887 at Blue Canyon, on the southeastern end of Lake Whatcom. Operating as the Blue Canyon Coal Mining Co., the mine produced coal from 1891 to 1904. It was at this mine in 1894 that a mine gas explosion killed 23 miners, which made it the worst mine disaster in Washington. From 1904 until 1907 the mine operated sporadically under several different managements. In 1907 the mine was reorganized by M. M. Walter as the Whatcom County Coal Mining Co. Operations were continuous until 1919, at which time the mine was permanently closed (Jenkins, 1923). Production during that last 12 years was 50 to 75 tons per day, or 6,000 to 8,000 tons per year, most of which was sold to local markets. According to the U.S. Bureau of Mines, the total production for the mine was 280,000 tons. In 1894, 1895, and 1896 the U.S. Government used some of the coal for its Alaskan fleet.

The Blue Canyon coal seam was mined from two separate underground workings by room and pillar mining methods. The portal to the early workings was 1,200 feet in a N. 25° E. direction from the S. ¼ cor. sec. 15, T. 37 N., R. 4 E., and at an altitude of 1,122 feet. In 1892 these workings were abandoned and a new tunnel was started 1,750 feet to the west of the portal of the old tunnel and at an altitude of 660 feet. Starting from a point 575 feet west of the above quarter corner, the main entry for the new workings headed N. 10° E. into the steep mountainside for 800 feet to the coal seam. The seam averaged 7 feet in thickness and dipped 40° to 50° north. Because of the nature of the coal seam, mining proved difficult. The seam was irregular in thickness, highly fractured and soft, contained bad gas, and occurred in ground that caved easily. In places the coal rested directly upon a schist footwall. The coal was brought to the surface in mine cars. From the portal of the mine a rail tramway carried the coal to bunkers on the shore of Lake Whatcom, along which the Bellingham Bay and Everett Railroad ran.

Glacier coalfield

The Glacier coalfield, which was discovered by hunters in 1907, attracted considerable interest because of its anthracite coal. In the years that followed the discovery, several short adits were driven to explore various coal seams, and in the 1920's a small amount of diamond core drilling was undertaken. Also, a tunnel was started a short distance south of Glacier with the hope of intersecting the coal seam at depth. However, after several thousand feet of tunneling, and before any coal was encountered, the project was abandoned. A small amount of anthracite coal has been mined and used locally, but regular mining operations were never started. At different times there has been renewed interest in the Glacier coal seams, but most plans have been abortive. To date, most work has centered around the Discovery tunnel, at the southern edge of the coalfield. The Discovery tunnel, which is about 750 feet long, is in the SE¼SE¼ sec. 19, T. 39 N., R. 7 E. Currently, Glacier Land Co., of Yakima, Wash., owns about 5,280 acres of the Glacier coalfield.

Since the discovery of the Glacier coalfield, many controversies have arisen. The field has been extolled by some workers and degraded by others. In a report by Green (1943, p. 13) appears the following quotation from a 1908 private report by Wm. F. Dodge, mining and consulting engineer from the anthracite region of Pennsylvania:

> The coal is bright in appearance and ignites freely, being fully as lasting in duty as the better grades of Pennsylvania anthracite coal of the same specific gravity and density. To my mind there is no question but that the coal found on these lands is anthracite coal pure and simple, of the best quality. The coal is not exceedingly bright, but hard and brittle and free from smut, and in fracture, when blasted with slow powder and properly treated through machinery adapted to the manufacture of anthracite coal, will be an attractive commodity for market and will closely resemble the product of the Mammoth vein, the purest and best of all the anthracite veins of Pennsylvania.

In 1912 the field was examined by E. G. Woodruff, of the U.S. Geological Survey (Woodruff, 1914, p. 389-398). Woodruff's conclusions were as follows:

> The coal is mostly anthracite or high-grade bituminous, but some of it is lower grade. Generally, the percentage of

ash in the coal is very high, especially when the whole of the bed is considered. From the data obtained, the writer concludes that the field contains coal in pockets, some of which are large enough to furnish a small supply of fuel, but as yet the prospecting has not developed coal enough to warrant the expectation that the field will produce coal in commercial quantities.

Since the publication of Woodruff's report, the field has been examined by several consulting geologists and engineers, most of whom are of the opinion that 45 to 50 million tons of anthracitic coal is contained in the three lowest coal seams of the seven known seams of the Glacier field. The most recently published estimate of reserves is that of Beikman and others (1961, p. 14), which places the reserves at 4.8 million tons of inferred coal.

The most recent utilization study of the Glacier anthracite was undertaken in 1951, when the coal was considered as possible source material for electrode carbon (Klemgard, 1953). Studies indicate that by subjecting the coal to heavy density sink-float, acid leaching, and calcining, low resistivity coke having a specific resistivity of less than 0.00200 ohms per cubic inch can be produced from Glacier anthracite. However, according to Klemgard, the cost of producing the coke would be in the neighborhood of $50 per ton, as compared to petroleum coke that sells for $39 per ton (Klemgard, 1953, p. 34).

Glen Echo mine

In 1920 the Glen Echo Coal Mining Co. was organized with M. L. Dickerson as president. The mine is 5 miles northeast of Bellingham, near the headwaters of Anderson Creek, and near the common corner of secs. 5 and 9, T. 38 N., R. 4 E. Mining was carried on from 1920 until 1948, but the production of coal was sporadic and small. In 1932 only 18 tons of coal was produced, and in 1937 the production was about 9,000 tons. In most years the production of coal was in the neighborhood of 2,000 tons. The total mine production was about 65,000 tons. In 1948, mining ceased because of the narrow and folded seam that made mining impractical; in 1948 the company was dissolved. During the last several years of operation the mine was operated by West Coast Mines, Inc. The greater part of the company's assets are owned by Mr. J. A. Jussel, of Bellingham.

The mining of coal was undertaken on the lowest of five coal seams; the seam that was mined averaged about 5 feet in thickness. From the steep south bank of Anderson Creek the main slope followed the seam in a general northwesterly direction for about 1,200 feet. Entries were driven from the main slope to the northeast and southwest, and the room and pillar method of mining was employed. On the third right entry the coal seam had a N. 30° E. strike and the dip varied from 10° to 15° NW. (Hill, 1945); near the surface the dip steepened to 30°. After the coal was mined it was hoisted to the surface by way of the main slope and processed in a washing plant that was about 1,000 feet downstream from the portal of the mine. The washed and graded coal was stored in bunkers at the mine and later trucked to markets in Bellingham. When mining operations ceased, the underground workings had an areal extent of about 15 acres.

Other coal mines

In the west part of the county and as far east as Glacier, numerous coal seams were discovered and prospected; however, none became a major producer. The coal seams in most of these mines were less than 3 feet thick. The mines having a record of production, though small, are as follows:

Mine	*Location*
Goshen	SW¼ sec. 19, T. 39 N., R. 4 E.
Whatcom Creek	SW¼NE¼ sec. 28, T. 38 N., R. 3 E.
Geneva	NE¼SW¼ sec. 34, T. 38 N., R. 3 E.
Rocky Ridge	SW¼ sec. 31, T. 38 N., R. 4 E.
Van Zandt	Sec. 17, T. 38 N., R. 5 E.
Manley's Camp	SE¼ sec. 12, T. 37 N., R. 3 E.

For the most part, nothing remains at these mines. The workings are caved, and the mine dumps of most of the mines are overgrown with brush so as to be barely discernable.

Oil and Gas

In 1893, while digging a water well near Fairhaven, a man named Clark ignited gas that had seeped into the well. According to legend, the resulting explosion burned off Clark's beard. The gas was probably nothing more than methane or "marsh gas," which is known to occur in many parts of western Whatcom County. However, the discovery of this gas was of sufficient interest to initiate drilling for oil and gas.

In 1901, near the site of Clark's water well, in what is now South Bellingham, the Pacific Oil Wells Co. drilled a well known as the Happy Valley well to a depth of 1,000 feet. No oil was discovered, but small amounts of gas were reported. After this failure, it was not until 1914 that another attempt was made to drill for oil; 3 miles north of Ferndale, near Enterprise, the National Oil & Gas Co. drilled a well known as Enterprise No. 1. After 1,000 feet of drilling, the well was abandoned because of a crooked hole. Near the first hole, Enterprise No. 2 was drilled to 3,615 feet and, according to the driller's log, oil showed at 2,500 feet and several gas showings were reported. However, insufficient oil and gas were present to place the well into production. In the following years several wells were drilled in different parts of western Whatcom County, but only minor gas showings were encountered.

In November 1929, much excitement occurred in Bellingham when a street department crew discovered an oil seep at Alabama and Orleans Streets. From a hole about 7 feet deep more than 3,000 gallons of oil and gasoline was bailed. To test the seep a small derrick was erected, but drilling stopped at 293 feet when the depth of the hole reached the limit of the drilling ability of the light rig. Some questions were raised as to the possibility of the gasoline and oil coming from a leaking storage tank, and at the request of Mayor Kellogg, Harold E. Culver, State Geologist, was asked to examine the occurrence. After his examination, and based on the findings of analyses by the chemistry department of Washington State College, Culver stated that it was without any question a natural oil of paraffin base. Although the gasoline and oil continued to seep from the ground in this area for several years, and attracted considerable attention among the local citizens, a well was never brought into production.

In 1933, on the Lange farm about 1 mile east of Ferndale, good gas showings were encountered at 175 feet in the Whatcom No. 1 well of the Whatcom Natural Gas Corporation. The capacity of this well was rated at 3 to 4 million cubic feet per day at 50 pounds per square inch pressure (Glover, 1935, p. 40). Several other wells drilled on this structure resulted in five producing gas wells. In 1934 the County Farm, as well as nearby farms, utilized the natural gas.

Until 1938 most wells in the county had been shallow and averaged only about 1,000 feet in depth. In 1938, Pelican Dome No. 1 well was spudded in the southeastern part of Bellingham by the Peoples Gas & Oil Development Co. This well was designed to test the full possibilities of the Chuckanut Formation. After 3 years of drilling and many difficulties, the hole was bottomed at 5,458 feet in metamorphic rocks. Minor gas showings were found at different horizons, but oil was not encountered. In 1945 the Standard Oil Co. of California drilled a hole to a depth of 6,231 feet without penetrating the Chuckanut Formation. This well, known as the Ferndale Community well, was near Kickerville, 7 miles northwest of Ferndale. No gas or oil was encountered in this well. Other wells were drilled by different companies, and minor gas showings were reported, but no oil was discovered.

The most recent well to be drilled is that of Can-American Petroleum Limited. Known as the Stremler No. 1, this well is 3 miles north of Lynden and 2 miles south of the Canadian border. Drilling began in March 1962, and after many difficulties the well reached a total depth of 8,343 feet in early 1965. Gas showings were encountered at several horizons, and attempts to produce oil from several zones proved futile. Although this well was reported to have encountered several oil showings, this fact could not be verified by the writer. However, this well does have the distinction of being the deepest in the county.

Wells that have been drilled for gas and oil from 1901 to 1965 are listed in Table 5, and their locations are shown on Plate 3.

Geology

The Whatcom Basin area of Whatcom County is a glacial debris- and alluvium-covered lowland that is underlain by nonmarine Late Cretaceous-early Tertiary sedimentary rocks. Beneath these rocks is a basement complex that consists of intensely folded and faulted Mesozoic and late Paleozoic phyllite, schist, argillite, and graywacke, as well as ultrabasic and basic igneous rocks. The Late Cretaceous-early Tertiary sedimentary rocks, for the most part, consist of the Chuckanut Formation; however, along the eastern edge of the basin the Chuckanut is overlain unconformably by an early Tertiary rock sequence that is lithologically similar to the Chuckanut Formation. The rocks of the Chuckanut Formation and the post-Chuckanut sequence consist of thick beds of conglomerate, sandstone, siltstone, shale, and minor coal seams. The total thickness of these rocks in Whatcom Basin probably exceeds 12,000 feet. The post-Chuckanut sequence is correlative with the Huntingdon Formation (upper Eocene-lower Oligocene) of southwestern British Columbia. Although post-Huntingdon rocks do not crop out on the edges of Whatcom Basin, palynology studies by Hopkins (1966) on cuttings from several oil wells indicate the presence of over 2,000 feet of Miocene rocks.

As a result of post-depositional regional mountain building, the Late Cretaceous-early Tertiary sedimentary rocks of western Whatcom County have been arched into northward- to northwestward-trending folds. These are clearly evident in the mountains that border the lowland, but the structure under the Pleistocene and Recent sediments of the lowland is poorly known. Although several highland areas, such as the hills west of Ferndale and the hills east of Sumas, form prominent topographic features in the lowland area, it is not known whether they are related to structures in the underlying rocks.

The highly folded Chuckanut Formation south and east of Bellingham contains many dips as steep as 70°. Within the lowland area to the north, the few outcrops that are present have low dips of 10° to 20°, and cores from several wells show dips of as much as 20°. It is probable that these low dips represent the dips of the late Eocene rocks that rest unconformably upon the underlying Chuckanut Formation, in the rocks of which steeper dips and close folds may be present. The major folds of the Chuckanut Formation in the western part of the county are shown on Plate 3.

Gas

Although gas has been reported in many wells, the only significant discovery to date is the shallow gas field near Ferndale, in secs. 27 and 28, T. 39 N., R. 2 E. Five wells in this field tested 750,000 to 5,000,000 cubic feet per day at 27 to 70 pounds per square inch pressure. These wells are listed in Table 6, on page 29.

TABLE 5.—*Oil and gas wells drilled in Whatcom County (1901-1965)* 1/

Map no.	Company	Well name	Location and elevation	Date spudded	Depth (feet)	Remarks
	Mr. Clark	Clark water well	Bellingham area. SE¼ sec. 7, (37-3E)	1893	30	Gas showing, discovery well.
1	Pacific Oil Wells Co.	Happy Valley (Fair-haven)	Bellingham area. SE¼ sec. 7, (37-3E) near the Clark water well	1901	1,000+	Cable tools. Gas showing reported.
2	National Oil & Gas Co.	Enterprise No. 1	Ferndale area. SE¼SE¼ sec. 6, (39-2E)	1914	1,000+	Cable tools. Results unknown. Abandoned because of crooked hole.
3	National Oil & Gas Co.; Canadian Oil & Venture Co.	Enterprise No. 2	Ferndale area. SE¼SE¼ sec. 6, (39-2E), 15 ft. from Enterprise No. 1	1914	2,411, 3,615	Cable tools to 2,411 ft., diamond drill to bottom. Base of Pleistocene at 650 ft. Oil showing at 2,500 ft. and several gas showings reported. Salt water at 2,165 ft. Driller's log.
	(?)	Holman water well No. 1	Bellingham area. SW. cor. sec. 2, (38-3E), on Holman farm	1914?	160	Cable tools. Poor gas showing. Gas analysis.
	(?)	Holman water well No. 2	Bellingham area. SW. cor. sec. 2, (38-3E), 300 ft. N. of Holman No. 1	1914	127	Cable tools. Gas showing. Oil showing reported.
4	Bellingham Natural Gas Co.	Well No. 1	Deming area. Near N. line of NW¼ sec. 33, (39-4E)	1917	78	Cable tools. Gas showing.
5	Bellingham Natural Gas Co.	Well No. 2	Deming area. Near N. line of NW¼ sec. 33, (39-4E)	1917	58	Cable tools. Good gas showing. No water.
6	Bellingham Natural Gas Co.	Well No. 3	Deming area. ¼ mi. S. of N. line of NW¼ sec. 33, (39-4E)	1917	102	Cable tools. Good gas showing. No water.
	W. T. Lange	Lange coal test	Ferndale area. SE¼NE¼ sec. 28, (39-2E)	1920	168	Cable tools. Hit gas and brackish water at 161 ft.
7	(?)	Anderson	Blaine area. Near center W½ sec. 32, (40-1E), on old Anderson farm	1927	250	Cable tools. Gas, 55 p.s.i. at 250 ft.; used domestically.
	N. H. Jepson	Jepson water well	Bellingham area. SW. cor. sec. 10, (38-3E), on Jepson farm	Prior to 1930	270	Cable tools. Gas at 210 ft., used domestically. Base of Pleistocene at 90 ft. Gas analysis, driller's log.
	Henry Luce	Luce water well	Bellingham area. At Geneva. NE¼ sec. 34, (38-3E) (?)	1930	450+	Cable tools. Gas at 235 ft. Gas analysis.
8	Home Petroleum Co.	Home No. 1	Blaine area. SW¼SE¼ sec. 31, (40-1E), on Irwin farm	11-12-30	650	Cable tools. Results unknown.

(See footnote at end of table, p. 29.)

TABLE 5.—*Oil and gas wells drilled in Whatcom County (1901-1965)* 1/—(continued)

Map no.	Company	Well name	Location and elevation	Date spudded	Depth (feet)	Remarks
9	Home Petroleum Co.	Birch Bay No. 1	Blaine area. Sec. 32, (40-1E), 200 ft. E. of Auburn well	5-31-30	268	Gas showings at 140 and 210 ft. Driller's log, gas analysis.
10	International Pipe Lines Co., Ltd.	International No. 6 (California Creek)	Blaine area. On W. R. Allen farm on California Creek	1930	300+	Cable tools. Results unknown.
11	International Pipe Lines Co., Ltd.	International No. 4 (Goshen)	Nooksack area. NE¼SE¼ sec. 14, (39-3E), on Graetzer farm	1930	1,206	Cable tools. Results unknown.
12	Acme Oil & Gas Co.	Acme No. 1	Ferndale area. S½SE¼ sec. 13, (39-1E)	1930	310	Cable tools. Gas showing reported.
13	Acme Oil & Gas Co.	Acme No. 2, also called Acme No. 1	Ferndale area. S½SE¼ sec. 13, (39-1E), 20 ft. from Acme No. 1	1930	1,241	Cable tools. Gas and oil showings reported. Driller's log.
14	Kulshan Natural Gas & Oil Co.; M. & M. Oil & Gas Co.	Lange No. 1	Ferndale area. SE¼NE¼ sec. 28, (39-2E), about 50 ft. from Lange coal test	1930	1,180	Cable tools. Gas showings from various depths.
15	International Pipe Lines Co., Ltd.	International No. 5 (Laurel)	Near Laurel. May be in sec. 19, (39-3E)	1930	970	Cable tools. A continuation of 383-ft. water well. Gas showing reported at 630 ft. Driller's log.
16	International Pipe Lines Co., Ltd.	International No. 3 (Jepson No. 1)	Bellingham area. Probably near SW. cor. sec. 10, (38-3E), on Jepson farm	1930	1,000(?)	Cable tools. Results unknown.
17	Ives Gas & Oil Corp.	Ives No. 1	Nooksack area. NW¼NW¼ sec. 21, (40-4E), on H. O. Brown farm	1931	275	Cable tools. Results unknown.
18	International Pipe Lines Co., Ltd.	Ridge No. 1	Bellingham area. Center sec. 15, (38-3E), on Alabama Ridge	1931	1,625	Cable tools. Gas showing at 685 ft. Three feet of glacial drift. Driller's log.
19	Ives Gas & Oil Corp.; Curtis Natural Gas Co.	Ives No. 2	Nooksack area. Sec. 21, (40-4E), on H. O. Brown farm	1931	1,000, 1,350	Cable tools. Gas showing at 990 ft. Driller's log from 1,024 ft. to bottom.
20	M. & M. Oil & Gas Co.	Lange No. 2	Ferndale area. SE¼NE¼ sec. 28, (39-2E), 14 ft. E. of Lange coal test	1931	2,008	Rotary to 450 ft. Cable tools below. Base of Pleistocene at 154±. Several gas showings; used domestically. Driller's log, gas analysis, well cuttings.
21	Geo. Cowden et al.	Ridge No. 2	Bellingham area. Probably near center sec. 15, (38-3E)	1931	420	Cable tools. Results unknown.
22	Olsen-Orloff Syndicate	Molin No. 1	Bellingham area. Sec. 7, (38-4E), on Molin farm	1931	110+	Cable tools. Results unknown.
23	Grate-McDonald	Ross No. 1	Bellingham area. Sec. 17, (38-4E), on Ross farm	1931	100±	Cable tools. Results unknown.

(See footnote at end of table, p. 29.)

TABLE 5.—*Oil and gas wells drilled in Whatcom County (1901-1965)* 1/—(continued)

Map no.	Company	Well name	Location and elevation	Date spudded	Depth (feet)	Remarks
24	Grate-McDonald	Jensen No. 1	Bellingham area. NE¼NE¼ sec. 19, (38-4E), on H. W. Jensen farm	1931	200	Cable tools. Hit nitrogen gas at 125 ft.
	Greenacres Memorial Park	Greenacres water well	Ferndale area. Near SW. cor. SE¼ sec. 22, (39-2E)	1932	775	Cable tools. Gas showing at 530 ft. Driller's log.
25	Whatcom Natural Gas Corp.	Whatcom No. 1 (Lange No. 3)	Ferndale area. E. ¼ cor. sec. 28, (39-2E), on Lange farm	1933	175	Cable tools. Good gas showing at 175 ft.; used domestically. Driller's log, well cuttings, gas analysis.
26	Whatcom Natural Gas Corp.	Lingbloom No. 1 (Chamber of Commerce No. 1)	Ferndale area. NW¼SW¼ NW¼ sec. 27, (39-2E), on J. E. Lingbloom farm	11-12-33	171	Cable tools. Good gas showing at 171 ft.; used domestically. Driller's log, gas analysis.
27	Whatcom Natural Gas Corp.	Lingbloom No. 2 (Chamber of Commerce No. 2)	Ferndale area. SW¼SW¼ NW¼ sec. 27, (39-2E), on O. H. Lingbloom farm	1933	172	Cable tools. Good gas showing at 172 ft.; used domestically. Gas analysis.
28	Whatcom Natural Gas Corp.	Lingbloom No. 3 (Chamber of Commerce No. 3)	Ferndale area. NE¼SW¼ NW¼ sec. 27, (39-2E), on J. E. Lingbloom farm	1933	212	Cable tools. Dry hole.
	Van-Bell Holding Co.	Bettsinger No. 2	Ferndale area. SE¼NE¼ SW¼ sec. 27, (39-2E), on E. Bettsinger farm	1933	(?)	Cable tools. Results unknown.
29	Whatcom Natural Gas Corp.	Whatcom No. 2 (Lange No. 4)	Ferndale area. 650 ft. W. of E. ¼ cor. sec. 28, (39-2E), on Lange farm	1934	216	Cable tools. Dry hole.
30	Whatcom Natural Gas Corp.	Lingbloom No. 4 (Chamber of Commerce No. 4)	Ferndale area. SE¼SW¼ NW¼ sec. 27, (39-2E), on O. H. Lingbloom farm	1934	166	Cable tools. Good gas showing at 166 ft.; used domestically. Gas analysis.
31	Whatcom Natural Gas Corp.	Chamber of Commerce No. 5	Ferndale area. SW. cor. sec. 27, (39-2E), on F. E. Brown farm	1934	701	Cable tools. Poor gas showing with salt water at 696 ft. Driller's log, well cuttings.
32	Abbotsford Oil & Gas Co.	Beyers No. 1	Ferndale area. Near the SE. cor NE¼NW¼SW¼ sec. 27, (39-2E	1934	238	Cable tools. Dry hole. Driller's log.
33	Van-Bell Gas & Oil Co.	Cowden No. 1	Ferndale area. Near center SE¼NE¼ sec. 28, (39-2E), 75 ft. E. of Livermore No. 1	1934	390	Cable tools. No gas; reported oil doubtful.
34	Van-Bell Gas & Oil Co.	Cowden No. 2	Ferndale area. Near E. ¼ cor. sec. 28, (39-2E), 200 ft. N. of Whatcom No. 1	1934	205	Cable tools. Dry hole.
35	Van-Bell Holding Co.	Bettsinger No. 1 (Van-Bell No. 1)	Ferndale area. SE¼NE¼ SW¼ sec. 27, (39-2E), on E. Bettsinger farm	1934	603	Cable tools. Poor gas showing; reported oil showing doubtful. Salt water at 500 ft. Driller's log, well cuttings.

(See footnote at end of table, p. 29.)

TABLE 5.—*Oil and gas wells drilled in Whatcom County (1901-1965)* 1/—(continued)

Map no.	Company	Well name	Location and elevation	Date spudded	Depth (feet)	Remarks
36	A. W. Hunter	Harden No. 1 (Hunter No. 1)	Ferndale area. SW. cor. NE¼SW¼ sec. 27, (39-2E), on L. W. Harden farm	1934	193	Cable tools. Good gas showing, 193 ft.; used domestically. Driller's log.
37	A. W. Hunter	Harden No. 2 (Hunter No. 2)	Ferndale area. NW¼SE¼ SW¼ sec. 27, (39-2E), 650 ft. S. of Harden No. 1	1934	415±	Cable tools. Gas showing at 200 ft. Well cuttings.
38	A. W. Hunter	Hunter No. 3	Ferndale area. Near SE. cor. NE¼SW¼ sec. 27, (39-2E)	1934	330	Cable tools. Good gas showing at 330 ft. reported.
39	Abbotsford Oil & Gas Co.; W. Hale	King No. 1 (Hale No. 1)	Ferndale area. SE¼SE¼ SW¼ sec. 27, (39-2E), on C. C. King farm.	1934	1,370	Cable tools. Bottom of Pleistocene at 342 ft. Gas showing with salt water at 780-800 ft.; 970-1,010 ft.; 1,160-1,370 ft. Pressure 470 p.s.i. Driller's log, gas analysis, well cuttings.
40	Shale Oil & Gas Co.	Shale Oil & Gas No. 1	Bellingham area. SE¼NW¼ NW¼ sec. 3, (38-2E), on Harry Brown farm	1934	251	Cable tools. Dry hole. Driller's log.
41	Van-Bell Holding Co.	Holman No. 3	Bellingham area. SW. cor. sec. 2, (38-3E), 30 ft. E. of Holman No. 1	1934	151	Cable tools. Dry hole. Driller's log.
42	Covey-Baus	Hanson No. 1 (Covey-Baus No. 1)	Ferndale area. NW¼NE¼ sec. 35, (39-2E), on Hanson farm	1934	300±	Cable tools. Dry hole. Well cuttings.
	(?)	water well	Bellingham area. SW¼SW¼ sec. 2, (38-3E)	Prior to 1935	28	Gas showing at 28 ft.
43	(?)	Selien No. 1	Blaine area. Center E½ sec. 22, (40-1E), on R. Selien farm	Prior to 1935	335	Cable tools. Dry hole. Top of Chuckanut 155 ft. Driller's log.
	(?)	water well	Ferndale area. NE¼NW¼ sec. 6, (38-4E)	Prior to 1935	156	Cable tools. Poor gas showing with water, 156 ft.
44	(?)	diamond drill hole	Bellingham area. SE¼ sec. 6, (38-4E)	Prior to 1935	962	Gas showing, 495 ft. Driller's log.
	Mr. Green	Green water well	Deming area. NW¼ sec. 33, (39-4E), on Green farm	Prior to 1935	68+	Cable tools. Gas showing, 68 ft. Gas analysis.
	Mr. Erickson	Erickson water well	Deming area. Near N. line of NW¼ sec. 33, (39-4E) (?)	Prior to 1935	61	Cable tools. Gas, 61 ft; used domestically. Gas analysis.
	Mr. Barnhart	Barnhart water well	Deming area. SW¼ sec. 32, (39-4E) (?) about 1 mi. SW. of Erickson farm	Prior to 1935	80+	Cable tools. Gas showing, 80 ft. Deepened for water.
	(?)	water well	Deming area. Near S. line of SW¼ sec. 28, (39-4E)	Prior to 1935	(?)	Cable tools. Gas with fresh water.

(See footnote at end of table, p. 29.)

TABLE 5.—*Oil and gas wells drilled in Whatcom County (1901-1965)*1/—(continued)

Map no.	Company	Well name	Location and elevation	Date spudded	Depth (feet)	Remarks
	(?)	water well	Deming area. Near center E½ sec. 32, (39-4E)	Prior to 1935	80	Cable tools. Fresh water and gas at 80 ft.
	Mr. Sinnes	Sinnes water well	Ferndale area. NW¼SW¼ sec. 24, (39-2E), on Sinnes farm	Prior to 1935	492	Cable tools. Poor gas showing. Bottom of Pleistocene at 325 ft.
45	(?)	Livermore No. 1	Ferndale area. Near center SE¼NE¼ sec. 28, (39-2E), about 300 ft. S. of Lange No. 1	Prior to 1935	225	Cable tools. Dry hole. Driller's log.
46	West Coast Oil & Gas Co.	Russler No. 1	Bellingham area. NW¼ SW¼ sec. 13, (39-3E), on Jennie Russler farm	10-21-35	4,175	Cable tools. Base of Pleistocene at 57 ft. Several gas showings reported. Driller's log, well cuttings.
47	Dome Holdings, Ltd.	Stewart-Hamilton	Bellingham area. NW¼ SE¼SW¼ sec. 20, (38-3E)	10-6-36	965	Cable tools. Base of Pleistocene at 353 ft. Dry hole. Driller's log.
48	Peoples Gas & Oil Development Co.	Peoples No. 1 (P.G.O. Lingbloom No. 1)	Ferndale area. NW¼SW¼ SW¼NW¼ sec. 27, (39-2E), on Lingbloom farm, 200 ft. NW. of Lingbloom No. 2	1937	1,085	Cable tools. Gas at 174 and 1,044 ft.; used domestically. Base of Pleistocene at 342 ft. Well cuttings.
49	Peoples Gas & Oil Development Co.; Pelican Petroleum Co.	Peoples No. 6 (called No. 5 after original No. 5 was abandoned)	Ferndale area. SW¼SW¼ SW¼ sec. 28, (39-2E)	1938	1,195+	Cable tools. Several poor gas showings. Well cuttings.
50	North Coast Oil & Gas Co.	North Coast No. 1	Ferndale area. Near SE. cor. NE¼ sec. 28, (39-2E), 30 ft. N. of Whatcom No. 1	1938	200±	Cable tools. Dry hole.
51	Peoples Gas & Oil Development Co.	Peoples No. 2 (originally Peoples No. 1)	Ferndale area. NW¼NW¼ NE¼ sec. 34, (39-2E), S. of County farm	1938	1,785	Cable tools. Bottom of Pleistocene at 240 ft. Salt water at 756 ft. Gas used domestically. Well cuttings.
52	Peoples Gas & Oil Development Co.	Peoples No. 3	Ferndale area. Near N. ¼ cor. sec. 34, (39-2E)	1938	560	Cable tools. Gas; used domestically. Well cuttings.
53	Peoples Gas & Oil Development Co.	Peoples No. 4	Ferndale area. NE. cor. SW¼NE¼NW¼ sec. 34, (39-2E)	1938	880	Cable tools. Gas, 660 ft.; used domestically. Well cuttings.
54	Peoples Gas & Oil Development Co.	Peoples No. 5	Ferndale area. SW¼SW¼ NW¼ sec. 34, (39-2E), 650 ft. SW. of Peoples No. 4	1938	160	Cable tools. Abandoned because of mechanical trouble.
55	Peoples Gas & Oil Development Co.; Pelican Petroleum Co.; Northern Oil Co.	Pelican Dome No. 1	Bellingham area. 200 ft. NW. of SE. cor. sec. 32, (38-3E)	1938	5,458	Cable tools to 1,088 ft., rotary below. Gas showings at various depths. Metamorphics below 5,385 ft. Stratigraphic column, well cuttings.

(See footnote at end of table, p. 29.)

TABLE 5.—*Oil and gas wells drilled in Whatcom County (1901-1965)* 1/—(continued)

Map no.	Company	Well name	Location and elevation	Date spudded	Depth (feet)	Remarks
56	Standard Oil Co. of California	Ferndale community	Ferndale area. 330 ft. S. and 1,650 ft. W. of NE. cor. sec. 5, (39-1E)	11-12-45	6,231	Dry hole. Well history and log, core description, well cuttings and cores, E log.
57	Pleasant Valley Gas and Oil Co.	Hillje No. 1	Blaine area. SW. cor. SE¼NW¼ sec. 32, (40-1E)	1947	432	Cable tools. Small gas showings at 132, 170, and 400 ft. Bottom of Pleistocene at 165 ft. Gas analysis.
58	Meridian Oil Corp.	Hillebrecht No. 1	Ferndale area. NW¼SE¼ sec. 6, (39-3E) Elev. 65 ft. topo	1947	3,492	Gas showings at 790 and 1,200 ft. Well history, driller's log, core description, well cuttings, E log, core analysis.
59	Pleasant Valley Gas and Oil Co.	Dahle No. 1	Blaine area. Center SW¼ NW¼ sec. 32, (40-1E)	1950	380	Cable tools (?). Good gas showings from three zones. Bottom of Pleistocene at 217 ft. Driller's log.
60	Pleasant Valley Gas and Oil Co.	Mills No. 1	Blaine area. SE. cor. SE¼NE¼ sec. 31, (40-1E)	1951	300	Cable tools. Dry hole.
61	Puget Sound Development Co.	Soderberg No. 1	Ferndale area. E½SW¼ NE¼ sec. 11, (39-1E)	12-13-51	1,902±	Cable tools. Suspended. Oil reported. Salt water from near bottom. Oil analysis.
62	Pleasant Valley Gas and Oil Co.	Hart No. 1	Blaine area. 330 ft. S., 330 ft. E. from W. ¼ cor. sec. 33, (40-1E)	1952	400±	Results unknown.
63	Pleasant Valley Gas and Oil Co.	Dahle No. 2	About 100 ft. NE. of Dahle No. 1	1952	204	Cable tools. Good gas showing.
64	Pleasant Valley Gas and Oil Co.	Hillje No. 2	About 400 ft. NE. of Hillje No. 1	1952	356	Cable tools. Good gas showing; used domestically.
65	Pleasant Valley Gas and Oil Co.	Seline No. 1	Blaine area. 640 ft. N., 480 ft. W. from E. ¼ cor. sec. 32, (40-1E)	1952	350+	Cable tools. Poor gas showing reported.
66	Pleasant Valley Gas and Oil Co.	Heinrich No. 1	Blaine area. SE. cor. NW¼NW¼ sec. 32, (40-1E)	1952	400±	Cable tools. Dry hole.
67	Pleasant Valley Gas and Oil Co.	Johnson No. 1	Blaine area. NW¼SW¼ NE¼ sec. 32, (40-1E)	1952	400±	Cable tools. Poor gas showing.
68	Lynden Gas & Oil Development Co. and Pacific Gas & Oil Development Co.	Thom No. 1	Lynden area. NE¼NW¼ sec. 14, (40-4E)	1-5-53	1,173	Cable tools. Some gas reported.
69	Evergreen Gas and Oil Co.	Ridgeway-Heppner No. 1	Lynden area. 50 ft. N., 400 ft. W. from SE. cor. NE¼SE¼ sec. 31, (41-3E)	1953	200-	Abandoned because of mechanical difficulties.

(See footnote at end of table, p. 29.)

TABLE 5.—*Oil and gas wells drilled in Whatcom County (1901-1965)*1/—(continued)

Map no.	Company	Well name	Location and elevation	Date spudded	Depth (feet)	Remarks
70	Evergreen Gas and Oil Co.	Ridgeway-Heppner No. 1-A	Lynden area. About 15 ft. E. of Ridgeway-Heppner No. 1. Elev. 145 ft. topo	1953	1,650	Results unknown.
71	Kris Petroleum Ltd.	Ridgeway-Heppner No. 2	Lynden area. 55 ft. W. of Ridgeway-Heppner No. 1-A	1953	2,853	Results unknown.
72	Kris Petroleum (Wash.) Inc.	Kris Whatcom No. 1	Delta area. 350 ft. S., 630 ft. W. from NE. cor. sec. 1, (40-2E) Elev. 125 ft. topo	4-4-55	5,710	Suspended. Lith log from 960 ft. to bottom.
73	Can American Petroleums	Can-Am Stremler No. 1	Lynden area. 235 ft. N., 210 ft. E. of S. ¼ cor. sec. 4, (40-3E)	4-12-62	8,343	Oil shows reported at 7,050 ft. to 7,100 ft., 7,110 ft. to 7,180 ft. Gas analysis: 88.2 percent methane 1.8 percent ethane 2.0 percent propane 8.0 percent nitrogen.
74	El Paso Natural Gas Co.	Ross No. 1	1,125 ft. N., 365 ft. E. of SW. cor. sec. 17, (38-4E)	8-22-62	4,707	E log 480 ft. to 2,035 ft. Sonic log 480 ft. to 2,032 ft. Drill-stem test 3,413 to 3,533 ft.
75	Puget Sound Development Co.	Sherman No. 1	Ferndale area. 500 ft. W., 200 ft. N. of E. ¼ cor. sec. 14, (39-1E)	11-1-65	4,600	Suspended.

1/ Livingston, 1958, p. 44-51.

TABLE 6.—*Gas wells having a record of production*①

Well name	Location	Depth (feet)	Capacity; cubic feet per day	Pressure; pounds per square inch
Whatcom No. 1	E. ¼ cor. sec. 28, T. 39 N., R. 2 E.	175	3,000,000 to 4,000,000	50
Chamber of Commerce No. 1	NW¼SW¼NW¼ sec. 27, T. 39 N., R. 2 E.	171	900,000	27
Chamber of Commerce No. 2	SW¼SW¼NW¼ sec. 27, T. 39 N., R. 2 E.	172	1,250,000	28
Chamber of Commerce No. 4	SE¼SW¼NW¼ sec. 27, T. 39 N., R. 2 E.	166	750,000	52
Hunter No. 1	SW. cor. NE¼SW¼ sec. 27, T. 39 N., R. 2 E.	193	5,000,000	70

①Data from Glover, 1935, p. 40.

The gas wells, which are 166 to 193 feet deep, are in Pleistocene glacial deposits that overlie the Chuckanut Formation. It is doubtful that the gas is related to oil deposits; this gas probably has been generated in coal measures of the Chuckanut Formation. The gassy conditions that were present in the coal mines of the area indicate that the coal measures are capable of generating gas. The upward-migrating gases were trapped in sandy units of the overlying glacial deposits where a cap rock of impervious clay was present to prevent the gas from escaping into the atmosphere. Reservoirs in the Chuckanut Formation would also retain gas, should a cap rock and a confining structure be present.

Analyses of gas from western Whatcom County show that methane (CH_4) and nitrogen (N_2) are the major constituents. Ethane (C_2H_6), carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2), and oxygen (O_2) are present in some or all of the gases. The analyses of gases from Whatcom County and vicinity as reported by Glover (1935, p. 41) are as follows:

TABLE 7.—*Analyses of gas from western Whatcom County and vicinity**

Location	Analyst	Methane (CH_4)	Olefines, etc. (C_2H_4)	Ethane (C_2H_6)	Carbon monoxide (CO)	Carbon dioxide (CO_2)	Hydrogen (H_2)	Nitrogen (N_2)	Oxygen (O_2)	Hydrocarbons	Illuminants	Specific gravity	B.t.u.
Near Abbotsford, B.C..... 1	R. J. Offord, Dept. of Mines, Ottawa	96.65	....	1.15	....	1.08	....	1.12	none	....	....	0.571 to 0.574	....
Near Kilgard, B.C......... 2	G. S. Eldridge & Co., Vancouver, B. C.....	95.1	none	1.5	none	0.2	....	2.8	0.4	....	....	....	950 to 1,000
Anderson farm (Birch Bay) 3	Unknown	59.0	....	....	....	0.1	....	40.2	0.6	....	0.1	....	598
Do. 4	..do.	52.2	....	....	0.8	0.6	6.4	37.3	2.0	....	0.7	0.706	594
Green farm 5	Bogardus, Seattle	69.75	....	....	0.70	0.10	5.15	23.90	0.15	0.25	....	....	745.5
Do. 6	C. A. Newhall Co., Seattle ..	68.50	....	....	0.60	0.15	5.68	24.62	0.05	0.40	....	....	....
Holman farm 7	Unknown	19.0	....	....	2.4	1.0	3.1	70.0	4.4	....	....	....	....
Jepsom farm 8	..do.	64.0	....	....	1.7	0.9	15.6	14.0	2.8	....	1.0	0.578	759
Lange farm (Well No. 2).. 9	Kansas City Testing Lab. .	93.4	0.0	2.7	....	0.96	....	2.53	0.41	....	....	....	982
Do. 10	W. Alexander, Seattle Gas Co.	53.2	....	0.1	0.6	0.0	0.2	44.5	0.8	....	0.0	0.741	534
Lingbloom farm, Chamber of Commerce No. 1......11	K. C. Test Lab.	36.2	0.2	15.0	....	0.0	....	48.4	0.2	....	....	0.835	630
Do. 12	W. Alexander, Seattle Gas Co.	69.1	....	0.4	0.5	0.0	2.2	27.0	0.8	....	0.0	0.663	701
Chamber of Commerce No. 2 13	..do.	65.7	....	0.7	0.55	0.0	0.55	32.0	0.4	....	0.1	0.691	630
Chamber of Commerce No. 4 14	..do.	60.5	....	1.6	0.5	0.0	2.7	33.4	1.2	....	0.0	0.695	640
Whatcom No. 1............15	..do.	63.5	....	0.4	1.4	0.2	0.7	33.5	0.1	....	0.2	0.700	648
Petroleum gas; Pittsb'g, Pa.	①	92.0	....	3.0	....	....	3.0	2.0	....	....	....	....	978
Natural gas; mid-cont. field	①	96.0	....	....	....	0.8	....	3.2	....	....	....	....	967
Coal gas; Scranton, Pa.....	②	94.20	0.39	....	1.3	1.06	....	3.31	0.92	....	....	....	....
Marsh gas; western Oregon	③	93.9	....	....	....	2.4	....	3.7	....	....	....	....	....

①Bagley, W. S., Non-metallic mineral products, p. 68, 1930.
②Ries, H., Economic geology, p. 78, 1930.
③Average of five analyses from Washburne, C. W., Reconnaissance of the geology and oil prospects of northwestern Oregon. U. S. Geological Survey, Bulletin 590, p. 108, 1914.
*Data from Glover, 1935, p. 41.

Exploration for new gasfields is difficult, as outcrops offer no clues to reservoirs in the Pleistocene deposits. Once a favorable gas showing is discovered, extensive drilling is required to evaluate the field's potential, as the gas reservoir is likely to be of irregular shape. Inasmuch as the Pleistocene deposits seldom exceed 600 feet in thickness, most drill holes to test these deposits are shallow.

Oil

The only oil thus far discovered in Whatcom County is that reported by drilling crews and that in a few oil seeps. Of the 75 wells drilled for oil and gas, four contained oil but only in minor amounts as films on drilling mud. Although oil was reported in the Soderberg No. 1 well, analyses of this material indicated that it was refined diesel oil. Analyses of oil reported from the other wells are not available. Wells from which the presence of oil has been reported are listed in Table 5.

Numerous oil seeps have been reported in the county, but when investigated, the majority were found to be nothing more than films of iron oxide and iridescent vegetal scums on stagnant pools. The most notable oil seep was one at Alabama and Orleans Streets in Bellingham (see p. 21). This seep was in Pleistocene glacial sediments and was in such large amount that an origin from a tank seepage was discounted. Drilling at the seepage in 1929 to a depth of 293 feet, and to 965 feet in 1936 and 1937, failed to discover oil at depth. At the site of the seep the Pleistocene sediments that overlie the Chuckanut Formation proved to be 353 feet thick.

It is doubtful that the oil could have originated from the buried remains of marine life in Pleistocene sediments, as such substances that could produce oil are small in amount. Glover (1935, p. 39) states that the oil seepages in the county could be the product of local distillation of resins and fossil hydrocarbons in the underlying coal measures of the Chuckanut Formation. Inasmuch as the Chuckanut is continental and is not known to contain oil shales, it appears highly improbable that the oil originated in this formation. An alternate hypothesis would be that the oil migrated eastward from Cretaceous marine rocks that are to the west beneath the waters of Haro and Georgia Straits. Although the idea that the oil and gasoline originated from a tank seepage was discounted because over 3,000 gallons were recovered, the writer still prefers this origin. The terrain is such that leakage from railroad cars on the Northern Pacific Railway line 1,000 feet to the north, as well as leakage from storage tanks along the line, would slowly flow downhill to the site of the seepage.

Peat

Peat is vegetal matter in partly decomposed and more or less disintegrated condition that forms under conditions of excess water and limited access to air. It is composed of different plants, depending on climatic and topographic conditions. The principal kinds are moss peat (sphagnum), fibrous peat (mostly sedge), woody peat, and sedimentary peat. The accumulation of peat requires a rather long time; the rate in some bogs, according to Rigg (1958, p. 9), is about 1 inch in 40 years.

The most common uses of peat are for soil improvement and for the manufacture of mixed fertilizers. Other uses include litter for barns and poultry yards and packing material for plants, fruits, vegetables, eggs, and other fragile articles. In the past, here and in other countries, peat has been used as fuel.

In western Whatcom County, peat deposits are mainly in undrained depressions on the glacial debris that mantles much of Whatcom Basin. Only three deposits have been mapped in the mountainous area east of the basin. The locations of the peat deposits of the county are shown on Plate 2, and data on individual deposits are given in Tables 8 and 9.

Although western Whatcom County has several large peat deposits, and over 6,000 acres is underlain by peat, the total production from the county has been small. The only major peat operation was at Mosquito Lake, where from 1935 to 1942 the Washington Peat Moss Co., of Deming, mined about 5,000 tons of sphagnum, fibrous, and sedimentary peat valued at about $52,000; this peat was sold mainly to out-of-county markets. The small amount of peat that was mined from other deposits in the county was used locally. At present, the production of peat in the county is sporadic and small in amount, and most of the peat is sold as a soil conditioner.

Sand and Gravel

The sand and gravel deposits of the county are advance and recessional outwash deposits of Pleistocene continental glaciers, also Recent alluvial deposits along flood plains of the largest streams. The deposits of glacial origin are confined mainly to Whatcom Basin, whereas the alluvial deposits occur throughout the county (Pl. 1).

In Whatcom Basin, glacial outwash material covers about 50 percent of the area and consists of gravel, coarse arkosic sand, and interbeds of silt and clay. The gravel is made up of mixed rock types, of which about 50 percent are granitic, gneissic, or dioritic rocks. The other 50 percent are metamorphic and volcanic rocks that are mainly argillite, chert, andesite porphyry, and basalt. Although most sands are arkosic, some subgraywacke is present.

The deposits of sand and gravel vary considerably in thickness throughout Whatcom Basin. The logs of many water wells in the basin (Newcomb and others, 1949, p. 93-133) show some sand and gravel beds to be as much as 160 feet thick, and individual beds of sand are as much as 40 feet thick.

The advance outwash glacial deposits are clean, water-washed, irregularly bedded gravels and coarse

TABLE 8.—*Peat deposits of western Whatcom County* 1/

Name of deposit	Map no.	Location	Area (acres)	Maximum thickness (feet)		Maximum depth to bottom of deposit (feet)	Remarks
				Sphagnum	Fibrous		
Barnhart Road -------	139	Sec. 3, (40-2E)	19	--------	11½	19+	
Blaine -------------	140	Sec. 35, (41-1E)	20	--------	1½	36	
Boundary-Meridian --	141	Secs. 35, 36, (41-2E); sec. 31, (41-3E)	420	2	20	30+	
Carlson ------------	142	Sec. 26, (38-5E)	18	--------	8	8+	
Custer -------------	143	Secs. 25, 26, 36, (40-1E); secs. 27, 28, 29, 30, 31, 32, 33, 34, (40-2E)	1,636	1	11	15	Some peat removed for local use.
Fazon Lake ---------	144	Sec. 13, (39-3E)	186	--------	25	37+	
Lake Terrell --------	145	Sec. 22, (39-1E)	98	--------	11	10	Strongly acid (pH 4.3 to 4.7)
Monument 9 --------	146	Sec. 34, (41-1E)	38	--------	8	10	
Mosquito Lake ------	147	SW¼ sec. 13, SE¼ sec. 14, (38-5E)	16	11	1	48+	Production from 1935 to 1942 about $40,000. Operated by Washington Peat Moss Co., of Deming, Wash.
Mountain View -----	148	Secs. 22, 27, (39-1E)	48	1	11	15	
Northwood ---------	149	Secs. 32, 33, 34, (41-3E); secs. 3, 4, 5, 7, 8, 9, (40-3E)	1,230	--------	12	13	
Pangborn Lake ------	150	Secs. 1, 2, (40-3E); sec. 6, (40-4E)	430	1	18	30	
Sweet Road --------	151	NW¼ sec. 9, (40-2E)	6	--------	4	7	
Wiser Lake ---------	152	Sec. 36, (40-2E); secs, 1, 2, (39-2E); secs. 29, 31, 32, 33, 34, 35, 36, (40-3E); secs. 2, 3, 4, 5, 6, 8, 9, 10, 11, 17, 18, (39-3E)	2,450	3	29	30+	

1/ Data from Valentine, 1960, p. 81.

TABLE 9.—*Chemical analyses of selected peat deposits*①

Source of Samples

Sample number	Name of deposit	Kind of peat	County	Profile	Hole	Depth at which sample was taken (feet)
1	Mosquito Lake	Sphagnum	Whatcom		1	0 to 4
2	Mosquito Lake	Sphagnum, fibrous, sedimentary	Whatcom		1	7 to 13
3	Mosquito Lake	Sedimentary	Whatcom		1	13 to 15
4	Mosquito Lake	Sedimentary	Whatcom		1	15 to 18
5	Mosquito Lake	Sedimentary	Whatcom		1	18 to 29
6	Mosquito Lake	Sedimentary	Whatcom		1	31 to 40
7	Pangborn Lake	Fibrous	Whatcom	A	6	0 to 3
8	Pangborn Lake	Fibrous, sedimentary	Whatcom	A	6	4 to 14
11	Wiser Lake	Sedimentary, marl	Whatcom	H	1	14 to 16
12	Wiser Lake	Sedimentary	Whatcom	H	3	10 to 14½

Sphagnum peat—Soil reaction, moisture content, chemical composition

Sample number	pH	Moisture as received (percent)	Composition of moisture-free material (percent)					
			Ash	Total N	P_2O_5	K_2O	Cl	S
1	3.7	93.4	1.63	1.18	0.09		tr.	0.049

Fibrous peat—Soil reaction, moisture content, chemical composition

Sample number	pH	Moisture as received (percent)	Composition of moisture-free material (percent)						
			Ash	Total N	P_2O_5	K_2O	SiO_2	Cl	S
7	5.4	90.1	63.2	2.02	0.09		58.6	0.013	0.017

Sedimentary peat—Soil reaction, moisture content, chemical composition

Sample number	pH	Moisture as received (percent)	Composition of moisture-free material (percent)						
			Ash	Total N	P_2O_5	K_2O	CaO	Cl	S
3	6.5	90.0	68.6	1.65	0.11			0.006	0.040
4	6.2	85.3	69.2	1.12	0.10			tr.	0.010
5	7.2	86.5	77.2	1.06	0.15			tr.	0.010
6	7.6	88.6	75.9	0.83	0.07			0.015	0.010
12	5.6	79.2	74.7	1.04	0.74			0.011	0.003

Mixed sedimentary and fibrous peat—Soil reaction, moisture content, chemical composition

Sample number	pH	Moisture as received (percent)	Composition of moisture-free material (percent)						
			Ash	Total N	P_2O_5	K_2O	SiO_2	Cl	S
8	4.9	88.8	61.1	0.91				0.083	0.014

Miscellaneous mixtures of peat and associated materials—Soil reaction, moisture content, chemical composition

Sample number	Materials	pH	Moisture as received (percent)	Composition of moisture-free material (percent)							
				Ash	Total N	P_2O_5	K_2O	CaO	SiO_2	Cl	S
2	Spaghnum, fibrous, sedimentary	5.8	93.5	7.20	1.40	0.05				tr.	0.031
11	Sedimentary, marl	7.6	55.0	66.3	0.29	0.52			23.5	0.009	0.010

①Data from Rigg, 1958, p. 253-256.

sands beneath a capping of till. According to Newcomb and others (1949, p. 33), the advance outwash gravel zones crop out around the steep slopes southeast of Blaine, in an area northward from King Mountain to Laurel, and in a small hilly area west of Sumas. The gravels have also been found in wells that penetrated the till on the northeastern side of the Mountain View upland northwest of Ferndale.

Elsewhere in Whatcom Basin the sand and gravel deposits are mainly recessional outwash. North of the Nooksack River, from the upland area east of Blaine to Sumas the outwash material is composed largely of sand and gravel. Elsewhere the deposits contain large amounts of clay, silt, and sand. Outside the boundaries of Whatcom Basin the deposits of outwash sand and gravel are generally small. However, an exception to this is the recessional outwash deposit that fills Columbia Valley north of Kendall. This deposit extends from the Canadian border southward for 7 miles to the vicinity of Kendall. According to Dee Molenaar, former geologist for the Washington Division of Water Resources, (oral communication, 1960), the deepest water well in the valley has penetrated 138 feet of sand and gravel without reaching bedrock.

Glacial till, locally known as "hardpan," occurs interbedded between the advance outwash and the recessional outwash material. The till consists of a compact mixture of clay, silt, sand, and pebbly gravel that contains occasional boulders and cobbles. It is recognized by its bluish-gray color on fresh exposures; upon exposure to weathering the till becomes yellowish brown. It ranges from a few feet to 50 feet in thickness and averages about 20 feet. Although glacial till is not commonly used as a source for gravel, some till having a high gravel content has been washed and crushed to provide aggregate for asphalt and concrete pavement.

The alluvial deposits of sand and gravel are confined to areas of active stream erosion and deposition, and consist mainly of material that has been derived from the erosion of glacial deposits. The gravel is composed mainly of pebbles and cobbles of mixed rock types that contain a larger percentage of soft sedimentary and metamorphic rocks than do the glacial gravels. Both sand and silt are commonly present in the gravels, and much of the sand is graywacke. The sand and gravel deposits are as much as 50 feet thick.

Along the course of the Nooksack River, bars contain sand and gravel in many places. In general, downriver from the confluence of Fishtrap Creek and the Nooksack the alluvial deposits consist mainly of sand and silt. Upriver, sand and gravel occur in bars of the river eastward on the North Fork as far as its headwaters and southward on the South Fork to the Skagit County line.

TABLE 10.—*Sand and gravel operations—1966*

Index no. on Plate 2	Name of operation	Location of pit	Product	Source
159	Cowden Gravel	Cedarville area Sec. 28, (39-4E)	Sand, gravel, crushed gravel	Glacial outwash
160	Lind Gravel Co.	Bellingham area Sec. 24, (38-2E)	Sand, gravel, crushed gravel	Glacial outwash
161	Lynden Ready Mix	Lynden area SW¼ sec. 21, (40-3E)	Sand, gravel	River run
162	Mulka Gravel Co.	Bellingham area SE¼ sec. 8, (38-3E)	Sand, gravel	Glacial outwash
163	Doug Pullar Sand & Gravel	Laurel area SW¼ sec. 20, (39-3E)	Sand, gravel, crushed gravel	Glacial outwash
164	Sumas Fuel & Transfer Co.	Sumas area NW¼ sec. 21, (40-4E) NE¼ sec. 34, (41-4E)	Sand, gravel, crushed gravel	Glacial outwash
165	Whatcom Builders Supply Co.	Lynden area SE¼ sec. 22 and NE¼ sec. 36, (40-2E)	Sand, gravel, crushed gravel	River run
166	C. V. Wilder Co.	Laurel area SE¼ sec. 19 and SW¼ sec. 20, (39-3E) Bellingham area SW¼ sec. 9, (38-3E)	Sand, gravel, crushed gravel	Glacial outwash

The deposits of sand and gravel that are presently (1966) being mined, as well as deposits that have been mined in the past, are shown on Plate 2. In 1967, six of the operations were utilizing glacial outwash material and three operators were obtaining their sand and gravel from river bars. The major uses for the sand and gravel include subbase and base material for highways, aggregate for concrete, and common borrow.

Sand and gravel constitutes a low-cost product having average pit prices that range from $1 to $1.25 per short ton. Washed and graded gravel has an average value of $3.50 to $4 per ton. Transportation costs from pit site to construction site add to these prices.

Building Stone

Sandstone of the Chuckanut Formation was one of the first rocks in Whatcom County to be used as building stone. In the late 1800's and the early 1900's a sandstone quarry in secs. 13 and 24, T. 37 N., R. 2 E., south of Bellingham, operated on a commercial basis. Known as the Chuckanut quarry, it supplied stone that was used in the construction of many large important buildings in the Northwest. Such buildings as the U.S. Customhouses in Portland, Oregon, and Port Townsend; the Dexter Horton Building, Seattle; and the old capitol building in Olympia were constructed of Chuckanut sandstone. However, like several other sandstone quarries in the State, the Chuckanut quarry was forced to close when brick, concrete, and terra cotta were substituted for sandstone.

In describing the quarry operations, Shedd (1903, p. 63) reports that the sandstone was broken into large masses by blasting and then worked into dimension stone by wedging and sawing. The mill consisted of two gangsaws, 14 by 7 feet, which were powered by a 40-horsepower steam engine. The quarry also contained a steam hoist and derrick for handling the stone. Because of the quarry's location on the waterfront of Chuckanut Bay, the stone could be loaded directly onto barges or boats. Also, the Great Northern Railway passed through the quarry yard and furnished another means of transportation.

The bed from which the sandstone was quarried was about 40 feet thick and had a N. 10° W. strike and a 60° W. dip. The sandstone, which is essentially an arkose that has a ferruginous cement, is greenish gray, fine grained, and well cemented. The texture is both coarse and fine; the fine-textured part of the bed made a very good stone for carving and ornamental work. Shedd (1903, p. 64) reports that the stone has a specific gravity of 2.727, a porosity of 10.91 percent, and a permeability of 4.47 percent. Perpendicular to the bedding plane the crushing strength is 10,740 to 11,070 pounds per square inch, and parallel to the bedding the crushing strength is 5,340 pounds per square inch. The chemical analysis of the sandstone as reported by Shedd is as follows:

	Percent
Silica (SiO_2)	90.19
Iron (Fe_2O_3)	3.50
Alumina (Al_2O_3)	1.92
Lime (CaO)	0.59
Magnesia (MgO)	1.78
Loss on ignition	2.32
	100.30

The chemical composition of the Chuckanut sandstone is almost the same as that of the Tenino sandstone, which occurs 115 miles south, near Tenino. In appearance these stones are so similar that both stones were used in the construction of the old capitol building at Olympia.

Although the only quarry that supplied dimension stone from the Chuckanut Formation was the Chuckanut quarry, other sandstone beds of the formation are just as well suited for this purpose. Well-indurated sandstone units of the Chuckanut Formation have also been quarried for use as riprap, jetty stone, and fill. The locations of the sandstone quarries in the county are shown on Plate 2, and the distribution of the Chuckanut Formation is shown on the geologic map of the county (Pl. 1).

In recent years a moderate amount of green andesite, known as "Shuksan Stone," has been quarried for use as building stone. The andesite forms extensive outcrops along the Nooksack River 8 miles east of Glacier and crops out mainly in secs. 5 and 6, T. 39 N., R. 8 E., and in sec. 33, T. 40 N., R. 8 E. All the andesite is within the Mount Baker National Forest.

The Shuksan Stone that has been quarried to date has come mainly from a quarry on Wells Creek near its junction with the Nooksack River and from another quarry 1 mile northeast on State Highway 542 (Pl. 2). Sporadic production of rough building stone and rubble has come from these quarries since about 1948.

The andesite is dark bluish green, aphanitic, and contains dark-green oval inclusions as much as 10 inches in maximum length. Under the petrographic microscope the andesite is seen to be composed of about 70 percent andesine that is highly altered and contains abundant sericite. The rest of the rock consists mainly of green chlorite and an occasional grain of augite. The chlorite, which gives the andesite its green color, appears to have been formed by the alteration of the original pyroxene. The andesite contains horizontal and vertical joints that are irregularly spaced from 1 to 15 feet apart. The joints aid greatly in quarrying the stone, which is very resistant to breaking.

The andesite is of Jurassic age and has been mapped by Misch (1952) as the Wells Creek Volcanics. It is overlain by Upper Jurassic-Lower Cretaceous graywacke, argillite, and siltstone. The outcrop area of the andesite is designated by the map symbol Jv on the geologic map of Whatcom County (Pl. 1).

In addition to the Chuckanut sandstone and Shuksan Stone, several other rocks of the county are suitable for use as building stone. An easily accessible deposit of white quartz is 4 miles northwest of Kendall, in the NE¼NW¼ sec. 17, T. 40 N., R. 5 E. This quartz, which has been used in the manufacture of cement, is discussed under Quartz on page 35 of this report.

Limestone, which is used mainly by the cement and paper industries of the county, also has been found suitable for use as building stone. The limestone is white to dark gray, dense to crystalline, and massive to well bedded. Some limestone is fossiliferous, and much of it is highly fractured. As a building stone, the limestone is most commonly used as rough stone and rubble for walls and fireplaces. Most limestone deposits occur on Sumas, Red, and Black Mountains, which form the western foothills of the Cascade Mountains. However, other occurrences exist in the county but have yet to be developed. The locations of the limestone quarries of the county are shown on Plate 2, and the limestone deposits are discussed on pages 39 to 49 of this report.

Asbestos

Asbestos occurs in Whatcom County, but none of the deposits discovered to date have been proven to be of commercial value. The asbestos is associated with serpentinized phases of olivine and occurs as thin veinlets that are usually less than ¼ inch in width. The asbestos is the cross-fiber type known as chrysotile, a form of serpentine. Although some of the asbestos is of good quality, the veinlets are too sparsely distributed to be mined economically.

Although thin seams and stringers of asbestos can be found in most serpentine deposits of the county, in only two areas do the asbestos veinlets have widths of around ¼ inch. One such deposit is in the NE¼SW¼ sec. 36, T. 37 N., R. 6 E., near the southwest end of Twin Sisters Mountain. Other veinlets of asbestos have been reported in serpentinized rocks in the NW¼ sec. 29, T. 38 N., R. 6 E., on Bowman Mountain, about 4 miles northwest of Twin Sisters Mountain.

Quartz

Quartz (SiO_2, silicon dioxide) occurs in many parts of the county, but most deposits are small. Common quartz occurs mainly in veins and irregular-shape lenses and pods in a wide variety of host rocks. The veins generally do not average much more than 6 inches in width; however, some quartz veins are as much as 15 feet wide. The veins occur most commonly in the mining districts of the county, where they form the gangue minerals for ore deposits. The irregular-shape bodies of quartz are generally small; however, at the Columbia Cement Co. deposit a body of quartz is about 280 feet long and 50 feet wide.

Chert, a cryptocrystalline variety of quartz, occurs in the western part of the county as beds in the Chilliwack Group. The chert is light green, gray, and white and ranges in thickness from several inches to as much as 20 feet. The chert most commonly occurs interbedded in argillite, but nodules and lenses are also present. No attempt will be made to describe all deposits of chert in the county, but two areas are worthy of mention. In the SW¼ sec. 17, T. 40 N., R. 7 E., on Canyon Creek, a bed of white chert 15 feet wide crops out for several hundred feet on a southeast-facing slope. The area has been logged, and the chert forms a distinct outcrop that can be seen from parts of the Canyon Creek logging road. On the northeastern end of Sumas Mountain and in the NW¼SW¼ sec. 21, T. 40 N., R. 5 E., white chert beds as much as 20 feet wide crop out. These beds are made up of many small beds that range from ½ to 1½ inches in width. Because of overburden, the beds cannot be followed much more than 100 feet along their strikes.

South of Lake Whatcom, near Reed Lake and the W. ¼ cor. sec. 29, T. 37 N., R. 4 E., Glover (1935, p. 10) describes an unusual deposit of quartz. Four feet above the base of the Chuckanut Formation a conglomerate is composed almost entirely of quartz. The conglomerate, which is 72 feet thick, is made up almost entirely of angular and subangular fragments of quartz that average about 1 inch across. The matrix consists of a fine-grained aggregate of quartz grains and schist fragments. Glover states that the conglomerate has a strikingly white color and forms a resistant bed. In the NW¼ sec. 26, T. 37 N., R. 3 E., which is on the northeastern shore of Lake Samish, a similar conglomerate is exposed in a highway roadcut. The conglomerate is 4 to 6 feet above the base of the Chuckanut Formation and is 1½ to 10 feet thick.

Columbia Cement Company quartz deposit

Location and accessibility.—A deposit of common quartz owned by the Columbia Cement Co. is in the NE¼NW¼ sec. 17, T. 40 N., R. 5 E., about 4 miles southeast of Sumas. An unimproved road leads west from the Wayne Crosby farm on the Frost road for about an eighth of a mile to the deposit. The Bellingham-Maple Falls line of the Chicago, Milwaukee, St. Paul and Pacific Railroad is a quarter of a mile to the north.

History.—The quartz was originally staked as the Copper King and Sumas mining claims by John Post in 1897. Donovan (1897) reports that in 1897 the Quartz Mountain Gold and Copper Mining and Milling Co. was following a pay streak 20 inches wide that carried 8 to 20 percent copper and $4.50 in gold. In 1906, G. C. Hyatt relocated the deposit as the Tommy Atkins and Tuesday mining claims. Some time after 1912 the claims were granted patent number 434110.

The Olympic Portland Cement Co. acquired the property in 1935, and until 1947 mined the silica for use in the manufacture of a low-temperature cement. Much of this cement was used in the construction of Grand Coulee Dam.

Geology.—The deposit is on the northeast end of a small rocky knob that crops out through the glacial outwash deposits of the valley. White quartz has been exposed by quarrying operations over a horizontal dis-

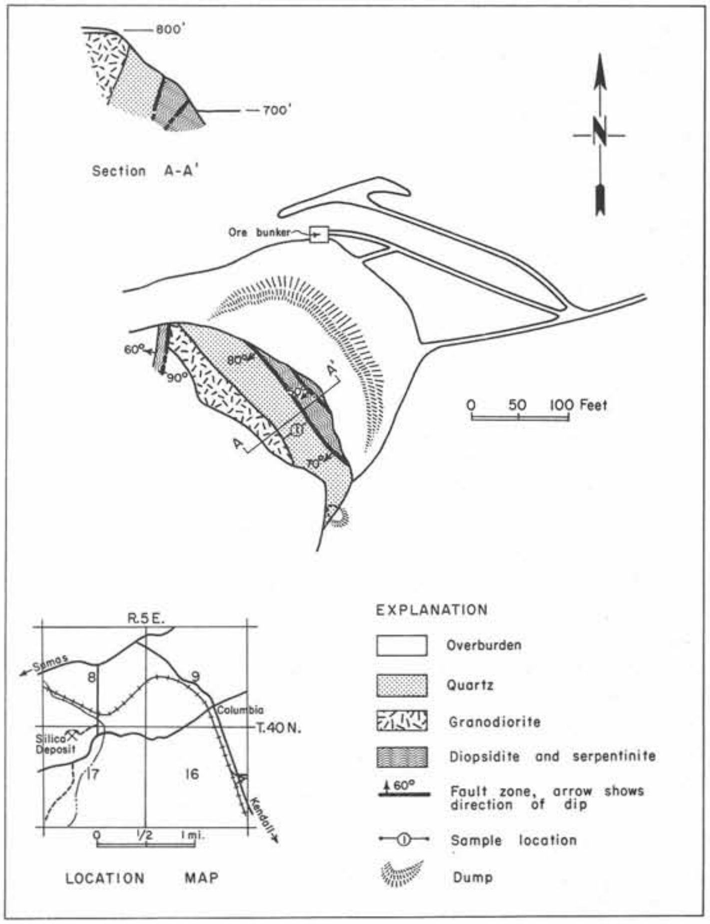

FIGURE 10.—Sketch map of Columbia Cement Company silica deposit.

tance of about 280 feet. The quarry face is about 60 feet high. The quartz mass has a general strike of N. 50° W., and it dips 70° to 80° SW. It is underlain by sheared and slickensided grayish-green diopside, which in hand specimen resembles serpentinite. Microscopic examination of the diopside shows it to be microbrecciated. Also present, but visible only in thin section, are hornblende and enstatite. The quartz and the underlying diopside are in fault contact.

The quartz is massive and is traversed in all directions by joints and fractures. Some of the fracture surfaces are coated with iron oxide from the oxidation of the chalcopyrite that is disseminated in parts of the quartz. Minor malachite and azurite also occur as thin coatings on some fracture surfaces. Petrographic examination of several samples that appeared to be the highest grade quartz showed about 98 percent quartz and 2 percent feldspar. The quartz occurs as subhedral and anhedral grains that contain many minute inclusions of unidentifiable material. The feldspar is interstitial to the quartz and is turbid. Chemical analysis of a 45-foot chip sample across the face of the quarry that was sampled by the writer is as follows: 97.0 percent SiO_2, 1.01 percent Fe_2O_3, and 1.36 percent Al_2O_3.

Hodge (1938c, p. 156) gives the following analyses for the quartz as reported by The Olympic Portland Cement Co.

TABLE 11.—*Chemical analyses of quartz from the Columbia Cement Co. silica deposit*

Constituents	Red, iron-stained (percent)	Green, copper-stained (percent)	White (percent)
SiO_2	82.50	90.96	96.98
Fe_2O_3	7.00	3.00	0.60
Al_2O_3	4.96	1.88	1.30
CaO	0.30	1.20	0.50
MgO	2.00	0.79	trace
SO_3	.....	.....	trace
Loss on ignition	2.08	1.30	0.58
	98.84	99.13	99.96

The copper that was reported to have been mined when the quartz was first discovered occurs in its greatest concentrations on the southeastern end of the quartz deposit. However, the ore bodies are small, the largest being about 5 feet in diameter. A short adit was started on one of the ore bodies but abandoned after passing through 5 feet of it. The predominant copper mineral is chalcopyrite, which in no place makes up more than about 8 percent of the ore bodies. Both malachite and azurite are associated with the chalcopyrite but do not exceed 3 percent.

The quartz is overlain by dark greenish-gray, medium-grained metaquartz diorite. Parts of the diorite are migmatitic and contain dark-gray inclusions. In thin section the rock exhibits a hypidiomorphic texture. Feldspar, which is the most abundant mineral, consists of andesine and orthoclase. Much of the plagioclase is altered and contains inclusions of epidote and hornblende. Actinolitic hornblende, altered in part to chlorite, is the most abundant mafic mineral. Quartz occurs as anhedral grains and contains many unidentified minute inclusions. Sheaflike masses of prehnite fill many of the fractures in the diorite.

The relation between the massive quartz and the diorite hanging wall suggests replacement of the diorite by the quartz. The contact is gradational, and inclusions of diorite occur in the quartz adjacent to the contact. The abundant prehnite in the diorite could indicate metasomatic transformation of calcic plagioclase by heated magmatic waters during emplacement of the quartz.

The structural relation of the quartz and its wall rock to the neighboring rocks of the area is obscured by glacial drift. However, the deposit appears to be part of the basement complex that has been faulted up by high-angle, northeastward-trending faults.

Development and operation.—The quarry has been developed horizontally for 280 feet and to a maximum height of 150 feet. At present (1966), the quarry is abandoned, but Hodge (1938c, p. 156) reports that mining operations in the past were as follows:

> The top half of the face is a natural cliff. The quarry is equipped with a compressor and drilling equipment, a truck, and a bulldozer. The rock is broken, dozed from the quarry floor to a loading platform, where it drops through an opening into the truck below. The truck transports the rock from the quarry ½ mile to the Chicago, Milwaukee, St. Paul and Pacific Railroad, where it is loaded into cars and hauled by rail to the cement plant, a distance of about 30 miles. The truck makes a round trip every 10-15 minutes and fills 2 cars a day. Eight men are employed in the operation.

Although this deposit may contain as much as 50,000 tons of silica, it cannot be considered a source of high-grade silica. Extensive sampling by The Olympic Portland Cement Co. indicates that the deposit averages 90 percent SiO_2 (Hodge, 1938c, p. 155).

Olivine

Whatcom County has one of the largest known deposits of olivine in the United States. Few residents of the county are aware of the fact that Twin Sisters Mountain (Fig. 11) is composed mainly of olivine, let alone know what olivine is.

Olivine is a magnesium-iron silicate mineral containing variable proportions of the magnesium silicate, forsterite (Mg_2SiO_4), and the iron silicate, fayalite (Fe_2SiO_4). Pure fresh olivine is semitransparent, olive green in color, has poor cleavage, and has a vitreous luster. Its hardness is between 6.5 and 7; its specific gravity, depending upon its magnesium and iron content, ranges from 3.2 to 4.4. On weathered surfaces olivine has a typical yellowish-brown (dun) color. Rocks composed almost entirely of olivine are called dunite.

The largest body of olivine in Whatcom County—Twin Sisters Mountain—is 24 miles east of Bellingham and 18 miles south of the Canadian border. The mountain is 10 miles long in a north-northwest direction and averages about 3½ miles in width (Pl. 2). The south end of the mountain extends about 3 miles into Skagit County. When viewed from the west, even as far away

FIGURE 11.—Twin Sisters Mountain, northeastern slope, at the headwaters of the South Fork of the Nooksack River. (Photo courtesy of John C. Pierce.)

as Mount Constitution, on Orcas Island, Twin Sisters Mountain forms an impressive scene. Its barren, reddish-colored rocks form jagged pinnacles and serrated ridges that rise several thousand feet above the green foothills. Altitudes range from 6,932 on the summit of the South Twin peak to about 2,000 feet in the valley of the Middle Fork of the Nooksack River at the northern end of the mountain. Above the 4,000-foot contour line the dunite is well exposed and has very little overburden; below 4,000 feet glacial drift and vegetation cover most of the rock.

Recent studies by Gaudette (1963, p. 19) show that the ultramafic body contains 80 to 90 percent dunite, which consists mainly of forsterite (Fo_{94-90}). Saxonite, which occurs as blocks with indefinite boundaries, makes up about 10 per cent of the body, and the remainder consists of serpentinite and veins and pods of chromite. The serpentinite occurs mainly as a marginal rind as much as a quarter of a mile wide around the dunite mass and as veins along fracture zones within the central part of the body.

The dunite is holocrystalline and contains anhedral grains of olivine that range from less than 0.1 millimeter to more than 8 millimeters in diameter. In addition to olivine, the minerals enstatite, chromite, magnetite, and serpentine are present. Modal analyses of 38 specimens by Gaudette (1963, p. 23) show an average of 93.1 percent olivine; 4.7 percent enstatite; 1.9 percent chromite; and 0.8 percent other constituents, mainly serpentine. Systematic sampling over the 35-square-mile area of the Twin Sisters dunite has not been undertaken; however, the many analyses that have been made by different workers in the past indicate an average magnesium oxide content of 49.0 percent. Analyses of 13 individual samples from different areas are given in Table 12.

TABLE 12.—*Selected analyses of Twin Sisters olivine*

Constituents	Samples number:					
	1	2	3	4	5	6
MgO	49.0	46.6	49.4	47.62	48.96	48.39
Mg	29.6	28.2	29.9	28.8	29.6	29.0
SiO_2	41.8	43.7	41.2	41.74	43.6	40.08
Fe_2O_3	....	....	7.1	.....	.....	8.82
Fe	....	....	....	6.87	.....	.....
FeO	7.2	7.3	....	.....	10.2	.....
Al_2O_3	....	1.5	....	.....	0.38	2.22
CaO	0.2	0.3	0.2	.....	.....	0.24
Loss on ignition	0.2	....	0.3	1.98	.....	.....

NOTE: All figures are shown as percentages.

Sources of analyses:

1. Bengtson, K. B., 1956, Olivine: Abstract of paper presented to Pacific Northwest Regional Conference of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Olympic Hotel, Seattle, Wash., May 4, 1956.
2. Pfeiffer, D. H., 1945, Thermomineralogical changes of olivine from the Twin Sisters Mountain of Washington: B.S. thesis in Mining Engineering, University of Washington, Seattle.
3. Northwest Olivine Company, Northwest olivine in your foundry: Bulletin no. 100-58.
4. Scheel, H. P., [1953], Assays by Gutberlet Laboratories, Seattle, Wash., April 24, 1953. Average of seven samples.
5. Knowles, P. H., [1939], written communication.
6. Olivine Corporation, undated analyses report.

The most systematic sampling to date was carried out by Gaudette (1963, p. 102-104) for the determination of cobalt, chromium, manganese, nickel, and iron.

Five traverses were made across the mountain, and 73 specimens were collected. Analyses of these specimens are as follows:

Constituents	*Percent*
Cobalt	0.007 to 0.018
Manganese	0.064 to 0.150
Chromium	0.021 to 0.312
Nickel	0.143 to 0.612
Iron	4.7 to 7.3

The pyrometric cone equivalent, or fusion point, of the olivine as reported by Wilson and Skinner (1940, p. 137) ranges from 30 to 36.

The Twin Sisters dunite appears to have been emplaced along the trace of a high-angle N. 30° W.-trending fault. The predominant rocks east of the dunite are Carboniferous-Permian sedimentary and volcanic rocks of the Chilliwack Group that consist mainly of graywacke, siltstone, argillite, and minor altered basaltic rocks. West of the dunite, pre-Jurassic graphitic and quartzose phyllite predominate (Pl. 1). Small isolated outcrops of pre-Carboniferous altered gabbroic rocks and pyroxenite, as well as small bodies of sandstone and conglomerate of the Chuckanut Formation (Late Cretaceous-early Tertiary), crop out around the western edge of the dunite. On the basis of the intrusive relation of the dunite to the Chuckanut Formation, a post-Paleocene age has been assigned to the dunite by Misch (1952), Ragan (1963), and Gaudette (1963).

The dunite mass for the most part contains two prominent joint patterns (Fig. 12). The dominant joints strike approximately N. 30° W., which is nearly parallel to the elongation of the dunite, and N. 60° E., transverse to the elongation. This well-defined jointing was first reported by Bennett (1940). Gaudette (1963, p. 26) points out that the pyroxene and chromite veins in the dunite exhibit a general N. 30° W. trend that is parallel to the major joint set.

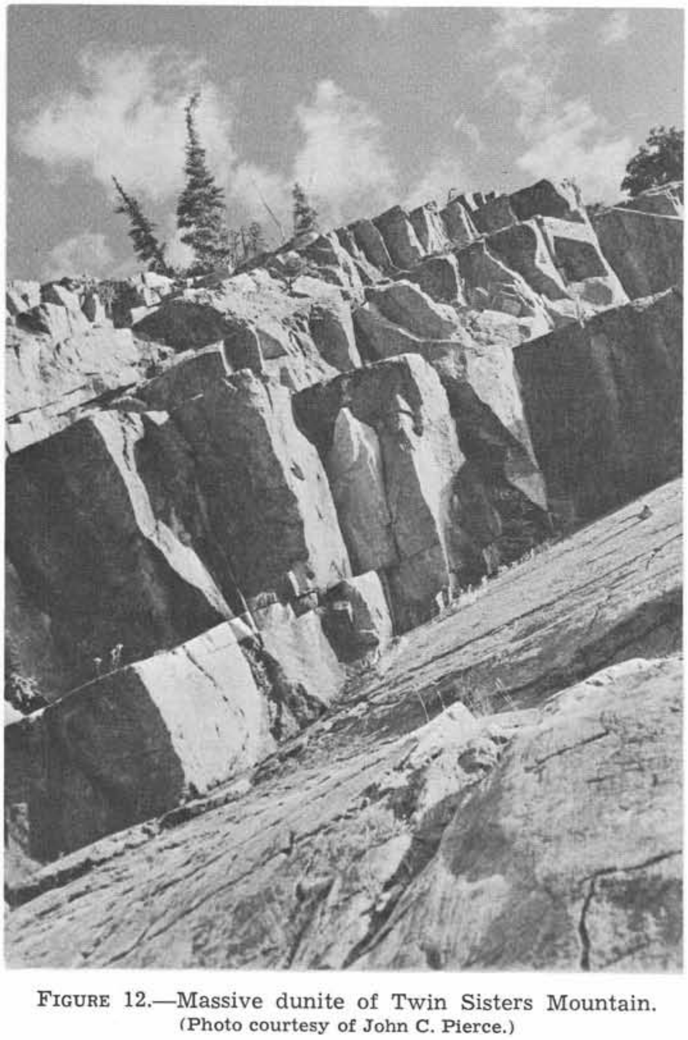

Figure 12.—Massive dunite of Twin Sisters Mountain. (Photo courtesy of John C. Pierce.)

Reserves

It is difficult to comprehend the enormous reserves of olivine in Twin Sisters Mountain. Based on planimetric calculations at 500-foot intervals (from the 2,000-foot contour line to the 5,500-foot contour line), the mass of the mountain is computed to be 12.5 cubic miles. At a density of 3.3 (9.7 cubic feet per ton), the mountain contains about 190,000,000,000 tons of dunite. Assuming that 85 percent of the dunite is free of serpentine, enstatite, chromite, and wall rock inclusions, 160,000,000,000 tons of olivine is present. Of this amount, approximately 80 percent, or 128,000,000,000 tons, is in Whatcom County.

Utilization

It is only natural that a mineral occurrence so vast in size would attract the attention of individuals interested in mineral development. Since the early 1900's the deposit has been considered for its olivine and chromite possibilities. Milnor Roberts (1947) stated that papers written on various phases of the development of the olivine, which are on file at the University of Washington, totaled 773 pages. One of the first investigations of the Twin Sisters dunite was made in 1938, when the olivine and chromite potentials of the deposit were studied under Works Progress Administration Project 7058 (Knowles, 1939). The results of this survey indicate that the character and distribution of the chromite deposits make them unsuited to conventional methods of mining. However, the report expresses a belief that the olivine would become of commercial value if it could be sold as refractory material.

In 1946 H. P. Scheel, of Seattle, mined several thousand tons of olivine from the southeastern end of Twin Sisters Mountain. The olivine was shipped to Harbison-Walker Refractories Co. plants in the East for use in the manufacture of refractory brick. However, a steady market for the olivine failed to materialize. Not until 1956 was a steady market for the olivine established. At that time Northwest Olivine Co., of Mount Vernon, began mining, processing, and marketing foundry sand. From 1957 to date (1966) there has been a steady increase in the market for foundry sand, and Northwest Olivine Corporation (present name) is a major olivine producer in the United States. A few carloads of olivine have been shipped from Skagit County by several small producers. In 1963 the Olivine Corporation, of Bellingham, constructed a grinding plant at Bellingham and began quarrying operations on the northwestern end of Twin Sisters Mountain. This company, which processes olivine for foundry sand, is the only current producer of olivine in the county.

Most olivine mined to date has been used as foundry sand; however, since the early 1930's, research for other possible uses has been undertaken. Other uses include refractories, blast sand, a source of magnesium, and fertilizer by fusion of rock phosphate with olivine. At present (1966) a pilot plant at Bremerton is in operation to determine whether it is economical to produce magnesium chloride from olivine.

Olivine Corporation

The quarry of Olivine Corporation, of Bellingham, Corliss M. Smith, President, is in the SE¼NE¼ sec. 34, T. 38 N., R. 6 E., on the northwestern end of Twin Sisters Mountain (Pl. 2). The quarry is 9 miles east of Acme and 1¼ miles south of the Middle Fork of the Nooksack River. It is at an altitude of about 2,600 feet. Access to the quarry from Welcome Grange on State Highway 542 is by way of Mosquito Lake road south for 10.1 miles to the Nooksack Lookout road. The road to the lookout and well-used logging roads are then followed 11 miles east to the quarry. The quarry is on Puget Sound Pulp and Timber Co. land, which has been leased by Olivine Corporation; the corporation has also staked several mining claims on olivine within the Mount Baker National Forest, which adjoins the quarry.

The quarry site is on the western slope of a N. 15° W.-trending ridge, which is one of several ridges that form the northwestern end of Twin Sisters Mountain. At the quarry an area 200 by 700 feet has been stripped of overburden. On the surface the olivine has weathered to tones of red and brown. At depths of 2 to 8 feet the weathered olivine grades into dark-gray to light-green slightly altered olivine, most of which is highly fractured.

The olivine commonly is holocrystalline and consists of anhedral grains that range from 0.5 millimeter to 5 millimeters in diameter. About 10 percent of the olivine contains disseminated grains of enstatite, chromite, magnetite, and serpentine. Parts of the olivine contain 1- to 2-inch-wide veinlets of enstatite. On the weathered surfaces of the olivine the enstatite appears as well-defined silvery veinlets in the brownish olivine. The chromite in the olivine that is being quarried makes up less than 1 percent of the rock and occurs as dustlike particles and grains as much as 1 millimeter in diameter. Some of the chromite grains exhibit a crude alignment, but for the most part the chromite is irregularly distributed in the olivine.

When operations first started in 1963, talus was mined. However, the company is currently (1966) mining a ledge of solid olivine. Standard quarrying methods of drilling and shooting are used, after which the olivine is loaded into 22-ton dump trucks by means of a DC 6 caterpillar with a front-end loader. The olivine is then trucked 40 miles to the company's plant at Bellingham for processing into olivine sand.

At the processing plant minus 18-inch olivine is crushed in a 15- by 24-inch jaw crusher. The plus ⅝-inch material is conveyed to a 24-inch disc crusher, and the minus ⅝-inch material is dried and fed to a 16- by 24-inch roll crusher. The crushed olivine is screened to produce 14- to 20-mesh material, and 8- to 18-mesh blast sand and 40-mesh foundry sand. Other foundry sand sizes include 70-, 78-, 112-, 130-, and 200-mesh. After sizing, the olivine sand is stored in bins for later bagging into 100-pound paper bags or for bulk shipment. The present plant installation enables a 3-man crew to process 7 tons of 40-mesh olivine sand per hour.

Limestone

Since the early 1900's, limestone has been one of the most important mineral products of the county. Currently (1966), about 500,000 tons of limestone is produced annually from deposits on Red Mountain, north of Kendall, and from deposits north of Maple Falls. Since 1926 the limestone has been used chiefly by the cement and pulp industries of Whatcom County. Production figures are not available for limestone, but a conservative estimate for production from 1912 to 1965 would be in the neighborhood of 10,000,000 tons.

The major limestone deposits are mainly in the western half of the county and are of Devonian, Early Pennsylvanian, and early Permian age. In the eastern part of the county the deposits are small and of Early Cretaceous age. The Devonian limestone deposits consist of small coral reefs and beds of argillaceous limestone and calcareous shale. The Pennsylvanian and Permian limestones form thick lenticular beds that are commonly argillaceous and siliceous. All limestone deposits are associated with argillite, chert, and graywacke or basic volcanic rocks, which are shown as Carboniferous-Permian and Lower Cretaceous rocks on the geologic map of the county (Pl. 1).

Tufa, which is a light, porous limestone that forms in springs, is also present in the county. However, only three deposits, of limited size, are known. In western Whatcom County the tufa crops out on Red and Church Mountains, and in the eastern part of the county it crops out on Lime Creek, near Chancellor. In 1964 a small amount of tufa from the Church Mountain deposit was mined for agricultural purposes, and in the 1930's the Lime Creek tufa was used as flux in a matte furnace at the Azurite mine. However, the production of tufa has been small and insignificant.

In the following brief discussion of the limestone deposits, except for the Kendall quarry, analyses of the limestones are not included under each specific deposit but appear in tabulated form in Table 15, on page 47 of this report. The limestone reserves of the county are given in Table 14, on page 46. Limestone deposits of the county were mapped and described in detail by Danner (1966).

Balfour quarry

Location and accessibility.—The Balfour quarry limestone deposits are in the NE¼ sec. 28, T. 40 N., R. 5 E., 1¼ miles northwest of Kendall, (Fig. 13 and Pl. 2). Two miles north of Kendall a graveled road extends west to the deposits, which are near the base of Sumas Mountain. The lowermost outcrop of limestone is about 100 feet above the floor of Columbia Valley, whereas some limestone is exposed as much as 1,000 feet above the valley floor. Railroad loading facilities are available half a mile east of the deposits, and the rail haul to Bellingham is about 30 miles.

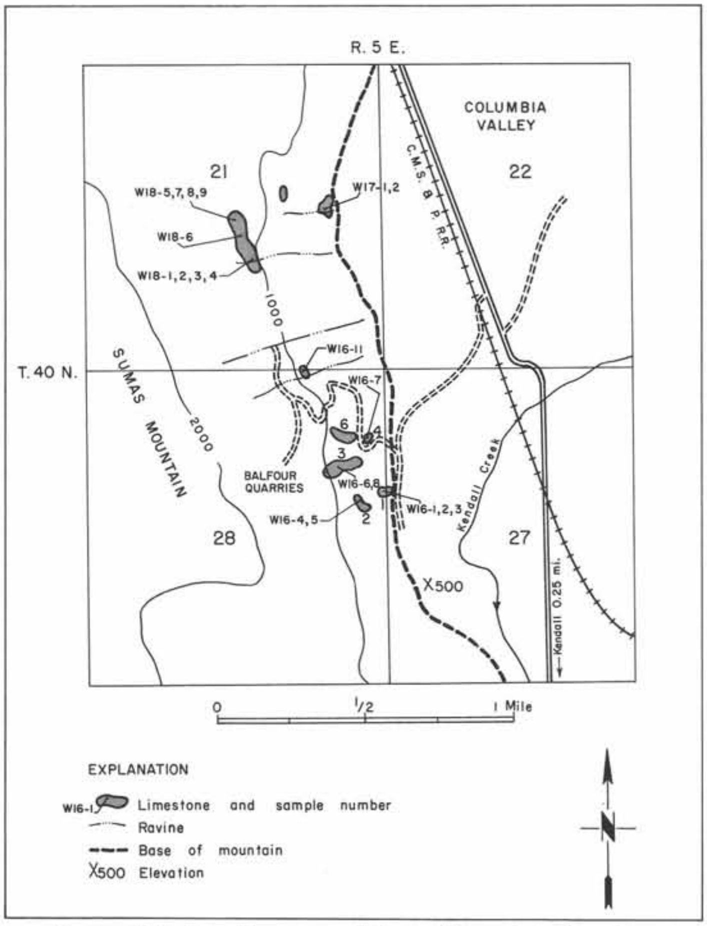

FIGURE 13.—Location map of Sumas Mountain limestone deposits.

Geology.—The quarries are in limestone, which, according to W. R. Danner (written communication, 1960), is of Devonian age. Thick overburden and dense underbrush conceal most of the limestone except where it has been uncovered by quarrying operations.

The limestone is medium to dark gray, fine to coarsely crystalline, and massive to well bedded. It is highly fractured, and recrystallized calcite fills many of the fractures. Coral occurs throughout the limestone but is not abundant. The average strike of the beds is N. 80° E., and the dips range from 50° to 80° S. In places the limestone is highly contorted.

The limestone is interbedded with dark-gray argillite, quartzite, and graywacke that, like the limestone, are highly contorted and fractured. Whether the limestone deposits at the Balfour quarry represent several beds or one bed that has been repeated by folding has not been determined. The beds vary in thickness, but the maximum thickness appears to be about 150 feet. The deposits are as much as 200 feet wide and 400 feet long. Much of the limestone in the larger deposits has been quarried. Samples W16-1 through W16-14 were collected from the quarries and from several outcrops within the area. Figure 13 gives the general locations of these samples.

Development and operation.—The Balfour quarry was operated by The Olympic Portland Cement Co. from 1913 until 1929, at which time the company shifted operations to the Kendall quarry, on Red Mountain. The limestone was mined from four quarries, the highest one being about 300 feet above the valley floor. The limestone was utilized in the manufacture of cement at the company's Bellingham plant. Operations were suspended when the easily mined limestone had been removed. A small tonnage of limestone still remains, but much of it is contaminated with wall rock, and the deposits are too small for large-scale quarrying operations.

Boulder Creek quarry

Location and accessibilty.—The Boulder Creek limestone occurrence is in the W½ sec. 22, T. 40 N., R. 6 E., and is 3 miles northeast of Maple Falls (Fig. 14 and Pl. 2). It is on the west bank of the creek and about 1½ miles upstream from State Highway 1. Two miles of mountain road, the last mile of which has been abandoned, extends from the highway to the limestone deposit. Railroad loading facilities on the Bellingham-Maple Falls line of the Chicago, Milwaukee, St. Paul and Pacific Railroad are available at Maple Falls, a distance of about 4½ miles by road from the deposit. The rail haul is about 35 miles to Bellingham.

Geology.—The limestone crops out in the bottom of the ravine through which flows Boulder Creek, and it forms several impressive outcrops that are known as Marble Peaks. Very little of the limestone on Marble Peaks appears to be in place, but it occurs as piles of limestone blocks. Samples W5-2 through W5-4 were taken from this limestone, which occurs as scattered outcrops for about 1,200 feet along the banks of the creek. An abandoned quarry, now filled with water, is on one of the northernmost outcrops of the limestone. Sample W5-1 was taken from this quarry.

The limestone on Boulder Creek is white to gray, and crystalline. Much of it, especially in the quarry, is highly fractured and contains inclusions of serpentine. The beds in the quarry strike east to northwest and dip 70° N. The limestone in the other outcrops lacks bedding planes. According to Danner (1957), the limestone is of Early Pennsylvanian age. It contains large crinoid stems similar to those found in the Silver Lake and Kendall quarries.

No limestone occurs on the east bank of Boulder Creek; the rocks there are sandstone and conglomerate of the Chuckanut Formation (Upper Cretaceous-lower Eocene), which are in fault contact with the limestone of the west bank. West of the limestone the predominant rocks are highly sheared and contorted argillite, graywacke, chert, and basalt of the Chilliwack Group (upper Paleozoic).

No estimate can be made of the stratigraphic thickness of the limestone in this area. It appears limited in size and probably represents several fault

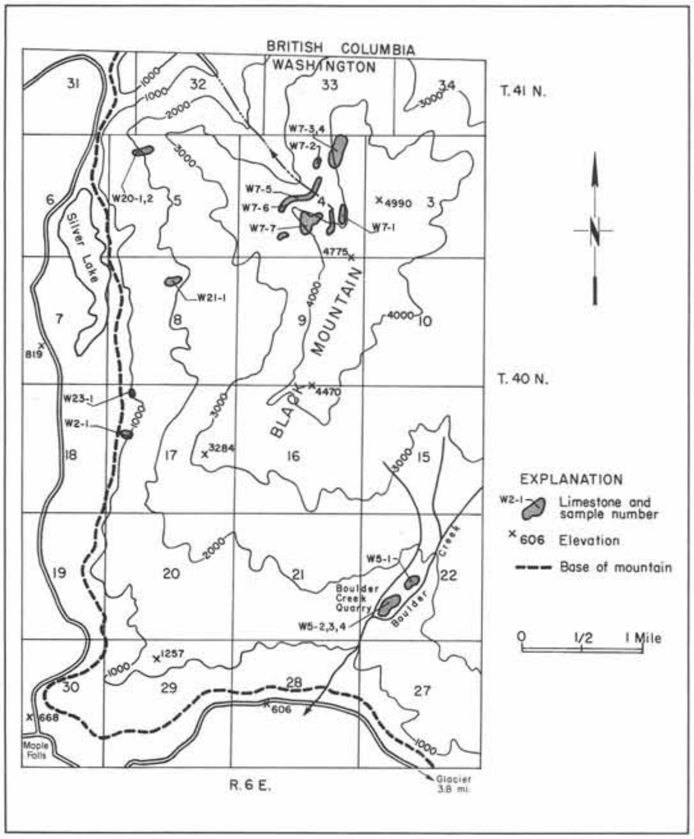

FIGURE 14.—Location map of Black Mountain limestone deposits.

blocks occurring within a fault zone that parallels Boulder Creek. Individual outcrops are as much as 350 feet long and from 50 to 150 feet wide. They occur as small lenticular masses along Boulder Creek for about 2,200 feet, extending from an altitude of 1,560 feet to 1,980 feet above sea level.

Development and operation.—The deposit was operated until 1952 by the Mitchell Bay Lime Co. as the Maple Falls Lime Quarry. During the time of this operation, two small quarries were developed that exposed about 25 feet of limestone in their faces. Most of the limestone was sold as pulp rock to the Puget Sound Pulp and Timber Co., in Bellingham.

Doaks Creek quarry

Location and accessibility.—The Doaks Creek limestone deposit is 1¼ miles north of Maple Falls and is near the center of sec. 19, T. 40 N., R. 6 E. (Fig. 15 and Pl. 2). A quarter of a mile of unimproved road leads to the deposit from a point on the Silver Lake road about 1¾ miles north of Maple Falls. The closest railroad shipping point is Maple Falls, which is about 35 miles by rail from Bellingham.

Geology.—The quarry is in dense to finely crystalline, medium- to dark-gray limestone of Devonian age. Interbedded with the limestone are beds of coral as much as 3 feet thick that are more resistant to weathering than the nonfossiliferous limestone. These beds make the limestone distinctly banded. The general strike of the beds is N. 60° E., and the dips range from 30° to 70° north and south. Outcrops are scarce, and neither the footwall nor the hanging wall of the limestone is exposed. Several poorly exposed outcrops suggest a thickness of at least 200 feet. The maximum lateral extent of the limestone is about 500 feet. Sample W4-1 is representative of the limestone exposed in the face of the quarry.

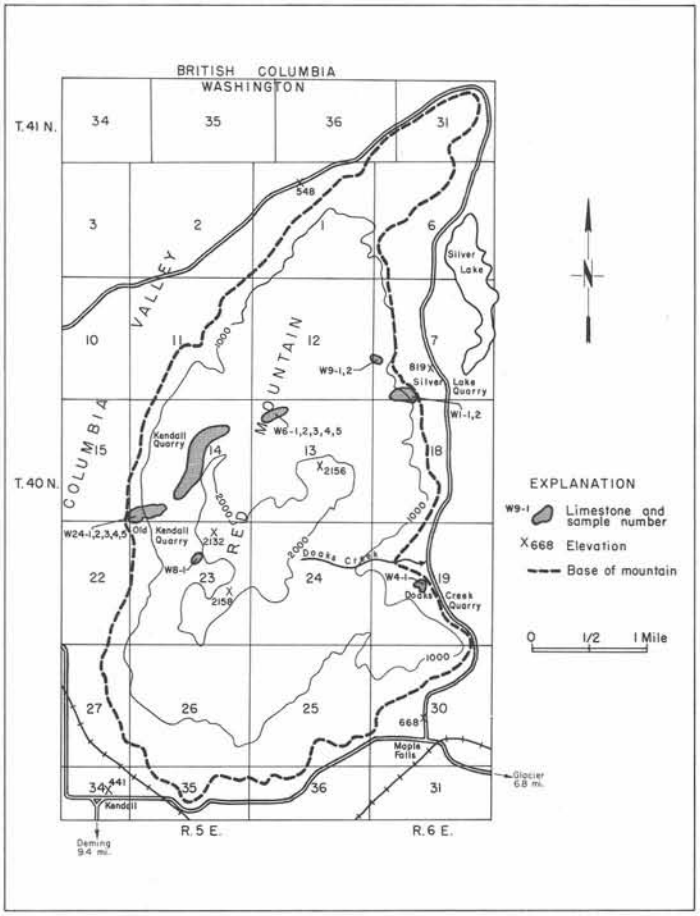

FIGURE 15.—Location map of Red Mountain limestone deposits.

Development and operation.—The quarry is abandoned, but was operated by the Mitchell Bay Lime Co. during 1953 and 1954. The company developed one quarry with a working face about 100 feet long. At its highest point the quarry face is about 40 feet above the floor. After mining, the limestone was trucked to Maple Falls for rail shipment to the Puget Sound Pulp and Timber Co., in Bellingham.

Kendall quarry

Location and accessibility.—The Kendall quarry of the Columbia Cement Co. is 2 miles north of Kendall on the western side of Red Mountain and is near the center of sec. 14, T. 40 N., R. 5 E. (Fig. 15 and Pl. 2).

The quarry floor is at an elevation of 1,760 feet, which is 1,260 feet above the floor of Columbia Valley. A spur of the Chicago, Milwaukee, St. Paul and Pacific Railroad extends to loading facilities at the base of Red Mountain. The rail haul to Bellingham is about 30 miles.

Geology.—The limestone of the Kendall quarry is of Early Pennsylvanian age (Danner, 1957). It is medium to dark gray, dense to crystalline, and massive to well bedded. The limestone is fossiliferous, and some thin beds are composed almost entirely of crinoid columnals. Much of the limestone is intensely fractured, and many fractures have been filled by secondary calcite. Some parts of the limestone are siliceous, whereas other parts of it are high in magnesia. Several lenses of argillite are present in the limestone, and in the north-

A

B

FIGURE 16.—Kendall limestone quarry of the Columbia Cement Company.

A. Quarry as seen from Sumas Mountain; crushing plant at left center of photo.

B. Main quarry face, with a maximum height of 240 feet. (1960 photo.)

ern end of the quarry the limestone contains an interbed consisting of tuffaceous greenish-gray siltstone and a chert pebble conglomerate. The total thickness of this interbed is about 50 feet.

The limestone beds strike northeast, and dips range from 45° to 55° southeast. The limestone is underlain by dark-gray siliceous and cherty argillite and black to dark-brown shale. It is overlain by dark-gray argillite and graywacke that contain interbeds of andesite. Although the maximum thickness of the limestone is not known, exposures in the quarry suggest a thickness of almost 500 feet (Fig. 16). The deposit is almost 4,000 feet long and trends northeast; in width it is 120 to 700 feet (Danner, 1966, p. 213). Except in the vicinity of the quarry, where the limestone has been exposed in quarrying operations or by stripping, a thick cover of underbrush and glacial drift covers the area, making outcrops hard to find.

Two small abandoned quarries are half a mile southwest of the main quarry and at the base of the mountain. The limestone is the same as that in the main quarry but is more intensely sheared and contorted. It appears to have been offset to the west from the limestone in the main quarry by N. 75° E.-trending high-angle faults. The deposit has a northeasterly strike length of 860 feet and is 100 to 300 feet wide. Outcrops in the quarries and on the hillside have a thickness of 425 feet (Danner, 1966, p. 213). Samples W24-1 through W24-5 were collected from outcrops in and adjacent to the old quarry workings.

Chemical analyses of Permanente Cement Company, Red Mountain limestone①

Sample no.	Location	Sample length (feet)	$CaCO_3$ (percent)	$MgCO_3$ (percent)	Loss on ignition (percent)	CaO (percent)	MgO (percent)	SiO_2 (percent)	R_2O_3 (percent)		P_2O_5 (percent)	Alkali (percent)
	Analyses from Permanente Cement Co., E. J. Baldwin, analyst											
Upper quarry area	Upper quarry ..	Average, 1951			39.65	48.65	1.03	9.47	1.52			
	Upper quarry ..	Average, 1952			39.00	48.43	1.36	9.87	1.68			
	Upper quarry ..	Average, 1953			38.70	46.50	1.14	12.75	2.00			
	Upper quarry ..	Average, 1954			37.40	46.06	1.80	13.57	2.32			
	Upper quarry ..	Average, 1955			38.90	47.0	1.29	10.83	1.78			
									Fe_2O_3	Al_2O_3		
	Upper quarry ..	4 months' average in 1959			40.56	48.94	1.51	7.19	0.56	1.26		
	Quarry face, middle	120-ft. hole			42.32	52.62	0.50	3.13	0.46	0.97		
	Quarry face, south	120-ft. hole			42.18	51.61	1.10	3.46	0.46	1.20		
	Quarry face, north	120-ft. hole			37.83	46.11	1.04	11.40	1.15	2.47		
	Quarry face, north	120-ft. hole			31.83	38.38	....	24.20	1.17	3.10		
	Middle north end, deposit..	120-ft. hole			43.13	52.31	1.00	1.77	0.31	1.03		
	Siliceous shale, south				12.63	4.88	2.92	58.32	5.21	15.98		
	Shale, north....				7.05	0.90	....	68.25	6.15	13.20		3–4

①Danner, 1966, p. 218.

Development and operation.—Prior to 1926 the quarry was operated by the International Lime Co. for the manufacture of hydrated lime. After 1926 the quarry was taken over by The Olympic Portland Cement Co. to supply the limestone demands for its cement plant in Bellingham. In 1958 the Permanente Cement Co. purchased The Olympic Portland Cement Co.; however, in 1960 the company was given notice by the Federal Trade Commission that it must sell its operation. In July 1966 the quarry and cement plant at Bellingham were purchased by the Pittsburgh Plate Glass Co., of Pennsylvania, which operates the plant and quarry as the Columbia Cement Co.

The quarry is presently (1966) being operated in 40-foot lifts. The quarry face is about 1,500 feet long and is about 240 feet high at its highest point above the floor (Fig. 16). The limestone is moved from the quarry to railroad storage bins at the base of the mountain by gravity and belt conveyor system. Production is about 500,000 tons of cement rock per year (Conners, 1960, p. 58).

Silver Lake quarry

Location and accessibility.—The Silver Lake limestone deposit is near the SW. cor. sec. 7, T. 40 N., R. 6 E., and is 2½ miles north of Maple Falls (Fig. 15 and Pl. 2). A hard-topped county road extends to Maple Falls from the quarry. At Maple Falls, loading facilities are available on the Chicago, Milwaukee, St. Paul and Pacific Railroad's line to Bellingham, a rail haul of about 35 miles.

Geology.—The quarry is in limestone of Early Pennsylvanian age. The limestone is gray to brownish gray, buff weathering, medium to coarsely crystalline, and greatly jointed. Large clay- and silt-filled cavities commonly occur in the limestone, and white secondary calcite has crystallized along many of the fractures. The beds have a general N. 80° W. strike, and they dip about 45° S. In places the limestone is so intensely contorted and sheared that it is impossible to ascertain the direction of the strike and dip of the beds. The limestone is overlain by greatly sheared argillite and underlain by argillite, graywacke, and volcanic breccia of the Chilliwack Group. Beyond the limits of the quarry the limestone is concealed by a thick cover of overburden and dense underbrush. Samples W1-2 and W1-1 (Table 15, on p. 47) were collected from the quarry face.

At its widest point in the quarry the limestone is about 400 feet from north to south and possibly 175 feet thick. Outcrops to the west and uphill from the quarry indicate that the deposit might extend for at least 1,000 feet in a westerly direction. About 1 mile west of the quarry and near the top of Red Mountain, similar limestone crops out. However, the lack of outcrops between the two deposits makes it impossible to determine whether they represent one continuous bed or two separate limestone lenses.

FIGURE 17.—Silver Lake limestone quarry of the Mitchell Bay Lime Co.

Development and operation.—The limestone is being worked by the Mitchell Bay Lime Co., of Seattle. The operation is confined to one quarry, which begins at the level of the valley floor. When the writer visited the property in 1965, mining was proceeding from a bench about 80 feet above the valley floor (Fig. 17). The quarry face is about 85 feet high. A ¾-yard shovel loads the dump trucks, which haul the limestone to railroad loading facilities at Maple Falls. After shipment to Bellingham, the limestone is used by the Puget Sound Pulp and Timber Company's pulp plant.

Other limestone deposits

In addition to the limestone deposits of the area that either have been or are being mined, there are at least three occurrences that appear to contain moderate to large tonnages. Sumas, Red, and Black Mountains each contain a significant occurrence.

On the northeastern end of Sumas Mountain, near the center of sec. 21, T. 40 N., R. 5 E., limestone of Devonian age is poorly exposed. Part of the limestone is fairly uniform in composition, but much of it contains interbeds of shaly and siliceous limestone. It is similar to the limestone beds in the Balfour quarry, about half a mile to the south, and is probably a northerly extension of these beds. The limestone occurs as scattered outcrops over an area 200 to 300 feet wide and nearly 1,200 feet long, ranging in altitude from 1,200 to 1,800 feet. Many of the small outcrops are less than 30 feet in diameter, whereas the larger outcrops are as much as 50 feet wide and 250 feet long. The average strike of the beds is N. 70° W., and dips range from 30° to 60° S. Exposures of limestone in a creekbed suggest a thickness of at least 200 feet. Samples W18-1 through W18-9, the locations of which are shown in Figure 13 (on p. 40), were collected from several of the outcrops. Although most of the area is poorly accessible, abandoned logging roads extend to within 200 feet of several of the limestone outcrops.

In the NW¼ sec. 13, T. 40 N., R. 5 E., near the top of Red Mountain, limestone of Early Pennsylvanian age is exposed. It is light gray, crystalline, well bedded, and contains numerous fossiliferous beds. The beds of the limestone strike N. 50° E. and dip 60° SE. Most of the limestone is concealed by glacial drift and underbrush, but outcrops indicate a length of about 1,500 feet and a width of 350 feet for the deposit. On the northwest corner of the deposit a cliff of limestone 50 feet high and 150 feet long is well exposed. The limestone appears to be a lens of the Kendall quarry limestone, which crops out less than half a mile to the west. Access to the deposit is by means of a logging road that begins near the north end of Silver Lake. This road passes within 100 feet of the deposit. Samples W6-1 through W6-5 are representative samples of this limestone occurrence (Fig. 15, on p. 41).

Several large deposits of Lower Pennsylvanian and lower Permian limestones are exposed near the summit of Black Mountain. They are mainly in the E½ sec. 4, T. 40 N., R. 6 E. The limestones are similar to those in the Kendall and Silver Lake quarries, except that the lower Permian limestone contains more chert and has a higher magnesia content. The limestone occurs in two main beds, which are interbedded with argillite, graywacke, and conglomerate. The Lower Pennsylvanian limestone has a maximum thickness of 300 feet, and the lower Permian limestone, about 400 feet. At least two other beds occur stratigraphically above the lower Permian limestone, but poor exposures make it impossible to determine their thicknesses.

Except where they form cliffs, the limestone beds are covered by glacial drift. Scattered outcrops indicate that the limestone extends for at least half a mile north-south. It is faulted in several places by high-angle eastward-trending faults that offset the beds and also form the northern and southern boundaries of the deposits. Samples W7-1 through W7-7 were collected from several of the larger outcrops in the area (Fig. 14, on p. 41). Although logging roads at one time extended to within a few hundred feet of most of the limestone outcrops, the roads are not usable, as they are no longer maintained.

Several other limestone deposits occur on Sumas, Red, and Black Mountains, but for the most part they are small deposits of limited tonnage. Also, some of them are so poorly exposed that it is impossible to properly evaluate them without extensive drilling or stripping. A tabulation of these occurrences is given in Table 13.

TABLE 13.—*Miscellaneous limestone deposits*

Deposit	Sample no.	Location	Remarks
		T. 40 N., R. 5 E.	
Hilltop	W19-1, W19-2	NW¼ sec. 9	Devonian limestone as a fault block of limited tonnage. Outcrop area 80 feet by 150 feet.
Sumas Mountain	W17-1, W17-2	SE¼NE¼ sec. 21	Pennsylvanian (?) limestone poorly exposed in road and stream cuts. Argillaceous, siliceous, and dolomitic. Limestone not over 100 feet long and 20 feet wide.
Northwestern Lime Co.	W8-1	SW¼NE¼ sec. 23	Devonian limestone in fault contact with crystalline basement rocks. Outcrop 100 feet long and 50 feet wide.
		T. 40 N., R. 6 E.	
German No. 1	W2-1	SW¼NW¼ sec. 17	Small outcrop of dense gray limestone. Poorly exposed, but may contain small tonnage.
Silver Lake No. 2	W9-1, W9-2	NW¼SW¼ sec. 7	Dense gray limestone containing chert and argillite. Poorly exposed on steep hillside, but could produce small tonnage.
Northwest Black Mountain No. 2	W20-1, W20-2	N½NW¼ sec. 5	Argillaceous limestone containing interbedded shale, sandstone, and conglomerate. Not of commercial value. Age unknown.
Northwest Black Mountain No. 1	W21-1	NW¼NE¼ sec. 8	Several small outcrops of Devonian limestone. Largest outcrop not over 50 feet long.
German No. 2	W23-1	NE¼NW¼ sec. 17	Poorly exposed medium-gray crystalline limestone. Outcrop 150 feet long and 50 feet wide.

About 1½ miles north of Glacier, limestone is exposed in roadcuts along a logging road. The limestone is in the N½SE¼ sec. 32, T. 40 N., R. 7 E., on the southern slope of Church Mountain at an altitude of 2,600 feet. At least three roadcuts expose limestone in sheared and contorted argillite, siltstone, chert, and greenstone of possible Devonian age. The limestone is thin bedded, gray, and crystalline; it is 12 to 20 feet wide and crops out for about 300 feet. Samples W12-1, W12-2, and W13-1 are representative samples of this deposit.

On Ridley Creek, 4½ miles southwest of Mount Baker, limestone forms several extensive outcrops. The limestone is exposed in a creekbed in the SE¼SE¼ sec. 3, T. 37 N., R. 7 E., and also on Park Butte trail in the NE¼NE¼ sec. 10, T. 37 N., R. 7 E. Altitudes range from 3,000 feet on the lowest limestone outcrop to 4,000 feet on the highest. The limestone, which is Early Pennsylvanian in age, is in argillite of the Chilliwack Group. According to Walter Gonnason, who has staked mining claims on the limestone, the largest outcrop is 2,200 feet long and has a maximum width of 400 feet. Reserves are estimated at 20 million tons. Analyses of the limestone are reported by Gonnason as follows:

	Gonnason No. 1 (percent)	*Gonnason No. 2 (percent)*	*Gonnason No. 3 (percent)*
SiO_2	0.13	0.67	0.12
Fe_2O_3	0.13	0.22	0.25
Al_2O_3	0.56	0.62	0.61
CaO	55.22	53.97	54.67
MgO	0.24	0.90	0.27
Loss on ignition	43.17	43.44	43.63
Na_2O	0.01	0.01	0.00
K_2O	0.00	0.01	0.00
$CaCO_3$	98.60	98.20	98.0

Limestone is exposed along the Dock Butte trail 3 to 5 miles west of Baker Lake and near the Skagit County line. In the NE¼NE¼ sec. 33 and NW¼NW¼ sec. 34, T. 37 N., R. 8 E., and at altitudes that range from 3,250 to 3,420 feet, the limestone crops out as five belts that are as much as 30 feet wide and 200 feet long. The limestone, which is associated with shales and volcanic rocks of the Chilliwack Group, is bluish gray, sugary textured, and high in silica (Danner, 1966, p. 260). Limestone from sec. 33 is represented by analyses W29-1 through W29-5.

About 1 mile southwest of the above-mentioned limestone, between Blue Lake and Dock Butte, limestone crops out over an area of about ¼ square mile. The outcrop area is in the SW¼ sec. 32, T. 37 N., R. 8 E., and at altitudes of 4,400 to 4,900 feet. The limestone, which is interbedded in shale and basic volcanic rocks, is light gray and finely crystalline and forms outcrops as much as 200 feet wide and 300 feet long (Danner, 1966, p. 263). Samples W27-1 and W28-1 through W28-4 are representative samples from several outcrops in the area.

Tufa deposits

The Church Mountain tufa deposit is 1½ miles northeast of Glacier, near the center of sec. 33, T. 40 N., R. 7 E. The tufa crops out in the bed of a small creek flowing down the southern slope of Church Mountain and is at altitudes of 1,300 to 1,750 feet. The deposit, which averages 2 feet in thickness and ranges from 10 to 20 feet in width, is exposed for about 500 feet along the bed of the stream. The tufa is brownish yellow to buff, crumbly, and forms irregular masses and hard layers. Sample W25-1 represents the tufa from this deposit. In 1964 Fred Burr, owner of the property, mined several tons of the tufa for agricultural purposes, but at present (1966) the property is idle.

The Silver Lake tufa deposit is 4 miles north of Maple Falls and is on the northeastern end of Red Mountain. The deposit is in the NW¼SW¼ sec. 7, T. 40 N., R. 6 E., on land owned by Oliver Ferry. It consists of argillaceous tufa that is creamy white in color. The deposit appears to be small and is less than 6 inches thick (Danner, 1966, p. 438). It contains more silica and less calcium than the Church Mountain tufa. Representative samples of the Silver Lake tufa are W10-1 and W10-2.

The Lime Creek tufa deposit is in the eastern part of the county, in the NW¼ sec. 32, T. 38 N., R. 17 E. Lime Creek, which is a tributary to Slate Creek, is crossed by the Harts Pass-Chancellor road about 1 mile southeast of Chancellor. At Lime Creek a roadcut exposes creamy white crumbly tufa for about 150 feet along the road and to a maximum depth of 10 feet. The tufa can be traced upstream for about 100 feet, but for the most part it is covered by vegetation. Because of the inaccessibility of the deposit, no attempt has been made to develop it. However, as mentioned earlier in this report (on p. 39), a small amount of the tufa was used in the early 1930's as flux in a matte furnace at the Azurite mine.

Reserves

Danner (1966, p. 57) has estimated the limestone reserves of Whatcom County at about 121,524,500 tons. Four deposits contain 20 to 50 million tons, two deposits contain 2 to 4 million tons, and two deposits contain 200 to 250 thousand tons. The rest of the deposits contain less than 25 thousand tons each. A listing of the limestone reserves for specific properties is given in Table 14.

TABLE 14.—*Limestone reserves of Whatcom County*①

Deposit	Development	Use	Reserves (tons)
WHATCOM COUNTY			
Boulder Creek	Quarried	Pulp rock	±5,000
Columbia Cement, Kendall quarry	Operating	Cement rock	+50,000,000
Red Mountain	Undeveloped	....	+2,000,000
Silver Lake No. 1	Operating	Pulp rock	±4,000,000
Silver Lake No. 2	Undeveloped	....	±200,000
Balfour No. 1	Exhausted	Cement	±1,000
Balfour No. 2	Exhausted	Cement	±1,000
Balfour No. 3	Exhausted	Cement	±1,000
Balfour No. 4	Exhausted	Cement	±1,000
Balfour No. 5	Undeveloped	....	−500
Balfour No. 6	Undeveloped	....	±20,000
Hilltop	Undeveloped	....	±1,000
Sumas Mountain No. 1	Undeveloped	....	±1,000
Sumas Mountain No. 2	Undeveloped	....	±20,000,000?
Northwestern Lime Co. North	Undeveloped	....	±25,000
Doaks Creek	Operating	Pulp rock	250,000
German No. 1	Undeveloped	....	±1,000
German No. 2	Undeveloped	....	±10,000
Northwest Black Mountain No. 1	Undeveloped	....	±1,000
Northwest Black Mountain No. 2	Undeveloped	....	±1,000
Dock Butte	Undeveloped	....	Unknown
Black Mountain	Undeveloped	....	+25,000,000
Church Mountain	Undeveloped	....	±5,000
Ridley Creek	Undeveloped	....	20,000,000
		Whatcom County total	±121,524,500

①Danner, 1966, p. 57.

Chemical Analyses

During the course of the investigation of the county's mineral resources the writer made no attempt to sample any of the limestone deposits. All sampling was done by W. R. Danner in connection with the preparation of his report on the limestone resources of western Washington (Danner, 1966).

The analyses of Danner's samples are included in this report to give the reader a general idea of the composition of the different limestone deposits. Figures 13, 14, and 15 show the locations of the deposits from which the samples were taken.

TABLE 15.—*Chemical analyses of Whatcom County limestone*①

Sample no.	Loss on ignition (percent)	SiO_2 (percent)	$R_2O_3$② (percent)	CaO (percent)	MgO (percent)	P_2O_5 (percent)	Remarks
Silver Lake Quarry (SW¼ sec. 7, T. 40 N., R. 6 E.)							
W 1–1	39.72	10.22	0.89	45.54	3.26	0.024	Lower quarry face
2	43.62	0.50	0.18	54.79	0.84	0.030	Upper quarry face
Balfour Quarries (NE¼ sec. 28, T. 40 N., R. 5 E.)							
W16–1	41.90	3.81	0.96	52.75	0.28	0.004	Quarry No. 1
2	38.54	11.25	0.97	48.43	0.36	0.009	Do
3	42.70	2.16	0.64	54.19	0.18	0.010	Do
4	41.13	5.50	0.93	51.88	0.31	0.004	Quarry No. 2
5	37.80	11.87	2.00	47.55	0.46	0.023	Do
6	39.04	9.43	1.43	49.19	0.47	0.026	Quarry No. 3
7	42.67	2.43	0.47	53.96	0.26	0.010	Quarry No. 4
8	42.60	2.72	0.72	53.68	0.15	0.012	Quarry No. 3
9	42.32	2.76	0.84	53.15	0.46	0.008	Do
10	42.73	2.06	0.62	54.05	0.23	0.007	
11	40.25	7.33	1.05	50.98	0.10	0.010	Outcrop (NW¼NE¼ sec. 28, T. 40 N., R. 5 E.)
12	40.68	6.25	1.22	51.43	0.18	0.006	Quarry No. 6
13	39.84	8.84	0.71	50.38	0.14	0.008	Do
14	42.32	2.28	0.71	53.75	0.45	0.004	Do
Boulder Creek Quarry (NW¼ sec. 22, T. 40 N., R. 6 E.)							
W 5–1	42.97	0.67	0.32	55.63	0.16	0.200	Quarry
2	43.12	0.37	0.26	55.71	0.10	0.248	Outcrops south of quarry
3	43.37	0.09	0.09	55.33	0.19	0.150	Do
4	43.10	0.40	0.37	55.36	0.19	0.209	Do
Doaks Creek Quarry (Center sec. 19, T. 40 N., R. 6 E.)							
W 4–1	42.57	2.43	0.55	53.89	0.31	0.010	Across face
Kendall Quarries (SW¼ sec. 14, T. 40 N., R. 5 E.)							
W24–1	39.65	8.74	0.97	49.74	0.77	0.024	Old lower quarry (SW¼ SW¼ sec. 14, T. 40 N., R. 5 E.)
2	33.60	20.96	2.91	41.01	1.20	0.034	Do
3	36.90	14.90	0.86	45.75	1.08	0.026	Do
4	35.56	17.27	2.30	43.52	1.03	0.049	Streambed east of old quarry
5	43.22	2.56	0.38	50.79	2.92	0.020	Streambed northeast of old quarry
Red Mountain Limestone (NW¼NW¼ sec. 13, T. 40 N., R. 5 E.)							
W 6–1	42.26	3.68	0.68	52.24	1.15	0.022	East end
2	39.74	8.75	2.85	50.10	0.32	0.024	Do
3	39.84	7.45	0.44	49.78	0.52	0.023	North center face
4	35.60	18.66	0.73	44.52	0.53	0.035	West end
5	42.72	2.57	0.83	53.21	0.81	0.030	Do
Red Mountain Limestone (SW¼NE¼ sec. 23, T. 40 N., R. 5 E.)							
W 8–1	39.84	8.52	1.08	50.16	0.31	0.011	Outcrop on logging road
Red Mountain Limestone (NW¼SW¼ sec. 7, T. 40 N., R. 6 E.)							
W 9–1	40.70	7.70	1.48	50.08	0.46	0.050	West end
2	39.97	8.16	1.66	49.78	0.55	0.049	East end

(See footnotes at end of table, p. 49.)

TABLE 15.—*Chemical analyses of Whatcom County limestone*[1]—Continued

Sample no.	Loss on ignition (percent)	SiO_2 (percent)	R_2O_3[2] (percent)	CaO (percent)	MgO (percent)	P_2O_5 (percent)	Remarks
Sumas Mountain, northeast end (Center sec. 21, T. 40 N., R. 5 E.)							
W18– 1	40.44	7.16	0.90	50.73	0.46	0.008	Upper part of beds in creek
2	40.20	6.91	1.72	50.22	0.62	0.009	Lower part of beds in creek
3	26.12	33.61	7.45	32.67	0.15	0.072	Composite sample of beds in creek
4	41.92	2.61	1.46	53.53	0.23	0.008	Outcrop north of creek
5	42.69	2.41	0.71	53.89	0.21	0.005	North end of outcrop
6	43.60	2.27	0.94	52.19	1.31	0.007	East side of deposit
7	43.10	1.48	0.52	54.47	0.18	0.090	North end of outcrop
8	43.45	0.26	0.16	55.27	0.20	0.004	Do
9	42.21	3.15	1.03	53.33	0.14	0.007	Do
Sumas Mountain, northeast end (SE¼NE¼ sec. 21, T. 40 N., R. 5 E.)							
W17– 1	43.89	6.67	0.54	28.18	20.85	0.016	Outcrop on logging road
2	38.47	17.04	0.99	30.26	13.76	0.020	Outcrop along creek
Black Mountain (NE¼NW¼ sec. 17, T. 40 N., R. 6 E.)							
W23– 1	40.83	6.49	0.82	51.36	0.12	0.016	Outcrop along logging road
Black Mountain (N½NW¼ sec. 5, T. 40 N., R. 6 E.)							
W20– 1	35.70	15.72	2.65	44.33	0.69	0.066	Most favorable looking bed
2	24.52	37.38	6.62	29.50	1.74	0.013	Composite of several beds
Black Mountain (NW¼NE¼ sec. 8, T. 40 N., R. 6 E.)							
W21– 1	39.32	9.70	0.77	49.73	0.21	0.014	Along strike of outcrop
Black Mountain (Sec. 4, T. 40 N., R. 6 E.)							
W 7– 1	44.33	2.05	1.02	44.02	7.76	0.026	SE¼ sec. 4
2	38.34	11.01	1.63	48.52	0.40	0.018	NE¼ sec. 4
3	27.72	34.53	2.70	34.04	1.08	0.046	Do
4	43.72	2.72	0.57	47.57	5.70	0.019	Do
5	41.66	4.51	0.91	52.59	0.34	0.010	SW¼ sec. 4
6	42.84	1.90	0.60	54.29	0.28	0.018	Do
7	37.28	14.70	0.47	47.17	0.20	0.012	Do
Black Mountain (SW¼NW¼ sec. 17, T. 40 N., R. 6 E.)							
W 2– 1	42.39	3.04	0.52	53.69	0.30	0.010	Site of old quarry
Hilltop (NW¼ sec. 9, T. 40 N., R. 5 E.)							
W19– 1	40.43	6.95	1.09	50.79	0.44	0.030	East-west on outcrop
2	41.32	5.05	0.82	51.95	0.55	0.021	North-south on outcrop
Church Mountain, southwest end (N½SE¼ sec. 32, T. 40 N., R. 7 E.)							
W12– 1	42.69	2.43	0.71	53.71	0.22	0.056	
2	42.77	2.25	0.75	54.02	0.25	0.009	
W13– 1	42.85	1.72	0.94	54.12	0.25	0.009	
Dock Butte area (NE¼NE¼ sec. 33, T. 37 N., R. 8 E.)							
W29– 1	40.26	7.34	0.97	50.41	0.30	0.026	
2	41.71	4.10	0.75	52.43	0.18	0.022	
3	42.09	3.30	0.67	53.33	0.22	0.022	
4	42.40	2.72	0.43	53.18	0.18	0.014	
5	41.01	5.27	1.35	50.93	1.05	0.022	
Dock Butte area (SW¼ sec. 32, T. 37 N., R. 8 E.)							
W27– 1	42.91	0.61	0.25	55.79	0.24	0.013	
W28– 1	43.53	0.35	0.30	54.83	0.19	0.020	
2	43.06	0.88	0.60	54.68	0.19	0.019	
3	43.48	0.41	0.34	54.90	0.15	0.025	
4	27.90	28.89	6.48	34.75	0.96	0.068	
Tufa							
Church Mountain, southwest end (Center sec. 33, T. 40 N., R. 7 E.)							
W25– 1	44.25	0.29	0.21	54.61	0.10	0.006	

(See footnotes at end of table, p. 49.)

TABLE 15.—*Chemical analyses of Whatcom County limestone*①—Continued

Sample no.	Loss on ignition (percent)	SiO_2 (percent)	$R_2O_3$② (percent)	CaO (percent)	MgO (percent)	P_2O_5 (percent)	Remarks
Silver Lake area (NW¼SW¼ sec. 7, T. 40 N., R. 6 E.)							
W10– 1	35.70	21.15	5.56	36.38	0.49	0.017	
2	41.04	8.04	1.94	48.32	0.40	0.018	
Lime Creek (NW¼ sec. 32, T. 38 N., R. 17 E.)							
③W 7–65-24A	36.70	0.35	0.82	53.8	1.22	0.020	

①Danner, 1966, p. 213-264. Analyses by Clarence S. Homi, Division of Industrial Research, Institute of Technology, Washington State University, Pullman, Wash.
②R_2O_3—Combined Fe_2O_3 and Al_2O_3.
③Sampled by Washington Division of Mines and Geology, 1965. Analysis by Bennett Laboratories, Tacoma, Wash.

Clay

Since the early 1900's, clay has been mined sporadically in Whatcom County for use in common brick and tile, for the manufacture of portland cement, and for fire brick and other heat-resistant ware. However, throughout the years there has been a steady decline in the mining of clay until at present (1966) clay is mined only by one small brick and tile operation near Everson and by the Columbia Cement Co., of Bellingham.

Most of the common brick that was produced in the Bellingham area came from brickyards that operated from 1910 to 1920 and utilized deposits of glacial clay. Near downtown Bellingham, J. F. Miller & Bros. operated a brickyard near Ellis and Gladstone Streets. J. R. Headrick & Co. also produced common brick in the Bellingham area and operated a brickyard at the intersection of Moore and Potter Streets. At Grandview Station, in South Bellingham, the Coast Clay Co. produced front brick and tile from shales of the Chuckanut Formation. Northeast of Bellingham, in the Sumas area, fire clays were discovered in the early 1900's, and the deposits were operated until as late as 1949. The companies that mined fire clays were the Sumas Fire Brick Co., Denny-Renton Clay & Coal Co., and Gladding, McBean & Co. North of Everson, near Hampton, common brick and tile were produced in the 1930's by the Hampton Brick and Tile Co. and in the early 1950's by Lynden Clay Products, Inc. In 1960, Lynden Clay Products, Inc., under new management, resumed operations and is currently producing small amounts of drain tile. The most continuous clay mining operation in the county is that of the Columbia Cement Co.; since 1912, glacial clay from its Brennan pit, 3½ miles northwest of Bellingham, has been used in the manufacture of cement.

Production figures for clay are not available; however, a conservative estimate for the production of clay in Whatcom County from 1900 to 1965 is in the neighborhood of $1,000,000.

The clays of the county are classified as "common" and "fire." Common clays fuse below pyrometric cone 12 and fire red. They are not refractory because of their high content of lime, magnesia, and iron. Fire clay is capable of withstanding high temperatures and usually is not fusible below about 3,000° F. (pyrometric cone 27 or 28). The refractoriness of fire clay depends largely on the alumina content. In general, fire clay contains more alumina (Al_2O_3) and less ferric oxide (Fe_2O_3) and lime (CaO) than does common clay.

Common Clay

The deposits of common clay in the county are mainly of glacial origin and are related to the last continental glacier that covered the area. The deposits represent accumulations of fine-grained material that was deposited by melt waters of the glacier, mainly during its advancing stage. As such, they differ from high-grade clays in that they are the result of attrition rather than weathering and decomposition.

Fresh glacial clays are dark to light blue when damp, and light gray when dry. When weathered, the clays are buff or brown. Sandy or silty phases of the clays are not uncommon, and in some places pebbles are scattered throughout the clays or form thin beds or lenses. Individual clay beds vary in thickness from several inches to as much as 235 feet and may cover several acres; the largest deposits occur in Whatcom Basin. Outside the basin, common clay is associated with glacial deposits that occur in the largest valleys. Although very few of the clay beds crop out, many wells that have been drilled in Whatcom Basin have penetrated beds of clay. Data from 98 wells (Newcomb and others, 1949, p. 93-131) show clay beds as much as 235 feet thick to depths of 366 feet. Wells that contain clay beds within 25 feet of the surface are listed in Table 16.

Chemical analyses are not available for most glacial clay deposits of the county. The analyses in Table 17 are presented only to give the general composition of several glacial clays. According to Glover (1941, p. 51), incipient fusion appears at approximately cone 02, with complete fusion between cones 2 and 6. The fired color of most glacial clays varies from buff brown to dark red.

TABLE 16.—*Glacial clay deposits of Whatcom Basin*

Well no. 1/	Depth to top of clay bed (feet)	Thickness of clay bed (feet)	Properties of the clay
38/3 - 1Q2	0	36	Yellow
38/3 - 5C1	10	36	Blue
38/3 - 10G3	2	103	Yellow and blue, hard
38/3 - 20L1	1	185	Yellow, hard; blue
38/3 - 22K1	1	15	Yellow, sticky
39/1 - 28M1	0	25	------------------
39/2 - 20C1	4	7	------------------
39/3 - 14D1	3	19	------------------
39/3 - 19E1	2	24	Gray, blue
39/3 - 32P1	2	41	Yellow, blue
40/2 - 4A1	0	15	Blue
40/4 - 19Q1	12	12	Blue
40/4 - 28F1	9	10	Blue
41/1 - 31Q1	14	159	Yellow, blue
*38/2	25	4	------------------
*38/2	20.5	4.5	------------------
39/1 - 34A1	50	50	------------------
38/3 - 5H1	20	50	------------------
38/3 - 9H1	20	11	Blue
38/3 - 10G2	3	86	Blue
38/4 - 6K1	0	38	Blue
39/1W - 13R1	24	98	Blue, sticky
39/1 - 1L1	15	47	Blue
39/1 - 1N1	13	60	Blue
39/1 - 6E1	9	132	------------------
39/1 - 6J1	20	135	Blue, sticky
39/1 - 11D1	12	41	Blue
39/1 - 11H1	7	156	Blue
39/1 - 18E1	23	91	Blue, sticky
39/1 - 26B1	0	50	Blue
39/1 - 29B2	20	190	Blue, sticky
39/1 - 34A1	0	50	------------------
39/2 - 7N1	0	57	Blue
39/2 - 8E1	24	31	Blue
39/2 - 19P1	20	41	Blue
39/2 - 20C1	23	73	------------------
39/2 - 20C2	14	63	Blue, hard and soft
39/2 - 24R1	15	20	Blue
39/2 - 30C1	20	45	Blue
39/2 - 30L1	20	50	Blue
39/2 - 31H1	17	155	Blue
39/2 - 36J1	10	40	Blue
39/2 - 36R1	0	49	Blue
39/3 - 33D1	12	68	Blue
39/4 - 31Q1	14	35	Blue, soft; gray, hard
39/4 - 32K1	12	39	Blue
39/4 - 33C1	12	48	Blue
39/4 - 34D1	22	39	Blue
41/1 - 1L1	17	83	Blue
40/1 - 4Q2	13	46	Blue
40/1 - 17P1	0	40	------------------
40/1 - 31N1	19	201	Blue, sticky
40/1 - 33P1	22	20	Blue, sticky
40/2 - 6E1	16	235	Blue
40/3 - 13Q1	2	178	Blue
40/4 - 10D1	14	15	Blue
40/4 - 22H1	12	61	Blue
41/2 - 31P1	23	137	Blue
41/2 - 33N1	21	233	Blue, sticky

1/ Well-numbering system is as follows:

First number is township;
Second number is range east unless followed by W, which means range west;
Number after hyphen is section;
Letter designates 40-acre tract within section, which is subdivided as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Last number is the serial number of the well or spring.

* Bellingham Coal Mines Co. core holes.

TABLE 17.—*Analyses of selected glacial clays*

Sample location			SiO_2 (percent)	Al_2O_3 (percent)	Fe_2O_3 (percent)	CaO (percent)	MgO (percent)	Loss on ignition (percent)	Reference no. ①
Sec.	Tp.	R.							
9	40 N.	5 E.	59.92	17.85	7.31	6.08	3.15	5.42	1
34	40 N.	5 E.	54.16	14.97	7.91	2.62	4.15	13.46	1
33	39 N.	2 E.	58.20	18.17	6.95	3.47	3.28	6.00	2
24	38 N.	2 E.	55.34	15.75	6.43	6.49	3.54	8.98	3

①1. Shedd, 1914, p. 214.
2. Glover, 1941, p. 352-353.
3. Charles Marriott, chemist, The Olympic Portland Cement Co., 1965.

Brennan pit

This clay pit is operated by the Columbia Cement Co. to supply its needs for alumina in the manufacture of cement. The pit, which is on a main line of the Great Northern Railway, is 5 miles northwest of Bellingham and is in the SW¼ sec. 33, T. 39 N., R. 2 E. At Brennan "siding" a short spur line leads to the clay pit, which is immediately west of the main line. A self-propelled rail-mounted dragline shovel is used to remove clay from the pit and load it into gondolas. Currently (1966) the pit is about 1,800 feet long, 700 feet wide at its widest point, and about 30 feet deep. When the writer visited the pit in 1965, clay was not being mined, as other sources were being utilized temporarily.

The clay at the Brennan pit is a typical glacial clay that is common to many parts of Whatcom Basin. It is bluish gray when fresh but turns buff upon weathering. In addition to silty phases, the clay contains some pebbles. The depth of the clay bed at the site of the pit is not known to the writer, but ¾ mile north of the pit, a well penetrated 200 feet of clay. According to Glover (1941, p. 352-353), an analysis of clay from the Brennan pit is as follows:

SiO_2 (percent)	Al_2O_3 (percent)	Fe_2O_3 (percent)	CaO (percent)	MgO (percent)	Loss on ignition (percent)
58.20	18.17	6.95	3.47	3.28	6.00

Hampton pit

This pit, which currently (1966) is being operated by Lynden Clay Products, Inc., is in the NE¼SE¼ sec. 24, T. 40 N., R. 3 E., and is 1½ miles north of Everson. Hampton, a railroad siding on a branch line of the Chicago, Milwaukee, St. Paul and Pacific Railroad, is ½ mile east of the property.

At one time the property was operated as the Hampton Brick and Tile Co. and produced common brick and tile; however, recent operations have been confined to the manufacture of drain tile. During early operations the brick and tile were fired in a beehive kiln, but currently a small natural gas-fired tunnel kiln is being used. This kiln has a capacity of about 50 tiles per firing.

Glacial silt and clay, which are used in the manufacture of tile, come from a small open cut immediately west of the buildings that house the tile plant. The silt and clay are thinly bedded, buff colored, and contain thin seams of vegetal matter. In places the clay is sandy and contains sparsely scattered pebbles. When fired, the clay becomes red.

Fire Clay

In 1959 the fire clay deposits of the Sumas area were investigated by the writer (Moen, 1962, p. 67-85). The discussion on fire clays that follows has been taken from this earlier report.

"Fire clay" refers to clays that are capable of withstanding high temperatures and usually are not fusible below about 3,000° F. (pyrometric cone 27 or 28). The clays are used chiefly for fire brick or other heat-resisting clay products. Fire clay is also used in the production of floor tiles and sanitary ware, terra cotta, conduits, pressed and paving bricks, portland cement, and plaster.

The presence of fire clays in the Sumas area of Whatcom County has been known since the early 1900's, and mining of the deposits was undertaken intermittently until 1949. The Denny-Renton Clay & Coal Co. and the Sumas Fire Brick Co. were the major producers until 1925, at which time the mining was taken over by Gladding, McBean & Co., one of the State's leading producers of brick and tile. Production figures are not available for all the years, but between 1922 and 1949 there was mined 53,418 tons of clay having a value of $151,000. In 1966 none of the clay deposits were being mined.

Location.—The largest known fire clay deposits in Whatcom County are confined to an area on the southwest end of Vedder Mountain, about 3 miles southeast of Sumas. About 5 miles north of these deposits, in British Columbia, similar fire clays occur on Canadian Sumas Mountain. These are the only true fire clays known in British Columbia (Cummings and McCannon, 1952, p. 19).

The locations of the fire clay deposits of the Sumas area are shown in Figure 18. At Area No. 1, approximately 525 feet of clay-bearing Tertiary sedimentary rocks have been cut by Saar Creek. Area No. 2, which is about 1 mile east of the No. 1 location, contains several clay strata in the bed of Saar Creek. These outcrops are small and poorly exposed. Area No. 3, the site of the abandoned Gladding, McBean clay mine, is underlain by about 220 acres of Tertiary sedimentary rocks. Although the rocks are poorly exposed, it is probable that there is present at this locality at least 200 feet of the basal part of the Tertiary section that includes the fire clays. At Area No. 4, fire clay crops out, but the clay is so poorly exposed that little is known about this occurrence.

The four areas shown in Figure 18 contain the only known deposits of fire clay in the area covered by this report. Other occurrences may be present, but because of a thick cover of overburden and dense brush no outcrops have been found.

Conditions of deposition.—During the early Tertiary period a sequence of conglomerate, sandstone, siltstone, and shale was deposited upon a basement of considerable relief. The basement complex in the vicinity of the fire clay deposits consists of folded and faulted argillite, quartzite, graywacke, and altered basic igneous rocks. These rocks for the most part are of Paleozoic age; however, some rocks of Mesozoic age are also present.

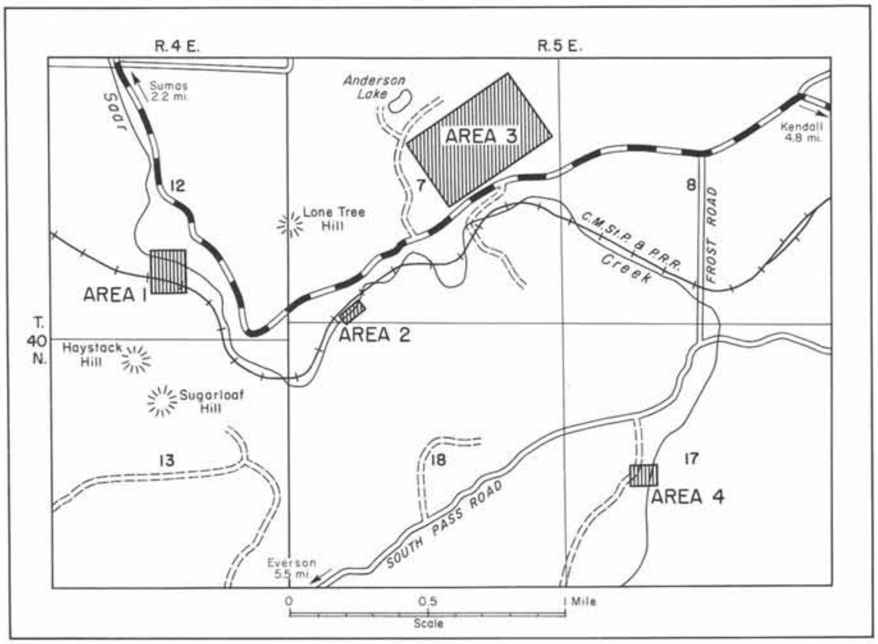

FIGURE 18.—Location map of fire clay deposits.

The Tertiary sedimentary rocks represent continental sediments that accumulated on a shallow coastal plain. It is probable that some of the shales, such as those associated with the fire clays, accumulated in a moderately deep basin. Unlike most of the lower Tertiary sedimentary rocks, which contain very little shale and large amounts of siltstone and sandstone, the rocks of the Sumas area contain much shale. Most of the material appears to have been derived from rapidly eroding landmasses to the east that consisted mainly of granitic rocks. Since the deposition of these sediments the area has been uplifted, faulted, and subjected to erosion. Within the area of the fire clay deposits, a few isolated masses are all that remain of a former continuous sequence of sediments.

Within the map area the clays occur as transported materials that were deposited about 100 feet or more stratigraphically above the basement rocks. In Canada, 5 miles to the north, near Kilgard, similar fire clay deposits are associated with intensely weathered plutonic basement rocks. The basement is kaolinized as much as 70 feet deep in places (Cummings and McCannon, 1952, p. 19). It is probable that the Sumas fire clays were derived from this or a similar area. The only probable source of the clays in the map area is a dacitic body in the NE¼ sec. 7, T. 40 N., R. 5 E. However, this rock in known exposures appears to be resistant to weathering and shows no signs of kaolinization.

Age and correlation.—The fire clays and the interbedded sandstone and conglomerate of the Sumas area have been called the Sumas "series" by Glover (1941, p. 308-309) and are correlated by him with the Huntingdon Formation of southwestern British Columbia. Because of the Eocene age of the Huntingdon Formation, Glover considered the Sumas "series" as lower Eocene, or the basal part of the Chuckanut Formation. Glover (1941, p. 309) pointed out, however, that the Sumas "series" differs somewhat in origin and lithology from the rest of the Chuckanut Formation. The rock of the Sumas area is more shaly, and because of its refractory nature the shale is markedly different from the usual shale of the Chuckanut Formation.

It is possible that the Sumas "series" is in part equivalent to the Burrard or the Kitsilano Formation of British Columbia and is of late Eocene age. If such is the case, the fire clay deposits would be of post-Chuckanut age.

The physical properties of the clays described in this report have been listed in tabular form and are included with the descriptions of the individual samples. The abbreviations used in the tables are as follows:

L.S. % d.l.—Linear shrinkage in percent of dry length
T.L.S. % d.l.—Total linear shrinkage (drying and firing) in percent of dry length
V.S. % d.v.—Volume shrinkage in percent of dry volume
Abs.—Absorption
A.por.—Apparent porosity
*—Indicates that the sample was fired to the given temperature in a commercial kiln.
S.H., Lt., Dk.—Steel hard, light, dark
P.C.E.—Pyrometric cone equivalent
D.T.A.—Differential thermal analysis

Area No. 1

Location and accessibility.—Area No. 1 is the site of the abandoned Denny-Renton Clay & Coal Co. mine that is in the SW¼SE¼ sec. 12, T. 40 N., R. 4 E. No road extends to the area of the clay beds, but the area can be reached by walking along the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad. The Sumas-Kendall road is about a quarter of a mile north of the abandoned mine workings (Fig. 19).

Geology.—Approximately 525 feet of the Sumas series in Saar Creek Canyon has been described by Glover (1941, p. 310-311). In the course of field work for this report an attempt was made to re-examine the section, but because of the great amount of weathering in the area only a small part of the section remains exposed.

The basement rocks of the area consist of quartzite and dark-gray argillite of the Chilliwack Group (upper Paleozoic), which within Area No. 1 are well exposed in the bed of Saar Creek. Upon the basement rocks, with a well-defined angular unconformity, rests the basal conglomerate of the Sumas series. The conglomerate is composed of pebbles of igneous and metamorphic rocks and quartz. These pebbles range from 1 to 2 inches in diameter, although some boulders as much as 18 inches in diameter are present in the basal part of the unit. The rest of the section consists of

TABLE 18.—*Stratigraphic section of the Sumas series, in the SW¼SE¼ sec. 12, T. 40 N., R. 4 E.*①

D-R* no.		Feet
	Top of section concealed	
1	Shale, coarse, concretionary (red-firing)	50
	Conglomerate	15
2	Shale, sandy (low-grade dark buff-firing fire clay)	12
	Conglomerate	20
3	Shale, sandy (red-firing medium-plastic)	10
	Shale, reddish-colored sandy	20
4-A	Shale (plastic, similar to 6-A)	3–6
	Shale	10
4	Shale, sandy greenish-blue (low-grade fire clay)	10
	Shale, sandy	15
5	Shale, blue, fine-grained (main bed worked for fire clay; medium plastic) Sample No. 207	4–12
	Shale, mottled red and yellowish (low-grade fire clay)	20
6	Shale, yellowish (low-grade plastic fire clay)	6
	Shale, yellowish (semiplastic)	12
6-A	Shale, yellowish-blue (plastic fire clay) Sample No. 203	4
	Conglomeratic sandstone	40
16	Shale, fine-grained, light-blue (fire clay) "Tiger" Sample No. 204	0–7
16-AA	Shale (fire clay similar to 17-A)	1½–2
	Sandstone	3
17	Shale, blue, red-mottled (plastic)	20
17-AA	Shale, blue sandy (plastic fire clay) Sample No. 208	2–3
	Sandstone	5
17-A	Shale, blue sandy (fire clay)	1–2
	Sandstone	4
17-B	Shale, similar to 18	4
	Sandstone; carbonaceous partings	4
18	Shale, fine-grained (plastic) Sample No. S-18	11
	Sandstone; carbonaceous partings	4–5
19	Shale, iron-stained (very plastic)	12
20	Shale, light blue ("flint fire clay")	3
21	Shale, fine, even-grained, red	30
	Sandstone and fine conglomerate ("ganister") Sample No. 206	40
22	Shale, light-blue sandy	3–4
23	Shale, red-stained	10
24	Shale, sandy red	5
	Conglomerate	3
	Shale	1+
	Conglomerate: pebbles average 1-2 inches in diameter and are as much as 18 inches at base of bed	80
	Total, approximately	525
	Unconformity	
	Argillite and quartzite, thin-bedded, slaty	

*D-R numbers are those by which the Denny-Renton Clay & Coal Co. designated the beds.
①Glover, 1941, p. 310-311.

interbedded shale and sandstone, and a few conglomerate beds. It is not uncommon to find gradations from sandstone to conglomerate within the same bed, as well as lensing out of the thinner beds. The series as a whole, however, is well stratified and uniform in structure. The average strike of the beds is N. 20° E., and the dip is 35° NW. Except for the exposures in Saar Creek Canyon, the Sumas series is overlain by glacial drift, and to the west it dips beneath the glacial deposits of Whatcom Basin.

A stratigraphic section of the Sumas series, including the clay beds that were mined and sampled by the Denny-Renton Clay & Coal Co., as reported by Glover (1941, p. 310-311), is shown in Table 18.

Mining operations.—The old mine workings of the Denny-Renton Clay & Coal Co. are beneath a trestle of the Chicago, Milwaukee, St. Paul and Pacific Railroad in the SW¼SE¼ sec. 12, T. 40 N., R. 4 E. Mining was undertaken from three drifts on seams 5, 16, and 18, the longest drift running about 500 feet on the No. 5 shale (Fig. 19). The breast-and-pillar system of mining was used, and the clay was shipped to the Renton and

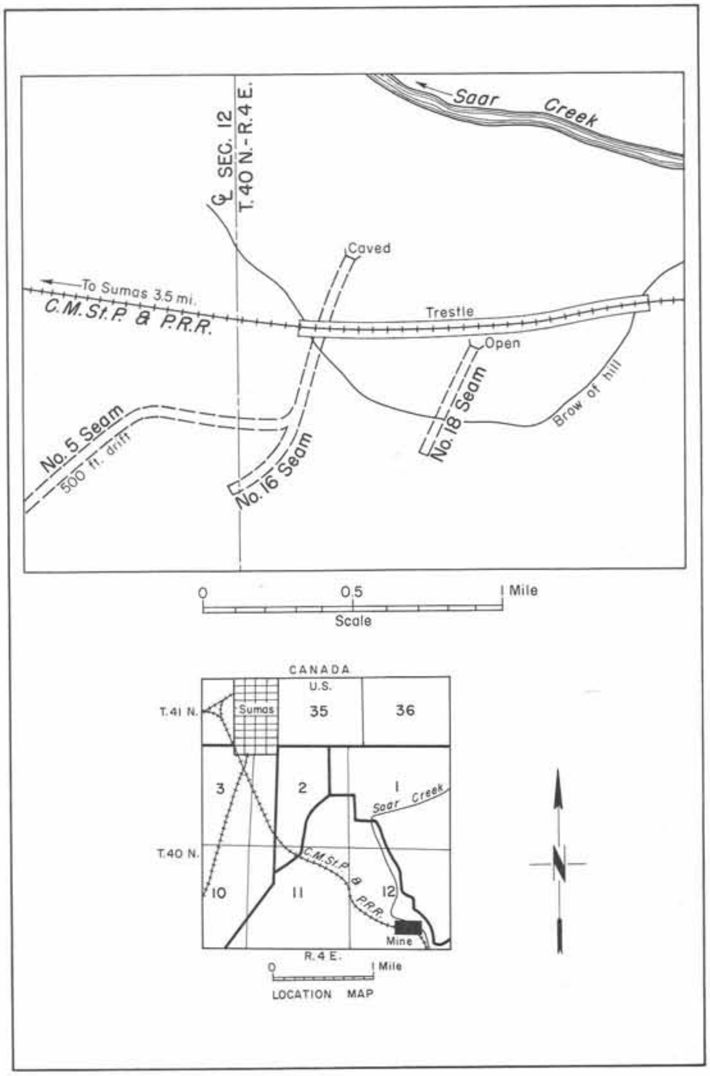

FIGURE 19.—Location map of Denny-Renton Clay & Coal Company mine.

Van Asselt plants of the company. At the time of the examination for this report (1960), only one drift remained partly open, this being on seam No. 18. Wilson (1923, p. 66) reported that in 1923 the company was mining clay at this location, but it is not known when operations ceased.

Figures are not available on tests for all the shale units of the Sumas series, but following is a compilation of the tests on the more favorable clay beds as reported by Glover (1941, p. 313-315). According to Glover, the red-firing shales, some of which are of excellent quality, were not mined.

Denny-Renton No. 6-A.—Seam 6-A is a varicolored medium-hard shale, 4 feet in thickness, that overlies a 40-foot conglomeratic sandstone member. The shale is predominantly yellowish green but has stains of purple, brown, and yellow on the joints. The texture is fine and uniform, and the material contains very little sand.

Remarks: When tempered with water, a fair plastic strength is developed. Hard bodies are produced when fired between cones 02 and 10. As cone 28-29 is the fusion point, a No. 2 refractory brick can be made from this sample. The fired colors are buffs and browns.

Denny-Renton "Tiger 16".—Seam 16 is a light bluish-gray shale that ranges from 0 to 7 feet in thickness. It underlies the conglomerate mentioned above. This shale member is nonuniform in texture and is moderately hard. It is partly very smooth, but contains layers and lenses of a friable material that is virtually fine-grained clayey sandstone.

Working properties of Denny-Renton clay seam No. 16

PLASTIC AND DRY PROPERTIES

Plasticity ....Good	Volume shrinkage..17.7% dry volume
Shrinkage water 9.1%	Linear shrinkage ... 6.3% dry length
Pore water 12.1%	Linear shrinkage ... 4.9% wet length
Water of plasticity 21.2%	Dry condition ......Good dry strength

FIRED PROPERTIES

Cone	Color	Condition	L.S. % d.l.	T.L.S. % d.l.	V.S. % d.v.	Abs.	A. por.
012	Lt. purple-gray	Soft, weak	......	......	......	16.8	30.8
01	Cream	Soft, weak	0.2	6.5	0.7	16.8	31.3
3-4*	Lt. buff	Soft, weak	......	......	......	15.4	32.3
6-7*	Buff	Soft, weak	1.2	7.5	3.7	15.0	28.2
10	Spotted buff	Good, hard	1.3	7.6	4.0	13.9	26.1
12*	Buff-brown	Good, hard	1.7	8.0	5.0	12.5	26.1

Remarks: Best firing range: 10-15. Cone fusion: 28. Class of ware: No. 2 refractory. Finer grinding may reduce required firing temperature for buff structural ware.

Denny-Renton No. 17-AA.—Seam 17-AA, from a 2- to 3-foot bed of very sandy shale, is a bluish-gray material containing abundant red grains. Dry lumps are moderately hard.

Working properties of Denny-Renton clay seam No. 17-AA

PLASTIC AND DRY PROPERTIES

Plasticity ....Weak	Volume shrinkage... 8.1% dry volume
Shrinkage water 3.9%	Linear shrinkage ... 2.8% dry length
Pore water 9.4%	Dry condition ......Weak dry strength
Water of plasticity 13.3%	

FIRED PROPERTIES

Cone	Color	Condition	L.S. % d.l.	T.L.S. % d.l.	V.S. % d.v.	Abs.	A. por.
010	Lt. purple-gray	Weak, very soft	-0.2	2.6	-0.6	15.5	29.7
02	Lt. gray	Weak, soft	-0.3	2.5	-0.9	16.6	31.4

Remarks: Best firing range: 6-12. Cone fusion: 23. Poor plastic and dry strength, which may be bettered by finer grinding with water. Class of ware: Gray and brown structural ware.

Denny-Renton No. 18.—Seam 18 is from an 11-foot shale member. It is bluish-gray and a fine-grained uniform material.

Working properties of Denny-Renton clay seam No. 18

PLASTIC AND DRY PROPERTIES

Plasticity ....Good	Linear shrinkage ....4.7% wet length
Water of plasticity 26.3%	

FIRED PROPERTIES

Cone	Color	Condition	L.S. % d.l.	T.L.S. % d.l.	V.S. % d.v.	Abs.	A. por.
012	Gray-buff	Very soft	......	......	......	16.4	30.9
01	Lt. buff	Good, hard	......	......	......	14.9	28.9
3-4*	Lt. buff	Good, hard	......	......	......	13.7	......
6-7*	Lt. buff	Good, hard	3.4	......	8.5	13.5	26.3
12*	Brown-buff	Good, S.H.	4.1	......	11.7	7.6	16.3
15	Spotted brown	S.H.	......	......	......	.....	......

Remarks: Best firing range: 4-15. Cone fusion: 26. Class of ware: Buff-colored structural ware.

Denny-Renton No. 22.—Seam 22 is a bluish-gray moderately hard shale that is almost free from grit. The texture is very fine and uniform.

Working properties of Denny-Renton clay seam No. 22

PLASTIC AND DRY PROPERTIES

Plasticity ....Good	Volume shrinkage...18.1% dry volume
Shrinkage water 9.4%	Linear shrinkage ... 6.4% dry length
Pore water 13.9%	Linear shrinkage ... 4.6% wet length
Water of plasticity 23.3%	Dry condition ....Good

FIRED PROPERTIES

Cone	Color	Condition	L.S. % d.l.	T.L.S. % d.l.	V.S. % d.v.	Abs.	A. por.
04	Cream	Soft	......	......	......	14.4	29.0
3-4*	Lt. buff	Soft	......	......	......	12.0	....
6-7*	Lt. buff	Good, hard	3.2	9.6	9.2	11.2	22.6
10	Lt. Buff	Good, hard	3.9	10.3	11.2	9.9	21.0
12*	Brown-buff	Good, hard	4.4	10.8	12.7	9.2	18.6

Remarks: Best firing range: 6-15. Cone fusion: 31. Class of ware: No. 1 refractory and buff structural ware.

*Chemical analyses of Denny-Renton clay seams*①

D-R no.②	Sample no.	SiO_2	Al_2O_3	Fe_2O_3
4	204	55.1	30.9	4.32
5	207	51.2	33.1	4.32
Top half of 5	207	46.57	32.73	4.10
6	....	66.4	25.2	1.74
18	S-18	54.9	30.8	4.32
20	....	47.0	40.6	1.44

①Analyses as reported by Glover (1941, p. 352-353).
②D-R numbers used by Denny-Renton Clay & Coal Co. to designate beds.

Wilson (1923, p. 135-136) gives the following analyses on seams No. 3 and 4 of the Sumas series:

No. 211.—Whatcom County. A hard, light-brown shale from seam No. 3, the Sumas mine, leased by the Denny-Renton Clay & Coal Co. Wet tensile strength, 1.6 pounds a square inch. Good dry strength. Fired colors: Buff-red, cone 05; brown-reds, cones 3 to 8; brown and black, cones 9 to 15. A hard structure is developed at cone 05, steel hardness at cone 3, and blisters at cone 9.

Remarks: Best firing range, cones 02 to 7. Cone fusion: 15. Possible uses: Red-burning structural wares.

No. 212.—Whatcom County. Light-brown soft shale from No. 4 seam, Saar Creek beds, Denny-Renton Clay & Coal Co. Wet tensile strength, 2.1 pounds a square inch. Good dry strength. Fired colors: Buff-reds to cone 4; brownish-reds, cones 5 to 8; gray-browns and blacks, cones 9 to 20. Hard structure is developed at cone 2 and steel hardness at cone 8.

Remarks: Best firing range, cones 2 to 10. Cone fusion: 23 to 26. Possible uses: Red and brown structural wares.

From the above data it is apparent that the clay beds of the Sumas series in the Saar Creek Canyon are quite variable in physical and chemical properties. The main refractory clays are confined to seams No. 5, No. 16, and No. 22. Mining operations were undertaken on seams No. 5, No. 16, and No. 18, as is shown on Figure 19, but it is not known whether any of the other refractory clays were mined. No mine dumps are present to indicate mining of the clays, but it is possible that the beds were worked from crosscuts on seams No. 5, No. 16, or No. 18. The southern boundary of the clay seams is not known. However, if they retain their refractory properties along the strike of the beds, they probably extend as far as Haystack Hill, which is about 1,000 feet south of Saar Creek.

Clay reserves.—Inasmuch as the old mine workings of the Denny-Renton Clay & Coal Co. are inaccessible, it is difficult to estimate the tonnage of fire clay that remains. The clay seams, which dip about 35° to the west, have been mined by means of drifts and stopes from one level. In the one drift that remains partly open on seam No. 18, it appears that a maximum of 20 feet of clay was stoped out in places. Assuming that at least 20 feet of clay has been removed from each seam along the entire length of the seam in a southerly direction, the reserves are estimated at about 70,000 tons. The tonnages are computed for a height of 30 feet, which represents the distance from the creekbed to the maximum elevation of the beds minus the 20 feet that has possibly been extracted from each clay bed. The strike length of the beds is considered to be about 500 feet. The estimated tonnages for individual seams are as follows:

*Clay reserves of Area No. 1*①

Seam no.	Average width (feet)	Sample no.	Possible tonnage②
5	8	207	8,000
6-A	4	...	16,000
16	3	...	2,700
17-AA	2.5	...	1,500
18	11	S-18	10,800
21	30	...	27,000
22	3.5	...	3.600

①Washington Division of Mines and Geology.
②Moist clay in place @ 1.8 tons per cubic yard.

The above-mentioned clay seams represent only those on the south side of Saar Creek at the site of the abandoned mine workings of the Denny-Renton Clay & Coal Co. The Sumas series crops out also on the north side of Saar Creek, but it is not known whether the clay seams have been mined at this place. As is the southern half of the Sumas series, the northern half also is covered with glacial drift. About 1,000 feet north of Saar Creek the Sumas series is in contact with the basement complex.

It is probable that the fire clays extend into the area north of Saar Creek. However, no data are available with which to compute tonnages. If the clay seams extend into this area, it may be assumed that at least one-half as much tonnage as is believed to be present on the south side of the creek is present on the north side. On this assumption, there would be about 34,800 tons of moist clay on the north side. This reduction in tonnage figures is due to the lower elevation of the Tertiary sedimentary rocks in the north half of the area.

Area No. 2

Location and accessibility.—Area No. 2 is about half a mile east of Area No. 1 and is within the right-of-way of the Chicago, Milwaukee, St. Paul and Pacific Railroad. The Sumas-Kendall road is about a quarter of a mile to the north (Fig. 20).

Geology.—Tertiary continental sedimentary rocks similar to those in Saar Creek Canyon crop out in the bed of Saar Creek in the NW¼NW¼ sec. 18, T. 40 N., R. 5 E. A generalized stratigraphic section of about 140 feet of these rocks is as follows:

Sample no.		*Thickness (feet)*
	Alluvium	
3 and 4	Shale, red	15
2 and 5	Shale, grayish-yellow	4
	Conglomerate, mixed pebble	6
	Sandstone, maroon	28
	Sandstone, gray	37
	Conglomerate, mixed pebble	18
	Sandstone, gray	3
	Conglomerate, mixed pebble	6
	Sandstone, gray	18
1	Shale, gray	8
	Concealed	

The beds have been folded into an asymmetrical syncline in which the beds on the north limb strike N. 50°-75° W. and those on the south limb strike N. 20° E. The south limb dips 70° N., and the north limb dips 30° to 40° S. A thick cover of glacial outwash material conceals most of the shale-bearing sedimentary rocks, and the nearest pre-Tertiary basement rocks crop out about 1,500 feet to the north, on Vedder Mountain.

Other than a few shallow prospect pits, there is no evidence of mining in this area. The shale beds have been sampled in the past, as Glover (1941, p. 316-317) reports the following analyses on two shales from this locality. Glover did not state from which part of the

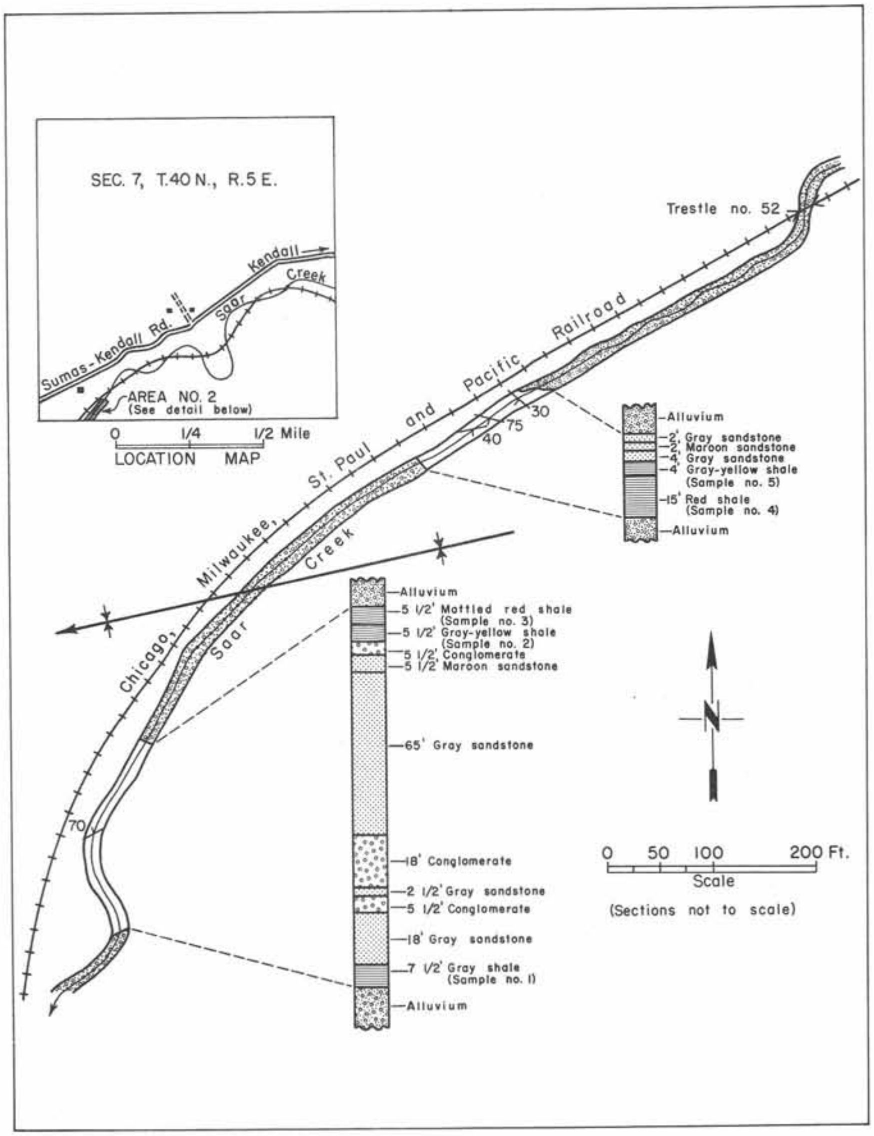

FIGURE 20.—Geologic sections of fire clay Area No. 2.

section the samples were taken; however, sample No. 201 is probably the uppermost shale bed in the section and sample No. 202 is the underlying shale.

Sample No. 201 is a dark reddish-brown shale. It is hard but very brittle and easily shatters into small angular pieces with sharp conchoidal fracture.

Remarks: The plasticity developed by this clay, when ground and tempered in the usual manner, is too poor for the handling of commercial wares. It is possible that better plastic strength can be produced by wet-grinding. May be usable by the dry-press process. The fired color is dark red-brown; the firing range is approximately between cones 3 and 10; and the cone fusion point is cone 16–17.

Sample No. 202 is from a thin bed lying between No. 201 and the sandstone. It is a hard, very brittle shale that breaks with a sharp, hackly fracture and is blue in color with yellow and reddish-purple mottlings.

Working properties of shale from the NW¼NW¼ sec. 18, T. 40 N., R. 5 E.

Sample No. 202 PLASTIC AND DRY PROPERTIES

Plasticity	Weak	Volume shrinkage	10.4% dry volume
Shrinkage water	5.1%	Linear shrinkage	3.6% dry length
Pore water	10.0%	Linear shrinkage	2.1% wet length
Water of plasticity	15.1%	Dry condition	Weak

FIRED PROPERTIES

Cone	Color	Condition	L.S. % d.l.	T.L.S. % d.l.	V.S. % d.v.	Abs.	A. por.
06	Lt. red-brown	Weak, soft	......	......	......	16.7	32.7
01	Buff-brown	Weak, soft	5.8	9.4	16.3	11.9	25.2
3–4*	Buff-brown	Weak, soft	6.1	9.7	17.3	11.3	22.4
6–7*	Buff-brown	Weak, soft	......	......	......	11.5	23.3
12*	Dark brown	Hard	5.9	9.5	16.8	11.8	31.9
15	Brown, black	Hard	6.6	10.2	18.5	11.6	25.5

Remarks: Best firing range: 8–14. Structure, granular. Cone fusion: 23-26. Needs fine grinding with water or dry-pressing, and high temperatures for fired strength. Class of ware: Brown structural wares.

P.C.E. and bloating tests on samples from several shale beds in the NW¼NW¼ sec. 18, T. 40 N., R. 5 E., are as follows:

Sample no.	P.C.E.	Fired color	Bloating type
1	12	Black	Low
2	18	Brown	None
3	20	Black	None
4	20	Black	None
5	18	Dark brown	None

(Analyses by U.S. Bureau of Mines Northwest Experiment Station, Seattle.)

Clay reserves.—Although semirefractory clays are present in Area No. 2, they are so poorly exposed that no attempt is being made here to report reserves. The clay deposits are also poorly suited for mining operations, as mining would have to be undertaken below the water table. Also, the steep dip of some of the beds would make surface mining impractical.

Area No. 3

Location and accessibility.—Area No. 3 is in parts of secs. 5, 6, 7, and 8, T. 40 N., R. 5 E., about 5 miles southeast of Sumas. It comprises about 200 acres and is the site of the abandoned Sumas clay mine of Gladding, McBean & Co. The caved adits of the mine workings are 300 feet north of the Sumas-Kendall road and 600 feet north of the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad (Fig. 18, on p. 52, and Pl. 4). Although a road extends to the mine, it is overgrown with brush and difficult to recognize.

History.—Almost all of the fire clay that has been mined in Whatcom County has come from this area. During the operation of the Sumas mine, which was worked intermittently from 1920 to 1949, the clay was shipped by rail to the company's Renton plant, where it was utilized with other clays in refractory blends. At the time of this examination (1960) the portals of the adits were caved, and other than one ore bunker, nothing remains of the surface plant.

Geology.—Very few outcrops are visible in this area, as the vegetation is dense and the overburden is thick. The sedimentary rocks consist of arkosic sandstone, carbonaceous siltstone and shale, and mixed pebble conglomerate. The general lithology resembles that of the Sumas series; however, definite correlation of the two sequences has not been established. Throughout the area most of the strata are nearly flat lying, but in the northern part some of the beds dip as much as 25° N.

A stratigraphic section of the rocks that contain the clay seams is not exposed on the surface. Hodge (1938b, p. 772) gives the following section for the refractory clays that were being mined:

Stratigraphic section of clay beds in Sumas clay mine, NE¼ sec. 7, T. 40 N., R. 5 E.

Thickness		Lithology
Ft	in	
		Sandstone hanging wall
2	0	Bone and carbonaceous shale
5–8	0	Refractory clay (No. 8 clay bed)
	4	Hard sandstone
	2	Coal
3–5	0	Clay (low grade) that requires sorting, No. 1 bed
		Sandy clay footwall

Hodge states that the quality of the clay varies; the best clay fuses at cone 31, but nearly all of the material mined averaged at least cone 28. The clay is not a true flint fire clay, because it breaks down in water quite readily, but is a shale that has no definite fissile structure. When dry it is gray to black, and on exposure to the weather it breaks down to form a semiplastic mass. Hodge (1938b, p. 770) reports on analyses of the two principal beds of the Sumas mine as follows:

Chemical analyses of refractory clay from the Sumas mine, NE¼ sec. 7, T. 40 N., R. 5 E.

Constituent	1	2	3	4	Sample identification
Silica (SiO_2)	45.56	47.96	44.2	46.6	(1) No. 8 bed
Alumina (Al_2O_3)	30.60	33.61	43.5	37.5	(2) Starkweather clay
Ferric oxide (Fe_2O_3)	4.28	3.95	....	....	(3) Sample No. 199
Lime (CaO)	1.39	1.94	....	....	(4) Sample No. 200
Magnesia (MgO)	0.54	....	....	....	
Loss on ignition / Moisture at 212° F.	15.72	12.88	....	....	
	98.09	100.34			

Hodge also reports that tests made on the light-gray clay (No. 8 bed) show the following:

> To use this clay alone for a medium-duty refractory, it is recommended that the firing temperature be carried above cone 14, 1,400° C., or 2,552° F., so that subsequent changes in use will not occur.
>
> The clay can be used as a bonding clay for refractory clays of higher cone fusion points but less plastic strength.
>
> As a blending clay it acts as a compensator for other clays, as it expands at higher temperatures where others contract, hence it aids in reducing shrinkage in use.
>
> Its pyrometric cone equivalent varies from cones 28 to 31, 1,615° to 1,680° C., or 2,939° to 3,056° F., when fired rapidly at 150° C. per hour.

Glover (1941, p. 315-316) gives analyses of several clays of the area that were taken from surface pits and outcrops. In 1966 an attempt was made to find the sample locations, but, because of the great amount of weathering in the area, the pits are no longer distinguishable.

Analyses of shales from near the center of the N½ sec. 7, T. 40 N., R. 5 E., follow:

> *Sample No. 198,* from the lowest of three hillside pits, is from a thick stratum of dark reddish-brown shale. It is a highly ferruginous material, almost devoid of ordinary sand but containing fine grains of magnetite. It is hard but very brittle and easily shatters into small angular pieces with sharp conchoidal fracture.
>
> Remarks: When dry-ground and tempered in the usual manner with water, only a feeble plastic strength could be developed. In this condition it may be possible to mold ware by the dry-press process. Grinding in water may develop better strength. When fired between cones 3 and 10, red-brown colors are produced suitable for dark structural wares. The sample deformed at cone 18–19.
>
> *Sample No. 199* is from a prospect (known as "S. P. No. 1") some distance above the preceding one, where spheroidally weathered shale is exposed. It is greenish buff colored and stained to dark brown on joints. The texture is very fine and uniform. It resembles sample No. 198 in being free from sand, hard, very brittle, and breaking with a sharp conchoidal fracture.
>
> Remarks: Further tests should be made to develop a No. 1 refractory body of this clay. Cone deformation point is cone 32. Plastic strength must be obtained by addition of a plastic bond or by grinding in water in a ball mill, or use must be made of the dry-press process.
>
> *Sample No. 200* is from a prospect (known as "N. W. No. 1") still farther up the hill. This shale is almost

identical with sample No. 199, except that it has a bluish-gray color.

Working properties of shale sample No. 200

PLASTIC AND DRY PROPERTIES

Plasticity ....Weak	Linear shrinkage ...10.2% wet length Dry condition.......Weak (gum added)

FIRED PROPERTIES

Cone	Color	Condition	L.S. % d.l.	T.L.S. % d.l.	V.S. % d.v.	Abs.	A. por.
06	Brown-buff	Good, S. H.	5.5	......	15.5	14.7	28.5
05	Lt. buff-brown	Cracked, S. H.	.....	......	......	13.2	25.9
04	Lt. buff-brown	Cracked, S. H.	6.9	......	19.2	12.8	25.4
3-4*	Deep buff	Cracked, S. H.	10.3	......	27.9	6.8	14.7
6	Deep buff	Cracked, S. H.	11.6	......	31.0	5.8	14.0
12*	Deep brown	Cracked, S. H.	.....	......	......	1.4	2.1

Remarks: Best firing range: 02-12. Cone fusion: 31. Shrinkage is high. Class of ware: No. 1 refractory. Needs bond clay or the development of plasticity by grinding in water. May be usable for dry-pressing.

Mining operations.—Four adits that were driven in a northerly direction into the southern slope of Vedder Mountain provided access to the underground workings of the Sumas mine. The clay seams were worked from 40 to 100 feet beneath the surface in benches off the main haulage level. The breast and pillar system of mining was used; the pillars were left for support during mining operations but were mined on retreat. From the mine workings the clay was trammed to bunkers near the portal of the mine and to a tipple alongside the railroad.

From mine maps made available through Gladding, McBean & Co., it appears that approximately 7½ acres has been worked out. Plate 4 shows the underground workings of the Sumas mine.

Clay reserves.—It is probable that a large amount of refractory clay still remains in the ground at Area No. 3. Of the 200 acres underlain by shale-bearing sedimentary rocks, mining appears to have been done in only about 7½ acres.

In estimating the ore reserves, the refractory clay beds that were mined (this being at an elevation of about 500 feet) were extended horizontally beyond the mining operations to the limits of the beds. The beds terminate against the basement rocks on the east, and the extensions in the other directions have been removed by erosion. If the clay beds retain their refractory properties and do not lens out, at least 1,440,000 tons of clay may remain. The P.C.E. of the remaining clay is not known, but the clay mined in the past averaged at least cone 18 and was 5 to 8 feet thick.

It is believed that a properly executed drilling program would prove that refractory clays are present beyond the limits of the mined-out parts of the deposit. In addition, drilling would also disclose any other clay beds that may lie either above or below the known clays. The possibility also exists that the clay seams could be worked from the northern slope of Vedder Mountain near Anderson Lake. This method would provide natural drainage for the mine workings, as the beds dip to the north in this area.

Area No. 4

Location and accessibility.—Area No. 4 is in secs. 17 and 20, T. 40 N., R. 5 E. It is about 1½ miles southeast of the Sumas clay mine and is on the northeastern end of Sumas Mountain (Fig. 18, on p. 52). The Paradise Valley logging road parallels the western edge of the area, and the South Pass road is a quarter of a mile to the north.

Previous operations.—There is no evidence of extensive mining in the area, and only one mine dump was seen in 1966, this being in the NE¼SW¼ sec. 17, on the east bank of Saar Creek. The adit is caved, but the waste on the dump indicates that mining was undertaken on one of the coal seams of the sedimentary rocks. Glover (1941, p. 317) reports that efforts were made to block out high-quality, refractory shales that probably occur along the footwall of the coal seam. The operation no doubt failed, as the property shows no indication of production.

Geology.—The area, for the most part, is covered with dense underbrush and thick overburden. Outcrops are scarce and consist chiefly of poorly sorted pebble conglomerates and interbedded thick beds of gray siltstone. Several beds of lignite and thin coal seams are present in the siltstones. The sedimentary sequence lies unconformably upon a basement complex of highly folded and faulted argillite, graywacke, serpentinite, and chert of late Paleozoic age.

The dips of the beds range from 70° E. to 70° W., and the strikes trend slightly east of north. The rocks have been folded into a closed symmetrical syncline, the axis of which trends N. 15° E. By being folded within the more resistant basement rocks, the Tertiary sedimentary rocks have been protected from erosion.

At only one locality in Area No. 4 was shale found that is of refractory quality. This shale crops out in a roadcut on the Paradise Valley road near the center of the W½ sec. 17. It is medium- to dark-gray, brittle, and contains small amounts of angular quartz, feldspar, and magnetite grains. These grains average less than 1 millimeter in diameter.

Though the refractory shale is poorly exposed, it appears to have been developed upon white to light-gray, highly fractured feldspathic rock. About 2 feet of the shale was sampled, but its lateral extent could not be ascertained. The results of tests on samples from two parts of the outcrop are as follows:

*Properties of refractory shale from the W½ sec. 17, T. 40 N., R. 5 E.*①

Sample no.	P.C.E.	Fired color	Bloating type	D.T.A.
7a	29+	Light-brown	None	High kaolinite
7b	30	Dark-buff brown	None	High kaolinite

①Analyses by U.S. Bureau of Mines Northwest Experiment Station, Seattle.

Clay reserves.—The refractory shale of Area No. 4 is so poorly exposed that no attempt was made to calculate reserves. The shale area is limited in size and appears to have little, if any, economic value.

SHALE

The common shales of the county have been little used in the manufacture of clay products. Around 1914, shale from the Chuckanut Formation was used in the manufacture of common brick and tile; however, the mining of shale did not prove practical and the operation lasted only a few years. The shale that was mined by the Coast Clay Co. is 4 miles south of Bellingham, in sec. 13, T. 37 N., R. 2 E., at what was then known as the Grandview Station of the Great Northern Railway. Glover (1941, p. 307-308) reports that the shale is very sandy and more nearly a sandstone. When fired between cones 05 and 1, its color becomes brownish red to dark reddish brown, which makes it suitable only for red-brown brick and tile.

Shales that have better firing properties are present in the Chuckanut Formation, as Glover (1941, p. 307) reports that tests on shale from the Bellingham Coal mine showed a cone fusion of 15 and fired brown-buff to dark brown at cone 08 to cone 2. Shale such as this is suitable for brown structural wares. It is also possible that some shales that occur as the walls of coal seams may be refractory (fuse above cone 27).

According to the U.S. Bureau of Mines (Harris and others, 1962), some shale beds of the Chuckanut Formation are suitable for the manufacture of expanded aggregate. Expanded aggregate is made by firing clay, shale, or slate. Firing causes expansion of the rock fragments, which results in a larger volume for a given weight. When the expanded material is used as aggregate in concrete, the concrete may be as much as one-third lighter and two-thirds as strong as conventional sand and gravel concrete products. This lighter weight results in savings in freight and construction costs.

The U.S. Bureau of Mines (Harris and others, 1962, p. 23, 31) reports the following physical properties of expanded aggregate from a shale bed in the SE¼ sec. 25, T. 37 N., R. 2 E., on Chuckanut Drive:

Physical Properties of Expanded Aggregate

Bloating range, °C.	1,080 - 1,130
Bulk density range, lbs./cu. ft.	62 - 40
Compaction strength range, p.s.i.	2,400 - 500
Absorption range, percent	5 - 13

Physical Properties of Concrete Shapes Made From the Expanded Aggregate

Bulk density, lbs./cu. ft.	
Aggregate	60.6
Concrete	101
Crushing strength, p.s.i.	3,410
Modulus of rupture, p.s.i.	810
Absorption, percent	11.0

BENTONITE

An impure bed of bentonite is reported (Glenn A. Bezona, field notes, undated) in the W½SE¼ sec. 11, T. 37 N., R. 3 E., on Lookout Mountain. The bentonite is interbedded in sandstone and shale of the Chuckanut formation, which in the area of the deposit has a general northerly to northeasterly strike and 30° to 70° westward dips. The bentonite appears to be quite widespread, as it is present at a depth of 4,552 feet in the Pelican Dome oil well, which is about 4½ miles northwest of the deposit.

According to Bezona (field notes):

> The bentonite of this area is of the nonswelling variety and is composed of the two clay minerals beidellite and montmorillonite. It varies in color from buff to blue gray and has an average thickness of 7 feet along the strike, which can be traced for about a mile. The bentonite lies between two layers of unaltered biotite ash, with the most pure material, which has undergone almost complete alteration, lying toward the center. From the center of the stratum the more pure material grades outward to the unaltered ash . . . . The ash is composed mainly of biotite, quartz, orthoclase, and microferromagnesium minerals. The several layers of ash vary in color as well as in composition.

Unlike most bentonite, the material of this deposit is nonswelling. The nonswelling nature of the bentonite condemns it for most commercial use, as the uses for bentonite depend mainly on its peculiar property of swelling when immersed in water.

Water

Few people think of water as a mineral, yet it is one of the most important mineral products of the earth. For example, in 1964 more than 17 billion gallons of water was used for domestic and industrial purposes in Bellingham (population 35,200); this consumption is in the neighborhood of 50 million gallons per day. According to Charles C. Gold, Bellingham's water superintendent (oral communication, 1965), the paper and pulp mills of Bellingham consume 39 million gallons per day; the oil refinery near Ferndale, 2.5 to 4.5 million gallons per day; and the aluminum plant, also near Ferndale, requires 12 to 15 million gallons per day. In addition to domestic and industrial uses, large amounts of water are consumed for irrigation during summer months. It is estimated (Washington Division of Water Resources staff, 1960, p. 129) that 70 percent of the surface water in Whatcom Basin is used for irrigation.

The fresh water resources of the county are contained in surface and ground water deposits. Although ground water is far more abundant than surface water, 75 percent of all municipal and irrigation supplies and 90 percent of all industrial supplies come from surface waters. According to the U.S. Geological Survey (1955 and 1962), the mean monthly flow of the Nooksack River near Lynden is 3,500 cubic feet per second and the mean monthly flow of the Skagit River at Newhalem is 5,000 cubic feet per second. The combined flow of these streams accounts for about 98 percent of the surface runoff for the county. Figure 21 shows the mean discharge of the Nooksack and Skagit Rivers over a 10-year period.

In addition to surface water, areas of western Whatcom County contain abundant ground water supplies. Most of the ground water is within the Nooksack

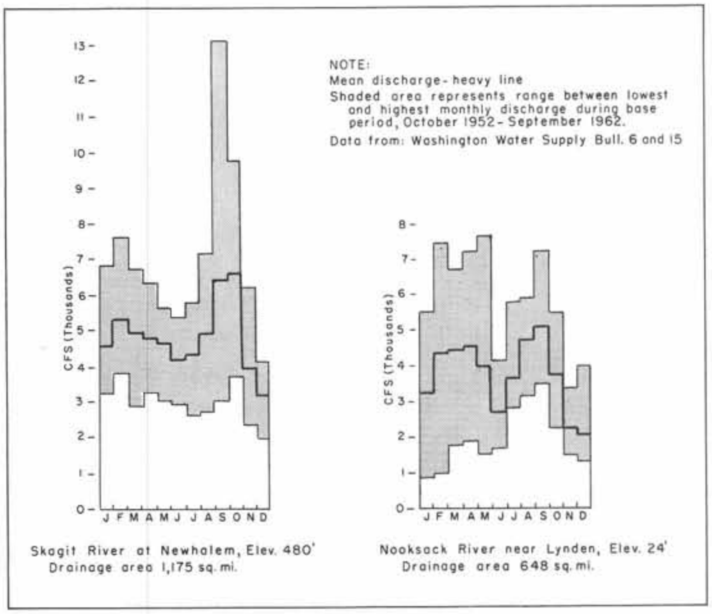

FIGURE 21.—Mean discharge of Nooksack and Skagit Rivers.

River basin, the water resources of which are fully described in "Water Resources of the Nooksack River Basin," (Washington Division of Water Resources staff, 1960).

In this report the following statement appears:

> In comparing the climate, geology, and hydrology of the Nooksack River basin to other regions, it is evident that here nature has provided an unusual setting suitable for the production of large quantities of water of excellent quality . . . . Approximately 85 percent of the precipitation and 60 percent of the total runoff from the Nooksack River basin occurs during the seven water-surplus months, October through April, which are corresponding periods of low demand. It then becomes evident that upstream storage in artificial reservoirs will be required to bring flow characteristics more in line with periods of demand.

Thus, whereas abundant surface water exists during the rainy season, demands in the summer months may exceed the supply, especially as the greatest demand for water in the future is expected to be in the western part of the county.

The ground water resources of Whatcom Basin vary from areas of low yield (less than 50 g.p.m. [gallons per minute]) to areas of high yield (more than 500 g.p.m.), which is adequate to meet present demands. East of the basin the ground water is confined mainly in the bottoms of the largest valleys. The ground water supply of the western part of the county is shown in Figure 22.

The major aquifers for ground water are recessional outwash sand and gravel deposits of the Fraser Glaciation and the flood plain sand and gravel deposits of the Nooksack River. In general, the till-capped upland

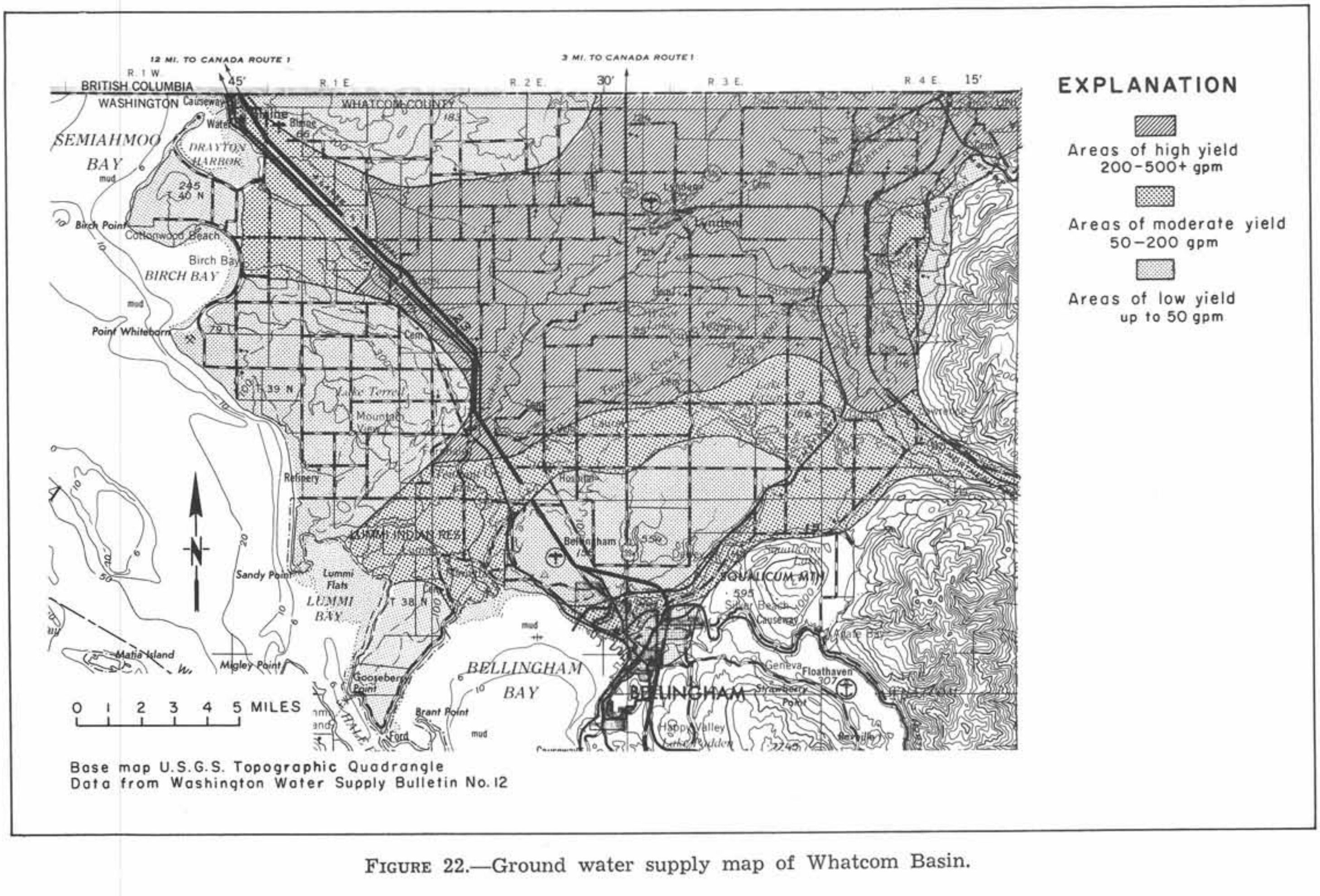

FIGURE 22.—Ground water supply map of Whatcom Basin.

areas around the edge of the basin are deficient in ground water. Also, some areas within the basin contain ground water high in iron that limits its use for domestic and some industrial uses.

In regard to quality of the water of Whatcom Basin, the following statement appears in "Water Resources of the Nooksack River Basin":

> The chemical quality of the groundwaters of the Nooksack River basin ranges from excellent to very poor. In most areas of the Whatcom Basin, the ground water is good to excellent with a few isolated areas of poor quality water due to high iron content. On the basis of available analyses, shallow wells appear to produce water of better quality than deeper wells, with the exception of the iron-rich areas around Everson, Deming, Lynden, and in the Sumas River lowland.
>
> The waters of the Nooksack River and adjacent streams are of excellent quality throughout the basin. They are soft, low in mineralization, relatively free of pollution, and suitable for municipal, agricultural, recreational, and most industrial uses. Analyses available at the time of the study disclosed the iron content of the Nooksack River water to increase progressively downstream. This moderate quantity of iron in the lower reaches of the river, together with suspended sediment load, are the most objectionable characteristics found in the Nooksack River water.

Hot Spring

Baker hot spring

The Baker is the only hot spring in Whatcom County known to the writer. It is in the NW¼SW¼ sec. 8, T. 38 N., R. 9 E., 3 miles north of Baker Lake. From the Baker Lake road at Boulder Creek a forest access road can be followed 4 miles to a trail that extends about 350 yards to the spring.

The spring reeks of hydrogen sulfide, has a temperature of about 105° Fahrenheit, and flows at about 6 gallons per minute. At times, gas bubbles rise to the surface. Except for boxing in the sides of the spring with cedar shakes to form a 6- by 8-foot pool, no attempt has been made to develop the spring.

METALLIC MINERAL DEPOSITS

Unlike the nonmetallic mineral deposits, which occur in almost all parts of the county, most of the metallic mineral deposits are in the mountainous regions, chiefly in the Mount Baker and Slate Creek mining districts, which for the most part are in the Mount Baker National Forest. The areas contained in these two mining districts are shown in Figure 23. The situation of the deposits in the rugged mountainous area of the county, the severe climatic conditions, and the lack of access roads are major factors that have hindered the development of the metallic mineral deposits. Snow covers much of the area for 7 months of the year, and only about 15 percent of the area is within 1 mile of existing roads.

From 1900 to 1965 the production of metallic minerals in Whatcom County amounted to $2,395,612. The production consisted of gold, silver, copper, lead, and zinc; gold accounted for 98 percent of the total (Table

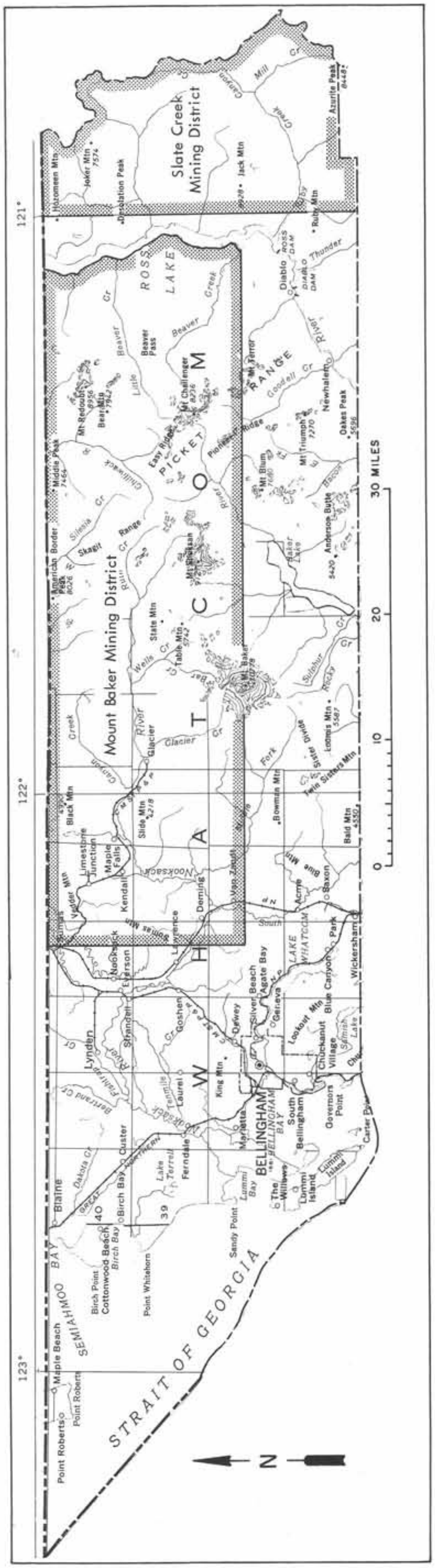

FIGURE 23.—Mining districts of Whatcom County.

2, on p. 13). However, since 1958 the production of metallic minerals has been insignificant. Small amounts of placer gold have been mined from creeks in the Slate Creek mining district, but the amount has not been reported. Currently (1966), no lode mines are operating, but exploratory work continues at several mines.

Minerals of arsenic, antimony, chromium, nickel, iron, molybdenum, and tellurium occur in the county, but not necessarily in commercial quantities. The arsenic, antimony, molybdenum, and tellurium occur mainly as accessory minerals in the ores of gold, silver, and copper, whereas chromium, nickel, and iron are the major minerals of several deposits.

The metallic mineral deposits of the county are discussed under the mining districts in which they occur. Only the more important properties, which contain significant development work or have a record of production, are discussed in detail. All mines and prospects are summarized in Appendix A, (on p. 125).

MOUNT BAKER MINING DISTRICT

The Mount Baker mining district, which was established in 1898 at a miners' meeting in Sumas, is delineated as follows:

> Beginning at the northwest corner of the town of Sumas, and thence running due south to a point due west of the summit of Mt. Baker; thence east over the summit of Mt. Baker to the Skagit River; then following that stream in a northerly direction to the Canadian Border, from whence it extended due west along the Boundary Line to the point of beginning. (Jeffcott, 1963, p. 119.)

Prior to 1898 the area north of Mount Baker was most commonly referred to as the Mount Baker or Nooksack mining district. The area southeast of Mount Baker was known as the Baker Lake mining district.

Mining History

The mining history of the county from 1852 to 1897—the year of the Lone Jack discovery—has been discussed on pages 10 through 12 of this report. A map of the Mount Baker mining district as it appeared soon after the discovery of the Lone Jack mine is shown in Figure 24.

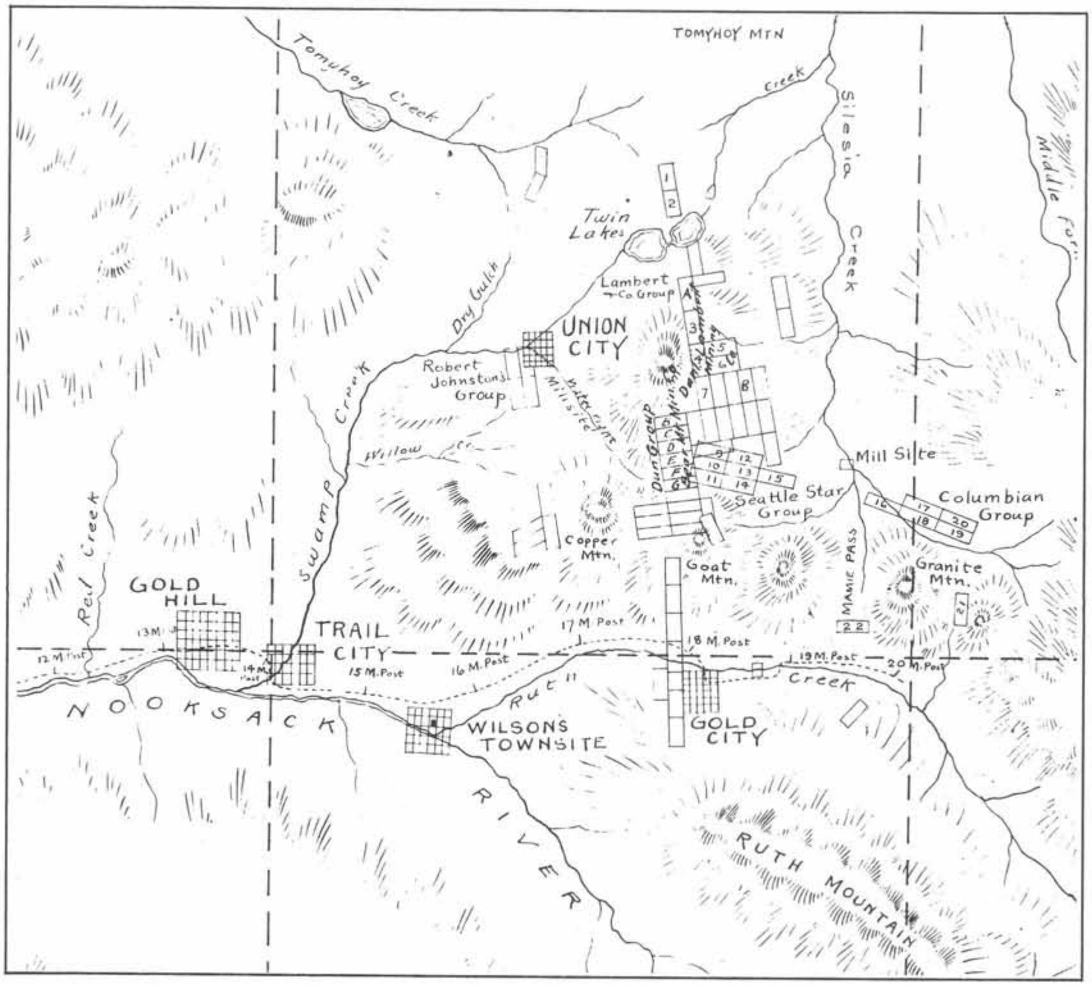

FIGURE 24.—Claim map of the Mount Baker mining district in 1897.
(Photo of map published by O. P. Anderson Map & Blue Print Co., Inc.)
(Map courtesy of Metsker Map Co.)

As would be expected, the discovery of visible gold in the Lone Jack lode attracted many prospectors. Claim staking increased in the area of Twin Lakes, near the Lone Jack discovery, and spread outward in the directions of Red Mountain, Tomyhoi Peak, Goat Mountain, and along the drainage of Silesia Creek. Extensive prospecting resulted in the second most important find of the district, which was the discovery of the Boundary Red Mountain lode in the summer of 1898. At this time C. W. Roth and party staked and recorded the Klondike and Climax claims, which are on the northern slope of Red Mountain, half a mile south of the Canadian border. The Red Mountain Gold Mining Co. was organized in 1900, and the company staked the Rocky Draw, Glacier, and Climax Extension No. 1 claims. As prospecting and staking of lode claims continued in the district, placer claims were staked along the Nooksack River and on Ruth, Swamp, and Silesia Creeks. However, the placer gold occurred mainly as dust, and nuggets were rare; all placer operations were small.

In 1901 Wm. Boyd and W. L. Martin located the Gold Run claim on the southern slope of Red Mountain; this claim later became the site of the Gargett mine. In the same year, L. A. Price and party staked the Saginaw claims northeast of Twin Lakes. At the Lone Jack mine a 15-stamp amalgamation mill had been constructed near Silesia Creek and a 4,000-foot aerial tram moved gold ore from mine to mill. In 1904 the Evergreen claim, near the headwaters of Swamp Creek, was staked by the Blonden brothers. Earlier, in 1900 and 1901, to the south of the Evergreen and near the summit of Goat Mountain, G. C. and R. O. Blonden had discovered several quartz veins that carried free gold. In 1904 the Mount Baker-Shuksan Mining Co. was actively engaged in developing the Red Crest claim on Damfino Creek, 4 miles west of Twin Lakes. Along the banks of the creek, tunnels were driven on gold, silver, and copper discoveries that had been made by G. B. Conway in 1900.

On Wells Creek, which is about 10 miles southwest of the Lone Jack mine, the Great Excelsior Mining Co. located and filed upon the Great Excelsior group in 1901, and by 1903 had placed a 20-stamp mill in operation and was shipping gold-silver concentrates to the Tacoma smelter. About this time, on the extreme western edge of the Mount Baker mining district, near Sumas, the Nooksack mine had put a 12-stamp mill into operation and was producing gold concentrates.

At the Boundary Red Mountain mine, mining and milling were carried out on a small scale until 1915, at which time George Wingfield, of Nevada, acquired the property and constructed a 10-stamp amalgamation mill. In 1916, milling operations began and gold bullion was shipped from the mine. Also in 1916, the Great Excelsior mine ceased operations on Wells Creek because of low mill recoveries and poor mineral values. Earlier, in 1908, the Nooksack mine had shut down for the same reason.

Although most prospecting and mining was in the area north of Mount Baker, a few prospectors explored the county north of Baker Lake and east of Mount Baker. Claims were staked along Swift, Shuksan, and Sulphide Creeks, as well as other tributaries of the Baker River. The most well-known prospector of this area was Joseph Morovits, who in 1891 homesteaded near the confluence of Swift Creek and the Baker River. In 1908 Morovits and other members of his party located and filed upon the Fourth of July group of claims, near the headwaters of Swift Creek. Although Morovits had filed upon other claims in the area, it was at the Fourth of July mine that he undertook the greatest amount of work. Almost singlehanded he moved a stamp mill from Birdsview, near Concrete, over 21 miles of trail to the millsite on Swift Creek (Connelly, 1957, p. 4). However, insufficient ore was found to keep the mill in operation, and mining ceased around 1912.

Production of gold continued sporadically until 1924 at the Lone Jack mine and until 1942 at the Boundary Red Mountain mine. During this time the gold production at the Boundary Red Mountain mine amounted to about $950,000; the Lone Jack mine had produced about $550,000. Other gold producers were the Gargett, Gold Basin, and Blonden mines; however, the combined production from these three mines probaly did not exceed $25,000.

Whatcom County records show that from 1890 to 1937 more than 5,000 mining claims were staked in the Mount Baker mining district. By 1937 the furor over gold no longer existed, and only a few diehard prospectors remained. In 1938 a small flotation mill was erected at the Evergreen mine by Evergreen Mines, Inc. Unlike other mines in the area, which were mined mainly for gold, the Evergreen ore contained galena and sphalerite. However, after operating one year the mine shut down, mainly because of insufficient ore to keep the mill in operation.

At the Silver Tip mine, which had been discovered in 1896, little in the way of mining had been undertaken. A few short tunnels had been driven on several silver-lead-copper veins, but no attempt had been made to develop the property into a producing mine. In 1938 the Silver Tip Mining Company Inc. was formed, and in 1945 a small flotation mill was constructed on the property. Small shipments of concentrates and ore were made to the Tacoma smelter, but during the winter of 1949-1950 the mill was destroyed by a snowslide.

In 1949 the road to the Twin Lakes area of the Mount Baker mining district extended from Shuksan up Swamp Creek for 4.8 miles to the Tomyhoi Lake trail. At this time, construction of a mine-to-market road to Twin Lakes was begun from the end of the existing road; it was completed to the lakes in 1950. However, by then the metal mines of the area were no longer in operation and most prospectors had left the district.

The last shipment of ore from the area was made in 1951, when the Glacier Mining Co. shipped 4½ tons of copper ore from the Midas mine, which is half a mile east of Glacier. The shipment brought the total metal production of the district to about $1,425,000, most of which production was of gold.

During the uranium rush of 1953 to 1957, prospectors once again searched the Mount Baker mining district. Areas of anomalous radioactivity were discovered on Coal Creek near Glacier and along Ruth Creek east of Shuksan; however, no significant uranium discoveries were made.

Elsewhere in the district and outside the boundaries of the Mount Baker National Forest, attempts were made to develop other metallic mineral deposits. In 1930 chromite was discovered on the north end of Sumas Mountain, and in 1946 the Super Chrome Co., of Seattle, began development of the deposit. The operations were suspended several years later, when the chromite was found to occur only as small lenticular bodies.

On the western slope of Sumas Mountain, south of the Nooksack mine, J. C. Compton and J. A. Hatton staked claims for iron in 1915. In 1938 the Hematite Iron and Gold Mines Development Co., of Seattle, acquired the property and began development work. Several short tunnels were driven and much rock sampled, but no production resulted. In the years that followed, several other mining companies examined the deposit and arrived at the same conclusion—that the deposit contained a small tonnage of low-grade material, which would make mining impractical.

Along Bells Creek, on the southern end of Sumas Mountain, placer gold was discovered in the early 1900's. In the depression years of the 1930's, several attempts were made to recover this gold; however, the scarcity of the gold made mining impractical.

In the late 1800's, copper float was found along Boulder Creek east of Maple Falls, but the source of the float was never discovered. In the early 1940's the Howe Sound Mining Co. explored the area but failed to discover a copper deposit that would justify a mining operation.

At present (1966) the mining of metallic minerals in the district is at a standstill. Most of the work on the claims is in the form of annual assessment work, but some exploration work has been undertaken to evaluate new discoveries. At the Boundary Red Mountain, Saginaw, and Lone Jack mines, which are patented mining claims, the owners are waiting for a rise in the price of gold.

Accessibility

From Bellingham, the western part of the district is accessible by way of State Highway 542, which extends as far east as Mount Baker Lodge, a distance of 58 miles. Within the Mount Baker National Forest, which extends eastward from Glacier to the Okanogan County line, access is mainly by way of forest access roads and trails. The main roads in the western part of the district provide access to the drainages of Canyon, Glacier, Swamp, Ruth, and Wells Creeks, as well as the North Fork of the Nooksack River. From these roads some other parts of the district can be reached by trails, but much of the district is still inaccessible by either road or trail. Outside of the national forest the district is accessible by county roads and many logging roads. In the western part of the district a branch line of the Chicago, Milwaukee, St. Paul and Pacific Railroad extends from Sumas to Maple Falls. The south-central part of the district is accessible only by trails from forest access roads in the vicinity of Baker Lake. The eastern half of the district is the most inaccessible area. Trails extend from Ross Lake westward up the drainages of Big Beaver, Little Beaver, and Silver Creeks. However, the starting points of the Little Beaver and Silver Creek trails on the shores of Ross Lake can be reached only by boat from Ross Dam and from a campground at the north end of the lake. The north end of Ross Lake at the International Boundary is accessible by way of logging roads in British Columbia. The trail up Big Beaver Creek connects with a trail to Ross Dam. From that dam a Seattle City Light Co. boat provides access south along Diablo Lake to State Highway 20 at Diablo Dam.

Topography

The Mount Baker mining district is on the western slopes of the Cascade Mountains and is characterized by rugged mountainous terrain (Fig. 25). The Nooksack River constitutes the main drainage in the western part of the district; the Baker and Chilliwack Rivers provide drainage for the central part; and the streams of the eastern part of the district drain into Ross Lake, which is part of the Skagit River drainage system. Along the valley of the Nooksack River, altitudes range from 900 feet above sea level at Glacier to 3,200 feet at the headwaters of the river, on the north side of Mount Shuksan. The Chilliwack River is at an altitude of about 2,000 feet at the International Boundary, and at its headwaters, 1½ miles east of Hannegan Pass, the altitude is about 3,200 feet. Baker River at the north end of Baker Lake is at 725 feet, and at its headwaters is around 2,000 feet. The average altitude of Ross Lake is about 1,600 feet.

From the valleys of these major drainages the mountains rise steeply to general altitudes of around 6,000 to 7,000 feet. Above the general summit level, jagged rocky glaciated peaks, many of which still contain glaciers, rise to 8,900 feet. Snow-capped Mount Baker, the summit of which is at an altitude of 10,778 feet, forms the dominant peak of the Mount Baker mining district. It is also the highest mountain in the county and the third highest mountain in the state (see Frontispiece).

In general, timberline is at 6,000 feet. Above this altitude the topography becomes alpine and consists of open meadows, cirque basins, serrated ridges, and steep rocky peaks. On the north slopes of several peaks, glaciers occupy cirque basins to altitudes as low as 5,200 feet. Glacial tarns are on many of the rocky benches above timberline, and below timberline several valleys contain lakes that have formed behind morainal dams and landslides.

Vegetation and Climate

Below timberline the mountain slopes are covered by thick stands of Douglas fir, western hemlock, and western red cedar. The bottoms of the larger valleys contain dense undergrowth that consists mainly of alder, maple, cottonwood, willow, salmonberry, blackberry, ferns, and devils club. Above timberline the

FIGURE 25.—Topography of the Mount Baker mining district. Looking west from vicinity of Ross Lake. Mount Baker in distance and Big Beaver Creek in lower left. (Photo courtesy of U.S. Forest Service.)

vegetation consists mainly of heather, blueberry, "buck brush," abundant wildflowers, and small stands of alpine fir and mountain hemlock.

Weather conditions are severe, and the mean precipitation is about 100 inches per year. Rain can be expected to fall from April to October; from October to April the precipitation is most likely to be in the form of snow. As much as 20 feet of snow falls yearly at altitudes above 4,000 feet, and snow often remains on the ground at higher altitudes until August.

The mean daily maximum temperature ranges from 32° to 65°, and the mean daily minimum ranges from 20° to 45°. Extremes of 90° in July and -12° in January have been recorded at Mount Baker Lodge.

Geology

The rocks of the Mount Baker mining district are Recent to pre-Carboniferous in age and consist of sedimentary, igneous, and metamorphic rocks (Pl. 1). In the west half of the district, rocks of the Chilliwack Group (Carboniferous-Permian), consisting mainly of clastic sedimentary and basic igneous rocks, are overlain by continental sedimentary rocks of the Chuckanut Formation (Upper Cretaceous-lower Tertiary). On Sumas Mountain, at the western edge of the district, the Chilliwack Group has been intruded by pre-Tertiary serpentinite and is overlain in part by post-Chuckanut continental sedimentary rocks. East of the Chilliwack-Chuckanut sequence are Jurassic-Cretaceous sedimentary rocks and Jurassic volcanic rocks. To the east of these rocks, sedimentary and volcanic rocks of the Chilliwack Group once again crop out. According to Misch (1966, p. 125), the rocks of the Chilliwack Group have been thrust over the Jurassic-Cretaceous rocks, which occur as a window in the thrust sheet. Erosional remnants of an older thrust sheet that moved westward from an eastern basement complex are also present in the west half of the district. The remnants of this thrust sheet form small isolated klippes of metahornblendite, amphibolite, gneiss, and metadiorite that rest upon rocks of the Chilliwack Group. Other rocks of the west half of the district consist of small bodies of Tertiary andesite and granite that are overlain by Quaternary andesite and tuff that make up Mount Baker. The largest valleys contain surficial deposits of Pleistocene glacial outwash material and Recent alluvium.

The predominant rocks of the east half of the Mount Baker mining district are Tertiary granodiorite of the Chilliwack batholith and pre-Jurassic Skagit gneiss. Parts of these rocks are overlain by Oligocene volcanic rocks that consist mainly of dacite, and andesitic breccias and tuffs. The volcanic rocks crop out mainly in the vicinity of Glacier Peak and Ruth Mountain, and on Silesia Creek near the International Boundary (Fig. 26). West of the Chilliwack batholith, pre-Jurassic greenschist and pre-Jurassic phyllite crop out from Baker Lake northward to Ruth Creek. The

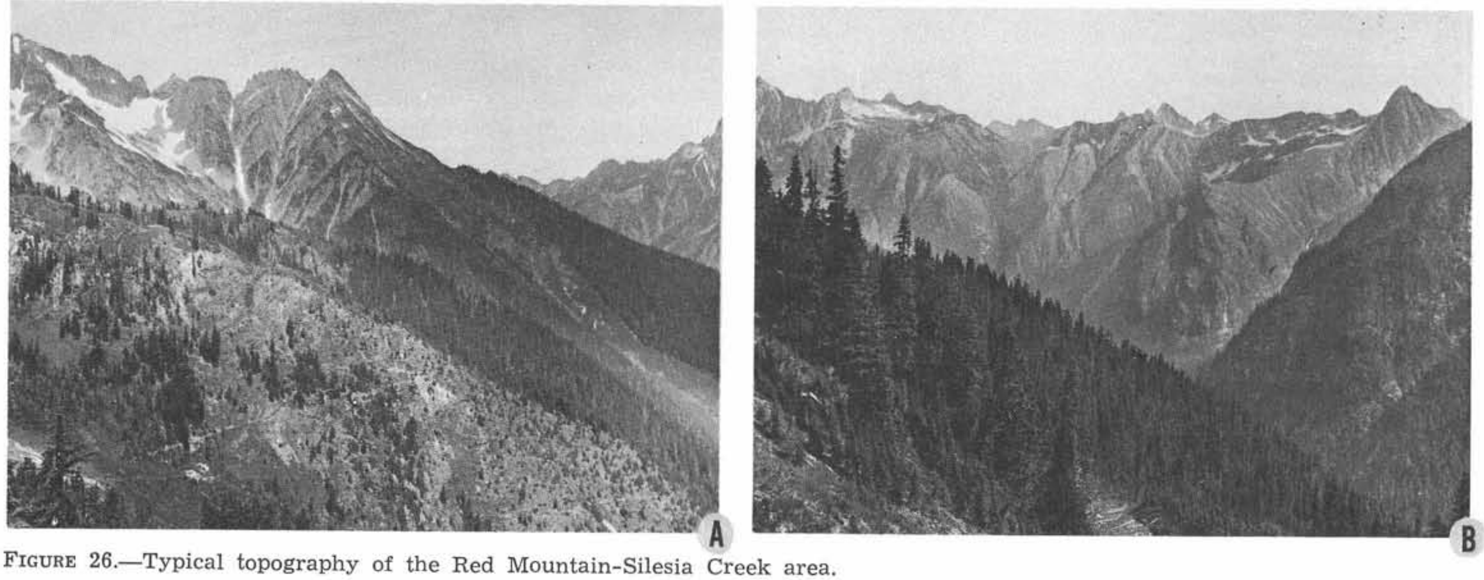

FIGURE 26.—Typical topography of the Red Mountain-Silesia Creek area.

A. Looking northwest toward Red Mountain from U.S. Land Monument No. 1. Lone Jack mine camp in lower left corner.

B. Looking north toward Silesia Creek from the vicinity of the Lone Jack mine. Mountains are part of the Chilliwack Batholith.

eastern edge of these rocks exhibits an intrusive contact with the Chilliwack batholith, and the western edge of the greenschist and phyllite has been thrust over sedimentary and volcanic rocks of the Chilliwack Group. In the vicinity of Yellow Aster Butte and Tomyhoi Peak, klippes of pre-Carboniferous metamorphic rocks, like those in the western part of the district, cap the summits of several peaks. The klippes and fault slices of Carboniferous-Permian rocks and pre-Jurassic phyllite form imbricated faults in the Tomyhoi Peak area. On the extreme eastern edge of the district, adjacent to Ross Lake, sedimentary and volcanic rocks of the Hozomeen Group and pre-Jurassic schist have been intruded by granitic rocks of the Chilliwack batholith.

Mineral Deposits

Mineral deposits of the Mount Baker mining district are syngenetic and epigenetic. The syngenetic deposits contain mainly chromite and hematite, and the epigenetic deposits are essentially gold, silver, copper, lead, and zinc veins.

The epigenetic deposits are most commonly fissure veins, in which fractures in rocks are filled with quartz and (or) calcite and ore minerals. The veins appear to have been formed from hydrothermal solutions in the mesothermal zone (intermediate temperatures and pressures). Such veins were formed at shallow to moderate depths.

The syngenetic deposits in the district are those of chromite and iron. This chromite occurs as veins, pods, and disseminated grains in olivine and serpentinite. It is probable that the chromite separated from the olivine during a late magmatic stage. The average Cr_2O_3 content of the chromite is around 50 percent, and the chrome-iron ratio is about 3:1. Segregation of the chromite forms well-defined veins and pods; however, most deposits are small.

The syngenetic iron deposits occur as residual deposits and as interbeds in sedimentary rocks. The iron oxide (Fe_2O_3) appears to have been formed as a result of the erosion of iron-rich peridotite bodies. The beds have a maximum thickness of about 100 feet and crop out for as much as 1,000 feet along their strikes; however, the average iron (Fe) content is only 25 percent.

Chromite

Most bodies of ultrabasic rocks in Whatcom County contain chromite, but in only two areas does chromite occur in significant concentrations. On Sumas Mountain and Twin Sisters Mountain (Pl. 2), veins, lenses, and irregular masses of chromite were discovered in the 1920's. However, except for several thousand pounds of chromite that was mined for testing purposes, there has been no production from these deposits.

The deposit of chromite on Sumas Mountain is the most accessible one, but development work in the 1940's revealed that the chromite occurs in lenses, no single one of which contains much more than 5 tons. Larger bodies of chromite are present on Twin Sisters Mountain but are inaccessible because of the rugged mountainous terrain.

Twin Sisters Mountain Deposits

The principal metallic mineral of the Twin Sisters dunite is chromite. Some dustlike particles of magnetite are also present but are scattered mainly in altered parts of the dunite. Much of the dunite contains disseminated grains of chromite that are clearly visible as small black specks. The grains, which are euhedral to subhedral and rarely exceed 1 millimeter in diameter, compose as much as 0.5 to 1.5 percent of the rock; they occur interstitial to grains of olivine and as inclusions in the olivine.

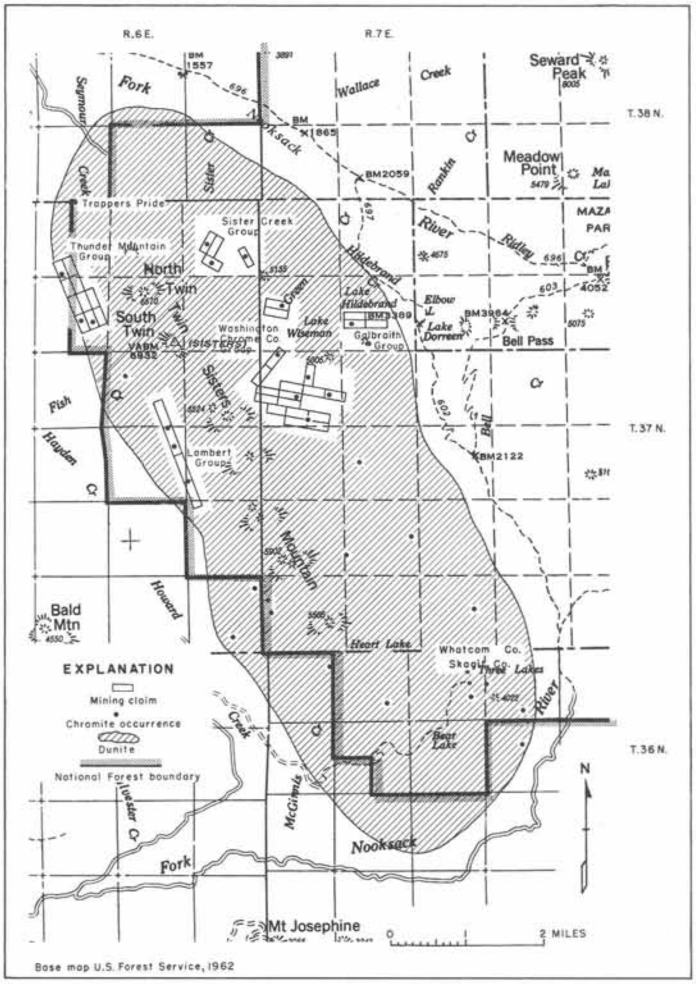

FIGURE 27.—Chromite deposits of Twin Sisters Mountain.

In some parts of the dunite, chromite grains have been segregated into veins and lenses that form well-defined structures appearing as black streaks against the brownish-yellow dunite. The veins, which appear to have developed along joints in the dunite, occur in two sets. One set strikes north to northwest, parallel to the major structural trend of the area, and the other set strikes east to east-southeast. The dips range from 50° to vertical. Spanski (1963, p. 16-17), after a study of many of the chromite veins, makes the following statement regarding their structure:

> The chromite veins are generally quite small and are commonly grouped in an en echelon pattern within "zones." These "zones" are from 1 to 40 feet wide and 10 to 150 feet long and contain from 3 to over 100 small, parallel, discontinuous veins. The veins exhibit a pinch and swell form, with swells rarely exceeding a few inches in thickness and a foot in length, and single veins rarely exceeding 20 feet in length.
>
> Large single veins exist, but they are isolated and rare. Two veins 20 to 50 feet long and 1 to 2 feet wide were examined; both developed into large, elliptical pods of chromite near their midpoints. The pods, in cross-section, average 8 feet in thickness and 12 feet in length, and change abruptly into veins 1 to 2 feet thick at either end.

The chromite deposits that were investigated by Spanski, as well as other known deposits, are shown in Figure 27. General information on the major deposits, as reported by other investigators, is given in Table 19.

Developments.—Unlike claims for metals such as gold, silver, copper, lead, and zinc, which were staked in the Mount Baker mining district as early as 1895, claims for chromite were not staked before 1926. On July 13, 1926, M. M. and S. S. Lambert filed on the Sister and the Skookum chromite claims, at the headwaters of Skookum Creek, northwest of Grainstack Mountain. In the 1930's, other claims were staked on what appeared to be the most promising chromite deposits of Twin Sisters Mountain. These claims were as follows:

Date	*Claimant*	*Property*
Aug. 7, 1930	S. S. Lambert	Lambert Group
Jan. 23, 1931	W. M. Elsey et al.	Washington Chrome Co. Group
July 27, 1931	A. Odmark et al.	Thunder Mountian Group
Aug. 25, 1934	J. Galbraith et al.	Galbraith Group
Sept. 7, 1934	G. Muehlberger et al.	Sister Creek Group

In 1933 Amos Slater, a mining engineer from Seattle, examined and reported on the chromite deposits of Twin Sisters Mountain (W.E.R.A. Project S-F2-33). According to Slater, development work had been undertaken on only the Ribbon and Danny claims. On the Ribbon claim a lens of chromite 20 feet long and 3 feet wide was mined to a depth of 15 feet. From this claim, chromite was transported on a 1,200-foot wire tramline to a camp on Green Creek and 20 tons of chromite was sent to Bellingham for testing. At the Danny claim about 3,000 pounds of chromite was mined from several lenticular veins. According to G. R. Cooley, of Washington Chromium Co. (written communication, undated), this chromite was shipped to Japan for testing purposes, but negotiations with the Japanese failed.

In 1940, as part of strategic minerals investigations, the U.S. Geological Survey examined all reported chromite occurrences in Twin Sisters Mountain (James and others, 1943). According to this report, the chromite of the district is richer in chromic oxide than most chromite from other districts in the United States. However, the known reserves of the Twin Sisters area are comparatively small; the largest of these deposits probably do not contain more than 1,000 tons each. It was also pointed out that many of the chromite occurrences are on cliffs or cirque walls, where mining would be expensive, if not impracticable.

In 1943 the U.S. Bureau of Mines published a report on the refractory properties of Washington chromite (Wilson and others, 1943). Pyrometric cone equivalent (P.C.E.) tests indicated that chromite from several Twin Sisters deposits is first-grade material and equals the best commercial ores. The cone equivalents of ore from the Danny, Good Hope, and Ribbon claims of the Washington Chrome Co. ranged from 39 to 41. Calcination tests on chromite from the Danny claim showed that the volume remained practically constant from cone 30 (1,650° C.) to cone 40 (1,885° C.). Between cones 19 (1,520° C.) and 26 (1,595° C.) the thermal expansion was rapid, gradually decreasing to cone 30,

TABLE 19.—*Chromite deposits of Twin Sisters Mountain*

Property name	Location	Structure of vein	Analyses	Remarks	Reference
Galbraith Group	SW¼ sec. 8, (37-7E)	N. 60° E.-trending chromite lens 5 to 6 ft. thick and 6 to 10 ft. long.	50.8% Cr_2O_3 12.87% Fe Cr/Fe 3.13	4 claims—Joe, Andy, Burton, and Amos. Veins on north and south shores of Lake Hildebrand.	Slater, 1935; James and others, 1943.
Lambert Group	SE¼ sec. 14, (37-6E); NE¼ sec. 23, (37-6E); SW¼ sec. 24, (37-6E). Elev. 4,000 ft.	Chromite in banded and disseminated ore zone 240 ft. long and as much as 50 ft. wide. Exposed to depth of 50 ft.	56.58 to 58.14% Cr_2O_3 14.59 to 15.03% Fe Cr/Fe 2.65	Analyses on cleaned chromite Anne, Cultus, Robert, Warren, Skookum, and Sisters claims.	James and others, 1943; Huntting, 1956.
	SW¼ sec. 14, (37-6E). Elev. 4,000 ft.	Chromite stringers 1 to 6 in. wide and 5 to 20 ft. long.	--------------------	Robert and Anne claims	Huntting, 1956; James and others, 1943
	SW¼ sec. 14, (37-6E). Elev. 3,600 ft.	Disseminated chromite in zone 5 ft. wide, 200 ft. long on Cultus and 10 to 30 ft. wide and 50 ft. long on Skookum.	16.49 to 36.92% Cr_2O_3 Cr/Fe 2.65	Cultus and Skookum claims	Huntting, 1956; James and others, 1943.
	SE¼ sec. 23, (37-6E)	Chromite vein 1 to 2 ft. wide, 20 ft. long. N. 20° W. strike.	45 to 52% Cr_2O_3	Sisters claim	Huntting, 1956; James and others, 1943.
Sister Creek (M & M)	S½ sec. 1, (37-6E). Elev. 3,000 to 3,500 ft.	N. 15° E. Stringers of chromite occur in three zones.	37.4 to 41.1% Cr_2O_3	4 claims—800 Kings, Peanuckle, 1000 Aces, and Lone Pine.	Slater, 1935.
Thunder Mountain Group	Secs. 3 and 10, (37-6E). Elev. 4,000 to 5,000 ft.	Strikes N. 20°-80° W. Stringers of chromite in 60-ft. E-W zone, 50 ft. long.	13.3 to 31.3% Cr 3.8% Fe 9.9% Mg	10 claims—Crater, Hard-Scrabble, Thunder group.	Slater, 1935.
Trappers Pride (Seymour Creek)	N. ¼ cor. sec. 3, (37-6E). Elev. 5,100 ft.	Stringers of chromite 1½ to 2 in. wide and 48 ft. long.	-------------------	At head of Seymour Creek	Huntting, 1956.
Washington Chrome Co.	Sec. 18, (37-7E). Elev. 3,800 to 5,500 ft.	N. 7° W. to N. 40° E.-trending chromite veins. On Dannie claim, lens 30 ft. long, 12 ft. wide at thickest part. On Good Hope claim, veins 6 to 8 ft. long and 12 to 18 in. wide.	44.09 to 51.16% Cr_2O_3 13.6 to 26.5% FeO 2.95 to 18.3% MgO 6.0 to 8.6% SiO_2 9.2 to 11.10% Al_2O_3 Cr/Fe 3.13	15 claims—Zoanne, Ford, Whistler, Pat, Good Hope, Jordan, Ranger, Bumper, Dare, Opportunity, Partner, Dannie, Last Notch, Joan, and Willie. 3,000 pounds chromite from Dannie claim mined for testing.	Slater, 1935.
	NW¼ sec. 18, (37-7E)	Lens of chromite 35 ft. long and 7 to 15 in. thick at center.	50 to 60% Cr_2O_3	Bumper claim	Huntting, 1956.
	SE¼ sec. 18, (37-17E). Elev. 3,800 to 4,200 ft	Banded and disseminated chromite.	52.8% Cr_2O_3 Cr/Fe ratio 3.06	Whistler claim	Huntting, 1956.
	S½NW¼ sec. 7, (37-7E); N½SW¼ sec. 7, (37-7E). Elev. 4,000 to 5,000 ft.	N. 20° E. strike, 87° NW. dip. Chromite lens 2 ft. wide and 20 ft. long. Mined to depth of 15 ft.	40.89 to 52.70% Cr_2O_3 (Ribbon claim)	Ribbon and Button claims on Green Creek. Wire tram from chromite outcrop at 3,800 ft. to camp at 3,000 ft. Some chromite mined in 1934.	Slater, 1935.

after which the expansion was slight (Wilson and others, 1943, p. 6). Other tests by the Bureau of Mines, relating to beneficiation of typical Twin Sisters chromite ores, show that 84.3 percent of the chromite can be recovered by flotation and 57.3 percent by tabling. By combining tabling and high-tension separation of the table middlings, a product containing 82.07 percent chromite can be obtained (U.S. Bureau of Mines, written communication, undated). Like previous investigators, those of the U.S. Bureau of Mines are of the opinion that the chromite occurrences are small and scattered; because of severe climatic conditions, rugged terrain, and transportation difficulties the development of these deposits may be prevented by high mining costs.

In 1937 the chromite occurrences were examined by the Washington Division of Mines and Geology. After examining many occurrences, W. A. G. Bennett, staff geologist, was of the same opinion as other investigators, in that no large single deposits are present but there are a large number of small deposits. These deposits each contain from 20 to 1,000 tons of chromite, which makes mining economically impracticable under present conditions.

Reserves.—The most complete estimation of the chromite reserves of Twin Sisters Mountain has been reported by James and others, (1943), as follows:

> The known reserves of the district are comparatively small, partly because little exploration has been done on the deposits of low-grade disseminated ore. The amount of shipping-grade ore containing 40 percent or more chromic oxide (Cr_2O_3) is probably between 2,000 and 5,000 long tons, and the reserve of milling-grade ore indicated by surface exposures is about 45,000 long tons, ranging from 10 to 25 percent Cr_2O_3. Additional possible reserves of 100,000 long tons of milling-grade ore might be revealed by surface trenching and subsurface exploration. Concentrates containing 45 to 50 percent Cr_2O_3 and having a chromium-iron ratio of 2.4 to 2.7 probably could be produced from the disseminated deposits unless the chromite slimes excessively during fine grinding, which may be necessary to free the finer grains of ore from the fresh dunite.

It should be pointed out that the reserves reported by James and others include reserves of several claims on the southeast end of Twin Sisters Mountain, in Skagit County.

Sumas Mountain Chromite Deposits

Serpentinite, the host rock for the chromite deposits of the area, underlies about 4 square miles of the northwestern part of Sumas Mountain. Most of the area that is underlain by serpentinite has a thick cover of overburden and vegetation, and very little bedrock is exposed. The few exposures are mostly in the bottoms of creeks and in steep rocky cliffs.

In the course of this examination many outcrops were checked for chromite, but no significant deposits were discovered. Several outcrops of serpentinite were noted to contain sparsely disseminated chromite, the largest of the outcrops being in the E½ secs. 30 and 31, T. 40 N., R. 5 E. Small stringers ¼ to ½ inch wide, as well as sparsely disseminated chromite, are present in the NE¼ sec. 1, T. 39 N., R. 4 E.

Breckenridge Creek Deposit

Location and accessibility.—The largest known deposit of chromite on Sumas Mountain is on the northern end of the mountain, in the N½SW¼ sec. 30, T. 40 N., R. 5 E. (Fig. 28), on a tributary to Breckenridge Creek. The occurrence is about 5 miles southeast of Sumas and is accessible by trail from the farm of A. P. Westergreen, on the South Pass road. The trail is blazed but can be followed only with difficulty. At one time a jeep road reached the deposit, but it is now overgrown with brush.

At about 300 feet above and on the south side of the creek, an area 60 feet long and 25 feet high has been stripped of overburden. From sections of the South Pass road the stripped area stands out as a scar on the otherwise wooded slopes of Sumas Mountain.

History.—The deposit was discovered in 1930 by Elmer Goodwin and John Dahlgreen while hunting in the area (A. P. Westergreen, oral communication, 1959). A 50-foot adit was driven on the outcrop, and a small amount of chromite was mined at that time. Later work at the discovery site covered the portal of the adit, which is now inaccessible.

In 1943 the U.S. Bureau of Mines reported (Wilson and others, 1943, p. 13) that J. M. Stine, Fred Shea, Ott (initials unknown), and John Dahlgreen had filed on most of sec. 30. Stine submitted to the Bureau chromite specimens that contained 45 percent Cr_2O_3. No mention was made of mining being undertaken on the property at that time.

In 1946 the Super Chrome Co., of Seattle, headed by Elmer Larson, attempted to develop the property. A jeep road was built to the chromite deposit, and a small-scale mining operation was started. Surface mining on the most promising outcrops produced several tons of chromite. However, the operation was suspended when most of the chromite lenses pinched out.

The property has been examined by several mining engineers and geologists since 1946, but no further mining has been undertaken. In 1952 the Yamate Trading Co. Ltd., San Francisco, obtained a 20-year lease on the property from the State.

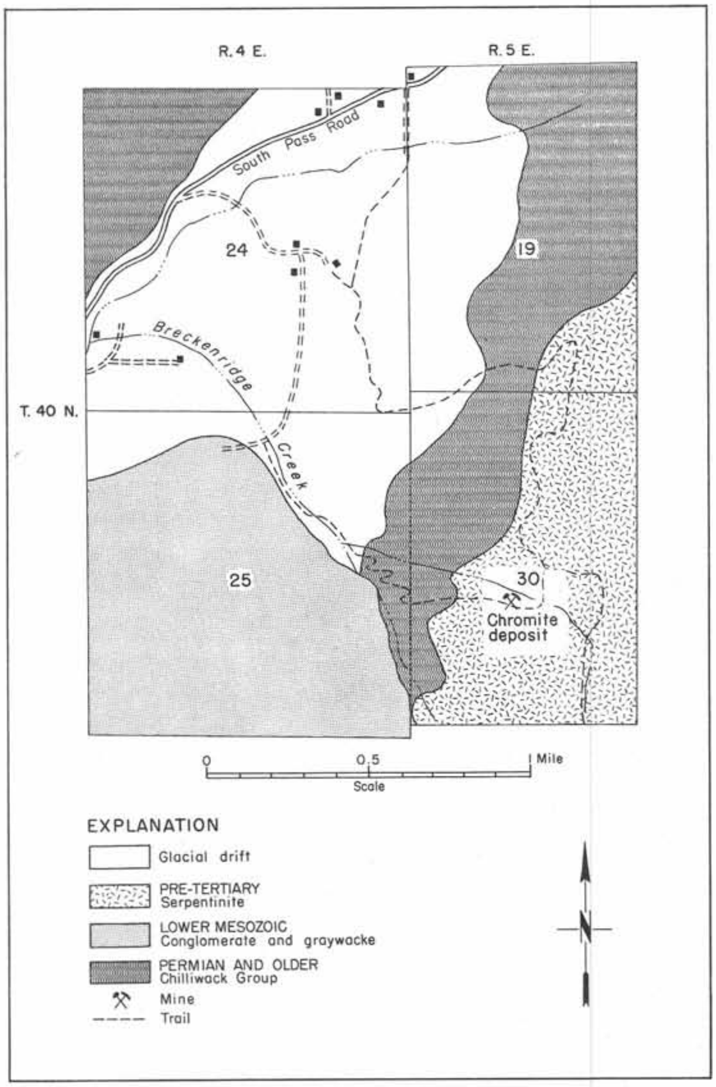

Figure 28.—Location and geologic map of Breckenridge Creek chromite deposit.

Geology.—The area in which the chromite occurs is underlain entirely by serpentinized peridotite. About 500 feet to the west, the serpentinite lies beneath graywacke and argillite of late Paleozoic age. Although most of the contact between the two units is concealed, several outcrops indicate an intrusive contact. The serpentinite has been mapped as being of possible Jurassic-Cretaceous age (Moen, 1962, p. 49).

The outcrops of the serpentinite form many prominent cliffs, exhibit a well-defined jointing system, and are yellowish brown on weathered surfaces. Beneath the weathered surfaces the rocks show the dark-green shades characteristic of serpentinite. A set of closely spaced joints strike N. 80° W.; they dip 35° SW., parallel to the chromite bands in the serpentinite. A second set of joints, some of which have developed into faults that offset the chromite seams, strike N. 15°W. and dip 50° NE. Intensely slickensided serpentine zones as much as 6 inches in width are present along the faults.

Examination of thin sections of several specimens reveals that the serpentine minerals of the serpentinite were derived from olivine. The olivine, which constitutes about 20 percent of the rock, occurs as anhedral grains averaging about 0.16 millimeter across. Serpophite, antigorite, and chrysotile, formed from the alteration of olivine, are present in equal amounts and compose about 60 percent of the rock. The chrysotile and antigorite occur as a mesh of veinlets enclosing cores of serpophite or relics of undestroyed olivine.

Chromite and magnetite are present in minor amounts in most of the serpentinite. The magnetite occurs as dustlike particles throughout the serpentinite, and in some places forms hairlike stringers along fracture lines. The magnetite probably is secondary, formed from the alteration of olivine. The chromite, which comprises less than 1 percent of the typical serpentinite, occurs as euhedral to subhedral grains, the average size being less than 0.50 millimeter across.

Mineralization.—Although some disseminated grains and small stringers of chromite occur between the 2,000- and 2,500-foot elevations in the creekbed below the mine workings, the largest concentrations of chromite appear to be at the site of the latest mining operations. Here the chromite is concentrated into a series of parallel bands from ¼ inch to 2 inches wide. In a few places the chromite grains increase in size and number to form lenticular bodies. The largest lens that was observed at the mine workings was 5 feet long and 4 inches wide. Massive chromite noted in a small stockpile indicates that some lenses may have been as much as 10 inches wide.

The bands of chromite, which alternate with layers of serpentinite, have a general strike of N. 80° W. and a dip of 35° S. The attitude of the chromite bands appears to be persistent. Most of the bands terminate against small cross faults and thicken and thin along their strikes and dips. The average thickness of the bands is about 1 inch.

As observed in the outcrops, the chromite bodies appear to consist of massive chromite, but under the microscope the chromite grains can be seen to be surrounded by serpentine. The grains average 1 millimeter across, are anhedral, rounded, and contain numerous minute antigorite-filled fractures. What little magnetite is present occurs as dustlike particles in the serpentinite.

Analysis of a relatively pure piece of chromite by the U.S. Bureau of Mines (Wilson and others, 1943, p. 23) is as follows:

Constituents	Percent	Constituents	Percent
Cr_2O_3	45.1	Al_2O_3	5.6
FeO	17.6	Loss on ignition	2.8
MgO	18.1	P.C.E.	39-40
CaO	trace	Cr/Fe	2.5:1
SiO_2	8.3		

It is believed that the banded chromite is of magmatic origin and crystallized in an olivine-rich differentiate of an ultramafic parent magma. Euhedral crystals of chromite, free of silicate inclusions, suggest that the chromite was first to crystallize. The early crystallization of the chromite was soon followed by the crystallization of the olivine. Whether the parallel bands of chromite are early crystal segregations or a result of later flowage of the rock in a semisolid or solid state has not been determined.

Conclusions.—Insufficient data are available to calculate ore reserves for the chromite deposits of Sumas Mountain. Disseminations and thin bands of chromite occur in different parts of the Sumas Mountain serpentinite, but past exploration has shown that the deposits are limited in size. Most do not contain more than 5 tons of chromite.

The possibility that concentrations of chromite in larger bodies are present should not be discounted. Probably all the exposed serpentinite has been examined at one time or another. Only by removal of the overburden or by geochemical or geophysical methods, such as magnetometer surveys, are concealed deposits likely to be located.

Iron

The iron deposits of Whatcom County occur as residual deposits, sedimentary deposits, hydrothermal deposits, and bog ores. Most of the larger deposits are in the west half of the county (Pl. 2). Although some deposits have been investigated several times, there has never been any production of iron ore. To date (1966), most exploration work has been at the Sumas Mountain deposit, on the eastern edge of Whatcom Basin. Most investigators are of the opinion that the iron deposits of the county lack volume and (or) grade to be of commercial value.

Residual Deposits

These deposits are formed through the accumulation of valuable residues after undesirable constituents are removed by weathering processes. Bateman (1951, p. 205) states that in order for residual deposits to form, several conditions must exist. The first requirement is that a rock must contain a valuable mineral that is resistant to weathering. Second, the climatic conditions must favor decomposition of the rock. Third, the relief of the land must not be so great that the weathered material is washed away as fast as it is formed. Fourth, there must be an interval of crustal stability that allows time for the mineral to accumulate and not be destroyed by later erosion. These conditions apparently existed in Whatcom County, as the Sumas Mountain iron deposit is of the residual type.

Sumas Mountain iron deposit

Location and accessibility.—The Sumas Mountain iron deposit, as described in this report, is mostly in the N½ sec. 2, T. 39 N., R. 4 E., but a small part of the deposit extends northward into sec. 35, T. 40 N., R. 4 E. It is 6½ miles south of Sumas and 4 miles east of Everson. The deposit is exposed in several streambeds on the western slope of Sumas Mountain at elevations between 1,000 and 2,000 feet above sea level. The location of the deposit is shown in Figure 29.

From the South Pass road, the general area can be reached by following the Lebrant road south for about 1.2 miles to an abandoned timber loading dock. A trail is then followed along an old logging road for three-quarters of a mile up a narrow valley to the deposit.

Washington State Highway 1A and the Sumas branch line of the Northern Pacific Railway are 3 miles to the west of the deposit.

History.—From as early as 1915, when the property was first staked for its iron oxide, until 1959, when the area was examined for this report, the Sumas Mountain iron deposit has been considered a possible source of iron. During this time very little work has been done on the property. Many samples have been taken, a few trenches dug, and one adit driven, but no mining has been undertaken.

To provide a brief outline of the history of the property, there are listed below some of the more significant developments between 1915 and 1957:

1915—J. C. Compton and J. A. Hatton staked area as the Ochre Point placer.

1917—J. A. Hatton et al. filed on 60 acres in sec. 2, T. 39 N., R. 4 E. Minerals unknown.

1919—R. A. Cole filed on seven contiguous claims in sec. 2, T. 39 N., R. 4 E., and sec. 35, T. 40 N., R. 4 E., known as the Hematite group.

1929—C. E. Phoenix, mining engineer, examined area and reported large tonnage (100,000,000 tons) of iron ore.

1938—Hematite Iron and Gold Mines Development Co., Seattle, Wash., acquired Hematite group. Sixty-foot tunnel present on property.

1941—Henry J. Landall, of Vancouver, B. C., Canada, requested financial assistance from the Northern Pacific Railway to explore the property. Request denied when property was examined and found to be of no commercial interest as a source of metallic iron.

1941-42—Northern Pacific Railway examiners studied deposit, results unpublished.

1952(?)—L. C. Noble leased 7 claims to Western Slope Construction Co., of San Francisco. Company planned to extract ore for shipment to Japan.

1952—Yamate Trading Co., Ltd., San Francisco, acquired 20-year lease on property.

1957—Waddington Mining Corp., Ltd., Vancouver, B. C., Canada, acquired 20-year lease on property.

1957—Northern Pacific Railway examined and sampled property.

Topography.—The Sumas Mountain iron deposit is on the western slope of Sumas Mountain at elevations between 1,000 and 2,000 feet above sea level. Whatcom Basin, 1 mile to the west, has an elevation of about 100 feet, and 1½ miles east of the deposit the mountain reaches its maximum elevation of about 3,350 feet. The western slope, for the most part, has a heavy cover of underbrush, but a few stands of fir and hemlock are also present. Outcrops are scarce, but where present are usually cliff forming.

Several streams have formed deep, steep-sided ravines on the western slope of the mountain, and stream erosion of the westward-dipping Tertiary sedimentary rocks has produced a series of "flatirons" along the western front of Sumas Mountain. The terrain in the vicinity of the iron deposit is moderately rugged and

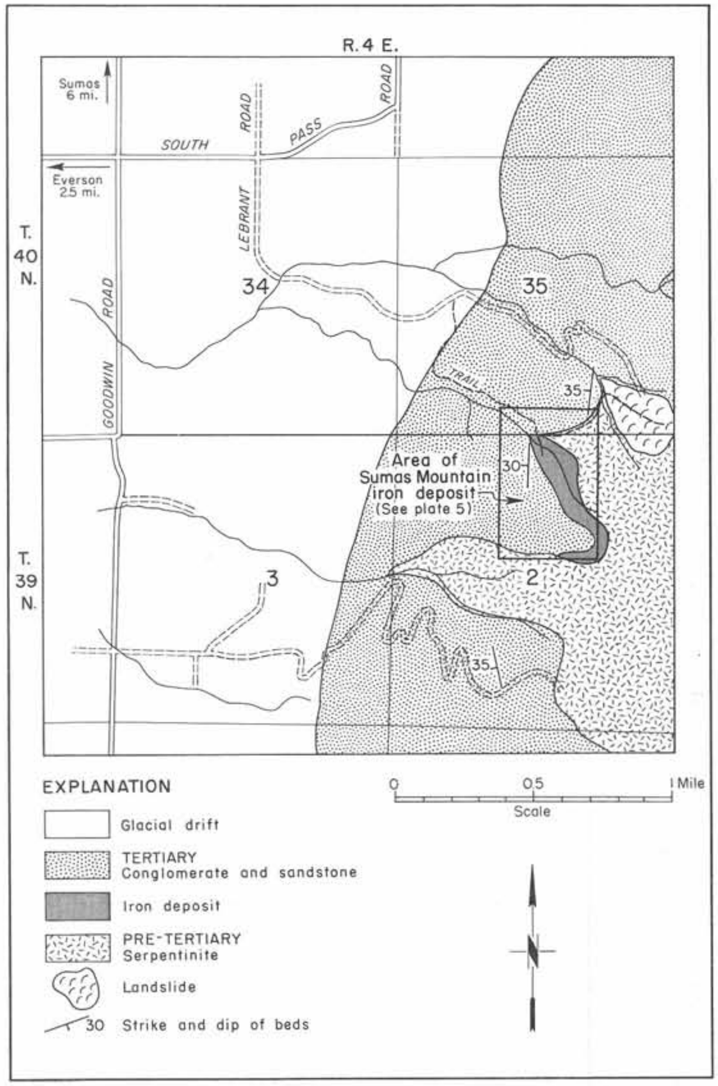

FIGURE 29.—Location and geologic map of Sumas Mountain iron deposit.

for the most part covered by overburden. Only where streams have cut through the overburden is the iron deposit exposed. Several small streams, sufficient for camp needs, occupy the larger ravines.

Geology.—The basement rock that underlies the Sumas Mountain iron deposit is pre-Tertiary serpentinized peridotite. Early Mesozoic(?) graywackes crop out 1 mile to the northeast, and graywackes, argillites, and basic volcanics of late Paleozoic age crop out 2 miles to the southeast. Overlying the iron deposit are Tertiary cobble conglomerates and arkoses.

During pre-Tertiary times, peridotite that is now highly serpentinized was intruded into a complex of older sedimentary rocks. The area was subjected to erosion that exposed the peridotite, which was then subjected to intense tropical weathering, resulting in the formation of iron-rich laterite over the surface of the peridotite. Following the formation of the laterite, some time during early Tertiary time the the area was covered with continental conglomerates and arkoses. Since then, the area has been gently folded and erosion has cut through the overlying sedimentary rocks to expose parts of the lateritic iron deposit (Pl. 5).

Character of the ore.—Much has been written on the process of laterization, and it is beyond the scope of this report to discuss the process in detail. In general, laterites develop under tropical conditions of high temperature and high rainfall. Although these climatic conditions do not exist in this area today, fossil plants indicate that the climate at the time the laterites formed was tropical to subtropical. In the process of rock decay, a clayey residual mass of alumina and ferric oxides is concentrated in the upper part of the weathered zone. Although the laterite on Sumas Mountain is but a ferruginous clay having a heavy reddish stain, it commonly has been called an iron ore.

On Sumas Mountain the rocks upon which the laterite developed consist of several varieties of dark-green peridotite. The peridotite is almost wholly serpentinized, but residual grains of olivine, chromite, and magnetite are plainly visible under the microscope. The rock is traversed by many joints, along which reddish iron oxide staining has developed. Weathering of the jointed serpentinite produces spheroidal remnants, many of which are visible in several streambeds.

The dark-green serpentinite grades upward into a grayish-green to reddish-brown horizon that consists chiefly of clay minerals. Scattered throughout the clay are angular fragments of serpentinite, their average size being 3 to 5 millimeters across. Scattered grains of chromite and magnetite are also present but compose less than 1 percent of the rock.

Above this horizon is a green to grayish-brown, dense, massive claystone. Fragments of the serpentinite from which the clay was developed are not visible in this rock; however, a few grains of chromite and magnetite are present in most specimens.

The two weathered zones that overlie the serpentinite do not exceed 8 feet in thickness, and in no two places are they the same thickness. These zones grade upward into the ferruginous claystone that comprises the so-called "iron ore" deposit.

This claystone is composed chiefly of extremely fine grained (clay size) hydrous aluminum silicates, limonite, hematite, and magnetite. A few grains of quartz and chromite are also present. The color varies from grayish brown through grayish red. Specific gravity determinations of several samples range from 2.67 to 3.09. The basal part of the claystone shows no bedding but exhibits some spheroidal weathering due to closely spaced joints. Bedding visible in the upper parts of the unit is shown by alternating layers of claystone and siltstone. Several sandy beds are also present. The beds range in strike from N. 20° E. to N. 20° W., and in dip from 25° to 40° W.

Although the ferruginous claystone has a maximum thickness of about 35 feet, the iron-rich part generally averages only 5 feet in thickness. In this section, much of the claystone is magnetic and contains magnetite oölites and pisolites and also fills small fractures in the iron beds. The chromium occurs as small grains of chromite, which are probably residual grains that have weathered out of the serpentinite. Nickel is present in the claystone, but the form in which it occurs is unknown. The absence of sulfides suggests that the nickel may occur as one of the hydrous nickel silicates.

The ferruginous claystone is overlain by lower Tertiary cobble conglomerates and arkosic sandstones, and appears to be concordant in structure. On the north bank of the creek near the N. ¼ cor. sec. 2, T. 39 N., R. 4 E., the contact is well exposed. Here a conglomerate can be seen resting upon bedded ferruginous claystone, which in turn is underlain by serpentinite basement rocks. The bedding in the upper part of the claystone suggests some reworking of the unit before the deposition of the conglomerate.

There appears to be little doubt as to the origin of the "iron ore." Evidence indicates that it formed as laterite on a peridotite erosion surface during early Tertiary time. It is possible, however, that before the deposition of the overlying sandstones and conglomerates some concentration occurred. Where closed basins or lagoons existed on the peridotite surface, they would act as settling ponds for surface drainage. The ferruginous claystone of Sumas Mountain appears to have been concentrated under such conditions, for on both the north and south boundaries of the deposit the claystone appears to lens out.

It is believed that the iron deposit of Sumas Mountain formed under conditions similar to those forming the iron ores of the Cle Elum district of Kittitas County (Lamey and Hotz, 1952, p. 54-59) and the Blewett district of Chelan County, Washington (Broughton, 1943, p. 13). Much has been written on these deposits, and it is generally believed that the iron ore there developed as laterite upon a peridotite erosion surface. Descriptions of the Cle Elum ore compare closely with that of the ore of Sumas Mountain, and in both localities the iron beds are covered by lower Tertiary continental sedimentary rocks of similar lithology.

Sampling and analyses.—The Sumas Mountain iron deposit has been sampled many times in the past, and the analyses disclose that the material sampled contains from 16.2 to 48.1 percent iron.

For comparison purposes the results of analyses, other than those taken by the Washington Division of Mines and Geology, are as follows:

TABLE 20.—*Compilation of chemical analyses of Sumas Mountain iron ore*

Constituents	Sample no. 1	2	3	4	5	6	7
Fe	37.31	29.92	21.9	40.3	19.4 to 29.1	18.76 to 25.9	48.10
SiO_2	20.83	33.90	......	23.5	26.9 to 36.5	40.06 to 47.3	......
Al_2O_3	......	......	22.46	10.1	11.9 to 19.3	19.16	......
CaO	......	......	trace	0.4	....	....	......
P	0.20	0.11	trace	0.058	0.026 to 0.073	0.04 to 0.85	0.058
S	0.008	trace	......	0.004	less than 0.01	0.10 to 0.12	0.002
Mn	......	0.32	......	trace	....	....	......
Ni	......	......	......	......	0.42 to 0.82	....	......
Cr	......	......	......	......	0.87 to 1.5	....	......
As	......	......	......	0.001	....	....	0.001
H_2O	......	......	......	6.25	....	....	......
Loss on ignition	......	12.10	23.40	4.7	10.1 to 11.8	....	......
Insoluble	......	......	17.76	......	....	....	......

Analyst and source of information:

1. R. P. Cope. Reported by Shedd and others (1922, p. 107).
2. Pacific Coast Steel Company. Daniel's report. Reported by Hodge (1938a, p. 17).
3. Hematite Iron and Gold Mines Development Company. Reported by Hodge (1938a, p. 17).
4. Old-time high-grade specimen. Reported by Zapffe (1949, p. 54).
5. U. S. Bureau of Mines, range of six samples. Reported by Binon (1959, p. 119).
6. Northern Pacific Railway, range of three samples. Reported by Binon (1959, p. 119).
7. J. H. Williams for J. E. England and M. Stephens, average of 10 samples. From private report of C. E. Phoenix, 1929.

The exact locations from which the samples in Table 20 were taken, as well as the thicknesses sampled, are unknown. Although the data furnish information as to the composition of the ore, the samples probably represent the richer parts of the deposit and do not by any means represent the entire deposit.

During the examination of the Sumas Mountain iron deposit for this report, the writer collected eight samples for analyses. The data from the analyses were used in estimating the tonnages. Approximately 10-pound samples were cut as channel samples across that part of the exposure that appeared to contain the most iron. At least one sample was taken from each outcrop of the ferruginous claystone, which extends over a lateral distance of about 2,250 feet. The locations of the samples and their thicknesses are shown on Plate 5. All samples were analyzed for Fe_2O_3, Al_2O_3, SiO_2, and loss on ignition. Sample No. 6, which was believed to be fairly representative of the deposit as a whole, was analyzed in more detail. The results of the analyses are as follows:

TABLE 21.—*Chemical analyses of Sumas Mountain iron ore*①

Sample no.	1	2	3	4	5	6	7	8
Sample length (feet)	5.0	4.5	6.0	4.5	5.0	3.0	3.0	5.0
Fe	27.2	31.8	25.5	33.7	16.2	26.8	20.0	28.6
Fe_2O_3	38.8	45.5	36.4	48.1	23.1	38.3	28.6	40.9
Al_2O_3	17.8	14.4	21.8	24.1	16.2	17.2	16.9	20.1
SiO_2	34.8	31.3	33.4	20.3	48.8	32.0	46.5	27.9
CaO	....	....	....	....	....	0.04	....	....
MgO	....	....	....	....	....	1.59	....	....
P	....	....	....	....	....	0.21	....	....
S	....	....	....	....	....	0.015	....	...
Mn	....	....	....	....	....	0.14	....	....
NiO	....	....	....	....	....	0.57	....	....
Cr_2O_3	....	....	....	....	....	0.91	....	....
TiO_2	....	....	....	....	....	0.22	....	....
H_2O	....	....	....	....	....	6.31	....	....
Loss on ignition②	5.48	5.56	8.20	6.56	7.20	8.49	7.02	8.49

①Sampled by Washington Division of Mines and Geology. Analyzed by Willis H. Ott, Metallurgical Laboratory, Seattle.
②Includes H_2O.

Brief descriptions of the samples in Table 21 are as follows:

Sample No. 1.—Medium-brown siltstone containing 10 percent quartz and 10 percent chromite grains that average less than 0.5 millimeter in diameter. Very fine-grained magnetite disseminated throughout sample.

Sample No. 2.—Grayish-red claystone containing less than 5 percent combined quartz and chromite grains. Sample appears to be mainly iron oxide.

Sample No. 3.—Grayish-brown claystone containing less than 0.5 percent chromite grains. Occasional pisolites of magnetite and about 1 percent clear and white quartz grains that average less than 0.5 millimeter in diameter.

Sample No. 4.—Grayish-brown claystone consisting chiefly of iron oxide. Occasional grains of quartz and magnetite compose less than 1 percent of the sample. Some fragments of altered greenish peridotite, in part serpentinite, occur throughout the sample. Sample from lowest exposure in lateritic zone.

Sample No. 5.—Medium yellowish-brown siltstone exhibiting sand phases. Abundant quartz grains and very little disseminated fine-grained magnetite.

Sample No. 6.—Grayish-brown claystone containing about 1 percent rounded magnetite grains from 1 to 4 millimeters in diameter. Quartz and chromite grains compose less than 2 percent of the sample.

Sample No. 7.—Grayish-brown claystone containing 1 percent rounded magnetite grains from 1 to 4 millimeters in diameter. Less than 2 percent chromite and quartz grains are present.

Sample No. 8.—Grayish-brown claystone that is silty in part. Silty phases give bedded appearance to outcrop. Grains of quartz, chromite, and magnetite less than 0.05 millimeter occur throughout sample.

The average specific gravity of five samples, as determined by the Division of Mines and Geology, is 3.0. This figure was used in the calculation of ore tonnages.

It is apparent from the analyses that the Sumas Mountain iron ore is definitely low grade. Although occasional assays of 40 to 48 percent iron are reported, the minable ore is more likely to be less than 30 percent iron. The silica and alumina are exceptionally high, whereas sulfur, phosphorus, and calcium tend to be low. The presence of nickel and chromium presents metallurgical problems.

Under present economic conditions, the Sumas Mountain iron deposit cannot be considered a source of commercial-grade iron ore.

Estimation of tonnages.—In estimating the possible iron ore tonnage of this deposit, only the ferruginous material exposed in the creekbeds between 1,000 and 2,000 feet in elevation was used. (See Pl. 4.) The lateral extent of these exposures is about 2,500 feet. Only the richer parts of the deposit would be mined, and sampling indicates that these parts would average about 5 feet in thickness. The average iron content for this thickness is 37.5 percent Fe_2O_3, or 26.25 percent Fe.

In calculating the tonnage of indicated ore, a width of 400 feet was used, this being the extreme distance between outcrops along the dip of the beds. Another 400 feet of width down dip was used for inferred ore calculations.

Based on these dimensions, the reserves of the Sumas Mountain iron deposit are about 375,000 tons of indicated ore and 375,000 tons of inferred ore having an average Fe content of 26 percent. These figures are almost identical with those of Zapffe (1949, p. 55), who estimated a possible reserve of 750,000 tons of ore with a 25 percent Fe content.

Conclusions.—The Sumas Mountain iron is a lateritic deposit that developed upon the erosion surface of a pre-Tertiary peridotite mass some time near the end of the Cretaceous period or the early part of the Eocene epoch. Burial of the laterite by upper Eocene (?) continental sediments preserved the deposit until late Tertiary time, when uplifting subjected the area to erosion and exposed the deposit.

Iron oxide staining is extensive on the western slope of Sumas Mountain; however, material containing as much as 25 percent Fe is confined to a small area, chiefly in sec. 2, T. 39 N., R. 4 E. The estimated reserves of this deposit are calculated at 750,000 tons of indicated and inferred ferruginous claystone containing 26 percent Fe.

Because of adverse physical and chemical properties, it is doubtful that the deposit would be of interest for use in the iron industry.

Bog Ores

The bog ores consist of dark-brown, rough and cellular masses or loose particles of iron oxide that fill depressions in the local topography. The deposits result largely from chemical and bacterial action in bogs that tends to precipitate iron from solutions of ferrous bicarbonate or ferrous sulfate. The iron mineral that is precipitated is generally one of the limonites.

Bog iron deposits occur at several places in Whatcom Basin, but their size is such that they cannot be considered as possible sources of iron. However, the largest known deposit is worthy of mention and its physical features are typical of the other bog iron deposits of the county.

Sturman and Herringa deposit

This deposit is in the NE¼ sec. 17 and the SE¼ sec. 8, T. 40 N., R. 3 E., and is about 1 mile north of Lynden. Shedd (Shedd and others, 1922, p. 103-105) reports that the deposit on Sturman's property covers 1 acre to an average depth of 2 feet. On Herringa's property the deposit covers about 5 acres and is from 0 to 3 feet thick. Analysis of the limonite is as follows: Iron (Fe), 39.67 percent; silica (SiO_2), 19.43 percent; phosphorus (P), 0.153 percent; sulfur (S), 0.013 percent. Although the iron content is nearly 40 percent, the limonite is classed as low-grade iron ore because of its high silica and phosphorus content.

The reserves of the deposit are estimated at 20,000 tons of limonite. The combined reserves of the other bog iron occurrences of the county are in the neighborhood of 15 to 20 thousand tons (Shedd and others, 1922, p. 104).

Sedimentary Deposits

The iron minerals of these deposits were laid down in marine sediments. Iron dissolved by surface water during the weathering of the rocks was carried in solution by streams to depositional basins in seas. Upon reaching the sea the iron was precipitated by mechanical, chemical, or bacterial action. The water in which the deposits accumulated was shallow, as indicated by the presence of current markings, shell fragments, and worm burrowings. Hematite and limonite are the most common iron minerals of these deposits. Magnetite is sometimes associated with the hematite and limonite, but it is probably a supergene mineral.

Although ferruginous sedimentary rocks are known to occur in many parts of the county, few deposits contain iron minerals in significant concentrations. The largest sedimentary iron deposit is the Church Mountain deposit, near Glacier.

Church Mountain iron deposit

This deposit is in the NE¼ sec. 35 and the SE¼SE¼ sec. 26, T. 40 N., R. 7 E., and is 5 miles east of Glacier (Pl. 2). The deposit crops out at several places on the south slope of Church Mountain at altitudes of 2,500 to 4,300 feet. On the Church Mountain lookout trail (about 1.6 miles from the start of the trail and at an altitude of 4,200 feet), part of the deposit is exposed.

The host rocks for the deposit consist of calcareous clastic sedimentary rocks of Jurassic-Cretaceous age. The rocks dip steeply north and south and have a general N. 80° E. strike. Several beds of the sedimentary sequence are fossiliferous, the dominant fossils being belemites and pelecypods.

The iron minerals appear to be contained in a sandy argillite bed that is approximately 100 feet thick; the bed appears to be calcareous in part. The iron minerals, which are mainly hematite, limonite, magnetite, and siderite, occur in a finely divided state throughout the argillite. Freshly broken rock is dark gray to maroon, brittle, and almost cherty in some places. The ferruginous bed is not uniform in composition, as sandy phases low in iron minerals are present. The length of the iron bed along its strike appears to be more than 1,500 feet. Along its dip the bed is at least 1,000 feet long. Two random samples of the deposit that were collected by the writer assayed 41.04 and 45.48 percent Fe_2O_3; about 8 percent of the samples was magnetite. An analysis of the ferruginous argillite, as reported by Zapffe (1949, p. 51), is as follows:

Constituents	*Percent*	*Constitutents*	*Percent*
Fe	29.42	CaO	16.56
P	0.264 to 0.397	Mn	trace
SiO_2	10.96	S	nil
Al_2O_3	3.14	Au	$2.72

Ferruginous siltstone and argillite similar to the rocks in the Church Mountain deposit crop out 1¼ miles south of that deposit (Pl. 2). In the SW¼NW¼ sec. 1, T. 39 N., R. 7 E., a 250-foot drift crosscuts 120 feet of ferruginous siltstone, sandstone, and conglomerate. The iron mineralization is the same as that of the Church Mountain deposit and probably represents the same bed that has been complicated by folding or faulting.

Hydrothermal Deposits

These deposits occur as fissure veins and disseminated iron sulfide minerals in a variety of host rocks. Such deposits are generally considered to be of igneous origin and formed from iron-rich hydrothermal solutions. The common iron minerals of these occurrences are pyrite, pyrrhotite, and magnetite.

Several conditions are usually required for the formation of hydrothermal deposits: (1) mineralized solutions; (2) openings in the rock through which solutions may pass; (3) available sites for deposition; (4) favorable temperature, pressure, and chemical conditions; and (5) a concentration of minerals at the site of deposition (Bateman, 1951, p. 101). Such deposits are usually found in close proximity to igneous intrusive rocks, from which the hydrothermal solutions originated.

Pyrite, pyrrhotite, and magnetite are the most common metallic minerals of the county, but they do not occur in concentrations of sufficient size to make them of commercial value for their iron content. Almost every metallic mineral deposit contains at least one or more of these minerals, but mainly as accessory minerals. In some of the larger disseminated deposits, pyrite and pyrrhotite are accompanied by gold and silver, but the average gold-silver value seldom exceeds $2 per ton. Data on the larger hydrothermal iron deposits of the county are given in Table 22.

TABLE 22.—*Hydrothermal iron deposits of Whatcom County*

Property	Location	Mineralization	Remarks	Reference
Great Excelsior mine	Sec. 6, (39-8E), about ½ mile south of confluence of Wells Creek and Nooksack River.	Disseminated fine-grained pyrite in brecciated and silicified Middle Jurassic slate and argillite. Pyritized zone 200 to 400 ft. wide and about 4,000 ft. long. Average gold content 0.09 oz.; average silver content 3.44 oz.	Deposit mined for gold and silver in early 1900's. Production about $69,000.	Stoess and Slater, 1935.
Iron Cap (Shuksan Arm)	NE¼ sec. 29, (39-9E), about 2 miles southeast of Mount Baker Lodge.	Silicified greenstone containing disseminated pyrite. NE.-trending mineralized zone as much as 1,000 ft. wide. Values to $16 per ton in gold. Average gold value $2.50 per ton. Pyrite makes up about 10% of rock.	Talus slide contains about 800,000 tons of pyritized rock. Sixty-ft. and 120-ft. adit on property.	Huntting, 1956, p. 177; Stoess, 1934.
Jim Mountain	Sec. 9, (38-17E)	Pyrrhotite veins 4, 6, and 12 ft. wide that contain 70 to 80% pyrrhotite. Country rock, Cretaceous shale.	Property could not be found by W. S. Moen in 1965.	Huntting, 1956, p. 204.
Ruth Mountain Pyrite	W½ sec. 8, (39-10E), about ¼ mile west of Hannegan Pass.	Disseminated pyrite in altered Miocene acidic volcanic rocks. Four veins 10 to 30 ft. wide. Gold values $0.28 to $176; average about $2.50. Pyrite makes up less than 10% of the rock.	One short adit on property	Huntting, 1956, p. 204.
Tooker-Lestrud	SE¼ sec. 31, (40-8E)	Disseminated pyrite and marcasite in altered Mesozoic volcanic and sedimentary rocks. Mineralized zone 10 to 25 ft. wide. As much as 2.903 oz. in silver and 0.103 oz. in gold per ton. Average pyrite content about 5%.	Reddish-brown to yellow iron oxide-stained zone very prominent on highway.	Huntting, 1956, p. 335.
Wells Creek Gossan	Sec. 5, (39-8E), about 1 mile southeast of confluence of Wells Creek and Nooksack River.	Disseminated fine-grained pyrite in strongly sheared and altered Middle Jurassic andesite. Shear zone about ½ mile wide and 1 mile long. Average pyrite content less than 3%. Assays up to 0.20 oz. in silver and 0.40% copper.	Several prominent iron oxide-stained zones. Geochemical sampling shows as much as 700 ppm in copper.	Sauers, written communication, 1966.

Nickel

Nickel-stained rocks in Whatcom County have attracted the attention of prospectors for years. Many prospectors believed that they had discovered copper, because the green secondary mineral garnierite closely resembles several secondary copper minerals.

Garnierite occurs mainly in a silica-carbonate rock that is composed chiefly of silica, magnesite, ankerite, and limonite. Garnierite is a hydrated silicate of magnesium and nickel, the composition of which is extremely variable. The outcrops of the silica-carbonate nickel deposits are distinctive. Because of the high limonite content, the deposits commonly are yellowish brown. Garnierite, which is light to medium green, forms thin veinlets and irregular-shape masses that contrast with the limonite groundmass.

The nickel-bearing silica-carbonate rocks probably originated by hydrothermal alteration of serpentinized peridotite along fault zones. As silica-rich hydrothermal solutions permeated the serpentinized rock, primary nickel minerals, such as nickeliferous pyrrhotite, were dissolved and redistributed as secondary nickel minerals. Small amounts of copper, gold, and silver are present in some of these deposits.

Yellow Aster prospect

This deposit is in secs. 17 and 20, T. 40 N., R. 9 E., on the east side of Yellow Aster Butte (Pl. 2). The deposit is about 10 miles east of Glacier and is west of Gold Run Pass, which is near the headwaters of Swamp Creek. About 1,000 feet west of the pass, at an altitude of 5,275 feet, a silica-carbonate deposit forms an outcrop that is 50 to 75 feet wide. Along the strike of the deposit, which is S. 10° W., the silica-carbonate rock crops out sporadically for about 2,500 feet. The north end of the deposit is well exposed on the face of a steep rocky cliff for about 50 feet before it becomes covered with talus. Because the south end of the deposit, which is below timberline, is covered with vegetation, it is difficult to follow the deposit to the south.

The nickel-bearing silica-carbonate rock consists of quartz, ankerite, magnesite, and limonite that contains garnierite and sparsely disseminated fine-grained pyrite. The nickel content ranges from 0.25 to 1.25 percent. The host rock consists of massive and highly sheared serpentine that occurs as large lenticular bodies in greenstone of the Chilliwack Group.

From 1909 until 1918 the property was held as unpatented mining claims by the Mount Baker Gold, Copper, & Tin Co. During this time the deposit was explored by means of open cuts and several short adits, but nickel ore was not mined. In recent years the most promising outcrops have been staked and restaked by several different parties. However, little, if any, exploration work was done on the deposit.

Goat Mountain prospect

This prospect is on the north slope of Goat Mountain at an altitude of 5,600 feet (Pl. 2). It is at the headwaters of Swamp Creek near the common corner of secs. 22 and 28, T. 40 N., R. 9 E.

The deposit consists of a small pocket of silica-carbonate rock, 150 feet wide and 100 feet long, in pre-Jurassic phyllite. In the silica-carbonate rock, green garnierite occurs as lenses and stringers. However, the average nickel content of the deposit is only about 0.25 percent.

This deposit appears to be the source of the numerous nickel-stained boulders and cobbles that occur along the bed of Swamp Creek. Most of the nickel-bearing rock probably has been removed by glacial erosion, as the deposit is in a cirque basin that still contains active glaciers.

Other deposits

In addition to the silica-carbonate deposits, nickel occurs also in the ultrabasic rocks of the county. Studies by Gaudette (1963, p. 57) on olivine of Twin Sisters Mountain report a nickel content of 0.143 to 0.612 percent and an average of 0.254 percent. These analyses were of 73 samples, from many parts of the olivine mass. According to Gaudette, the nickel is not contained in a nickel mineral but occurs as an octahedrally coordinated divalent cation in the olivine structure.

The second largest mass of ultrabasic rock in the county is the Sumas Mountain serpentinite. The serpentinite has not been analyzed for its nickel content, but some nickel is present, as the lateritic iron deposit (see p. 73) that was derived from the weathering of the serpentinite contains nickel. Analyses by the U.S. Bureau of Mines (Binon, 1959, p. 119) on six samples from the iron deposit showed 0.42 to 0.82 percent nickel.

Molybdenum

The most significant occurrence of molybdenum in Whatcom County is on Silver Creek, 1.5 miles west of Ross Lake and 2 miles south of the Canadian border (Pl. 2). The deposit, which is known as the Silver Creek prospect or the Davis property, is in the E½ sec. 8, T. 40 N., R. 13 E. Molybdenum has also been reported at the Casselman and the Dead Goat (Sulphide) claims on Sulphide Creek near Baker Lake; however, very little is known about these two deposits.

Silver Creek (Davis) prospect

Access to this prospect is by 42 miles of logging road that branches from the Trans-Canada Highway 2 miles west of Hope, British Columbia. From the end of the logging road on the north end of Ross Lake, the lake is crossed by boat to the start of 1½ miles of poor trail extending to the property, which is at an altitude of about 2,900 feet. The property consists of 11 unpatented claims that have been recorded as the Weezie No. 1 through No. 11. The claims are contiguous, trend north and south, and are in the E½ sec. 8, T. 40 N., R. 13 E.

In December 1913, L. Darrow et al. originally located the deposit for galena, and in July 1929, H. P. Davis relocated the deposit for molybdenum. A bunkhouse was built and a 75-foot adit was driven into the mineralized zone. Also, several prospect pits were dug. In 1958, Donald and Archie Lyon and Russell Perry relocated the deposit. The mineralization was explored by several diamond drill holes on the most promising outcrops. General assessment work has been carried on since 1958, but no mining has been undertaken. In the spring and fall of 1965 the present claims were relocated by A. R. Grant, of Bellevue, who undertook limited exploration work. Currently (1967), Inland Copper Ltd., of Vancouver, B. C., Canada, is exploring the property.

The property was examined by W. A. G. Bennett and H. E. Culver in July 1942. According to Purdy (1954, p. 87), their description of the property is as follows:

> The deposit on the south side of Silver Creek was examined in July 1942 by W. A. G. Bennett and H. E. Culver, then of the staff of the Division of Geology. According to Bennett, it is located in the bed of the easternmost northward-flowing tributary of Silver Creek, just below a small waterfall about 150 feet above the level of the creek. The deposit consists of ¼- to 1-inch stringers of quartz containing scattered chalcopyrite and clusters of molybdenite. The stringers, striking a few degrees west of north, are in granodiorite close to its contact with volcanic rock. At the outcrop the distance across the strike of the quartz stringers is about 10 feet. How far they may be traced along their strike is a question that could not be answered at the time of the examination because of the overburden and brush. On the southeast bank the quartz stringers run into the volcanic rocks which have been intruded by the granodiorite.
>
> As the outcrop area comprises only about 100 square feet, a fair appraisal of the deposit is difficult. However, judging from the examination of similar occurrences, it would seem that no commercial operation can be expected at this location.
>
> On the north side of Silver Creek the deposit is on the west bank of the easternmost southwestward-flowing tributary to Silver Creek, about 300 feet above the level of the creek. The deposit has been developed by an 85-foot adit and several open cuts above it.
>
> The adit has been driven along a fault striking N. 16° E. and dipping 80° W. On the east side of the fault, at the portal a dacitic volcanic breccia is exposed, and on the west side about waist high a granodiorite dike between 3 and 4 feet thick has been intruded into the volcanic breccia. The dike strikes about north and dips 15° W. About 15 feet inside the portal the lower granodiorite-volcanic contact has a quartz stringer ½ inch thick which angles off into the volcanic rock. The area that has been mineralized is exposed in the last 12 feet of the adit. This area is bounded on the south by a subordinate fracture to the main fault extending out to the northwest and dipping 80° S. The mineralization caused a bleaching and silicification of the volcanic breccia as chalcopyrite and molybdenite were sparsely distributed through the rock. Apparently the mineralization was controlled by the presence of a fracture zone, as evidenced by strong brecciation. A chip sample of the mineralized area as exposed in the adit gave the following analysis: gold, nil; silver, 0.40 oz. per ton; copper, 1.50 percent; molybdenite, 0.15 percent. The analysis was made by W. H. Ott, of Seattle, Washington.
>
> About 64 feet directly above the face of the adit is an open cut. At the east end of the cut is the fault along which the adit is driven. To the east of the fault is fresh volcanic breccia, whereas to the west of the fault and extending for 50 feet is bleached and silicified volcanic breccia, which contains scattered molybdenite and chalcopyrite in fair quantity. This material would undoubtedly assay about 1 percent molybdenite and 2 to 3 percent copper, thus making an interesting ore. However, several open cuts on up the hill only 100 feet beyond this mineralized zone, though they reveal the bleached and silicified volcanic rock, fail to reveal any sulfides. Also, no sign of sulfides can be seen in the small tributary streams flowing just below the adit. Consequently, the mineralized zone would appear to be strongly localized, perhaps roughly circular in horizontal plan, and possibly not more than 50 feet in diameter.

Casselman prospect

This prospect consists of the Big Gem and Treasure claims, which were recorded by D. A. Casselman on October 6, 1899. The Big Gem claim is at the foot of the third waterfall on Well-Hole Creek, which is a southwestward-flowing tributary to Sulphide Creek. The Treasure claim adjoins the Big Gem claim on the west. Both claims are near the center of the E½ sec. 7, T. 38 N., R. 10 E., and are about 3½ miles northeast of Baker Lake. Molybdenite is supposed to have been mined from this property in 1898, but there is no evidence of mining operations on the claims. Silicified quartz diorite crops out in the area and appears to be barren of molybdenite. However, it is possible that the molybdenite has been leached from the outcrops. About half a mile southeast of the claims, silicified quartz diorite on the Dead Goat claim contains disseminated molybdenite as well as molybdenite-bearing quartz veins. It is probable that the molybdenum mineralization on the Casselman and Dead Goat prospects is related.

Dead Goat (Sulphide Creek) prospect

The Dead Goat prospect, which is the most recent significant discovery in the Mount Baker mining district, is 3½ miles northeast of Baker Lake. It is in the SE¼ sec. 7, T. 38 N., R. 10 E., and is on a southwestward-flowing tributary to Sulphide Creek. From the end of the road on the northwest bank of Baker River, 2½ miles of improved trail and 1½ miles of unimproved trail lead to the prospect. The discovery site, which is in the bed of a steep, rock-bottomed creek, is at an altitude of 1,600 feet. In the fall of 1967, molybdenite was discovered in the creekbed by Lester McCullough, of Everson; Ben Hinkle, of Bellingham; and Clarence Keplinger, of Van Zandt.

On the Dead Goat claim the country rock consists of well-jointed quartz diorite that is a border phase of the Chilliwack Batholith. The diorite contains numerous stringers and veins of quartz, many of which contain molybdenite. The stringers and veins, which range from one-sixteenth inch to 2 inches in thickness, traverse the diorite in many directions and form a stockwork structure; however, the main molybdenite-bearing veins appear to be nearly horizontal. Between the quartz veins the diorite is distinctly altered. Much of the plagioclase of the diorite has been altered to kaolinite and sericite, and some of the biotite has been altered to chlorite; silicification of the diorite has also taken place.

The molybdenite occurs mainly in the quartz veins as disseminated flakes as much as 10 millimeters across or as solid masses as much as 2 inches thick and several feet across. In several veins, the molybdenite is accompanied by small amounts of molybdite and powellite. Between the quartz veins the molybdenite is fine grained and accompanied by pyrite and minor chalcopyrite.

The molybdenite-bearing quartz veins crop out along the creekbed for about 200 feet and for a vertical distance of more than 80 feet. The hanging wall consists of slightly altered quartz diorite that contains only scattered grains of molybdenite and pyrite. Because of debris in the creekbed, the footwall of the deposit is not exposed. And because of a thick cover of overburden, the quartz veins do not crop out for much more than 25 feet on either side of the creek. About half a mile northwest of the Dead Goat claim the owners report (oral communication, 1967) that molybdenite-bearing diorite crops out in the bed of another creek. This discovery has been staked as the Moly claim.

Gold, Silver, Copper, Lead, and Zinc

Gold, silver, copper, lead, and zinc occur mainly in hydrothermal quartz fissure veins and replacement deposits that appear to be related to the Tertiary granitic rocks of the Chilliwack Batholith. In general, the area north of Ruth Creek to the Canadian border and from Silesia Creek westward to Damfino Creek is the most highly metalized area in the district. Within this area, gold-bearing quartz fissure veins predominate. West of this area to the vicinity of Canyon Creek, copper minerals predominate. Should there have been a regional horizontal zoning of the ore deposits during their emplacement, it is possible that copper is the major metal east of Silesia Creek, as it is to the west of Damfino Creek. The area of the Mount Baker mining district in which mineral deposits are most concentrated appears to be near the western edge of the batholith, where granodiorite has intruded pre-Jurassic phyllite and schist and Carboniferous-Permian sedimentary and volcanic rocks. Within this area numerous shear zones provided depositional sites for metalliferous hydrothermal solutions that originated from the cooling granitic batholith. The major shear zones parallel the regional structural trend and strike N. 20°-60° W.; subordinate shear zones strike N. 60°-80° E., transverse to the major shear zones. The more significant gold deposits of the area appear to be confined to the transverse shear zones, whereas several base metal deposits are related to shear zones that parallel the regional structural trend.

In the gold-bearing quartz veins the gold occurs chiefly as free gold that is accompanied by minor pyrite, pyrrhotite, and chalcopyrite; some veins contain the bismuth telluride mineral tellurbismuth. The veins are irregular in shape and range from a few inches to as much as 10 feet in width; the average width is about 2½ feet. On the surface, most veins can be traced for 200 to 300 feet. The average gold content of the veins is about $6 per ton. At the Boundary Red Mountain and Lone Jack mines the ore averaged about $15 per ton at $20 per ounce gold prices. However, gold ore that assayed as high as $1,000 per ton was found in both mines. An assay map of the Boundary Red Mountain mine shows gold contents of $1.03 to $77 per ton at a gold price of $35 per ounce. According to Robert Cole, owner of the Lone Jack mine, the mill heads from the Lone Jack vein averaged about 2.5 ounces of gold per ton during the first few years of mining, and parts of the Lulu vein still contain 1.5 ounces of gold per ton.

Gold occurs also in disseminated replacement deposits. In these deposits, pyrite occurs disseminated in the host rock as grains and blebs that are accompanied by small pyrite veinlets. The host rock consists of acidic or basic volcanic flow rock that has been silicified. The boundaries are gradational and pass from pyritized rock through an altered zone into unaltered barren rock. The disseminated deposits vary considerably in size. They range in width from a few feet up to several hundred, and in length from several hundred up to several thousand feet. The maximum depth in several deposits is more than 1,000 feet. In most deposits the pyrite content does not exceed 10 percent. The average gold content of the disseminated pyrite deposits is about 0.01 ounce of gold per ton; however, individual samples have assayed as much as 3.00 ounces per ton. In the Great Excelsior mine, 200 samples had average contents of 0.09 ounce of gold per ton and 3.44 ounces of silver. In addition to the gold and silver, minor amounts of copper, lead, zinc, antimony, and arsenic have been reported in the disseminated deposits.

The base metal deposits of the district occur as fissure veins and as replacement deposits that contain chalcopyrite, argentiferous galena, sphalerite, pyrite, and gold. The common gangue minerals include quartz, calcite, and siderite. The known deposits are small, and to date (1966) production has been insignificant. The veins vary considerably in width, averaging 2 to 4 feet. In length, the veins seldom exceed 100 feet. The host rocks for the veins commonly are argillite or phyllite, and replacement deposits appear to be confined to calcareous phases of these rocks. The average gold content is about 0.15 ounce per ton. At the Silver Tip mine as much as 50 ounces of silver has been reported by the owners; the content is as high as 8 percent copper, 20 percent zinc, and 4 percent lead. In several deposits the base metal veins consist almost entirely of fine-grained pyrite and chalcopyrite and contain very few nonmetallic gangue minerals. The locations of these properties are shown on Plate 6.

Alvic prospect

This prospect is 900 feet east of Gold Run Pass and is on the crest of the ridge that extends from the pass to Winchester Mountain. It is in the NW¼NW¼ sec. 21, T. 40 N., R. 9 E., at an altitude of about 5,600 feet. Alfred Moore, of Seattle, staked the claim in September 1962 after discovering copper minerals. On a north-facing, nearly vertical cliff, a prospect hole exposes a thin veinlet that averages 1 inch in width and consists mainly of bornite and chalcopyrite. This veinlet occurs in greatly sheared and altered argillite along a major fault zone. Some of the copper sulfide minerals resemble clinker and are accompanied by pyrite and drusy quartz. Only about 4 feet of the veinlet is exposed in the prospect hole. About 150 feet east of this prospect hole, on the crest of the ridge near its precipitous north slope, a second prospect shaft has been sunk 6 feet in sparsely metalized dacite tuff. Here, pyrite and chalcopyrite occur as disseminated grains along closely spaced shear zones; much iron oxide and a small amount of malachite accompany the sulfide minerals. However, the metalized area does not appear to be extensive, as the country rock is barren a few feet away from the prospect shaft.

Blonden (Goat Mountain) mine

The Blonden mine is in the NE¼ sec. 28, T. 40 N., R. 9 E., on the north slope of Goat Mountain at an altitude of 5,000 feet. The mine is about 2,000 feet south-southwest of the Evergreen mill building on Swamp Creek and is now part of the Evergreen group of claims. In 1902 and 1903 a small portable one-stamp mill was used to crush free-milling gold ore that assayed $30 to $40 per ton in gold. The gold occurs in quartz fissure veins 6 to 12 inches wide that have a general northeast strike and that dip steeply southeast. The host rocks of the veins consist of sheared and contorted pre-Jurassic phyllite and graywacke. The lower adit of the mine, at an altitude of 5,000 feet, heads S. 45° E. for 520 feet. At about 300 feet from the portal a 5-foot-wide quartz-mineralized shear zone has been crosscut but not drifted upon. At the face of the adit a 9-foot-wide quartz vein was crosscut. The upper adit is about 300 feet south of the lower adit and is in the bed of a small creek. This adit heads S. 50° E. for 60 feet, at which point a drift follows a narrow quartz vein northeast for 35 feet and southwest for 24 feet. The quartz vein, which is 2 to 6 inches wide, assays 0.01 ounce per ton in gold and 0.18 ounce in silver. Fine-grained pyrite is the only metallic mineral that is visible in the quartz, and the pyrite makes up less than 1 percent of the vein. However, old assays show as much as $1,000 in gold from quartz veins at the Blonden mine.

Boulder Creek prospect

This occurrence is on the north bank of Boulder Creek in the SW¼ sec. 22, T. 40 N., R. 6 E., at an altitude of 1,500 feet. At this location small lenticular bodies of chalcopyrite and pyrite occur in a N. 70° E.-trending shear zone in basalt. The chalcopyrite and pyrite are accompanied by kidneys of fine-grained magnetite. Although the lenticular bodies of chalcopyrite and pyrite of the shear zone are small—not much more than 1 foot wide and several feet long—boulders as much as 6 feet in diameter and composed of a mixture of pyrite, magnetite, and chalcopyrite have been found in Boulder Creek. Several individuals, as well as at least one large mining company, have attempted to find the source of the copper-bearing minerals, but to date they have been unsuccessful.

Boundary Red Mountain mine

The Boundary Red Mountain mine is in sec. 3, T. 40 N., R. 9 E., and sec. 34, T. 41 N., R. 9 E., on the north slope of Mount Larrabee (formerly Red Mountain) (Fig. 30). The claims of the mine are one-quarter to three-quarters of a mile south of Border Monument 54 and are at altitudes of 4,000 to 5,500 feet. The Boundary Red Mountain group consists of six patented claims: Rocky Draw, Klondike, Mountain Boy, Glacier, Climax, and Climax Extension No. 1, all of which were surveyed under Mineral Survey 699. Tom Bourn, Kitsap Lake, Wash., and John P. Wiatrick, Chicago, Ill., are the owners of the claims.

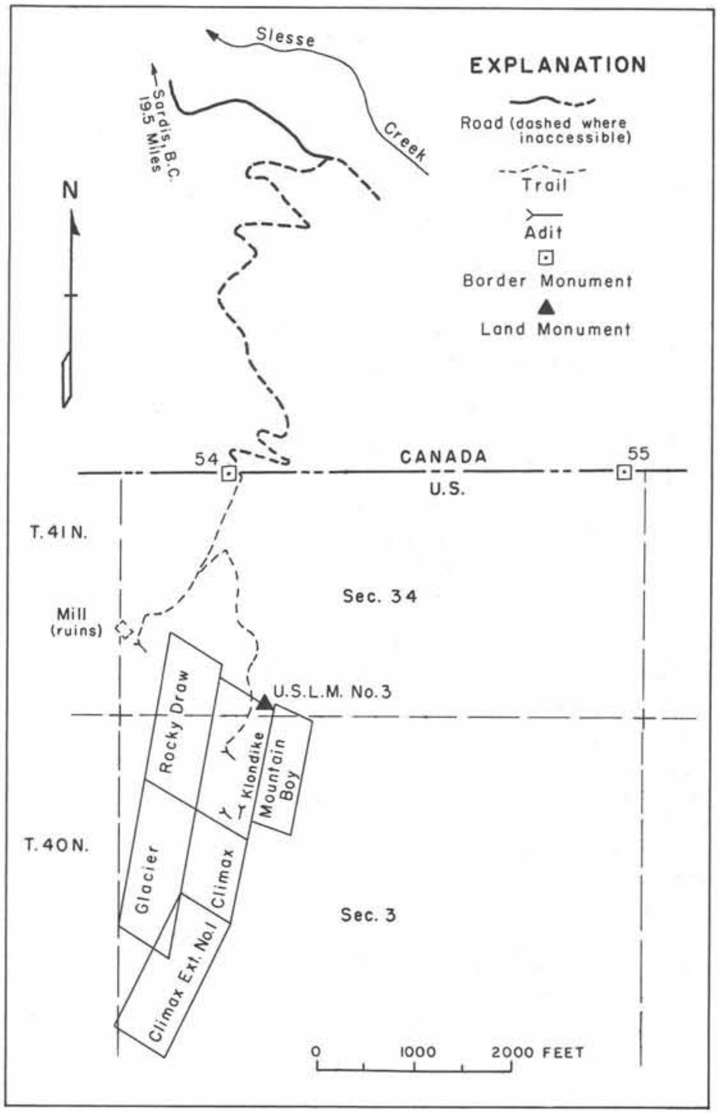

FIGURE 30.—Location and claim map of Boundary Red Mountain mine.

Accessibility.—Although the mine is accessible by 8 miles of trail from Twin Lakes, the most commonly used route to the mine is through Canada. From Sardis, British Columbia, which is about 18 miles northeast of Sumas, the Chilliwack River road is followed 13 miles to Slesse Creek, thence 6.5 miles up Slesse Creek to the end of the road. From the end of the road a roughed-in bulldozer road is followed south for about 1 mile to the International Boundary, from which point a trail leads about half a mile farther south to the old millsite at an altitude of 4,050 feet.

History.—The original claims, which were the Klondike and the Climax, were located in August 1898 by C. W. Roth et al. In 1900 the other claims of the group were staked for the Red Mountain Gold Mining Co., and under the leadership of Judge Elmon Scott, of Bellingham, development work was begun on the claims. By 1913 gold ore was being crushed in a 5-stamp mill, and in 1914 the mine was the main producer of gold in the county; the production for 1914 was about $15,000. In 1915 George Wingfield, of Nevada, leased the mine, and in the following year 5 additional stamps were added to the mill. From April to December in 1916 the gold production from 10,441 tons of ore amounted to $148,578; the mill heads ran $14.43 per ton at the existing $20 gold price. The chronological notes and production records on the Boundary Red Mountain mine that follow were compiled mainly from U.S. Bureau of Mines Yearbooks, company reports, and private reports:

1917—$132,000 produced, but because of fire and war conditions operations were suspended.
1918—Powerplant on Slesse Creek destroyed by fire.
1921—Production, $30,000; upper tramway destroyed by fire.
1922—Production, $95,679.
1923—Production, $60,000; ore averaged $14 per ton.
1924—Mill idle; mainly development work.
1925—Production, around $90,000.
1926—Mill idle; mainly development work.
1927—Production, $86,822; mine under lease to A. H. Westall as Boundary Red Mountain Mining Co.
1928—Production, $62,000.
1929—Production, $55,274.
1930—Production, $71,822.
1931—Production, $12,475.
1932—Production, $8,876.
1933—Production, $13,907.
1934—Property idle.
1935—Production, $15,831; operated as International Gold Mines, Ltd.
1936—Production, $2,000.
1939—Production, $12,000 from cleanup of 5-stamp mill.
1940—Production, $12,000.
1941—Production, $8,515.
1942—Production, $1,000; mill destroyed by snowslide.
1946—Production, $1,800 from tailings.

From 1913 to 1946 the total gold and silver production from the Boundary Red Mountain mine was $947,579, most of which was gold. Since 1946 the property has been under lease to several parties; however, mining has not been undertaken. In the mid-1950's a steep single-track road was roughed in to the International Boundary from existing logging roads on the Canadian side of the border; however, the road was never maintained and at present (1966) is suitable only for foot travel. The mill and bunkhouses at the mine, as well as the powerhouse on Slesse Creek at the border, are no longer standing.

Geology.—The Boundary Red Mountain vein is in schist and diorite that form a contact belt between Slesse Diorite and weakly metamorphosed rocks of the Chilliwack Group. The schist is composed mainly of carbonaceous amphibole and quartz schist, and the diorite is chiefly a fine-grained hornblende diorite. Disseminated fine-grained pyrite is present in both the schist and the diorite. The contact zone contains numerous faults and fractures; some of these have been filled with quartz, whereas others have offset the quartz veins. 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 that contained small amounts of pyrite, pyrrhotite, and chalcopyrite. Later, recurrent movement along the veins produced microbrecciation of the quartz that permitted hydrothermal gold-bismuth telluride solutions to infiltrate parts of the quartz vein. The main veins of the Boundary Red Mountain claims, as mapped by Krom (1937), are the Glacier, Boundary Red Mountain, and Mountain Boy. The Gold Basin vein appears to be part of the Red Mountain vein system but is not part of the Boundary Red Mountain group of claims.

The veins on Boundary Red Mountain are true quartz fissure veins in diorite and schist. The veins, which range in width from a few inches to 10 feet and average 3 feet, strike N. 14° E. and dip 50° E. to vertical. On the surface the veins crop out for as much as 900 feet along strike, but because of several northward-trending faults, continuous parts of the vein are not much more than 100 feet long. On the Boundary Red Mountain vein, mining was carried to a depth of about 850 feet beneath the outcrop. At about 1,000 feet below its outcrop the vein pinches to a narrow stringer along a gouge seam and the gold values are low.

The main ore mineral of the Boundary Red Mountain vein is native gold that is accompanied by minor amounts of pyrite, chalcopyrite, pyrrhotite, and the bismuth telluride mineral tellurbismuth. What little silver is present appears to be alloyed with the gold. The gold is distributed irregularly and has a tendency to follow microbrecciated parts of the vein that parallel the margins of the main vein. The brecciated zones contain distinctive wavy brown bands of iron oxide in an otherwise vitreous milk-white quartz. Although most of the gold occurs in a finely divided state that is invisible to the unaided eye, grains of gold as much as 2 millimeters across were present in several ore shoots. In some parts of the vein, gold occurred as sheets as much as 1 inch square that filled thin fractures in the quartz. The thickness of the sheet gold probably did not exceed 1 micron. The bismuth telluride that accompanied the gold occurred as steel-gray bladed flexible crystals that averaged about 1 millimeter in length; however, some crystals were as much as ¼ inch long. No records were kept on the telluride content of the veins. The average value of gold ore from the Boundary Red Mountain vein, based on mint sales from 1915 to

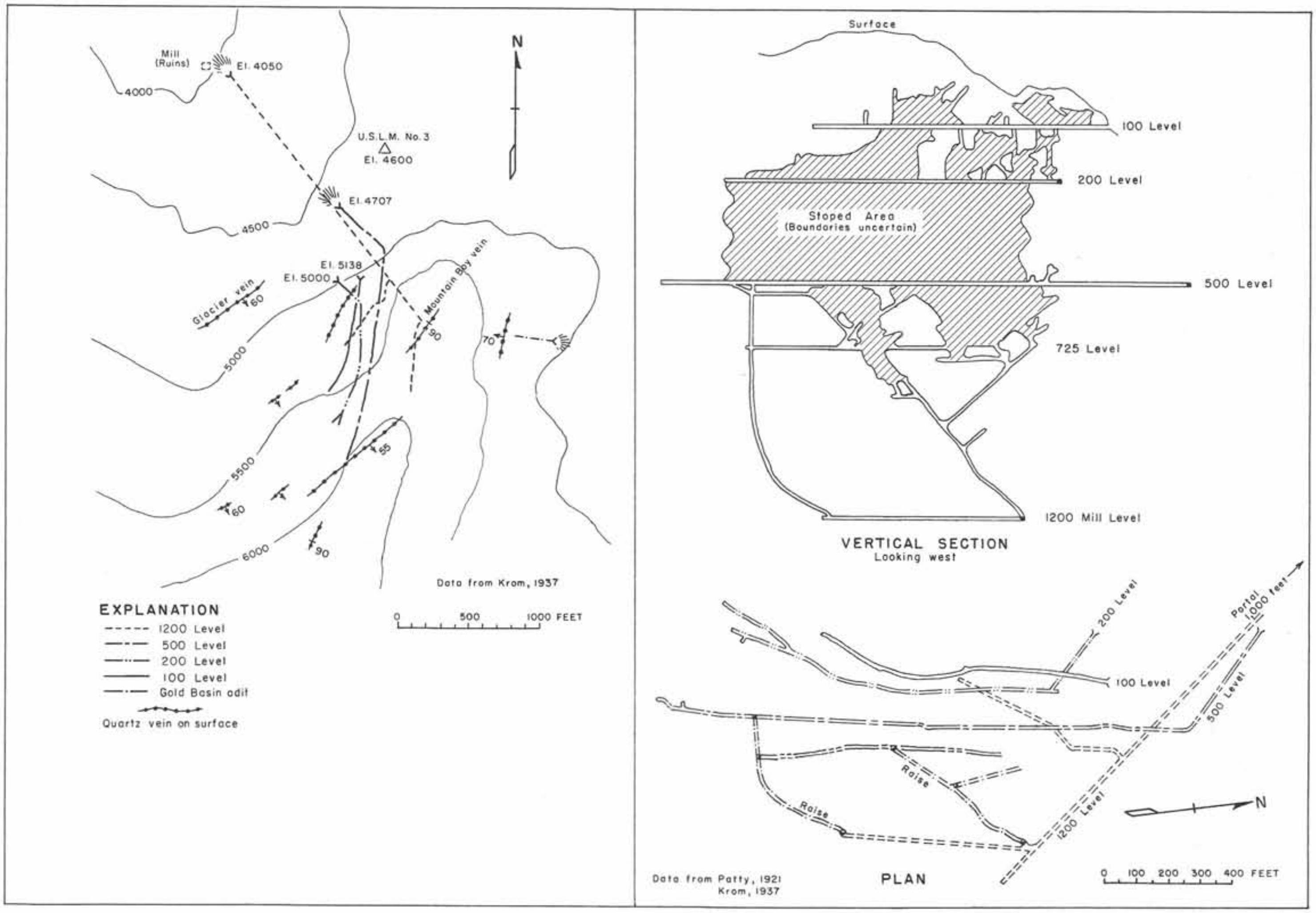

FIGURE 31.—Boundary Red Mountain mine workings and veins.

1931, was $12 per ton. This represents a low of $7 per ton in 1931 to a high of $14.43 in 1916, all at $20.67 gold prices. In 1935 the ore averaged $14.90 per ton and in 1941 it averaged $17 at $35 gold prices that had been in effect since 1934. The fineness of the gold ranged from 936 to 946, and the silver content of bullion shipments was less than 0.5 percent.

Mining and milling.—To date (1967), mining has been confined to the Boundary Red Mountain vein (Fig. 31). Steep mountainous terrain allowed the vein to be mined from four drifts and crosscuts over a vertical distance of 950 feet from the surface to the lowest workings of the mine. In the early years of mining, the uppermost 100-foot level, at the 5,138-foot elevation, was driven on the vein in a southerly direction for about 900 feet. Two ore shoots, which raked steeply south, were encountered and stoped for about 100 feet to near the surface. The 200-foot level, at the 5,000-foot elevation, crosscut the vein at about 300 feet from the portal, and the vein was drifted upon for 1,075 feet. The ore shoots that had been mined in the 100-foot level were encountered in the new drift and had increased in stope length. The first ore shoot had lengthened from 150 to 300 feet, and the second, from 200 to 500 feet. The average width of the vein on the 200-foot level was about 2½ feet, whereas on the 100-foot level the vein had averaged about 2 feet in width. In 1917 the 500-foot level was started at an altitude of 4,707 feet. The vein was crosscut at 370 feet and drifted upon for about 1,500 feet, at which point it was faulted off. At 1,200 feet on the vein a raise was driven to the 200-foot level. To the north of the raise the vein was mined from several stopes. In June 1923 the 1,200-foot level, which is the lowest and longest level of the mine, was begun at the 4,050-foot elevation, near the mill. In March 1924 the 10- by 10-foot crosscut encountered the vein 2,200 feet from the portal; however, the vein proved to be only 2 to 8 inches wide. The vein was drifted upon to the south in hope that it would increase in width, but only thin discontinuous quartz veins were found in the fault zone. After 500 feet of drifting on the fault zone, a raise was pushed to the 500-foot level. On the 1,200-foot level another raise, beginning at the vein intersection, was extended upward to the 500-foot level and connected with 525-, 725-, 765-, 800-, and 850-foot intermediate levels. As far as can be determined from mine maps, most mining took place above the 725-foot level. Below this level some stoping was done from the 765-foot and 800-foot levels. Parts of the Boundary Red Mountain vein have yet to be mined; however, any future mining operations will depend mainly on a rise in the price of gold. It is also possible that the faulted-off south end of the

Boundary Red Mountain vein can be found through detailed geologic mapping and diamond drilling.

Mining of the Boundary Red Mountain vein was by overhand stoping, and waste was used for fill, a method that made little timbering necessary (Patty, 1921, p. 308). Chutes were spaced at 25-foot intervals, and raises and manways at 150-foot intervals. During the summer months the mine was extremely wet; about 500 gallons of water per minute drained through the main adit. This excess water is due to melting glaciers that occupy a glacial cirque above the mine workings. Because of the wet mine conditions, as well as low wages, isolation, and poor working conditions, it was difficult to keep miners at the mine. Krom (1937, p. 26) makes the following statement regarding labor at the mine:

> Labor turnover was so rapid that it required the proverbial three crews—one coming, one working, and one going—to keep the mine in operation. Not uncommonly, men arrived and departed without having worked one full shift. During August, 13 men quit. During the single month of September, labor turnover was 96 percent.

Normally, about 30 men were employed in the mine.

Milling operations at the mine in 1920 have been described by Patty (1921, p. 308-309). His description of the milling operations is as follows:

> The ore is delivered to the tramway from storage bins near the portal of No. 5 level. The length of the tram is 1,600 feet, approximately, and the difference in elevation between the terminals is 700 feet. The buckets have a capacity of 850 pounds of ore, and the tram delivers to the mill 120 buckets during a 9-hour shift.
>
> The buckets dump into a mill bin, from which the ore is drawn over a grizzly set to 1 inch. The coarse rock is broken to 1 inch in a 7- by 10-inch Blake jaw-crusher, and then joins the fines, which are by-passed to the stamp bins. Two Challenge feeders deliver the ore to a battery of 10 stamps weighing 1,000 pounds each. The height of drop varies between 7 and 8 inches; rate of drop, 101 times per minute, and the height of discharge, 6 inches, the ore being crushed to pass a 12-mesh battery screen. There are two outside amalgamation plates separated by a slight drop. The plates are both 5½ by 10 feet and are set with a slope of ¾ inch to the foot. The pulp next passes through a mercury trap delivering to a classifier. The classifier makes two products, sand and slime. The sands go to a small Marathon mill for re-grinding and are then returned to the plates. An amalgamating head is attached to the Marathon mill. The slimes are delivered to a Little Betty amalgamation barrel.

By 1935 the mill circuit had been changed slightly and corduroy was used to save additional gold. According to Krom (1937) the following recovery was obtained:

	Percent
No. 1 mortar, inside	31.94
No. 2 mortar, inside	33.37
No. 1 amalgam plate	11.68
No. 2 amalgam plate	12.28
Corduroy cloth in front of stamps	1.32
Rod mill and tailing corduroy	4.79
Classifier clean-up	1.98
Tailing amalgam plates	2.40
Miscellaneous recovery, amalgamated copper	0.24
	100.00

Mining and milling costs for 1921 and 1925 are reported by Krom (1937, p. 25-26). It is interesting to note that in 1921, ore that averaged $12.26 per ton was mined and milled for $14.36, at a loss of $2.10 per ton. In 1925, $15 ore was mined and milled for $7.62, at a profit of $7.38 per ton. Krom gives the following breakdown for mining and milling costs:

Mining and milling costs at Boundary Red Mountain mine, 1921 and 1925

	1921	*1925*
Mining	$7.159	$3.1187
Development	1.407	1.4449
Tramway	0.292	0.2573
Milling	2.487	1.3693
General	3.000	0.8070
Administrative	.....	0.6245
Total	$14.36	$7.62

Power for the mine was generated at a powerhouse on Slesse Creek at the International Boundary. Under a 30-foot head a Hendy-Francis turbine drove a 25-kv.-a. generator. The electrical power of 2,300 volts was utilized at the mine, where three 25-hp. 2,300-volt motors drove three 9- by 8-inch compressors for drills. The mill required 70 hp. (Patty, 1921, p. 308).

Chain Lakes prospect

This prospect is in the NW¼ sec. 24, T. 39 N., R. 8 E., on a narrow strip of land that separates Galena and Hayes Lakes. The altitude of the lakes is about 4,800 feet. Several open cuts and one short adit (35 feet long) expose disseminated marmatite, as well as small amounts of pyrite, chalcopyrite, and bornite, over a width of 12 to 20 feet and a length of 300 to 400 feet. The host rock for the minerals consists of brecciated iron oxide-stained andesite. Although the ore minerals are generally sparse, select samples as much as 6 inches in diameter consist almost wholly of massive marmatite and pyrite. According to Stoess (1934, pt. 163, p. 1), a select sample assayed 47.8 percent zinc, 11.3 percent iron, and 1.6 ounces in silver.

Conway prospect

This property is 1.75 miles north of Welcome Pass and is in the SW¼ sec. 24, T. 40 N., R. 8 E.; the altitude is about 3,600 feet. The property once consisted of 12 claims that were staked in 1900 at the headwaters of Damfino Creek by J. Conway, president of Mount Baker-Shuksan Mining Co. According to a prospectus issued by the company in 1904, the ore body is over 840 feet wide and 3,000 feet long and carries gold, silver, and copper. Assays as high as $231 per ton have been reported; however, the average value is reported as $4.25 per ton. The metallic minerals consist of chalcopyrite, pyrite, and free gold that occur in quartz veins and as disseminated grains in argillite and greenstone of the Chilliwack Group. On the Red Crest lode an adit was driven east for over 500 feet. The adit is on the east bank of Damfino Creek and is about 200 feet south of a creek that flows off the west slope of Yellow Aster Butte. Because of a caved portal, the adit is inaccessible.

Copper King prospect

This prospect consists of the Tommy Atkins and Tuesday patented mining claims, which are in the NE¼NW¼ sec. 17, T. 40 N., R. 5 E. This is also the site of Columbia Cement Company's silica deposit that is in the valley between Sumas and Vedder Mountains. The deposit contains thin stringers and podlike masses of chalcopyrite that occur in massive white quartz. In the early 1900's a short adit was started on a chalcopyrite-rich outcrop, but was abandoned when the deposit proved to be less than 5 feet in diameter. Although the quartz deposit is over 280 feet long and 600 feet high, only the southeast end of the deposit contains copper minerals. This occurrence is discussed in more detail in the section on quartz, on pages 35 and 36 of this report.

Evergreen mine

The Evergreen mine is in the NW¼ sec. 21, T. 40 N., R. 9 E., near the headwaters of Swamp Creek. The property consists of 11 contiguous unpatented claims that have been staked along the valley of Swamp Creek and on the mountainsides above the creek (Fig. 32). Charles Stone, of Bellingham, holds the claims by possessory title.

Accessibility.—Access to the property is by way of the Swamp Creek road to Twin Lakes. Six miles from Shuksan a poor road extends to the mill, which is on the south bank of Swamp Creek. From the mill building, which is at an altitude of about 4,070 feet, a steep trail leads up the hillside to adits at altitudes of 4,350 and 4,400 feet.

History.—The original Evergreen claims were located by the Blonden brothers in 1904. However, very little work was undertaken on the claims. In 1936, O. A. Lowry relocated the claims and Evergreen Mines, Inc. was formed, with Ray Block as president. A small flotation mill, which was moved from the Lone Jack Mine, was erected on the property in 1938 and several short adits were driven on copper-lead-zinc-bearing outcrops above the mill. Insufficient ore was present to keep the mill running, and in 1939 the operations ceased. In 1958 Charles Stone relocated the claims, which had become invalid due to the lack of annual assessment work. Very little exploration work has been undertaken on the claims.

Geology.—The rocks in the vicinity of the mine consist of green to gray calcareous argillite and chloritic schist of pre-Jurassic age. The ore minerals are in irregular parallel veins as much as several inches wide that cannot be traced for much more than 10 feet. The veins vary considerably in strikes and dips but appear to be confined to a northwestward-trending steeply dipping shear zone. Along the shear zone, quartz and calcite occur as small parallel veinlets ⅛ inch wide and as lenses as much as 8 inches wide that contain sphalerite, galena, chalcopyrite, and pyrite. The sphalerite, which is commonly the iron-rich variety marmatite, occurs as small veinlets and irregular shape masses ¼ to 1 inch across. The galena and chalcopyrite occur as disseminated grains ⅛ to ¼ inch across. The wall rock adjacent to the metalized veins contains kaolinite, sericite, and fine-grained pyrite.

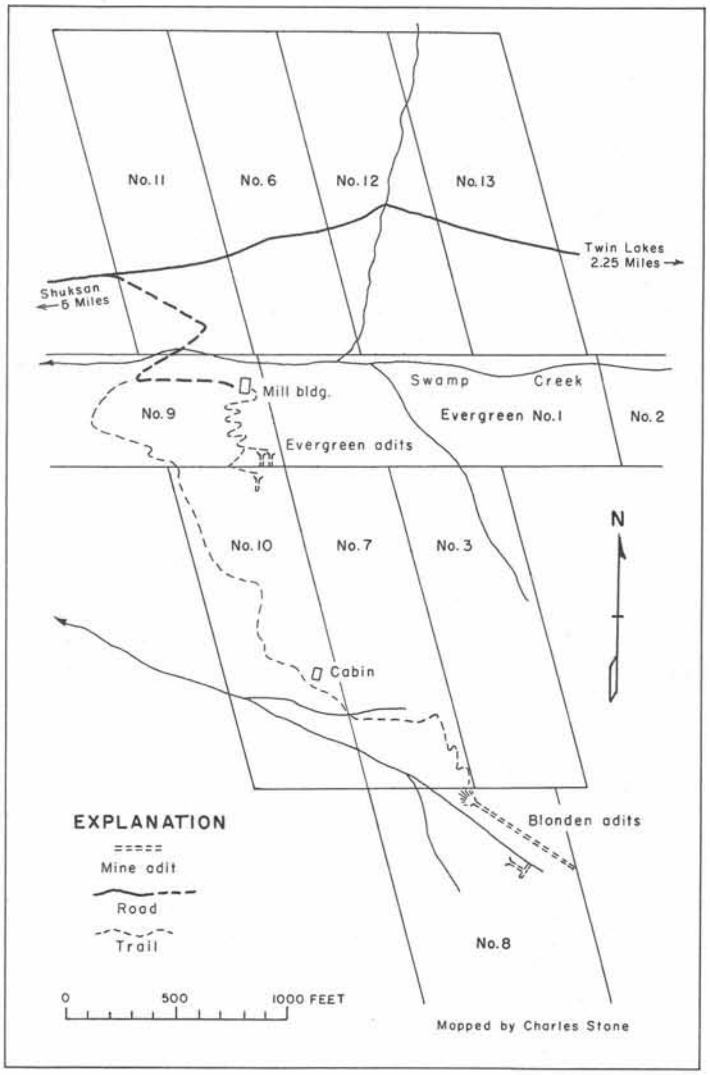

FIGURE 32.—Evergreen mine claim map.

The ore bodies have been explored by three short adits. The lower adits are about 350 feet above the elevation of Swamp Creek, and the upper adit is about 100 feet above the lower adits. The two lower adits, which are only 8 feet apart, have been driven south for 25 feet and 50 feet into the hillside; the upper adit heads south for 12 feet and then southwest for 8 feet. The adits reveal only scant ore minerals, suggesting that the ore occurred as small pockets that were removed during mining operations. According to Foster (1937), ore from one of the lower adits assayed 2.03 percent lead, 2.82 percent zinc, 1.08 ounces in silver, and 0.02 ounce in gold. Milling tests by Foster indicated that 85 percent of the galena and 83 percent of the sphalerite can be recovered by flotation. Native gold is not present, and the silver is contained in the galena. According to Ray Block (oral communication, 1949), the ore that was milled in 1938 averaged about $17 per ton.

First Chance prospect

This prospect is in the SW¼ sec. 31, T. 40 N., R. 8 E., about half a mile west of the powerhouse on the Nooksack River. The dump of what appears to have been the main underground workings of the prospect is 200 feet north of the intersection of Highway 542 and the road to the Nooksack powerplant, and is visible from the highway. Slide-rock blocks the portal of the adit, but the size of the dump suggests several hundred feet of underground workings. The rock in the vicinity of the prospect consists of Jurassic andesite that contains stringers and veins of white quartz. Stoess (1934) states that the quartz is gold bearing, and as much as 0.75 ounce in gold was reported by the original owners of the property.

Fourth of July mine

The Fourth of July mine is at the headwaters of Swift Creek, about 3 miles south of Mount Baker Lodge. It is in the NE¼NW¼ sec. 5, T. 38 N., R. 9 E., and the SE¼SW¼ sec. 32, T. 39 N., R. 9 E. Altitudes at the property range from 3,600 to 4,800 feet. The Fourth of July claim is one of a group of six claims that were staked in 1907 by Joseph Morovits et al. In 1919 the claim was surveyed under Mineral Survey 1,151, and it was patented in 1922. Mr. J. B. Hall, of Mount Vernon, Wash., is the present owner of the claim. A small stamp mill at one time stood on the east bank of Swift Creek, and an aerial tramway extended from the mill to the mine, which was high on the mountainside to the east of the mill. Gold proved to be sparse, and the operation was not profitable. The gold occurs in pyritized shear zones in argillaceous sedimentary rocks and basic volcanic rocks of the Chilliwack Group. Three shear zones, 10 to 30 feet wide, occur near the contact of a small quartz diorite stock that crops out in the vicinity of Lake Ann, north of the property. The shear zones strike north, are steeply dipping, and have been explored by means of at least six adits. The two longest adits head southward into the hillside for 125 feet and 175 feet.

Gargett mine

This property is 1½ miles south of the Boundary Red Mountain mine and is in the N½ sec. 9, T. 40 N., R. 9 E. Remains of the old mill, as well as the portal to the main underground workings, are at an altitude of 6,000 feet on the southern slope of Mount Larrabee. The original claim, recorded as Gold Run, was staked by Wm. Boyd and W. L. Martin in 1901.

Accessibility.—From Twin Lakes the mine is reached by 2 miles of narrow mountain trail that traverses the north slope of Winchester Mountain. At High Pass, between Winchester Mountain and Mount Larrabee, the trail forks; the west fork leads to the millsite and main adit, and the north fork leads to the upper workings. The millsite is near timberline on the Tomyhoi Lake drainage, and the upper workings are at an altitude of about 6,800 feet on a steep rocky slope of Mount Larrabee.

History.—After the discovery of the Gold Run claim in 1901, the Gold Run Mining and Milling Co. was formed and a small amount of development work was undertaken. In 1910 LeRoy and Clyde Gargett, of Sumas, located five claims adjacent to the existing claim, and in the following year the Gargett brothers and the Gold Run Mining and Milling Co. merged their claims. A sawmill was built in the timber below the mine, and a water turbine was installed to provide power for compressors. At the millsite a 2,000-foot crosscut was driven northwestward into the mountain with the intention of intersecting a vein that cropped out higher on the mountainside; however, the vein was never crosscut. A Sunfelt mill was installed at the mine in the mid-1930's, and in 1938 about 5 tons of ore from the upper workings was milled and sent to the Tacoma smelter. According to Huntting (1956, p. 177), the shipment contained 1.03 ounces of gold, 4.34 ounces of silver, 0.78 percent copper, and 8 percent lead. Because of the low metal content of the ore, operations ceased. The claims have been relocated by several different parties since 1940. All that remains of the mill is rusting machinery strewn with rotting timbers, the building having been crushed by snow many years ago.

Geology.—The main adit, which is at the site of the mill, has been driven in a general northwesterly direction for about 2,000 feet. The rocks in the adit consist mainly of gray siliceous limestone, light-gray to buff quartzite, and black carboniferous argillite of the Chilliwack Group (Carboniferous-Permian). About 300 feet from the portal a gray porphyritic andesite dike, which roughly parallels the adit, was encountered and followed for 160 feet. This dike is 8 feet wide and crops out on the surface. At 1,750 feet from the portal a 1-foot bed of siliceous limestone that contains bands of sphalerite, galena, and pyrite was crosscut; disseminated pyrite is present throughout most of the adit (Valentine, field notes, 1938). The adit also contains a steep crooked raise that does not reach the surface.

The upper workings (at an altitude of 6,800 feet) consist of an open cut 20 feet long and 10 feet deep on a white vein of quartz. The vein strikes N. 35° E., is vertical, and ranges in width from less than 1 inch to 14 inches, the average width being about 12 inches. It can be followed southeast in gray siliceous limestone for about 100 feet before it pinches out. In order of decreasing abundance, the minerals of the vein are marmatite, galena, chalcopyrite, pyrite, silver, and gold. Oxidation products of the vein consist of malachite, chalcocite, azurite, limonite, and a yellow oxide of lead. Ore minerals make up about 5 percent of the quartz vein and occur as bands and segregated masses.

The ore minerals at the Gargett mine occur in quartz fissure veins and replacement bodies in limestone; they appear to have been deposited by hydrothermal solutions that originated from granitic bodies. Although granitic rocks are not present on the claims, they crop out elsewhere on Mount Larrabee.

Glacier (Midas) mine

The 14 unpatented claims of the Glacier mine are in secs. 4, 5, 8, and 9, T. 39 N., R. 7 E. The main adit is 100 feet south of State Highway 542 at a point 1½ miles east of Glacier. The mine is owned by the Glacier Mining Co., of Seattle, the president of which is Mr. Ralph La Flamboy, of Seattle.

Little is known about the early history of this property except that J. B. McLean et al., of Hamilton, Wash., owned the property in 1944 (Huntting, 1956, p. 106). In 1949 the property was acquired by the present owners, and in 1951 about 4.5 tons of copper ore was shipped to the Tacoma smelter. This ore consisted of large boulders of pyrite-chalcopyrite that occurred as float on the surface of the claims. In 1952 a government loan was obtained and an area of iron gossan was explored by means of eight dozer cuts and three adits. No copper ore was found at this time. In 1954 several diamond drill holes were drilled from the surface as well as from the end of the lower adit. However, no significant ore discovery was made. In recent years, only limited exploration and assessment work has been undertaken at the mine.

Because of a thick covering of glacial drift, the bedrock in the area of the claims is poorly exposed. The rocks that do crop out consist mainly of slaty argillite of Late Jurassic-Early Cretaceous age. Much of the argillite is greatly fractured and contains numerous calcite and quartz stringers. Widely scattered pyrite nodules, most of which are not much more than 2 inches in diameter, are also present in the argillite. The leaching of these pyrite bodies by ground water causes much of the argillite to be iron oxide stained; in several places, minor copper staining is present.

The chalcopyrite-bearing cobbles and boulders that have been found on the surface of several claims may have originated as replacement deposits along shear zones in the underlying argillite; however, the exploration work undertaken thus far has failed to reveal any sizable bodies of ore similar to that found as float on the surface. Several copper-rich boulders were 3 to 4 feet in diameter and assayed 4.59 percent copper, 0.02 ounce in gold, and 0.89 ounce in silver.

The general appearance of much of the terrain resembles a landslide area. If the surface material is landslide debris, the copper-bearing boulders may have originated from some place other than the immediate area of the claims.

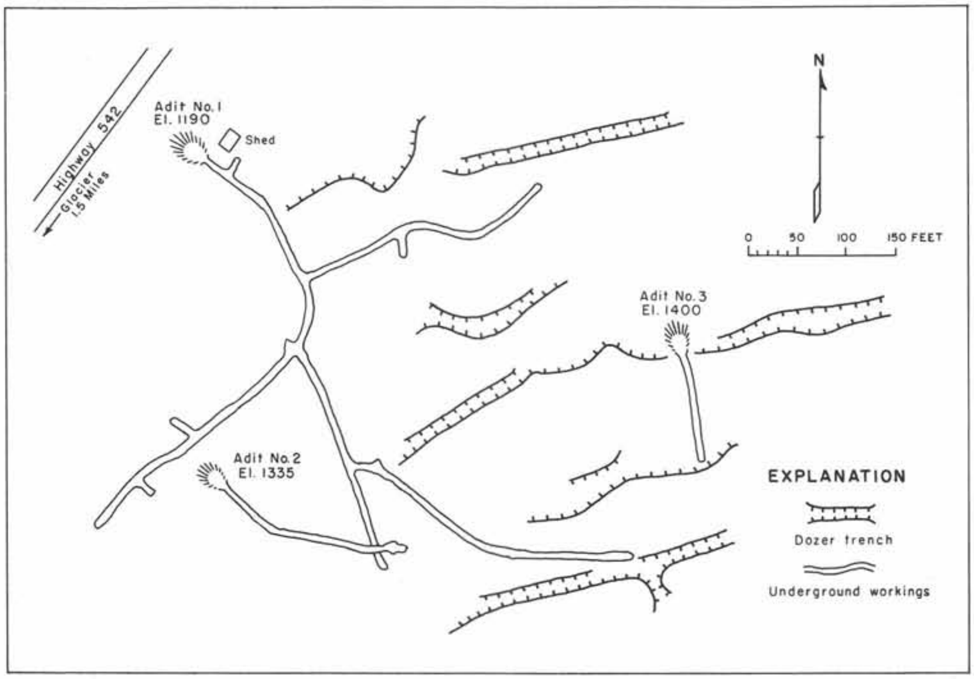

FIGURE 33.—Adits and surface cuts at the Glacier mine.

To date (1966), the area of the chalcopyrite float has been explored by 1,670 feet of underground drifts and crosscuts, about 1,280 feet of dozer trenching, and by at least 1,500 feet of diamond core drilling (Fig. 33). Adit No. 1 is near road level and at an altitude of 1,190 feet. This adit heads south and contains about 1,360 feet of drifts and crosscuts, none of which expose ore. Adit No. 2 is 320 feet south of the lower adit and is at an altitude of 1,335 feet. This adit heads east for about 200 feet in argillite. About 480 feet east of the upper adit, at an altitude of 1,400 feet, another adit (No. 3) heads south for about 110 feet in what appears to be a basic igneous dike. Although abundant iron oxide is present near the portal of the adit, copper minerals are not present in the adit. Abundant iron oxide was noted by the writer in several dozer cuts, and minor copper oxides were present in a cut 200 feet east of the No. 1 adit as well as in the dozer cut near the portal of adit No. 3. In no place did the writer observe pyrite and chalcopyrite in significant concentrations.

Gold Basin mine

This property is east of the Boundary Red Mountain mine and is on the northeast slope of Mount Larrabee. It is in sec. 6, T. 40 N., R. 9 E., and altitudes on the property range from 2,500 to 4,500 feet. The original Gold Basin claims were staked in 1900, shortly after the discovery of the Boundary Red Mountain veins. In the early 1900's a small single-stamp mill was built and operated on the property and gold ore, which consisted mainly of quartz float, yielded around $17,000 in free gold. After milling the readily available quartz float and being unable to find the vein from which the quartz originated, the owners halted milling operations in the 1920's. The property has been restaked by several parties; however, because of the inaccessibility of the area, very little exploration work has been undertaken. The fact that white quartz containing small specks of free gold can be found in the slide-rock still encourages prospectors to seek the source of the gold, and as much as 2 ounces per ton in free gold has been reported. At least one quartz vein crops out on the property. The vein, as much as 4 feet wide, strikes N. 5° E. and dips 70° W. A crosscut begins 300 feet east of the vein and extends about 200 feet into the mountainside, but does not intersect the vein. The rocks of the area consist of quartz diorite and argillaceous sedimentary rocks of the Chilliwack Group.

Great Excelsior mine

The Great Excelsior mine is in sec. 6, T. 39 N., R. 8 E., on the west side of Wells Creek half a mile above its junction with the Nooksack River. Ten unpatented mining claims known as the Wells Creek group make up the property. The American Smelting and Refining Co. holds the claims by possessory title. A claim map and underground workings of the mine are shown on Plate 7.

Accessibility.—Access to the property is by way of trails from the Wells Creek or the Deadhorse Creek logging road. On the Wells Creek road, 1 mile from State Highway 542, a barely discernible trail extends west and across Wells Creek to the mine, the distance being about ¼ mile by trail. On the Deadhorse Creek road, about 2 miles from Highway 542, an old wagon road can be followed for about 1 mile to the mine.

History.—The Great Excelsior lode was discovered by W. H. Norton et al. in August 1900, at which time the Golden Rule and Golden Rule Extension claims were staked. In 1902 the Great Excelsior Mining Co. was incorporated and a 20-stamp mill was constructed on the property. Shipments of concentrates were made, and the silver content was found to exceed that of gold. However, problems showed up in milling, and about 50 percent of the gold was lost through sliming. Around 1905 the President Group Mining Co. was formed by Hugh Eldridge and the claims were renamed after past Presidents. New ore bodies were developed on the Lincoln claim, and in 1914 a new cyanide mill was installed, which replaced the amalgamation mill used earlier. However, after an expenditure on the mine of more than $250,000, mining proved uneconomical, and the mill was shut down in 1916. As poor recoveries had been obtained by cyaniding, some time after 1916 the mill was modified for flotation, but this also proved impractical. In 1922 H. E. Barnes relocated the claims, which had become invalid due to the lack of annual assessment work, but, other than the required assessment work, he undertook no work on the claims. In 1934 a complete examination of the property was made by the State (Stoess and Slater, 1935). In 1960 the claims were abandoned by Mr. Barnes, and in September 1966 the deposit was restaked by the American Smelting and Refining Co.

Geology.—The ore minerals at the Great Excelsior mine occur in fractured andesite, argillite, and slate of Jurassic age. The fracture system occurs over a length of about 4,000 feet and has a width of 200 to 400 feet. The main fractures trend N. 5° E. on the south end of the claims and N. 15° E. on the north end; secondary fractures trend N. 10°-40° W. The spacing of the fractures is irregular; the average distance between fractures is only several inches. Many of the fractures are filled by thin veinlets of quartz that contain as much as 3 percent pyrite and smaller amounts of gold and silver; sparsely disseminated grains of chalcopyrite, arsenopyrite, galena, and sphalerite are also present in some of the quartz. In the wall rock adjacent to fractures, only sparsely disseminated pyrite is present. In the underground workings of the mine, gold and silver occur in a well-developed breccia zone. The breccia consists of fragments of quartz and slate that range from 0.125 to 1 inch in maximum dimension. The matrix is composed of finely granulated slate and quartz that contain fine-grained pyrite. Except for minor malachite, the writer did not observe any ore minerals in the breccia. Keith Whiting (geologist, American Smelting and Refining Co.) suggests that the silver could be contained in very fine-grained tetrahedrite, because assays show the presence of copper and antimony.

The breccia as exposed in the mine workings is 400 feet long from north to south and 270 feet wide from east to west. It has been explored to a depth of 325 feet. The eastern border of the breccia has been crosscut by the Blacksmith and Lower tunnels and dips 55° W.; the footwall consists of fractured slate and argillite. None of the other borders of the breccia have been reached in the underground workings.

In the 1934 examination of the property, around 200 channel and crosscut samples were taken in the underground workings of the mine (Stoess and Slater, 1935). The highest gold assay was 0.54 ounce per ton, and the highest silver assay was 111.70 ounces. The average gold content is 0.09 ounce per ton, and silver averages 3.44 ounces per ton. At least 1,250,000 tons of metalized rock exists between the surface and the depth of the lowest mine workings. Milling tests of the rock showed that 85 percent of the gold and silver can be recovered. A breakdown of the gold and silver contents for the different underground workings, as reported by Stoess and Slater, is as follows:

	Gold (oz./ton)	*Silver (oz./ton)*
Mill Level tunnel	0.024	4.34
Blacksmith tunnel	0.014	1.70
Big stope	0.010	1.73
Lower tunnel	trace	0.38

Development.—The development of the property consists of about 1,700 feet of drifts, crosscuts, and open stopes (Pl. 7). The Lower tunnel, which is at an altitude of 1,697 feet and is about 140 feet vertically above Wells Creek, extends 450 feet into the hillside at a heading of S. 60° W. Above this tunnel and at an altitude of 1,878 feet, the Blacksmith tunnel has been driven at a heading of S. 61° W. for 350 feet. About 600 feet of drifts are present in this tunnel. The Mill Level tunnel is about 225 feet northwest of the Blacksmith tunnel and is at an altitude of 1,889 feet. This tunnel heads S. 50° W. for 280 feet. At 200 feet from the portal a drift heads south for 240 feet. This drift provides access to a 65-foot drift and two stopes, the largest of which is 40 by 60 feet. Near the 65-foot drift, which is about 350 feet from the portal, a manway leads up 40 feet to the Big Stope. This stope is 180 feet long and has an average width of 60 feet. In parts of the stope the ceiling is as much as 80 feet above the floor. Midway on the east wall of the stope and at an altitude of 1,970 feet, a 20-foot drift has been driven to the surface. In addition to the above-mentioned workings, there are a 30-foot adit known as the Discovery tunnel and a 50-foot adit known as the Winze tunnel. Near the face of the Winze tunnel a vertical shaft extends downward 125 feet to the Blacksmith tunnel.

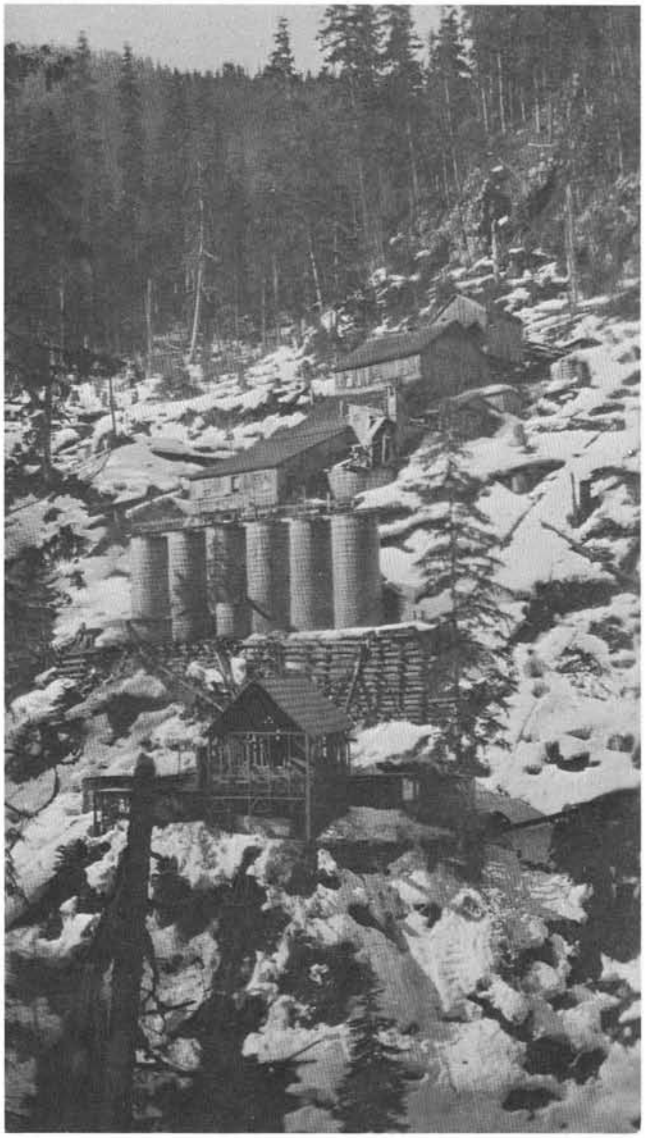

FIGURE 34.—The Great Excelsior concentrating mill in 1917. (Photo courtesy of Walter M. Stephen.)

The Great Excelsior mill was built downslope from the Mill Level tunnel. The original 20-stamp mill was operated by a water-powered turbine. Water for the turbine was carried from a tributary of Wells Creek in a 2,200-foot flume to a penstock above the mill. From the penstock the water flowed through a 500-foot pipeline under a 300-foot head to the mill. When the mill was rebuilt in 1914, a powerline was built from the mill to a powerhouse on the Nooksack River, a distance of about 1 mile, and electricity was used to power the mill. Instead of stamps, a rodmill was used to grind the ore, but sliming caused a loss of 45 to 50 percent of the values. Although the mine was supposedly shut down because of poor mill recovery, Stoess and Slater (1935, p. 12) report that flotation concentration tests on 30 tons of crude ore showed a 90 percent gold recovery and an 80 to 85 percent silver recovery at a 30 to 1 concentration ratio.

The only published production figure for the mine is that given by Huntting (1956, p. 177), of 10,000 tons that netted $20,276. U.S. Bureau of Mines production figures (Table 2, on p. 13) for 1903, 1904, and 1905 report $39,757 in silver. The greater part of this production probably came from the Great Excelsior mine, as the production of silver from other mines was insignificant for these years. In addition to silver, the mine produced about $26,000 in gold that accompanied the silver. Combined with a production of $3,400 for 1917, the total production amounts to $69,157.

Iron Cap prospect

This property is 1 mile east of Austin Pass on Shuksan Arm, a ridge trending westward from Mount Shuksan. The original claims were staked in the NE¼ sec. 29, T. 39 N., R. 9 E., where altitudes range from 4,500 to 5,000 feet. The claims cover a northeastward-trending silicified and pyritized zone in Carboniferous-Permian greenstone. The pyritized area is well defined, as oxidation of the pyrite imparts a rusty brown color to the otherwise grayish-green greenstone. In the valley of Swift Creek, on the south end of the deposit, the pyritized zone is about 750 feet wide; however, on Shuksan Arm, about ¼ mile north of the creek, pyritized rocks crop out for about ½ mile. From Shuksan Arm the pyritized rocks extend northeastward toward White Salmon Creek for about ½ mile. The vertical extent of the metalized area is about 1,000 feet and can be seen on the steep rocky cliff that forms the south face of Shuksan Arm. The pyrite, accompanied by minor pyrrhotite, occurs as thin seams as much as 3 millimeters in width and as disseminated grains that range in size from dustlike particles to single grains as much as 5 millimeters across. The average pyrite-pyrrhotite content of the silicified greenstone is about 3 percent. Stoess (1934) reports gold values of 0.4 ounce per ton; assays on 7 representative samples of the pyritized zone taken by the writer showed only a trace of gold, 0.02 to 0.14 ounce in silver, and 0.05 percent copper. The gold probably is associated with the pyrite and pyrrhotite, as native gold does not appear to be present. Stoess also reports the presence of a 120-foot adit and a 60-foot adit. The 60-foot adit is on the north slope of Shuksan Arm at an altitude of 4,400 feet. The 120-foot adit is on the south slope at an altitude of 4,500 feet and is near the center of the pyritized zone. Neither adit is conspicuous.

Lone Jack mine

The Lone Jack mine is in secs. 22 and 23, T. 40 N., R. 9 E. It is on the east slope of Bear Mountain at an altitude of about 5,000 feet. The property consists of 7 patented claims and 17 unpatented claims. The patented claims are: Lone Jack, Whist, Lulu, Jennie, and Sidney (Pl. 8), which were surveyed in 1899 under Mineral Survey 534, and the Jumbo and the Mt. Vernon, both surveyed in 1903 under Mineral Survey 744. The property is under lease to R. J. Cole, of Maple Falls, Wash., from Harry Bullene, of Bellingham.

Accessibility.—The mine can be reached from Shuksan, on State Highway 542, by 8.5 miles of Forest Service road to Twin Lakes. From the lakes a single track dozer road and a trail lead 1.5 miles to the mine. Very seldom is the route from Twin Lakes to the mine accessible by means other than by foot, for near the lakes the road is covered much of the time with rockslides and snowfields. The topography of the area is shown in Figure 26, on page 66.

History.—The original Lone Jack discovery was made by R. S. Lambert, Jack Post, and L. G. Van Valkenberg in August 1897. In 1898 the claims were sold to Henry Hahn and Leo Friede, of Portland, Oreg., for $50,000, and the Mount Baker Mining Co. was organized. In 1900, by means of a steam donkey and horses, a 10-stamp mill was hauled over a trail from Glacier and erected near Silesia Creek at a point 4,000 feet from the mine. In 1901 a 50-ton aerial tram was installed between the mine and the mill; 5 additional stamps were also added to the mill. From the beginning of mining operations the Lone Jack vein contained sufficient free-milling gold to mine profitably by single jacking with hand steel. The mine became the main producer of gold in the county, but operations ceased in July 1907, when the mill was destroyed by fire. In 1915 the mine was leased to Messrs. Clark and Sperry, who organized the Boundary Gold Co. A 10-foot Lane grinding mill was built on the hillside above the old mill; most of the gold from this operation was recovered on amalgamation plates. After only several hundred tons of ore had been treated, mining and milling operations were halted in 1917. In 1919 Philip Brooks, of Portland, Oreg., purchased the mine, and operations were begun under the direction of an associate, Carl Willis. In 1923 a 100-ton mill was completed on the hillside below the Lulu portal, and for power a hydroelectric plant was built on Silesia Creek. In 1924, after the mill was destroyed by a snowslide, the mine was deeded to Brooks-Willis Metals Inc. The company then built a new 75-ton amalgamation mill near the site of the destroyed mill. By mining ore from the Lulu vein, the company recovered $18,770 in gold before operations were suspended. Operations at the mine were usually carried on during the 5 or 6 months of favorable weather, as during the winter months as much as 20 feet of snow was on the ground; the average was 8 to 12 feet. Inasmuch as the mill and bunkhouse were on the steep slope of Bear Mountain, snowslides were a constant threat. After 1924 no gold was produced, but general improvements were made at the mine until 1928. In 1941 the mine was leased by R. J. Cole, who has performed annual assessment work on the unpatented mining claims. Much of the work has consisted of building a road from Twin Lakes to the mine, a distance of about 2 miles. At present (1966), about 1 mile of road remains to be built.

One of the latest developments in the history of the Lone Jack mine occurred on August 27, 1964. At that time U.S. Forest Service officials became alarmed by 500 cases of dynamite that had been stored in the Lulu drift since the 1920's, and they exploded the powder. Other than destroying the mine tracks and air lines, little damage was done to the underground workings.

Accurate production figures are not available for the mine, but it is estimated that from 1902 to 1924 the production of gold was about $550,000. Of this amount, $332,583.65 can be verified by mint receipts. Although mining was undertaken on both the Lone Jack and Lulu veins, the Lone Jack was by far the richest. From 1902 until 1905 the Lone Jack vein produced $360,000 in gold (Huntting, 1956, p. 178).

Geology.—The veins of the Lone Jack group are quartz fissure veins in pre-Jurassic black phyllitic schist. The schist also contains numerous stringers and lenses of exsolved quartz that formed during the metamorphism of the schist. Except for small amounts of fine-grained pyrite, the exsolved quartz is barren of metallic minerals. At least three well-defined quartz fissure veins occur on the Lone Jack claims—these are the Lone Jack, Lulu, and Whist veins. The gold-bearing vein quartz is younger than the exsolved quartz, and is probably related to granitic rocks of the area. Although no sizable bodies of granitic rocks crop out on the Lone Jack claims, the western border of the Chilliwack Batholith (Miocene) is 1 mile east of the claims.

The Lone Jack vein has a general N. 10°-20° W. strike and it dips 45° W. The vein crops out for about 500 feet and ranges in width from 1 to 6 feet; the average width is about 2½ feet. The south end of the vein pinches out, and the north end terminates against a fault. Ordinarily, the gold in the vein is not visible to the unaided eye, but in some parts of the vein gold and tellurbismuth occur as grains up to pinhead size. The gold is localized in ore shoots that occur near and parallel to the wall rocks of the vein. At least two generations of quartz are present in the gold-bearing veins. The early quartz is white, coarse-grained, allotriomorphic quartz that contains small amounts of pyrite and pyrrhotite. Movement along the vein microbrecciated some of the quartz, which was later recemented by fine-grained quartz. The gold and tellurbismuth occur in this second-generation quartz, which is generally iron oxide stained. On the basis of mint receipts and the volume of quartz mined from the Lone Jack vein, it is estimated that the ore averaged about 2.5 ounces of gold per ton (R. J. Cole, oral communication, 1966).

The Lulu vein is about 700 feet northeast of the Lone Jack portal and crops out on the face of a steep rocky cliff. The vein has a general eastward strike, and it dips 8° to 60° S.; it pinches and swells from several inches to 9 feet in width and in the main stope has an average width of about 6 feet. In order of decreasing abundance, the vein contains pyrrhotite, pyrite, chalcopyrite, tellurbismuth, and gold. Polished section work by Lindstrom (1941) showed the following paragenesis: Pyrite → pyrrhotite → chalcopyrite → tellurbismuth → gold. According to Lindgren (1933), the mineral assemblage is that of the mesothermal zone of deposition. The gold and tellurbismuth for the most part occur in a finely divided state; however, some parts of the vein contain pinhead-size specks of gold and platy flakes of tellurbismuth as much as ⅛ inch in diameter. The value of the ore mined from the Lulu vein was from $15 to $35 per ton at $20.67 gold prices. In the last year of operation (1924), 1,557 tons of ore yielded 907 ounces of gold and 38 ounces of silver, which amounts to 0.58 ounce of gold per ton and 0.024 ounce of silver. Assuming that all the silver was alloyed in the gold, the fineness of the gold was about 955.

The Whist vein, which is the smallest vein of the Lone Jack group, is about 150 feet north of the Lulu vein. The Whist averages about 2 feet in width, strikes N. 10° E., and dips 80° SE. It consists of white quartz that contains sparsely disseminated pyrite and chalcopyrite. Only about 80 feet of the vein is exposed on a steep rocky cliff, as the ends of the vein are concealed by talus. To date (1966), no exploration or development work has been undertaken on the Whist vein. However, the vein has possibilities, as is indicated by an assay of the vein showing 0.83 ounce in gold and 0.10 ounce in silver per ton.

Mining and milling.—The Lone Jack vein was mined from an adit the portal of which is at an altitude of 5,300 feet, about 130 feet vertically below the outcrop of the vein. The adit heads N. 75° E. for about 400 feet, and 310 feet from the portal an ore chute and manway connect with a sublevel 65 feet above the adit level. From the sublevel several raises extend upward for about 30 feet to the vein. The vein was stoped to the surface and mined for about 350 feet along its strike before it terminated against several faults. Mining was not undertaken below the sublevel.

The Lulu adit (Pl. 8) is at an altitude of 4,400 feet and extends westward 680 feet into the mountain; several crosscuts and raises have been driven from the adit. At 460 feet from the portal a raise extends 45° upward for 40 feet to a transfer level on the Lulu vein. From the transfer level the vein has been stoped for about 200 feet along the strike of the vein and from 80 to 120 feet along its dip. Parts of the stope are open to the surface on the steep rocky face of the mountain above the Lulu portal.

The first mill that was built at the Lone Jack mine in 1900 utilized 15 stamps to crush the ore, after which the free gold was recovered by amalgamation on plates. To recover the non-amalgamable tellurides, the tailings were tabled. When the second mill was built, in 1915, a 10-foot Lane grinding mill replaced the stamps. When the mill was rebuilt in 1923, rodmills, amalgamation plates, and flotation cells were used to give the mill a 100-ton-per-day capacity. The percentage of recovery from the milling operations is not known. However, tests by Lindstrom (1941, p. 44-52) on ore from the Lulu vein indicate that as much as 97 percent of the gold can be recovered. Amalgamation tests showed a recovery of 82 percent by grinding 68 percent of the ore to minus 100 mesh, and an 80 percent recovery by grinding 78 percent of it to minus 100 mesh. Flotation recovered 60 to 70.2 percent of the gold, and cyanidation recovered 80 to 97 percent.

Lone Star prospect

The Lone Star prospect is on Willow Creek, a tributary to Swamp Creek. The prospect is on the north slope of Goat Mountain and is in the SE¼ sec. 20, T. 40 N., R. 9 E., and the NE¼ sec. 29, T. 40 N., R. 9 E. The claims of the Lone Star prospect were staked by Henry Ehlers et al. in 1897, and development work consisted of two adits that were driven on a 25-foot vein of white quartz (Landes and others, 1902, p. 45). In 1901 the adits were 60 and 20 feet long, but inasmuch as work continued at the property until the 1920's, several hundred feet of underground workings may exist. The quartz vein contained native gold, some of which was visible to the unaided eye, and tellurides. The writer attempted to find the adits on several different occasions, but was unsuccessful.

Many Sisters prospect

This property is in the NE¼ sec. 33, T. 40 N., R. 8 E., at an altitude of 2,700 feet on Many Sisters Creek. Although a narrow-gauge wagon road at one time led from State Highway 542 to the prospect, the road is no longer discernible. The property is best reached by following Many Sisters Creek upstream from the highway for about ½ mile to the prospect. On the east side of the creek near the 2,700-foot elevation, two adits have been driven on a northward-trending shear zone in Jurassic-Cretaceous phyllite. The two adits are badly caved and are connected by a 50-foot raise. Both adits follow a 6- to 18-inch-wide quartz-calcite vein that contains sparsely disseminated pyrite and arsenopyrite. Gold and silver are present in the vein; however, the vein does not average more than $2 in combined gold and silver.

Nooksack mine

The Nooksack mine is 6 miles south of Sumas and 4 miles east of Everson. It is on the western slope of Sumas Mountain. The mine workings are near the W.

¼ cor. and in the N½SW¼ sec. 36, T. 40 N., R. 4 E., at an altitude of about 1,600 feet. Access to the property is by way of ¼ mile of trail from the site of a small portable sawmill on the upper part of the Lebrant road. The mine is on forest lands owned by the State.

The Nooksack Mining Co. was formed as a gold mining company in about 1900. In 1903 a 12-stamp mill was erected and more than a quarter of a mile of drifts and crosscuts were driven. Around 1908, mining operations ceased and the property was abandoned. Nothing remains of the mill but its foundation, and the principal mine adit is full of water. It is probable that the Nooksack mine never was a major gold producer of the county, as no gold from it was ever sold to the U.S. Mint, nor are there any records of production.

The mine workings, which consist of three adits, are in lower Mesozoic sedimentary rocks that consist mainly of graywacke and conglomerate. About 50 feet west of the lowest adit the Mesozoic rocks are overlain unconformably by Tertiary continental arkosic sandstone and conglomerate. Except for white quartz stringers that traverse the graywacke in the vicinity of the mine, it appears that no well-defined veins were followed during the mining operations. The quartz stringers contain no gold or other metallic ore minerals. What little gold is present appears to be associated with the disseminated iron pyrite that occurs in many parts of the graywacke. The average value of more than 50 channel samples that were taken in all the drifts and crosscuts was $3.50 per ton in gold (U.S. Works Progress Administration, 1936).

The three adits are within 100 feet of a small creek that flows down the western slope of Sumas Mountain. The lowermost adit, which appears to have been the main workings, is at creek level and is now flooded with water from the creek. The adit was driven at a heading of S. 70° E. into the south bank of the creek at an altitude of about 1,600 feet. Little remains of the mine dump, for most of it has been washed away by the creek. About 1,300 feet upstream, on the north bank of the creek, is the site of the second adit. It is about 50 feet above the creek and was driven at a heading of N. 20° E. for about 135 feet. Six hundred feet farther upstream, on the south bank of the creek, is the site of the uppermost adit. This adit heads south for about 120 feet. In none of these adits is there a metalized vein; however, thin quartz stringers are present.

Peterson-Nelson prospect

This prospect is in a steep rocky draw that is about 1,500 feet west of the south end of lower Twin Lake. The prospect adit is on the south slope of Winchester Mountain and is in the SW¼SE¼ sec. 16, T. 40 N., R. 9 E., at an altitude of about 5,200 feet. The most accessible route to the prospect is by a trail that extends westward from Twin Lakes. The deposit contains disseminated pyrite, chalcopyrite, and sphalerite in a northward-trending shear zone in altered volcanics, limestone, and argillite of the Chilliwack Group. The metalized shear zone has been explored by means of a 45-foot adit that heads N. 5° W. into the mountainside. Near the portal of the adit a short drift heads N. 55° E. for about 12 feet. Only at the junction of the drifts were any ore minerals noted. At this point a small lenticular body of quartz contains disseminated chalcopyrite and pyrite. A small stockpile of quartz containing sphalerite and chalcopyrite indicates that sphalerite accompanies some of the chalcopyrite that most probably occurs as lenses in the shear zone. Assays made in 1936 for Peterson and Nelson, owners of the property, showed 10 percent copper, 7.80 ounces of silver, and 0.37 ounce of gold per ton.

Pierce (Copper Queen) prospect

This property is described by Lyon (Landes and others, 1902, p. 45) as being on Silica Creek about 5 miles from the Lone Jack mine. Claims cover a 3-foot-wide gold-bearing vein that has been traced for several thousand feet. According to Lyon, the vein averages 0.6 ounce in gold. In 1900 the property was developed by means of two shafts, one 40 feet deep and the other 50 feet deep; about 60 feet of tunnel was also present.

According to Whatcom County records, the only Pierce claims in the county are 2 miles east of Hannegan Pass, about half a mile up Copper Creek. This location places the claims in the N½ sec. 10, T. 40 N., R. 10 E. The claims, the Pierce No. 1 and No. 2, and the Copper Queen No. 1 and No. 2, were recorded by Charles Wilson et al. on August 20, 1897. The property is shown on old maps of the area and most commonly referred to as the Copper Queen mine.

Power House group

The Power House group is composed of five patented claims that are in the SW¼ sec. 32 and the SE¼ sec. 31, T. 40 N., R. 8 E., at the confluence of the North Fork of the Nooksack River and Wells Creek. The group includes the following claims: Iron Cap, Minnehaha, Falling Water, Nooksack, and Wells Creek. The claims, which were patented in 1904, cover ground used by the Puget Power & Light Co. for its powerplant (pen-stocks and diversion dam) on the Nooksack River. Pyritized andesite crops out on several of the claims and contains sporadic silver and gold up to several dollars per ton. However, there is no evidence of past mining operations.

Quartz Mountain prospects

These prospects are three-quarters of a mile southwest of Yellow Aster Butte and are in the SW¼ sec. 18, T. 40 N., R. 9 E. They can be reached by following Keep Cool Trail for about 3 miles from its starting point, which is at an altitude of 3,050 feet on the Swamp Creek road. Inasmuch as the prospects are on a rocky glaciated bench above timberline, prospect pits and adits are plainly visible once the area is reached.

At a general altitude of 5,500 feet, many quartz veins form impressive outcrops on the glaciated rock surfaces. At least eight of the quartz veins have been explored by means of shallow prospect pits and adits.

Most pits are not much more than 3 feet deep, and the longest adit is only 10 feet long.

The quartz veins have a general strike of N. 60° W. and are steeply dipping. Several veins are intensely folded, and most veins exhibit post-depositional faulting, as is shown by well-developed striae on quartz adjacent to the wall rock. The veins can be traced on the surface for as much as several hundred feet, and they range in thickness from less than 1 inch to 4 feet. The quartz is mostly white and is unusually vuggy. Many of the vugs are filled with well-formed quartz crystals, some of which are as much as ⅜ inch across and 2 inches long. Parts of the vein contain abundant iron oxide staining; however, the veins appear to be devoid of iron sulfide minerals. An assay of the iron oxide-stained quartz showed a trace of gold and 0.06 ounce of silver per ton.

The host rock of the quartz veins is mainly pre-Jurassic metaquartzite that has been intruded by quartz diorite. Small bodies of serpentine and talc are also present and occur as lenticular bodies along fault zones. Near the central part of the area one body of serpentine contains several shallow prospect pits. In the 1940's an attempt was made to recover free gold from the serpentine by means of a small homemade mill. Parts of the mill still remain at the site of this unsuccessful operation.

Red Bird prospect

The Red Bird prospect is 3 miles northeast of Glacier and is in the NE¼SE¼ sec. 28 and the NW¼SW¼ sec. 27, T. 40 N., R. 7 E. It is near the headwaters of Coal Creek, at an altitude of 4,200 feet on the south slope of Church Mountain. The prospect consists of 7 unpatented contiguous claims recorded as the Red Bird Group 1 through 7. Newton Baker, of Forks, Wash., and Oliver Lynn, of Goshen, Wash., are the claim owners.

Access to the property is by way of State Highway 542 east from Glacier. At 2.4 miles east of Glacier the Canyon Creek forest road and a tributary logging road are followed 6 miles to Coal Creek. On the east bank of Coal Creek a poor trail is followed for about three-quarters of a mile to the main workings of the prospect. At an elevation of about 3,650 feet on the trail, an old log cabin of 1900 vintage is used for a camp. Above the cabin the terrain is steep and rocky, making access difficult in places.

Most of the work undertaken to date (1966) is on the Red Bird No. 7 claim, where several prospect pits expose copper-bearing fissure veins in argillite of the Chilliwack Group. The veins, which range in thickness from less than 1 inch to as much as 42 inches, consist of fine-grained pyrite and chalcopyrite. Minor bornite, sphalerite, malachite, and quartz are associated with the pyrite and chalcopyrite, and fine-grained pyrite also occurs disseminated in the wall rock. The veins have a general N. 70° E. strike and they dip 35° NW. One vein has been exposed by trenching over a distance of 33 feet. This vein is 42 inches wide at its west end and narrows to 12 inches at its east end. In 1957 an attempt was made by the owners of the property to diamond drill the vein; however, all holes were shallow and few data were gained. The following assays are the result of the writer's sampling of the main vein and stockpile:

Sample location	*Copper (percent)*	*Gold*
West end (42 inches)	7.21	trace
Middle (14 inches)	5.85	trace
East end (12 inches)	6.62	trace
Stockpile	8.45	trace

To date (1966), no ore has been shipped from the property, although about 20 tons of ore is stockpiled there. This ore is vein material that was mined during trenching operations.

Ruth Mountain Pyrite prospect

This deposit is at the headwaters of Ruth Creek and is about half a mile west of Hannegan Pass. It is in the W½ sec. 8, T. 39 N., R. 10 E., where altitudes on the prospect range from 4,500 to 6,000 feet. The south end of the deposit crops out on the Hannegan Pass trail about half a mile from the pass. In the area of the deposit, middle Tertiary acidic volcanic rocks overlie quartz diorite of the Chilliwack Batholith (Lower Cretaceous) in a depositional contact. These rocks are traversed by at least four pyritized shear zones that are 10 to 30 feet wide. The shear zone near the top of the mountain is 30 feet wide, the ones halfway down are 15 and 20 feet wide, and the one near Ruth Creek is 10 to 15 feet wide. Gold is erratically distributed in the shear zones, which assay from a few cents to as much as $176 per ton (Huntting, 1956, p. 204). All shear zones contain conspicuous limonite resulting from oxidation of the pyrite; the feldspars, for the most part, are altered to clay minerals, sericite, and cryptocrystalline quartz. Only one short adit is on the property. The adit is about 50 feet in elevation below the Hannegan Pass trail at a point where the trail leaves the heavy timber and enters open meadows below the pass. This adit heads northeastward for about 30 feet into a pyritized shear zone at an altitude of about 4,600 feet.

Saginaw prospect

The Saginaw prospect is in sec. 15, T. 40 N., R. 9 E., near Skagway Pass, which is ½ mile northeast of Twin Lakes. Altitudes at the property range from 3,600 to 5,200 feet. The Saginaw group consists of four patented claims: Saginaw, Saginaw No. 2, Northern Light, and Titabawasse, all of which were surveyed under Mineral Survey No. 1,065, and three unpatented claims. Mr. Robert Averill, of Bellingham, is owner of the property.

Accessibility.—From Twin Lakes a single-track dozer road leads about ¼ mile to the south end of the claims. From the end of the dozer road a poor trail extends to adits on the Saginaw claims that are on a steep northwestward-facing slope above Winchester Creek.

History.—The Saginaw claim was located by L. A. Price in 1901; in 1912 the Saginaw and other claims of the group were patented. Several shallow prospect pits and four adits were dug to explore gold- and copper-bearing quartz veins. In 1946 Mr. Averill purchased the claims, which were sold by the county because of unpaid taxes, and in 1948 he organized the Saginaw Gold & Copper Mines. To date (1966), with the exception of building a road to the property and doing assessment work on the unpatented claims, the company has not undertaken any development work nor has there been any production.

Geology.—The rocks in the vicinity of the Saginaw group consist of limestone and tuffaceous sandstone of the Chilliwack Group that have been intruded by Tertiary diorite dikes and sills. The diorite contains quartz veins 2 to 9 inches wide that strike N. 70° W. and dip 70° S. On the trail from the mine camp to the main adits, several of the quartz veins have been explored by shallow prospect pits. The quartz veins pinch and swell; they crop out for not much more than 50 feet. Parts of the veins contain sparsely disseminated chalcopyrite, galena, and pyrite. Malachite and iron oxide, which formed through the oxidation of these minerals, stain some fracture surfaces of the otherwise white quartz.

The main quartz veins, upon which most of the underground work has been undertaken, are on the Saginaw claim. The south end of the claim is about 750 feet north of the camp and is at an altitude of 4,400 feet. Three hundred feet north of the south end of the claim, near its west side line, a 75-foot adit heads southward to diorite. About midway in the adit a 35-foot crosscut heads west. This adit was driven to explore a zone in the diorite that contains disseminated chalcopyrite. Near the center of the Saginaw claim a crosscut heads in a southward direction for 300 feet. Several quartz veins, the widest of which is 3 feet, have been crosscut and drifted upon for a total of 200 feet. The veins, which have a general N. 70° W. strike, and dip steeply south, contain sparsely disseminated chalcopyrite. In addition to the above-mentioned workings, a 36-foot adit is near the south end line of the Saginaw claim and a 15-foot adit is near the center of the Saginaw No. 2 claim. All adits are caved at their portals and are inaccessible. Figure 35 shows the location of the Saginaw group of claims and the different workings.

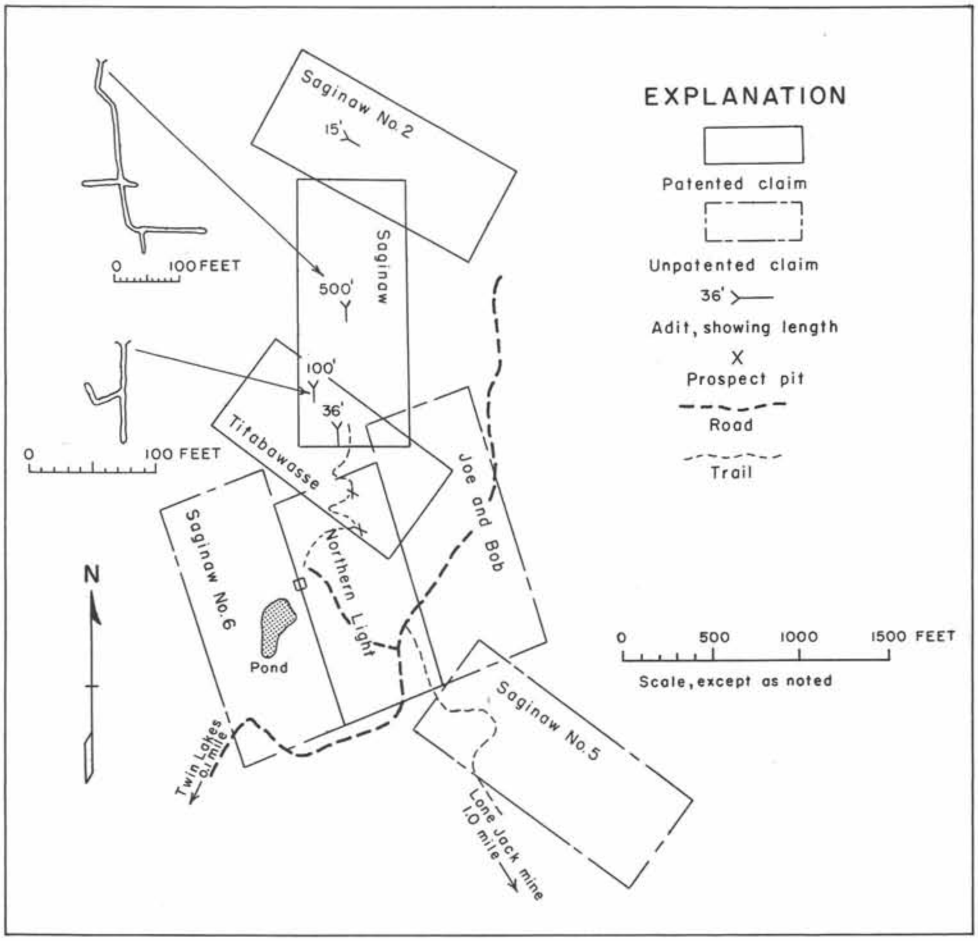

FIGURE 35.—Claim map and adits of the Saginaw group.

According to Huntting (1956, p. 179), picked samples assayed 0.20 ounce in gold, 200 ounces in silver, and 70 percent lead. Other samples contained 0.34 to 1.82 ounces in gold, 0.78 to 2.06 ounces in silver, and traces to 2.13 percent copper. However, the average values are about $6 per ton in gold, silver, and copper.

Silver Tip mine

This mine is 3 miles east of Shuksan and is mainly in the W½ sec. 34, T. 40 N., R. 9 E. It is on the Ruth Creek drainage at an altitude of 3,575 feet on the south slope of Goat Mountain. The property consists of 12 contiguous unpatented claims, which are recorded as Silver Tip No. 1 through No. 12. The property is owned by Ray Block and is under lease to Paul Olson, L. R. Lahey, and Hans Anderson, of Tacoma.

Accessibility.—The property can be reached by driving 3.5 miles east on the Ruth Creek road from its junction with State Highway 542 near Shuksan. From the mine's camp on Ruth Creek a barely discernible trail leads northward to two adits at 3,575 feet in elevation on the west bank of a tributary to Ruth Creek. The distance from the camp to the adits is about ½ mile.

History.—The Silver Tip vein was discovered by H. C. Wells in 1896 and was one of the first discoveries of the district. The principal metals of the vein proved to be gold, silver, and copper. With the exception of a few shallow prospect pits, very little development work was undertaken on the vein in the early days, as the gold content was low and the gold was not free milling. Although some ore was high in lead, zinc, and copper, the mining of base metals was considered impractical. In 1938 the Silver Tip Mining Company, Inc. was formed by Ray Block, of Seattle. A small flotation

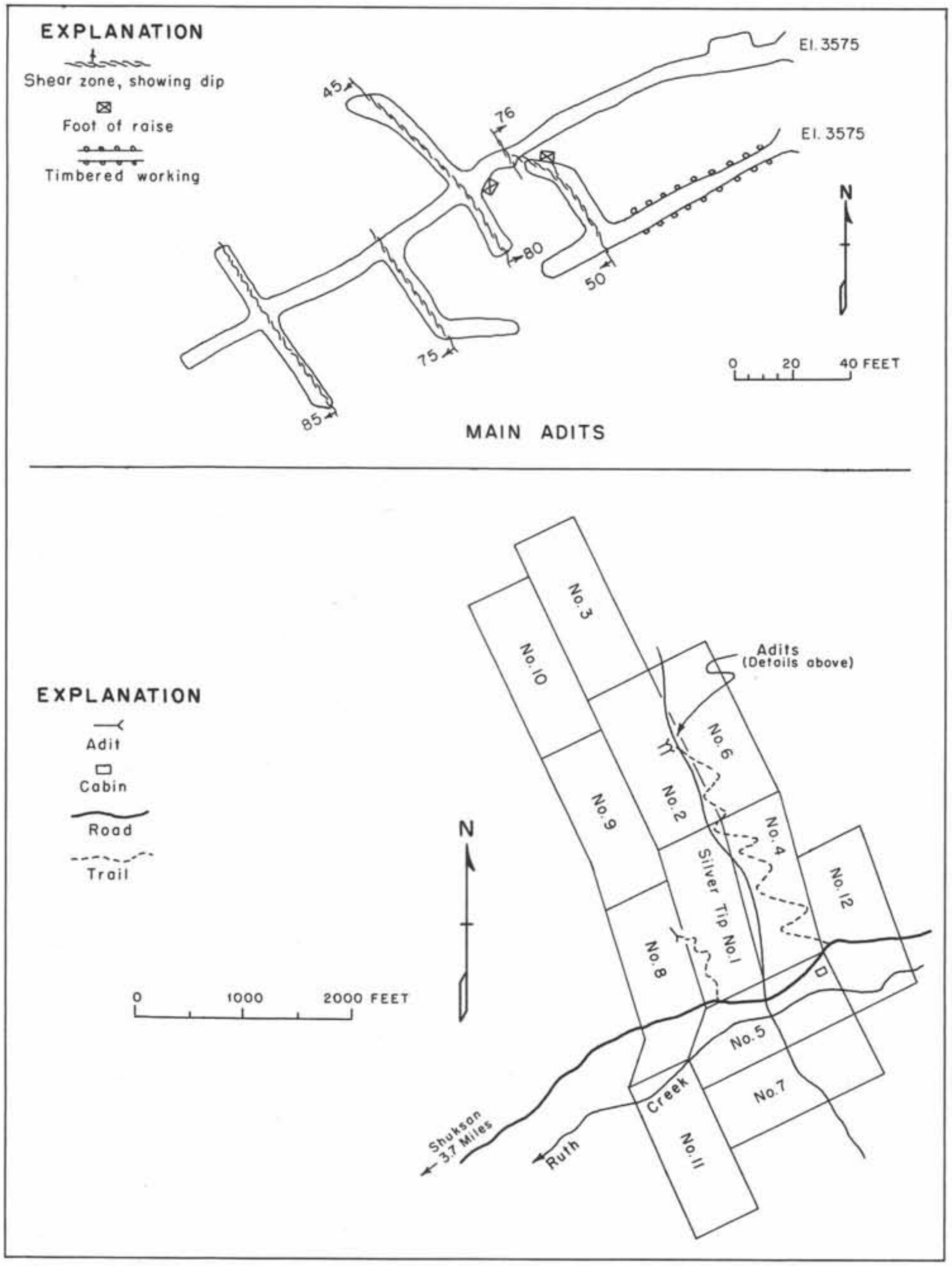

FIGURE 36.—Silver Tip mine claim map and adits.

mill was constructed on the property in 1945, and shipments of concentrates and ore were made to the Tacoma smelter in 1947, 1948, and 1949. In the winter of 1949-50 a snowslide destroyed the mill. In 1955 C. M. Cass, of Tacoma, acquired a lease on the property and undertook a limited amount of exploration work. In 1960 Messrs. Olson, Lahey, and Anderson acquired a 10-year lease on the property and are currently (1966) engaged in evaluating several metalized shear zones.

Geology.—The ore minerals appear to be confined to N. 45° W.-trending shear zones in pre-Jurassic phyllite and siliceous schistose marble. The shear zones dip 50° SW. to 80° NE. and contain veinlets of calcite as well as stringers of quartz. In most parts of the shear zones, metallic minerals are sparse and consist of disseminated pyrite, pyrrhotite, and arsenopyrite. However, some parts of the shear zones contain ore shoots of sphalerite, chalcopyrite, and galena. These ore shoots appear to be lenticular replacement bodies in siliceous marble. The ore shoots discovered to date are small; they are about 1 foot wide and generally less than 10 feet in length along the strike and dip of the veins. The metallic minerals are accompanied by quartz, calcite, and, in some places, siderite. In some ore shoots sphalerite, chalcopyrite, and galena occur as well-defined bands with little, if any, gangue; in other ore shoots the minerals occur disseminated in vuggy quartz. The sphalerite occurs mainly as iron-rich marmatite. Although ore is not exposed in the underground workings of the mine, ore-grade material crops out along several shear zones. Assays of representative material from these ore shoots as well as float showed the following values:

Gold	0.11 to 0.42 oz./ton
Silver	1.60 to 49.00 oz./ton
Copper	0.49 to 6.41 percent
Lead	0.05 percent

Although samples were not assayed for zinc, some samples were composed of as much as 50 percent sphalerite.

The main underground workings of the mine consist of two adits at the 3,575-foot elevation, both of which were driven southwestward into the west wall of a steep rocky gulch (Fig. 36). The longest adit is 240 feet long and it crosscuts four snear zones that have been drifted upon for a combined length of 180 feet. Near the first crosscut, which is about 100 feet from the portal, a 30-foot inclined raise leads to a small stope. It appears that the ore mined from this adit came mainly from the stope, as ore is not visible in other parts of the adit, nor were any other parts of the vein stoped. About 35 feet south of the main adit and at the same elevation, a 90-foot adit crosscuts a shear zone 70 feet from the portal. A drift follows the shear zone 40 feet northwestward, and near the face of the drift a 20-foot raise was driven, but no ore is exposed. Both of the above-mentioned adits are on Silver Tip No. 2 claim. About 1,500 feet southwest of these adits, at an altitude of about 3,200 feet, another adit has been driven N. 50° W. into the hillside. The adit is caved 25 feet from the portal, but the size of the dump suggests that there are at least 100 feet of underground workings. This adit appears to be the latest exploration work that was undertaken on the property, and it probably was driven in hope of crosscutting a blind lead. It is doubtful that any ore was discovered in this adit, as there are no signs of a stockpile nor are any ore minerals present in the dump material.

When the mill was in operation (1945-49), a two-bucket aerial tram connected the main adit to the mill that was built near the Ruth Creek road. The tram was about 2,600 feet long and had a difference in elevation of about 1,000 feet. The mill contained a jaw crusher, a 15-ton ball mill, a rake classifier, flotation cells, and Wilfley tables. Gasoline engines and electric motors supplied power to the mill. Air for the drills and mucking machine at the mine was furnished by a 315 c.f.m. gasoline engine Schram compressor, which still remains inside the portal of the main adit.

Terra Alta prospect

This property is about 3,000 feet south of the Lone Jack mine and is in the SE¼ sec. 22, T. 40 N., R. 9 E., at an altitude of about 5,200 feet. U.S. Mineral Monument No. 1 is 200 yards north of the property. In 1901 several adits were driven by the Terra Alta Mining Co. on what was believed to be the southern extension of the Lone Jack vein. The main adit is about 500 feet long and extends westward into black phyllite that contains thin stringers of white quartz. A small creek flows from the portal of the adit, because the adit is under a cirque basin that contains melting snowfields during the summer season. About 100 yards south of this adit, another adit extends S. 75° W. for 100 feet into iron oxide-stained quartzite. A short distance south of the last-mentioned adit another adit heads west for 10 feet into quartzite. None of the adits contain quartz fissure veins that resemble the Lone Jack vein. The mineral values at the property reportedly occurred as gold and tellurides to the amount of $306 per ton (Landes and others, 1902, p. 44). Except for sparsely disseminated pyrite, the writer observed no ore minerals. Assays of quartz samples collected by the writer from the dump of the largest adit showed 0.01 ounce per ton in gold and 0.36 ounce in silver.

Tooker-Lestrud (Little Dutchman) prospect

The claims of this prospect cover the pyritized rocks that crop out along State Highway 542 near the top of what is locally known as Power House Hill. Currently (1966), the Dutchman Consolidated Mines, of Glacier, owns the property. The prospect is in the SE¼ sec. 31, T. 40 N., R. 8 E., at an altitude of 2,000 feet. Because of its proximity to the highway and because of the colorful nature of the rocks due to oxidation of the pyrite, this property probably has been examined more than any other claim in the Mount Baker mining district. The deposit consists of disseminated pyrite and marcasite in a wide zone in altered andesite and highly sheared argillite. The zone is several hundred feet wide. Assays of the pyritized rock show as much as 3 ounces in silver per ton but an average of only .05 ounce in gold. One short adit, which is caved near its portal, is on the property.

Verona (Galena) prospect

This prospect is about 4 miles by road below the Mount Baker Lodge and is on State Highway 542 in the vicinity of Galena Creek. It is in sec. 20, T. 39 N., R. 9 E. The altitude of the property averages 3,200 feet. The property, which consists of several unpatented mining claims, is owned by Mount Baker Mining and Milling Co., of Bellingham. The main workings are accessible by means of a dozer road that extends south from the highway at a point about 0.3 mile above Galena Creek bridge. At the end of this road, at an altitude of about 3,400 feet, a prospect adit heads S. 15° W. for 57 feet into fractured green andesite. Forty-five feet from the portal a crosscut has been driven west for 24 feet. The fractures in the andesite are filled with narrow veins of quartz, calcite, and iron oxides; these veins are as much as 6 inches wide. Fine-grained pyrite occurs disseminated in the wall rock and also forms narrow stringers; however, no well-defined vein is present. Sampling of the pyritized rock by the writer showed 0.02 ounce per ton in gold and 10.38 ounces in silver. Huntting (1956, p. 179) reports that one assay showed 0.21 ounce in gold, 1.0 ounce in silver, and 14.5 percent lead. Although galena was not noted in the adit, sparsely disseminated galena is present in outcrops along the west bank of Galena Creek about 200 feet upstream from where the company's road crosses the creek. Also near this location, an adit on the west bank of the creek extends southward for about 100 feet, but its portal is covered with rock from recent bulldozing work. About 250 feet north of the Galena Creek bridge and about 100 feet west of the creek there is another prospect adit. This adit, which is at an altitude of 2,920 feet, heads S. 35° E. for 60 feet and follows narrow quartz stringers in green andesite. No sulfide minerals are present in the quartz, but it is possible that some of the quartz stringers contained gold and silver.

Wells Creek Gossan prospect

This property is 1 mile southeast of the confluence of the North Fork of the Nooksack River and Wells Creek. It is mainly in sec. 5, T. 39 N., R. 8 E., where altitudes range from 2,000 to 2,500 feet. Within this area the Glacier Mining Co., of Seattle, has staked 19 claims that cover an area of pyritized and sheared andesite.

In the fall of 1964 an aeromagnetic anomaly of 57,200 gammas was detected on the property in an area where the background is 56,960 gammas. According to Jack Sauers, consulting geologist for the Glacier Mining Co., (written communication, 1966), magnetometer readings indicate a copper deposit 700 to 900 feet beneath the surface. The company undertook diamond drilling in the area of the magnetic highs; however, the holes were too shallow to prove the existence of an ore body. In 1966 a geochemical survey was made over the area of the claims and as much as 700 parts per million in copper was detected in soil near the south end of the claims.

The copper anomaly occurs in strongly sheared and altered andesite of Middle Jurassic age that has been mapped by Misch (1966, p. 118) as the Wells Creek Volcanics. Near the north end of the claims the andesite is overlain by a small outlier of Pleistocene andesite from Mount Baker. The shear zone in the area covered by the claims strikes north on the north end of the claims and N. 45° E. on the south end of the claims. Within the shear zone, which is about ½ mile wide and more than 1 mile long, silicified and sericitized andesite contains fine-grained disseminated pyrite. As much as 10 percent pyrite is present in some andesite; however, the average pyrite content is about 3 percent. Oxidized parts of the andesite, which are rich in pyrite, contain abundant iron oxides that impart a rusty color to the outcrops. Assays of the pyritized andesite by the writer showed 0.20 ounce per ton in silver and no gold. Assays by the Glacier Mining Co. show as much as 0.40 percent copper.

The Wells Creek Gossan appears similar to two other properties in the area. About ½ mile to the northwest, at the Great Excelsior mine, pyritized slate has been mined for gold and silver; traces of copper also are present. At the Tooker-Lestrud prospect, which is about ½ mile north of the Wells Creek Gossan, pyritized andesite and sedimentary rocks contain traces of copper and as much as 3 ounces of silver per ton.

White Salmon prospect

The White Salmon prospect is on the northeast slope of Shuksan Arm, in the SE¼ sec. 20, T. 39 N., R. 9 E. The prospect is at an altitude averaging about 4,800 feet and is about 1,000 feet north of the outcrop of the Iron Cap claim on Shuksan Arm. Except for a few caved open cuts that were dug on several narrow pyritized shear zones in silicified greenstone, very little in the way of exploration work has been done. The pyrite of this deposit appears to be a border phase of the pyritized zone that occurs at the Iron Cap claim.

White Swan prospect

From 1909 to 1918 the Mount Baker Gold, Copper, and Tin Co. undertook limited exploration work on this property. The claims are at the headwaters of a tributary of Barometer Creek at a general altitude of 4,800 feet and are in sec. 3, T. 39 N., R. 8 E. Nothing is known about this property except that several short adits were driven on gold- and silver-bearing quartz veins occurring in Jurassic-Cretaceous sedimentary rocks that consist mainly of slaty argillite.

SLATE CREEK MINING DISTRICT

The Slate Creek mining district is in the eastern part of Whatcom County and extends from longitude 121° eastward to the Whatcom-Okanogan County line (Fig. 23, p. 61). The Canadian border is the northern boundary for the district, and the Skagit County line forms the southern boundary. (About 20 percent of the Slate Creek mining district is in Skagit County, but that part is not discussed in this report.) The entire district is in the Mount Baker National Forest, and the greater part of it is in the North Cascade Primitive Area. Prior to 1893 the district was known as the Ruby Creek and Canyon Creek mining districts.

Mining History

Although placer mining had been carried on in the Slate Creek district since the 1870's, the main rush to the district did not take place until 1894—the year following the discovery of the Eureka lode by A. M. Barron. Upon the discovery of free-milling gold ore at the surface, trails were opened into the district from the Skagit River on the west and from the Methow River on the east in Okanogan County. Prospectors rushed into the district, and the mining camp of Vera Cruz sprang up near the site of the new gold discovery. In 1896 a stamp mill was erected on the west bank of Bonita Creek, and by means of a surface tramway the ore was conveyed from the mine high on the mountainside to the mill at creek level. During 2 years' operation, $120,000 in gold was produced from the "Glory Hole" on the Eureka claim, but operations ceased when the gold values declined. By 1898 most of the area, which was then known as Eureka Gulch, had been staked and adits were being driven on many quartz veins. A map of the mining district as it was in 1899 is shown in Figure 37. The Mammoth vein, which is about a mile southeast of the Eureka lode, also proved to be rich in gold, and a stamp mill was built on the property. From 1898 to 1901 about $397,000 in gold was produced from this mine. By 1900 the gold rush had subsided and most properties were abandoned. Many prospectors left the area for the Alaskan gold rush of 1898, and others were discouraged when it became apparent that the free-milling gold ore gave way to base metals at depth. Others were discouraged when mining experts said that the ore was too low in grade for treatment and that it would be impossible to follow the veins for any distance because of their faulted nature. However, optimism still prevailed at several properties, and stamp mills were constructed at the Goat, North American, Minnesota, and Anacortes mines. Amalgamation was the principal means of recovering gold, and only the richest gold ores could be worked profitably. At several mills the ores were treated by unskilled millmen, and therefore in some instances the gold recovery was less than 50 percent. Trails were still the only means of access, and all equipment and supplies were packed to the mines on horses. However, from Ventura, which was at the confluence of the Methow River and Lost River, a narrow-gauge (26 inches wide) wagon road led as far west as Harts Pass; around 1903 the road was widened to 36 inches and was extended to Barron.

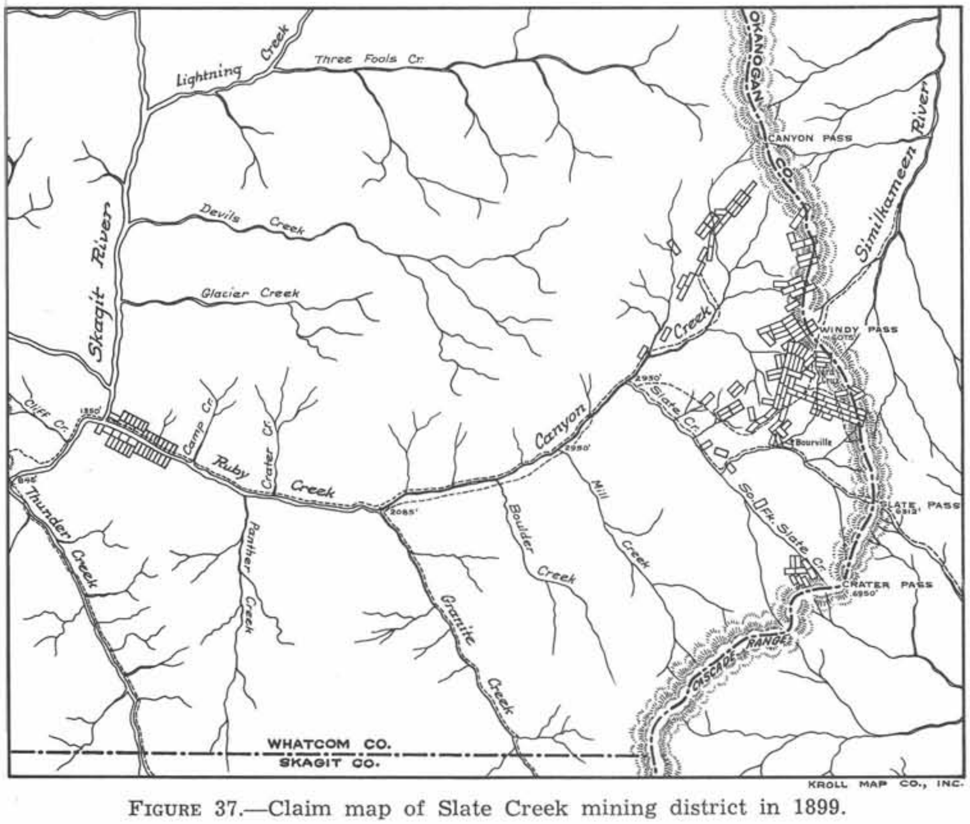

FIGURE 37.—Claim map of Slate Creek mining district in 1899.

Around 1900 the mining camp of Barron, named after A. M. Barron, who had discovered the Eureka lode, was established on Bonita Creek downstream from the Eureka mill, but a few years later the townsite was relocated a short distance east of Bonita Creek near its junction with Slate Creek. The settlement consisted of a store and a tavern that supplied the basic needs of several hundred prospectors, whose tents dotted the landscape. A miner's wages were then $2.50 for a 10-hour day. It was near here that the second Mammoth mill was built in 1905, the remains of which are still visible from the Slate Creek road. Also in 1905, the Chancellor Mining Co. built a powerplant at the confluence of Slate and Canyon Creeks. Electricity generated by the plant was used by the Bonita Gold Mining Co., which was mining and milling ore from the Eureka lode. Mining was also undertaken at the Tacoma, Goat, Indiana, and Illinois mines, and at mines in Allen Basin; all mines were within a few miles of Barron. Seven miles west of Barron, near the confluence of Canyon and Mill Creeks, the North American Mining Co. built a stamp mill in 1907; and at the Minnesota mine, on Canyon Creek a short distance downstream from Mill Creek, another stamp mill was built in 1908 by the Seattle-St. Louis Mining Co. (Fig. 42, on p. 113).

In 1915 new interest was shown in the area when it was rumored that a railroad was to be built up the Methow River to serve the district. In 1916 the financing for the Methow Valley Railroad began, but the project was soon abandoned. It was about this time that C. R. McLean, H. J. Ballard, and C. R. Ballard located the Azurite group of claims near the headwaters of Mill Creek. The Azurite Copper Co. was formed, mainly with the backing of eastern money, and exploration work was started on the claims. In 1925 the company was reorganized as the Azurite Gold Co. Work at the claims was expensive, because mining supplies had to be packed on horses 24 miles from the Methow River at a cost of $100 per ton. The company constructed a narrow-gauge road to the mine in 1930. After 18 inches had been cut off the axles of trucks, they were able to negotiate the steep mountain road. A small smelter was erected at the property, but it proved to be inefficient. However, a few tons of copper matte from smelting operations was shipped to the Tacoma smelter in 1933.

In 1932 a religious group moved into the district and established a colony in the vicinity of the Tacoma and Mammoth mines. Several sturdy log buildings were erected by the group, who had hoped to build a sawmill and operate the mines. However, after much difficulty, the squatters were persuaded by the legal claim owners and officials of the Forest Service that they were trespassing. By 1934 the last of the group had left the district.

In 1934 the price of gold rose from $20.67 per ounce to $35 and, as would be expected, there was renewed interest in the gold possibilities of the district. The American Smelting and Refining Co. acquired a 25-year lease on the Azurite mine and began extensive development work as well as construction of a 100-ton cyanide plant. The narrow-gauge road to Barron was rebuilt in 1935 by the Forest Service to accommodate conventional vehicles, and on Bonita Creek a new mill was constructed by the New Light Gold Mining Co. to treat gold ore from the Eureka lode (Fig. 44, on p. 116-117). The Azurite mill was put into operation in 1936 and operated continually until 1939; during this time the mine produced $972,000 in gold.

About 1¼ miles west of the Azurite mine, on a tributary to Granite Creek, the Gold Hill Operating Co. began development on several promising lead-silver veins. At the Eureka lode, mining and milling was undertaken on a small scale.

In 1942, Government War Order L-208 closed all gold mining operations in the United States; this order marked the end of major gold milling operations in the Slate Creek mining district.

In 1946, after the end of World War II, gold mining restrictions were lifted. In 1947, Western Gold Mining, Inc., which had acquired the Eureka property in 1940, mined and milled several hundred tons of gold ore from the Eureka lode, mainly for test purposes. However, full-scale mining operations were not resumed. At the Golden Arrow mine, on the Tacoma claim, small-scale mining operations were undertaken and shipments of gold-silver ore were made to the Tacoma smelter in 1951, 1952, and 1953. These shipments of ore were probably the last to be made from the district. At present (1966), the most active mining company in the district is Western Gold Mining, Inc. Although it is not in production, development and exploration work is carried out on its claims, which contain the original Eureka lode. A 120-ton gold mill is kept in a state of readiness for the day operations can be resumed.

In all, 2,812 claims were staked in the Slate Creek mining district from 1894 to 1937. The breakdown for the number of claims in different parts of the district is as follows: Slate Creek, 1,628; Canyon Creek, 405; Ruby Creek, 455; Mill Creek, 245; Granite Creek, 68; and Panther Creek, 11. Of these claims, 52 were granted patents, but the two major gold producers of the district, the Azurite and the Eureka, were never patented. Although most prospectors did not realize much in the way of monetary reward for their efforts, to them goes the credit for building most of the trails and roads that made the area accessible. Only at a much later date did the Forest Service begin to maintain the trails and roads.

Placer mining has been carried on in the district since the late 1870's, but the operations have been small and sporadic. Credit for the discovery of placer gold is given to a man named Rowley. At Rowley Chasm on Ruby Creek—about three-quarters of a mile downstream from Boulder Creek—Rowley discovered coarse gold nuggets in the south bank of Ruby Creek. As a result of his discovery, over $100,000 in gold was supposed to have been recovered by Rowley and other prospectors. At that time, access to the area was from Fort Hope, in British Columbia. From Fort Hope a trail led down the Sumallo River to the Skagit River, from which point an Indian trail extended to the mouth of Ruby Creek. Because of the inaccessibility of the area, only the rich bars were worked and then abandoned. In June 1891, Henry Benke and Hilmar Jacobson made discoveries of placer gold on Slate Creek "about 6 miles up from Canyon Creek." This discovery was followed by a general rush of prospectors to Ruby and Slate Creeks that resulted in the staking of many placer claims. Around 1895 the Old Discovery claims were being worked near the site of Rowley's original discovery and the Ruby Hydraulic Gold Mining Co. began operations on the Scougale claims at the mouth of Ruby Creek. Placer operations on Ruby, Slate, and Canyon Creeks continued on a small scale until around 1914. By that time only two placer deposits were still operating; the most active operation was that of the Granite Creek Mining Co., whose operations were on Slate Creek. It was not until the depression years of the 1930's that operations began once again in the district. By 1939 at least five placer mines were in operation on Ruby Creek, but production was insignificant. The total production in 1939, as reported by sales to the U.S. Mint, was only 22 ounces. Although placer mining ceased in 1941, a few individuals still pan gold along Ruby, Canyon, and Slate Creeks during summer months.

Accessibility

The Slate Creek mining district is one of the most inaccessible areas in the county. At present (1966) only 7 percent of the district is within a mile of an existing road. All the mines of the district are within a 10-mile radius of Harts Pass, which is 32 miles by road from Winthrop, in Okanogan County. From Harts Pass, which is on the crest of the Cascade Mountain Range and is at an altitude of 6,198 feet, a forest access road follows Slate Creek northwestward for 10 miles to the Chancellor campsite. Three miles west from the pass a steep mountain road branches from the Slate Creek road and follows Bonita Creek to the old townsite of Barron and to the headwaters of the creek at Windy Pass, for a total distance of 3 miles from the Slate Creek road. Forest access trails follow the Cascade crest from Harts Pass northward to within 4 miles of the Canadian border, and other trails follow several of the larger streams. The western part of the district is accessible only by trails. At present (1966) State Highway 20 has been constructed eastward as far as Panther Creek on Ross Lake. From Panther Creek a trail follows Ruby and Canyon Creeks 18 miles east to Chancellor. The North Cross State Highway (State Highway 20) will make the southern part of the district more accessible, as the road will follow Ruby and Granite Creeks to Rainy Pass, in Skagit County.

Topography

Rugged mountainous terrain prevails in the Slate Creek mining district, which is west of the crest of the Cascade Mountains. From Ross Lake, which is at an altitude of 1,600 feet on the west edge of the district, the mountains rise steeply to altitudes of more than 8,000 feet. Peaks that exceed 8,000 feet are: Jack Mountain (9,070 feet), Mount Hozomeen (8,080 feet), and Azurite Peak (8,440 feet). Along the crest of the Cascade Mountains the major passes are at 5,000 to 6,000 feet, and the main peaks along the crest have altitudes of 7,000 to 8,440 feet. The major peaks of the crest are: Slate Peak (7,438 feet), Three Fools Peak (7,965 feet), Castle Peak (8,310 feet), Tatie Peak (7,433 feet), and Azurite Peak (8,440 feet). In general, the timberline is

FIGURE 38.—Topography of the Slate Creek mining district. Diablo Lake in center of photo. North Cross State Highway follows southern shore of lake. (Photo courtesy of U.S. Forest Service.)

at 6,500 feet. Above this altitude the mountains are steep and rocky and exhibit typical alpine topography. Glaciers are not as extensive as they are in the Mount Baker mining district; they are confined to the north slopes of Jack and Crater Mountains at altitudes of 6,500 to 7,500 feet. The presence of many cirque basins above and below timberline indicates previous intensive alpine glaciation. The bottoms of the major valleys are occupied by Ruby, Canyon, Slate, Mill, Granite, Devils, Lightning, and Three Fools Creeks that form a dendritic drainage pattern.

Vegetation and Climate

Below timberline the slopes have moderate stands of Douglas fir, western hemlock, white pine, and western larch that are separated by rockslides and cliffs. In the bottoms of the wider valleys the timber gives way to dense brush that consists of willow, alder, salmonberry, blackberry, ferns, and devils club. A few stands of western red cedar grow along some valley floors. Above timberline the vegetation consists of scattered stands of alpine fir, western larch, Engelmann's spruce, and mountain hemlock in a parklike setting. The ground cover consists of alpine grass, heather, huckleberry, and abundant wildflowers that give way to lichen and moss on the highest rocky peaks.

The climate of the district is modified oceanic; however, the eastern edge is influenced by the intermountain steppe climate of eastern Washington. At Newhalem, temperatures over a 34-year period range from a high of 109° in June and July to a low of minus 6° in January. The annual precipitation for this period was 75.77 inches, of which a maximum of 12.23 inches fell in December of one year and a minimum of 1.32 inches was recorded in July of another year. Over a 29-year period the maximum annual snowfall was 52.9 inches, of which 18.8 inches fell in January of one year. In most years, snow can be expected to fall at any time from October to April. Miners who have spent the winter at several mines near the eastern edge of the district reported that as much as 10 to 15 feet of snow accumulated on the ground, and temperatures during January and February were at times below zero.

Geology

The major rock unit of the Slate Creek mining district is the Pasayten Formation of Early Cretaceous age. To the north, in British Columbia, Rice (1947, p. 15) has mapped similar rocks as the Dewdney Creek Group. The Pasayten Formation is well exposed west of the Cascade crest from Harts Pass to Foggy Pass; it consists mainly of thick beds of arkosic sandstone, graywacke, slaty argillite, and conglomerate. A few thin discontinuous beds of limestone are present in the formation but appear to be insignificant. Smith and Calkins (1904, p. 29) estimate the thickness of the Pasayten Formation to be at least 6,000 feet. Rice (1947, p. 18) states that the thickness of the Dewdney Creek Group north of the International Boundary exceeds 7,000 feet. In the Slate Creek district the beds have a general northwesterly strike, and they dip moderately to steeply northeast and southwest. Two sets of high-angle faults predominate; one set strikes N. 70°-90° E., and the other set strikes N. 30° W. Along the lower parts of Slate and Ruby Creeks, slaty argillite and interbedded quartzite strike northwestward and exhibit nearly vertical dips. The rocks are greatly sheared and jointed. Throughout the district, rocks of the Pasayten Formation have been intruded by small stocks of granodiorite and quartz diorite and by dikes of quartz porphyry and diabase. The mineral deposits of the district appear to be related to these intrusions, which probably represent cupolas of an underlying granitic body.

On the western edge of the district, slate and phyllite of the Pasayten Formation are overlain in a faulted relation by cherty argillite and greenstone of Daly's (1912, p. 500) Hozomeen Series.[1] West of the Hozomeen Group the predominant rocks are pre-Jurassic schist and gneiss and Cretaceous-Tertiary granite and diorite. The granite and diorite differ from the other granitic rocks of the district in that they appear to be products of granitization. Mapping by Misch (1952, p. 10-13) shows that the rocks have textures characteristic of rocks that crystallized in the solid state and retained part of their original gneissic texture. The contacts of these migmatitic granitic rocks are gradational; gneiss is to the west and schist is to the east. To the south they have been intruded by Tertiary granitic rocks.

The rocks of the Pasayten Formation in the eastern part of the district form a north-northwestward-trending closed asymmetrical anticline, the axis of which roughly parallels upper Canyon Creek. On the northeast limb of the anticline the dips range from 40° to 80°; the dips on the southwest limb range from 60° to vertical. In the western part of the district the Pasayten Formation has been folded into a northwestward-trending syncline. The trough of this syncline is occupied by rocks of the Hozomeen Group that were thrust over the Pasayten Formation prior to folding. Between the syncline and the anticline the rocks are steeply folded into at least one other anticline and syncline. The main orogeny that folded the Pasayten Formation as well as older rocks occurred in Late Cretaceous and early Tertiary time. Upper Cretaceous rocks were involved in the orogeny, but the Tertiary intrusive rocks of possible Oligocene age were emplaced after the folding. Adjacent to the Tertiary intrusions the sedimentary rocks have been pyritized and thermally metamorphosed into hornfels. In places, the brecciated nature of the sedimentary rocks indicates forceful intrusion.

Mineral Deposits

Most mineral deposits of the Slate Creek mining district consist of quartz fissure veins that contain native gold, stephanite, galena, sphalerite, and chalcopyrite. Pyrite, arsenopyrite, and pyrrhotite are the main iron sulfide minerals of the veins. Whereas the produc-

[1] The name Hozomeen Series was later changed to Hozomeen Group (Rice, 1947, p. 8).

tion of gold and silver from the veins of the district is more than one million dollars, the combined production of the other metals does not exceed one thousand dollars. Although the metalized veins of the district are predominantly quartz fissure veins, in the vicinity of the Azurite mine several veins consist almost wholly of sulfide minerals that contain base metals. With the exception of a small tufa deposit on Lime Creek near Chancellor, deposits of nonmetallic minerals are lacking.

The gold-bearing quartz veins are most numerous in the area drained by Bonita Creek. The predominant strikes of the veins range from N. 70°-90° E., and the dips range from 40° to 90° N. (Pl. 10). The veins appear as fracture fillings that exhibit banded and drusy textures. They pinch and swell along their strikes and dips and range from thin stringers less than 1 inch wide to massive veins as much as 10 feet wide. Any one vein has not been followed for much more than 200 feet vertically, but the outcrops of individual veins indicate that the quartz fissure filling took place over a vertical depth that exceeds 1,000 feet. Pyritization of the wall rock accompanied the vein filling, and oxidation of the pyrite imparts a rusty color to the wall rock. At least two stages of mineralization appear to be present. During the initial stage, one or several of the following minerals accompanied the quartz: pyrite, pyrrhotite, arsenopyrite, chalcopyrite, galena, and sphalerite. Post-mineral faulting microbrecciated the original quartz and provided depositional sites for later gold-silver hydrothermal solutions.

At the property of Western Gold Mining, Inc., on Bonita Creek, gold occurs in an extensive breccia zone. The breccia consists of fragments of slate and argillite that have been cemented by gold-bearing quartz and calcite. The breccia zone, which has the same general strike and dip as the quartz veins of the area, is 40 to 140 feet wide and has been found over a vertical distance of 1,100 feet. Pyrite, galena, chalcopyrite, and sphalerite are sparsely disseminated in parts of the breccia.

The veins on Majestic Mountain, which is the site of the Azurite and Gold Hill mines, occupy fissures in sheared and faulted quartzite and argillite of the Pasayten Formation. The predominant strikes of the veins are N. 50° E. and N. 10° W.; the dips are mainly north and west from 45° to 75°. Inasmuch as several of the veins crop out on steep rocky slopes on which there is little overburden, they are easier to follow than the veins of the Bonita Creek area. Several veins of the Majestic Mountain area exceed 4,000 feet in length, and mining on the Azurite vein indicates depths of more than 1,200 feet for some veins. Unlike the veins of the Bonita Creek area, which are essentially free-milling gold veins, the veins of Majestic Mountain are base metal sulfide veins that contain pyrrhotite, pyrite, chalcopyrite, galena, and sphalerite. Quartz is the main gangue mineral, but in some veins little, if any, quartz accompanies the sulfide minerals. On the Gold Hill claims, silver accompanies galena and sphalerite; in the Azurite vein the gold is accompanied by abundant pyrrhotite and minor chalcopyrite.

The fissure veins of the Bonita Creek and Majestic Mountain areas occur on faulted crests of major northward- to northwestward-trending anticlines and near granodiorite intrusions. The veins are predominantly transverse to the axis of an anticline. In the vicinity of the Anacortes mine, quartz fissures occur in an argillite-granodiorite contact zone, but elsewhere in the district the veins do not appear in close proximity to granitic intrusive rocks. However, it is possible that granodiorite or quartz diorite underlies much of the district. According to Lindgren's classification of metalliferous veins (1933, p. 529-532), most veins of the district are hydrothermal veins that formed in the mesothermal zone of deposition. Such deposits form near intrusive rocks at depths of 4,000 to 12,000 feet beneath the surface and at temperatures that range from 175° to 300° C.

Principal Gold, Silver, Copper, Lead, and Zinc Properties

Allen Basin group

Allen Basin is a glacial cirque basin that is west of Bonita Creek and is mainly in the E½ sec. 33 and the W½ sec. 34, T. 38 N., R. 17 E. The basin forms an eastward-facing natural amphitheater that is about 4,000 feet wide and nearly 6,000 feet long; its altitude, in general, is about 6,000 feet. The central part of the basin is accessible by trail from the Golden Arrow mine, a distance of about 0.8 mile. The basin is the site of 15 patented mining claims, most of which were staked by J. B. Allen in 1898 and 1899 and surveyed for patent in 1905 by M. C. and J. B. Allen. Since the 1930's the claims have been part of the Western Gold Mining, Inc. group of claims that is known as the Allen Basin group (Fig. 43, on p. 114). Ore was shipped from the property in the early 1900's and again in 1938-40, but the total value of the shipments is not known. According to data supplied by Western Gold Mining, Inc., smelter returns from 11.8 tons of ore showed 1.92 ounces in gold per ton and from 6.27 tons of ore showed 1.38 ounces per ton in gold. From 1898 to 1905, operations at the property consisted of mining near-surface pockets of high-grade gold ore that contained 1.25 to 3.00 ounces per ton in gold.

The rocks of Allen Basin consist of argillite and fine-grained arkosic quartzite that have a general strike of N. 30° W. and nearly vertical dips. Some quartzite is pebbly and some contains inclusions of dark-gray argillite fragments. In the bottom of the basin the rocks are concealed by a thick blanket of overburden, but those along the rim of the basin are well exposed. The rocks of the basin contain two fault systems. One N. 60°-70° E. set of faults, dipping 40°-60° NW., contains quartz veins that range from 6 to 30 inches in width (Fig. 39). These faults and the quartz veins are offset by several parallel N. 40° W.-trending faults that parallel the bedding planes of the rocks. These later faults appear devoid of quartz veins. In addition to the quartz veins, the argillite and quartzite contain several sill-like bodies of quartz porphyry and dacite porphyry. The quartz porphyry crops out a few feet south of a caved adit on the IXL claim, and the dacite porphyry crops out near the shaft on the south side line of the Uncle claim.

All underground workings on the quartz veins in Allen Basin are inaccessible, and little is known about them. The most extensive mine workings appear to be the caved adit on the IXL claim—the dump of which suggests about 100 feet of workings—and two inclined shafts on the Uncle claim. The size of the dumps at the latter claim suggests that the two shafts also contain about 100 feet of underground workings. The IXL claim adit appears to have been following a quartz porphyry sill, and waste rock on the dump indicates that quartz veins not much wider than 1 inch were encountered. Except for small amounts of pyrite, no metallic minerals are visible in the quartz. The shaft near the center of the Uncle claim appears to be the older of the two shafts; it was sunk in a northerly direction on a steeply dipping quartz vein. Ore in the bunker near the shaft consists of quartz that contains fine-grained pyrite, arsenopyrite, sphalerite, and galena. One speck of free gold was noted by the writer in quartz from the bunker. About 200 feet southeast of the old shaft, another shaft is inclined steeply northward on another quartz vein. The work on this vein appears to have been done at a much later date than that at the first shaft, but water makes the shaft inaccessible. The waste rock on the dump of the shaft consists of felsite porphyry; the porphyry crops out about 30 feet northwest of the shaft. The ore from this second shaft that is stockpiled in a nearby bunker consists of quartz resembling the quartz that is stockpiled near the older shaft. An assay of the quartz showed 0.44 ounce per ton in gold and 0.28 ounce in silver. The ore also resembles that of the Indiana and Golden Arrow mines, in that it contains thin parallel bands of finely divided sulfide minerals. Although the quartz vein is not now exposed at the surface, a strike length of at least 500 feet is suggested by the presence of quartz on the dumps of several open cuts along the concealed vein. Mapping by Western Gold Mining, Inc. shows several veins in the basin; the longest vein is offset by several parallel faults.

ALLEN BASIN CLAIMS

1. Nephew
2. Captain Jack
3. Harnessmaker
4. Sister Grace
5. Aunt
6. IXL
7. Uncle
8. Park Placer
9. Equinox
10. Solitare
11. Maccabbe
12. Blue Hen
13. Shanghai
14. Queen City
15. Black Dwarf

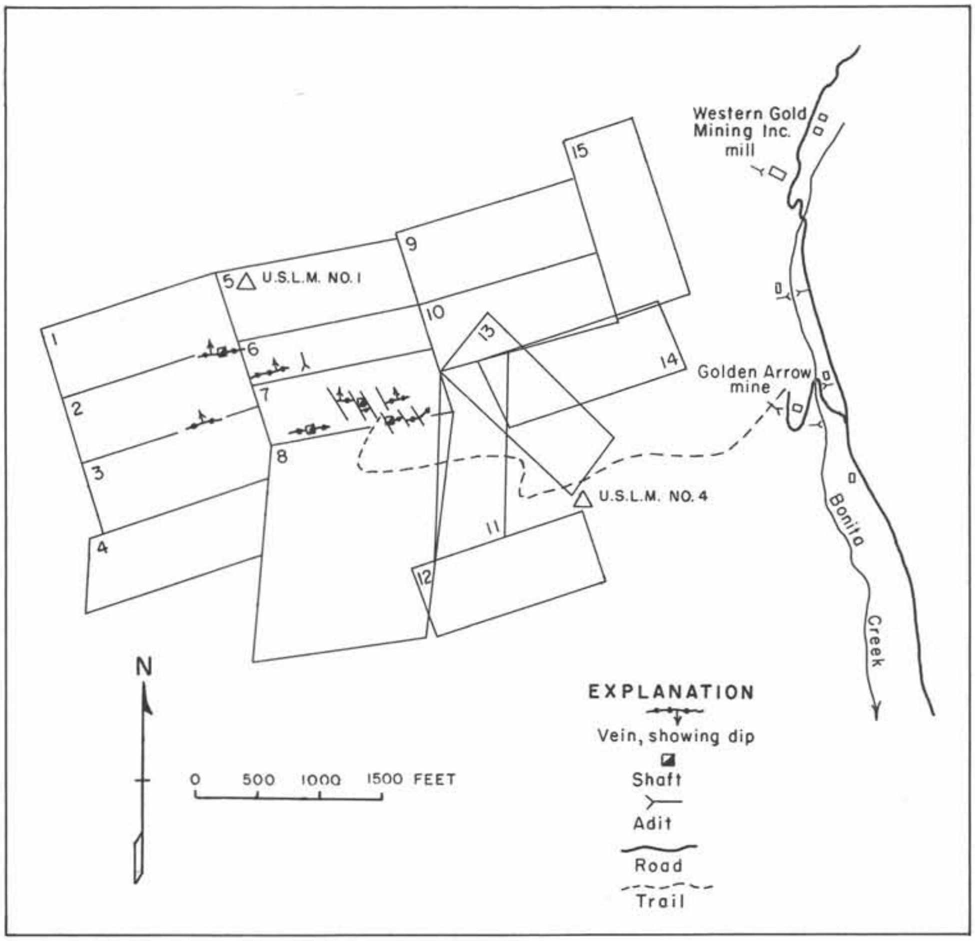

FIGURE 39.—Claims and veins of Allen Basin.

Anacortes mine

This property is near the headwaters of Cascade Creek, a tributary to the North Fork of Canyon Creek, and is in an area known as Hell's Basin. The claims are mainly within the W½ sec. 25 and the E½ sec. 26, T. 38 N., R. 16 E., where altitudes range from 3,000 to 6,000 feet. Access to the mine is by way of the Anacortes Crossing trail from Chancellor; by trail it is about 3¼ miles to the mine mill on the Anacortes claim.

The original Anacortes claim was staked by Henry Benke et al. in July 1891 and proved exceptionally rich. In 1895, ten pounds of quartz from the Anacortes claim yielded 3.8 ounces of gold, which would be worth about $130 at the present (1966) gold price of $35 per ounce. In 1901, seven claims had been staked upon two parallel quartz veins, and development work consisted of three adits that had a combined length of 500 feet. The gold content of the veins was reported to be $8 to $300 per ton (Landes and others, 1902, p. 49-50). In 1935 the claims were relocated by Owens Gold Mines, Inc. as the Anacortes, Tip Top, American, Fidalgo, Gold Coin, Silver Coin, California, Horseshoe, and San Jose mining claims. In 1936 the company installed a 5-stamp amalgamation mill at an altitude of 5,200 feet on the Anacortes claim. At that time the property had about 3,000 feet of underground workings, most of which were on the Anacortes and Tip Top claims. The principal mine adit was at the site of the mill. The amount of gold produced by Owens Gold Mines, Inc., as well as by the previous operators of the property, is unknown. The company maintained a watchman at the mine until 1943, and at present (1966) the mine is in a state of abandonment; no signs of recent assessment work are visible. At present, nothing much remains at the camp and millsite of the Anacortes mine. The roofs of the cabins have long ago been caved by heavy snows, and at the site of the mill some rusting milling equipment protrudes from rotting timbers that once composed the mill building. The identifiable mill equipment consists of a jaw crusher, a 5-stamp mill, a Hardinge conical ball mill, and parts of an old horizontal steam engine and boiler.

The rocks in the vicinity of the mine consist of arkosic quartzite and argillite that have been intruded by diorite; the diorite crops out mainly south of the mill. Several of the dumps contain diorite, quartzite, and argillite, which indicates that the underground mine workings are on or near an intrusive contact.

Landes (1902, p. 49-50) gives the following description of the main gold-bearing quartz vein:

> The principal ledge in the group is one of quartz carrying free gold, tellurides, and sulphides. Its outcrop can be followed for a long distance, and can be seen on both sides of the mountain through which it cuts. Its average width is 2 feet, and the widest part uncovered is 13 feet. Its strike is about 10 degrees west of north and it has a dip of 70 degrees to the southwest. Its hanging and footwall are both of slate, but in the upper tunnel about 14 inches of conglomerate occurs in the vein on the hanging wall side. The assay value of the ore ranges from $8 to $300 per ton [$20 gold], and some very high assays have been received on picked specimens.

When the writer visited the property in 1965, caved adits were noted at the 5,050-foot, 5,225-foot (mill level), 5,540-foot, and 5,650-foot altitudes on the main trail. Quartz on the dumps of all adits is iron oxide stained and contains disseminated pyrite. In addition to the pyrite, some quartz on the dump of the adit at the 5,540-foot altitude contains minor galena and sphalerite in hairlike stringers. The sizes of the dumps indicate that most of the workings are probably 100 to 200 feet in length; however, the mine dump at the site of the mill suggests about 500 feet of underground workings. An assay of vein quartz from the dump showed 0.34 ounce in gold per ton and 0.56 ounce in silver. According to M. S. Staatz, of the U.S. Geological Survey (oral communication, 1965), an adit at the 5,650-foot altitude on the trail follows a 4- to 8-foot-wide vein of white bull quartz N. 45° W. for 97 feet. The host rock for the vein is iron-stained calcareous argillite. About 1,500 feet northwest of this adit, near the 6,000-foot altitude, three adits are on a steep alpine meadow. Two of the adits are caved, but the open adit follows an 8- to 12-inch quartz vein N. 45° W. for about 100 feet in argillite and conglomerate.

Azurite mine

The Azurite mine, which was one of the principal gold producers of the county, is on the eastern slope of Majestic Mountain and is 4.5 miles up Mill Creek from its confluence with Canyon Creek. The claims of the Azurite group, none of which are patented, are mainly in the E½ sec. 30, T. 37 N., R. 17 E., where altitudes range from 4,400 to 7,400 feet. The main portal and millsite are in the NE¼NE¼ sec. 30, at an altitude of about 4,500 feet. At one time the property consisted of 40 contiguous claims, but at present (1966) only the Azurite, South Azurite, Ibex, and Chalcopyrite are held by possessory title by the Azurite Gold Co., of Auburn, Wash. The other 36 claims of the original group are invalid due to the lack of annual assessment work.

Accessibility.—At one time a steep single-track mountain road provided access to the mine from the Slate Creek forest access road; however, this road is no longer passable for vehicles and serves only as a trail. The old road begins 5.5 miles west of Harts Pass at the second bridge crossing Slate Creek. After following the South Fork of Slate Creek for 1 mile, the road switches back and crosses Cady Pass at an altitude of 6,000 feet. From the pass the road descends a steep mountain slope by a series of switchbacks and heads south to the mine on Mill Creek. The distance from Slate Creek to the mine is about 8.5 miles.

History.—The original claims of the Azurite group were filed by C. R. McLean, H. J. Ballard, and C. R. Ballard on October 1, 1915. This was followed by the staking of the Azurite and Ibex claims in the fall of 1916 by H. J. Ballard. In 1916 the Azurite Copper Co., of Delaware, was formed under the direction of C. R. Ballard and was backed by eastern interests. In 1918 the first drift was started on the Azurite vein, which contained up to 7.5 feet of solid sulfides and assayed around $50 in gold. About 2 miles below the Azurite mine, on the east bank of Mill Creek, a crude arrastre powered by an undershot water wheel was constructed to test the ore. Ten tons of ground ore was cyanided and yielded 19.5 ounces of gold. However, mining was slow, as hand drilling methods were used and all supplies were transported to the mine on pack horses for 24 miles from Lost River, on the upper Methow River in Okanogan County. The cost for packing supplies to the mine was around $100 per ton.

On April 25, 1925, the company was reorganized as the Azurite Gold Co., of Twisp, Wash., with C. R. Ballard as president and superintendent. By 1929, sufficient capital was raised through the sale of stock, and mining machinery was purchased. At a level lower than the original mine workings a new drift known as the Tinson M. M. drift was started, and by 1930 the Azurite vein had been drifted upon for about 1,100 feet. The year 1930 marked the beginning of extensive work at the mine, and the significant developments that ensued are as follows:

1930—Construction of a 24-mile narrow-gauge road from Lost River in Okanogan County to the mine began in April and was completed in November. Wenatchee tunnel was started 500 feet below the Tinson tunnel, near the level of Mill Creek.

1931—Eight tons of rich gold ore shipped to the Tacoma smelter netted $135.40 per ton in gold and silver. A 30-ton Mace matting furnace was installed at the property.

1932—Production reported, but amount unknown.

1933—Fifteen tons of copper matte shipped to the Tacoma smelter contained $2,344 in gold, $8 in silver, and $29 in copper. Matte furnace was dismantled in the fall.

1934—American Smelting and Refining Co. acquired a 25-year operating and developing lease and agreed to pay the Azurite Gold Co. 50 percent of net smelter returns.

1935—Azurite vein was intersected at 1,308 feet in the Wenatchee tunnel. Vein drifted upon for 1,275 feet, and a 627-foot raise was driven to the Tinson tunnel.

1936—After expenditure of $400,000, operation of a 100-ton cyanide plant was begun in November. Seventy-five men were employed at the mine.

1937—Mill capacity was increased to 125 tons per day, and 85 men were employed. Daily production was around $2,000.

1938—Mill operated 24 hours per day, treating $20 per ton ore. Mill recovery was 90 percent, and cost of milling was $7.937 per ton.

1939—Mill operations were suspended the first of the year; last production was in February. In April only one watchman was at the mine. Azurite Mining Co. carried out an exploration program to evaluate the Azurite vein at depth. J. M. Orr, of Northwest Testing Laboratories, Seattle, was in charge of 38 men.

1940—Exploration work continued at the property, mainly on the 1,050 level, which is 125 feet below the Wenatchee level. American Smelting and Refining Co. dropped its lease on July 1.

1941—Agreement reached between Azurite Gold Co. and the American Smelting and Refining Co. for Azurite to lease machinery, equipment, and supplies with an agreement to purchase. Azurite issued a report to stockholders that development work showed 8,300 tons of proved ore and 6,200 tons of probable ore, all of which contained $11 per ton in gold.

1942—Mine and mill equipment was removed from the property.

1962—Azurite Gold Co. retained only the Azurite, South Azurite, Ibex, and Chalcopyrite claims by performing annual assessment work.

In the years that the mine was under lease to the American Smelting and Refining Co., the mill operated from November 1936 until February 1939 and produced $972,000 in gold and silver. The average monthly production ranged from 2,500 to 3,000 tons of ore, which amounted to a total production of about 72,700 tons. From November 1, 1936, to September 30, 1938, a total of 58,358 tons of ore yielded 22,585 ounces of gold and 2,111 ounces of silver. This averaged 0.385 ounce of gold per ton and 0.036 ounce in silver. Prior to the acquisition of the Azurite mine by the American Smelting and Refining Co. in 1934, only about $3,500 in gold, silver, and copper was recovered from ore shipped to the Tacoma smelter.

Geology.—The predominant rocks in the vicinity of the Azurite mine are argillite, quartzite, and conglomerate of the Pasayten Formation. The rocks form the northeast limb of a northwestward-trending asymmetrical anticline, the crest of which is near the summit of Majestic Mountain, about ¾ mile west of the mine. On the Azurite claims, rocks of the Pasayten Formation have been intruded by small circular and elliptical bodies of fine-grained diorite of Tertiary age. The circular diorite bodies are about 250 feet in diameter, whereas the elliptical bodies are as much as 1,000 feet long and 300 feet wide. The elliptical bodies are elongated parallel to the regional northwest trend of the rocks. Small bodies of diorite have been encountered underground in the Azurite mine, where the rock is predominantly siliceous argillite. About ½ mile north of the mine, argillite and quartzite have been intruded by a small cupola of granodiorite. The main mass of the granodiorite crops out 2 miles south of the mine, near Azurite Peak. This pluton of granodiorite, which has been mapped by Misch (1952) as the Golden Horn Granodiorite, forms extensive outcrops in Skagit and Chelan Counties. Other intrusive rocks in the vicinity of the Azurite mine are dikes and pluglike bodies of monzonite porphyry and aplite. These rocks are younger than the diorite, as is shown by their crosscutting relation.

The veins of the Azurite group are mainly fissure veins that occupy N. 10° W.- and S. 50° W.-trending shear zones and dip 45° to 60° north and west. The quartz that fills the shear zones is accompanied by calcite, pyrrhotite, pyrite, sphalerite (marmatite), chalcopyrite, and arsenopyrite. The wall rock has been silicified, chloritized, sericitized, kaolinized, and pyritized. Although the veins consist mainly of quartz that contains disseminated sulfides, parts of the veins are made up almost wholly of sulfides. In the Tinson tunnel on the Azurite vein, parts of the vein consisted of as much as 7½ feet of massive iron and copper sulfides.

The largest veins of the Azurite group are the Azurite, Devils Hole, Monster, and Lucky Dog, which are shown on Plate 11. These veins, which in places are as much as 12 feet wide, can be traced for several thousand feet on the surface, as they crop out on the face of a steep rocky precipice that contains very little overburden. According to a report by the Azurite Gold Co., the widths of the veins on the surface are: Azurite, 2 to 7½ feet; Lucky Dog, 4 feet; and Monster, 10 to 12 feet. On the Zinc Oxide claim, brecciated argillite crops out over a length of 180 feet and a width of 80 feet. The matrix of the breccia contains fine-grained marmatite and small amounts of gold-bearing chalcopyrite and pyrite. Mining has not been undertaken on the deposit, but it has been drifted upon for 30 feet.

The Azurite vein, which is the principal vein of the Azurite group, crops out for 3,000 feet on the Greenwood, South Azurite, and Azurite claims. Beneath its outcrop the vein has been mined for a vertical distance of 819 feet and explored for 1,070 feet. Over this distance the vein pinched and swelled from 3 to 72 inches in width and averaged about 36 inches. Pyrrhotite and quartz, which are accompanied by sparse chalcopyrite, occur on most levels of the mine, and in the lower levels calcite accompanies the quartz. Sphalerite and arsenopyrite are mainly in the upper levels of the mine. The gold, for the most part, occurs as finely divided particles, mainly in the fine-grained pyrrhotite. The gold is not visible to the unaided eye, but when some ore is crushed and panned the gold becomes visible.

In the Azurite vein, gold occurs in ore shoots that rake steeply south. The part of the vein that was mined averaged 0.385 ounce per ton in gold and 0.036 ounce in silver. The nonproductive part of the vein averages 0.09 ounce in gold and 0.03 ounce in silver. Richardson (1939, p. 106) reports the following average gold content for the Azurite vein from its outcrop to the Wenatchee level, which is 819 feet vertically below the outcrop. These figures show decreasing gold values at depth.

	Ounces per ton
Surface to Tinson level (200 ft.)	0.536
Tinson level to 350 level (78 ft.)	0.477
350 level to 450 level (74 ft.)	0.410
450 level to Wenatchee level (342 ft.)	0.380

Later development work on the Azurite vein from the Wenatchee level to the 1,050 level, which is 125 feet below the Wenatchee level, showed an average gold content of 0.330 ounce per ton.

Mining and extensive assaying of the Azurite vein indicate that the gold is in shoots and decreases with depth; on the other hand, the silver is fairly consistent in the vein. This difference suggests separate gold-silver stages of mineralization. Studies by Richardson (1939, p. 58) indicate possibly three stages of mineralization, as follows:

1. Barren quartz-calcite deposition.
2. Arsenopyrite, quartz-pyrrhotite, sphalerite, and quartz-calcite deposition.
3. Gold-chalcopyrite deposition.

The low silver content (0.03 ounce per ton) of the vein might be attributable to the lack of galena. In the Blue vein at the Gold Hill mine, which is 5,000 feet west of the Azurite mine, the mineral assemblage is the same as that of the Azurite vein except for the presence of abundant galena. The galena is argentiferous and carries as much as $100 per ton in silver. Polished section work by Sylliaasen (1937) on ore from the Blue vein shows that galena was the latest mineral to form. Apparently, this galena stage of mineralization is not present in the Azurite vein.

Mining and milling.—Very little in the way of development work and mining had been undertaken on the Azurite vein prior to 1934, the year the American Smelting and Refining Co. began operations. The Discovery adit had been driven 100 feet; the Burnham adit, 75 feet; and the Tinson adit, 1,100 feet. In the Tinson adit a raise known as the Cooper raise had been driven 275 feet to the surface. The underground workings of the Azurite mine are shown on Plate 12. When the American Smelting and Refining Co. acquired the property, the Wenatchee crosscut had been driven only 87 feet; when the company drove the crosscut an additional 1,308 feet, the Azurite vein was intersected. From the point of intersection the vein was followed southward for 575 feet before ore was encountered. The drifting operations continued southward in ore for 420 feet and also for an additional 319 feet beyond the ore shoot. The total distance the vein was drifted upon southward from its point of intersection was 1,314 feet. Northward from the point of intersection the vein was drifted upon for about 250 feet before it pinched out. From this main drift, which is known as the Wenatchee level, a two-compartment raise known as raise No. 77 was driven upward 669 feet to the Tinson level. Between the Wenatchee and Tinson levels four main sublevels were established. Ore chutes were spaced at 25-foot intervals along the levels, and the ore was mined by shrinkage stoping. Stulls were used in some parts of the stopes, but in general the wall rock was firm and required no timbering. After being drawn from the ore chutes, the ore was trammed to the main No. 77 raise, which carried it to the Wenatchee level. The ore was drawn into 32-cubic-foot ore cars, and storage battery-powered electric mules conveyed the cars to bins at the mine portal. From the ore bins 650-pound-capacity tram buckets carried the ore over a 700-foot aerial tram to the mill on the east bank of Mill Creek. The following description of the mill has been extracted from the [Spokane, Wash.] Spokesman-Review of September 21, 1938:

> The reduction plant is known as continuous decantation method using cyanide process with 100-ton daily capacity. Mill building, 150 feet by 150 feet, has five levels with aerial tram of 700 feet connecting to mine level.
>
> The ore travels from bunker in mill to large endless belt with magnetic separator to an ore crusher, 13 by 24 inches, from which it gets on closed circuit, going over Plat-O-Vibrating screen ¼-inch mesh, the fine going to ball mill, and the coarse being diverted to fine ore crusher, with ore then going again over screen in closed circuit.

Fine ore ground in the ball mill to 92 percent 150 mesh, then to a classifier, 45-inch, with lime feeder in circuit to keep proper alkalinity. Litharge also added to assist in precipitation of objectionable salts.

From classifier the material travels to number one tank, passing over two corduroy tables, where coarse gold and high-grade concentrates are deposited. About 25 percent of values are extracted in this method.

From number one tank, the material goes into a closed circuit of agitator tanks and thickener tanks with sodium cyanide in proper proportions.

After metals are in solution, it is diverted through a clarification tank to clear all foreign matter and then through a vacuum tank to remove the air. Zinc dust is then added to solution, and metallic gold is then precipitated in bags. These are cleaned, and metallic gold is reduced to bricks in small melting furnace.

The tailings are gathered off a filter and discharged on the belt to tails tram, both discharge and barren solution being treated with ferrous sulphide to counteract sodium cyanide.

About 75 percent of the gold was shipped as bullion and 25 percent as concentrate.

Sampling in mill, three operations each half hour; one sample of ore off belt ahead of classifier, one sample of solution taken out of classifier discharge, and one sample of solution taken at number one tank. At midnight these samples are gathered, and separate assays of each are made for the day's run.

Electric power for mining, mine and tramway transportation, and milling was supplied by generators powered by two 400-hp. diesel engines. Coal-stoked furnaces supplied heat for the mill. To keep the mill running through the winter months, 150,000 gallons of diesel fuel was stored in five 30,000-gallon tanks.

The operating costs at the mine for mining and milling during 1937 are reported as follows by Richardson (1939, p. 117):

Mining	$ 99,955.05
Milling	105,699.11
General	49,711.44
	$255,365.60
Per ton cost	$9.277
Milling cost	$3.84 per ton
Stoping	$2.51 per ton
Total mining	$3.63 per ton

Mining operations by the American Smelting and Refining Co. were not undertaken below the Wenatchee level of the mine. However, after mining operations ceased in 1939, the Azurite Gold Co. sank a two-compartment winze on the Azurite vein to a depth of 250 feet below the Wenatchee level, which was the main haulage level. At 125 feet in the winze a drift known as the 1,050 level was driven along the vein for about 700 feet. The lowest level of the mine, known as the 1,200 level, is 125 feet below the 1,050 level and was driven along the vein for 650 feet. Sampling in these lower levels in 1941 by the Northwest Testing Laboratories disclosed two ore shoots that rake south. One shoot has a breadth of about 30 feet, and the other, about 100 feet. These ore shoots contain about 14,500 tons of combined indicated and inferred ore that averages 0.33 ounce in gold per ton.

Limited exploration work was also undertaken by the American Smelting and Refining Co. on the Monster vein. From the point of intersection of the Azurite vein by the Wenatchee tunnel, a crosscut was driven northward 950 feet to intersect the Monster vein. From this point the vein was drifted upon for 175 feet east and 175 feet west. The vein proved to be 3 feet or less in width and averaged only 0.02 ounce per ton in gold.

Baltimore prospect

This property is in the W½ sec. 27 and the E½ sec. 28, T. 38 N., R. 17 E., at the headwaters of Barron Creek in Baltimore Basin. From the upper mine workings of Western Gold Mining, Inc. a steep single-track mountain road extends 1.6 miles west to the main mine workings on Baltimore Creek and 0.3 mile beyond to the mine camp on Barron Creek.

The original Baltimore claim was filed by A. L. Hendrickson in November 1915, and the rest of the claims were staked by J. H. Hendrickson from 1930 to 1937, at which time the property consisted of 21 contiguous unpatented claims. In 1937 the property was organized as Baltimore Mines Inc., of Seattle, and underground work was undertaken to explore the extent of the gold- and silver-bearing veins on the Baltimore claim. Work was done on the claim sporadically from 1938 to 1950 and consisted mainly of driving a long exploratory crosscut. In 1954 the company was dissolved. At present (1966), the property appears to be in a state of abandonment, but location notices indicate that the property has been restaked several times by different parties.

The main adit at the Baltimore property is in interbedded argillite and quartzite that strike N. 10° W. to N. 10° E. and dip about 70° E. In the adit several faults are crossed that strike N. 70°-80° E. and dip 60° to 70° NW. Some faults have 2- to 6-inch-wide quartz veins that contain disseminated pyrite and, rarely, thin parallel seams of fine-grained galena and sphalerite. In addition to the quartz, some narrow seams of calcite are present.

The main adit heads approximately S. 72° E. for 1,190 feet. Seventy feet from the portal a branch leads S. 60° W. for 60 feet to the surface; this tunnel, a part of the original workings, was driven from Baltimore Creek along a galena-sphalerite-bearing fault zone. About 95 feet from the portal of the main adit a drift bears N. 70° E. at its start, makes a broad loop, and after 600 feet returns to the main adit at a point 190 feet from the portal. From this drift to the face of the adit, a distance of about 1,000 feet, the mine workings contain only a few thin seams of quartz. When the writer examined the underground workings in 1965, the portal of the main adit was caved; however, entry was gained by way of the old tunnel on Baltimore Creek. The workings show only thin discontinuous quartz stringers; no ore bodies of a size sufficient to warrant sampling were seen. According to Hancock

(1940), these stringers contained as much as 4.92 ounces of gold per ton and a maximum of 2.6 ounces of silver. The lowest value obtained in assays of the quartz was 0.08 ounce of gold and 0.9 ounce of silver. Material listed as "heads" contained 0.64 ounce of gold and 0.5 ounce of silver per ton.

Goat mine

The Goat mine is in the SE¼ sec. 4, T. 37 N., R. 17 E., about 2,000 feet N. 20° E. of the junction of the South Fork of Slate Creek and Slate Creek. The Goat claim is one of 12 contiguous unpatented claims known as the Goat group, which is part of the holdings of Western Gold Mining, Inc. in the Slate Creek mining district (Fig. 43, on p. 114). The mine can be reached by hiking northward up a steep hillside opposite Goat Falls to about the 4,800-foot altitude; the mine is about 2,000 feet from the road.

The original Goat claim was recorded as the Mountain Goat by Otto L. Olson et al. on July 24, 1895. In 1898 a 5-stamp cyanide mill was built on Slate Creek near Goat Falls and an aerial tramway was extended from the mine to the mill for a distance of about 2,000 feet and a difference in elevation of 1,000 feet. Production figures are not available for the mine, and nothing remains of the mill. Some of the claims of the present Goat group are relocations of old claims, and some are new claims staked by the New Light Gold Mining Co. in 1931 and 1935.

The Goat mine adit is caved at its portal, but steel straps on hand-hewn poles, which served as track for the mine cars, protrude from the caved workings and point out the antiquity of the mine. The adit appears to have been driven along a bleached and iron oxide-stained quartz-bearing shear zone in quartzite. The shear zone, about 4 feet wide, strikes N. 10° E. and dips 75° SE.; the quartzite has a general N. 10° W. strike and it dips 60° E. The dump contains fragments of iron oxide-stained drusy quartz that reveal minor flakes of malachite on fracture surfaces. No sulfide minerals were noted in the quartz. Gold, which, according to assays by Western Gold Mining, Inc., runs 0.52 to 1.14 ounces per ton, is the principal metal.

About 500 feet southeast of the caved adit and at an altitude of 4,650 feet, the portal of another adit is in the face of a steep rocky cliff. The portal of this lower adit is visible only when viewed from directly in front of the adit. The portal of the adit is also visible from the trail to the Azurite mine on the South Fork of Slate Creek. The adit heads northward for about 250 feet into the mountainside. About 40 feet from the face of the adit a raise more than 70 feet high was driven on a vertical quartz vein that strikes N. 70°-80° E. The vein, which is from 9 to 18 inches wide, was followed west for about 150 feet and east for about 80 feet. Malachite staining is present in parts of the vein that contain sparsely disseminated chalcopyrite. It appears that the raise connects with the upper adit level of the mine. A representative sample of vein quartz from the mine dump, 200 feet below the lower adit, contained a trace of gold and 0.02 ounce of silver per ton. Quartz from the face of the east drift in the lower adit showed a trace of gold and 0.08 ounce of silver.

Gold Hill mine

The Gold Hill mine, which in 1940 consisted of 40 unpatented lode claims and 2 millsites, is mainly in the E½ sec. 25, T. 37 N., R. 16 E. Most of the claims are on the southwest slope of Majestic Mountain and are west of the Azurite claims, which are mainly on the northeast slope of Majestic Mountain. Altitudes at the Gold Hill property range from 4,200 to 7,450 feet. East Creek, which is a tributary to Granite Creek, provides the main drainage of the area.

Accessibility.—The Gold Hill claims are some of the most inaccessible ones in the district and can be reached only by trail. From Ross Dam on the Skagit River or Chancellor on Slate Creek the distance is 18 miles to the property. Upon completion of the North Cross State Highway, which in part will follow Granite Creek, access will be by only 4 miles of trail up East Creek to the claims.

History.—The original claims of the Gold Hill group were recorded by H. I. Ballard et al. on November 6, 1930, and, under the name of Gold Hill Mining Co., limited exploration work was carried on until 1934. In 1935 the company was reorganized as the Gold Hill Operating Co., and in 1938 it was again reorganized as the Northern Cascade Mines. In 1940 Seattle and Spokane interests, headed by J. W. Hatly, of Wenatchee, obtained a 99-year lease on the property and surveyed a route for an 8-mile aerial tramway from the property to the confluence of Granite and Ruby Creeks, site of a proposed mill. On July 1, 1957, the Northern Cascade Mines was dissolved for nonpayment of corporation fees.

Most of the exploration and development work was undertaken by the Gold Hill Mining Co. and the Gold Hill Operating Co. under the direction of August Peterson. This work consisted mainly of exploring the Blue vein by means of two drifts for a total length of 1,780 feet, as well as digging prospect pits and trenches on other metalized quartz veins. In 1938 the Northern Cascade Mines undertook additional underground work on the Blue vein and increased the total underground workings of the property to around 3,500 feet. The Bellingham Herald of September 2, 1937, reported that 30,000 tons of "ore" was on the mine dump ready for milling at a mill that the company proposed to build. However, the mill was never constructed and the "ore" still remains at the property. At present (1966), Minerals Technology Corporation, of Minneapolis, holds the claims by possessory title.

Geology.—According to Bennett (1939), the predominant rocks of the area are black argillite and fine-grained greenish-gray quartzite of the Pasayten Formation. In this part of the district, rocks of the Pasayten Formation have been folded into a northwestward-trending asymmetrical anticline. In the vicinity of the mine workings the rocks dip moderately to the southwest; east of the workings, near the crest of Majestic Mountain, they dip steeply northeast. Near the crest of Majestic Mountain and on Mill Creek, ½ mile north of the Azurite mine, cupolas of granodiorite have intruded and thermally metamorphosed the sedimentary rocks. These cupolas are probably offshoots of the main body of the granodiorite that crops out ¼ mile south of the mine. The granodiorite forms extensive outcrops southward into Skagit County and has been mapped by Misch (1952) as the Golden Horn Granodiorite (early Tertiary). Also, the rocks in the area of the mine and on Majestic Mountain contain felsite, aplite, and andesite dikes as much as 20 feet wide that are probably related to the granodiorite intrusions.

Ore minerals at the Gold Hill property occur along several well-developed shear zones in argillite and quartzite. The shear zones exhibit three prominent trends, which are: E.-W., N. 50° E., and N. 10° W.; the dips are north and west 40° to 72°. The main shear zones, as well as those of the Azurite mine, are shown on Plate 11. C. E. Phoenix (1931), who was consulting engineer for Gold Hill Mining Co., describes the main veins as follows:

> The ore deposits of Gold Hill consist of four principal veins or lodes, and a number of cross-leads, some of them of fair size and richness. They are the Iron Mountain, Genevieve, Gouge and Virginia Lodes. The first three have a due easterly or westerly course. The Virginia Lode has a northerly, or southerly course. They are co-extensive with some of the principal lodes of the Azurite group.
>
> **Iron Mountain Lode**
>
> Iron Mountain Lode is traceable to its contact at the east end of the Apex location with a narrow but well-defined lead having a due easterly and westerly surface course, cutting perpendicularly across the east slope of the mountain and the strike of the Azurite and Devil's Hole Lodes.
>
> The gangue or matrix of the Iron Mountain Lode is chiefly quartz, bluish-gray to white or rust color, with dark-blue material, varied occasionally by light-gray lenses composed of silica, talc, and some calcite. The indicated width of ore is 5 to 7 feet.
>
> In the oxidized area of Iron Mountain Number 3, surface examination discloses the existence of three leads. The main lead is 5 to 15 feet wide; the other two are 30 to 36 inches wide. The oxidized area is about 700 feet long by 200 feet wide. The walls of the lode are granodiorite.
>
> **Genevieve Lode**
>
> The Genevieve Lode is quartz matrix carrying values in silver and gold, in the form of sulphides. The ore body is 4 to 12 feet wide, and is continuous with the main trend of the Monster Lode of the Azurite Group. It is traceable through the Genevieve and Hazel M locations of the Gold Hill Group, and the Monster and Iron Clad locations of the Azurite Group. The strike at the west end of the Genevieve locations is north 70 degrees east, with a 60 degree dip to the north. At the old discovery, the strike is north 71 degrees, 45 minutes east, and the dip 41 degrees, 30 minutes to the north. Nearer the summit of the mountain in the open cuts at the east end of the Genevieve location, the dip shows 50 degrees to the northwest.
>
> **Gouge**
>
> North of, and similar in character to the Genevieve, is the Gouge. The dip at the crest of the mountain is 65 degrees to the north. At the apex and for a considerable distance on either slope, the vein shows a width varying from 20 to 30 feet. Near the west end of the Genevieve location the width is over 4 feet.

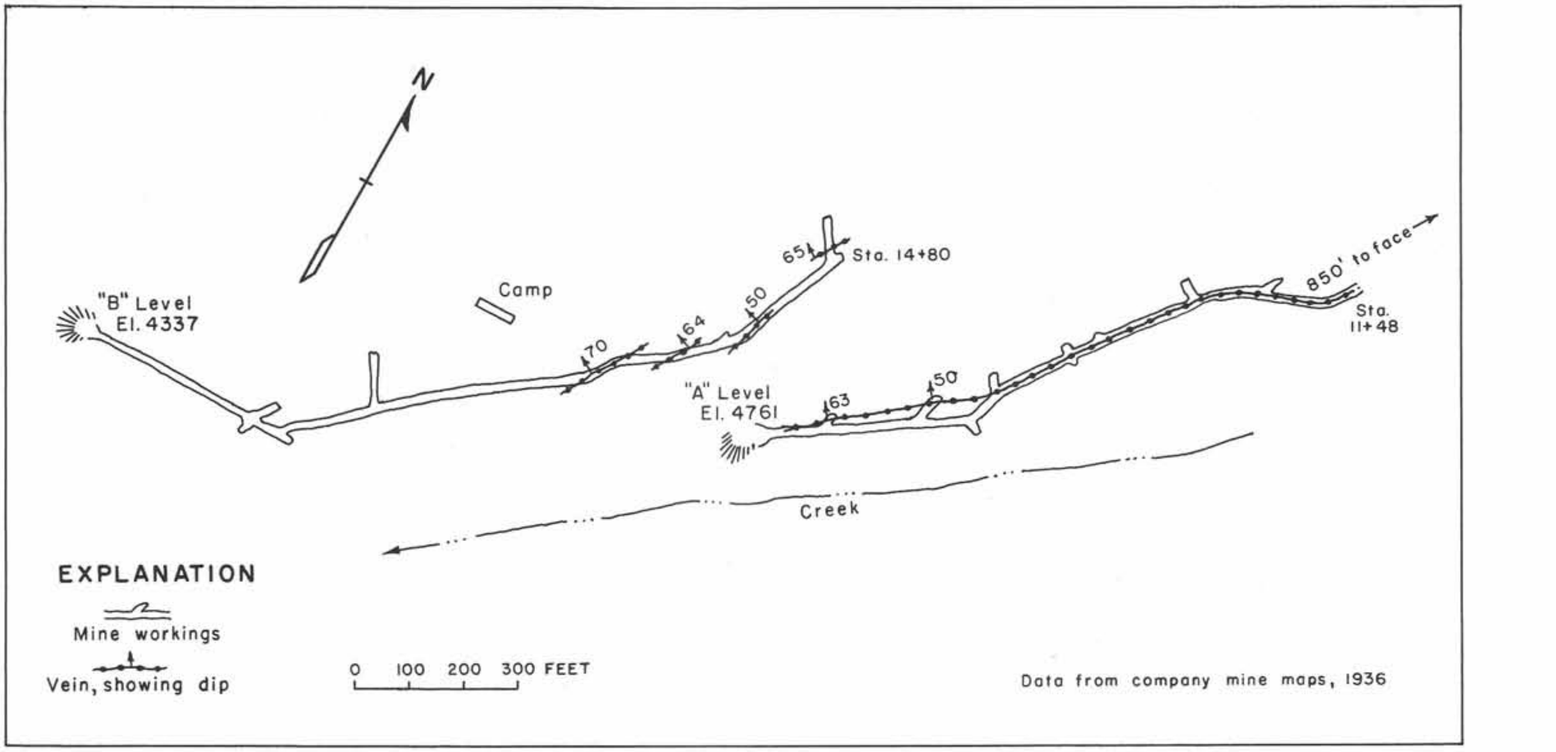

FIGURE 40.—Main adits of the Gold Hill mine.

Virginia

The Virginia shows fairly uniform width, 3½ to 4 and 5 feet, with well-defined walls. The lode strikes north and dips 45 degrees to 60 degrees to the west. The vein filling is of rusty and white quartz, with metal values in the form of fine sulphides.

The main sulfide minerals of the veins are galena, sphalerite, pyrrhotite, and pyrite. Chalcopyrite, stibnite, and arsenopyrite are the minor sulfide minerals. Gold occurs in a finely divided state and is associated with the pyrrhotite and pyrite, whereas the silver appears to be associated with galena. The sulfides most commonly are disseminated in the quartz veins; however, in some parts of the veins the sulfides form solid seams and veins. Bennett (1939, p. 11) reports significant deposits of sulfide minerals at the Glory Hole on the Hazel M claim in the form of pyrrhotite, galena, and sphalerite. Much of the pyrrhotite has altered to yellowish-brown limonite, and the galena in part has altered to gray anglesite.

Assays on 1.8 tons of ore that was shipped to the Bunker Hill & Sullivan Mining & Concentrating Co. in 1936 from the "A" level of the Blue Lode are as follows:

Gold	0.07 oz./ton
Silver	93.25 oz./ton
Lead	29.40 percent
Zinc	9.20 percent
Copper	0.25 percent
Antimony	0.40 percent
Arsenic	0.66 percent
Iron	7.00 percent
Lime	2.30 percent
Sulfur	13.40 percent

According to company mine maps of 1936, the vein in the "A" level (1,100 feet to 1,185 feet in the drift) averages 3.8 feet in width and contains 23.49 ounces of silver per ton, 0.03 ounce of gold, and 6.62 percent lead. In the "B" level, which is about 420 feet vertically below the "A" level and on the same structure, the vein width averages 5.8 feet from 90 to 175 feet in the drift. Over this 85-foot section of the vein, assays show 26.44 ounces of silver per ton, 0.027 ounce of gold, and 6.22 percent lead. Examinations of the mine workings by Bennett in 1939 and by geologists fom the American Smelting and Refining Co. in 1937 failed to reveal ore as reported by the Gold Hill Mining Co. Assays of the vein in the "B" level averaged 0.015 ounce per ton in gold and only traces of silver. Sampling of the vein in the "A" level showed 0.01 ounce of gold per ton, from 0.10 to 4.88 ounces of silver, and little, if any, lead. It is probable that the lead-silver ore occurs as lenses along the Blue vein.

Assays on other veins of the group, as reported by the Gold Hill Mining Co., are as follows:

	Gold (oz./ton)	*Silver (oz./ton)*	*Lead (percent)*	*Zinc (percent)*
Nigger vein	0.06	106.16	52.70	10.72
(Genevieve claim)	0.04	69.96	42.82	.....
	....	105.79	.....	.....
Genevieve prospect	0.06	2.20	.....	.....
Glory Hole	0.20	16.50	.....	13.60
(Hazel M claim)	0.07	27.04	.....	.....
	0.08	8.76	.....	.....

Most of the development work at the Gold Hill property was undertaken on the Blue vein, which is covered by the Sandusky, Iron Mtn. No. 5, Iron Mtn. No. 1, and Iron Mtn. No. 8 claims. The vein has been drifted upon for about 1,500 feet on the upper, "A" level and for about 2,000 feet on the lower, "B" level. About 250 feet of crosscuts are in the "A" level, and about 300 feet of crosscuts are in the "B" level. According to company reports, the vein averaged about 5 feet in width in both drifts; no stoping was undertaken in either drift.

From the mine camp, which consists of a log cabin bunkhouse and adjoining cookhouse, the "A" level is 540 feet east at an altitude of 4,757 feet. The portal of the "B" level is 750 feet S. 50° W. from the camp at an altitude of 4,337 feet. Both drifts are caved near their portals.

Although ore was never milled at the property, several flotation tests have been run on ore from the Blue vein by Sylliaasen (1937). These tests show that as much as 95.4 percent of the silver, 88.7 percent of the lead, and 81.6 percent of the zinc can be recovered when 82 percent of the ore is ground to 200 mesh.

Golden Arrow (Tacoma) mine

The Golden Arrow mine is on the west side of Bonita Creek about 4,500 feet above its junction with Slate Creek. The property consists of 3 unpatented claims (Golden Arrow No. 1, Golden Arrow No. 2, Park Creek Placer) that are held jointly by Walter Gourlie, of Port Orchard, and E. H. Spafford, of Seattle. The claims are mainly in the NE¼ sec. 34, T. 38 N., R. 17 E., and are about 800 feet northwest of the Mammoth mine camp.

The original Tacoma claim was recorded by G. C. Mathews et al. on April 13, 1895, and in the early 1900's the mine operated as the Gold Standard Mining Co. Mining operations were carried on in several adits at creek level, the longest of which was almost 1,000 feet in length, and in an inclined shaft on the outcrop of a gold-bearing vein 500 feet west of Bonita Creek. As the company did not erect a mill, it is probable that the ore from the Tacoma vein was treated at the Mammoth mill. Production figures are not available for the early years that the mine was in operation.

In 1950, Gourlie and Spafford acquired the property, and in 1951, 1952, and 1953, shipments of gold-silver ore that averaged $50 per ton were made to the Tacoma smelter. Mining was confined to the upper vein, upon which an inclined shaft had been sunk during early-day mining operations.

In the vicinity of the Golden Arrow claims the country rock is argillite and arkose of the Pasayten Formation. The general strike of the beds is N. 25° W., and dips range from 25° to 45° NE. Two sets of faults predominate. The major faults, which contain metalized quartz veins, trend N. 40°-70° E. and dip 40°-70° NW. These faults are offset by a series of later faults that strike N. 30° W. and dip 30°-60° NE. The wall rock of the major metalized faults contains disseminated pyrite, and oxidation of the pyrite imparts a reddish color to the otherwise gray to black argillite and arkose wall rock. Because of a thick cover of overburden, the veins do not crop out, and are exposed only where they have been dug upon or along the banks of the creek where the overburden has been removed by stream erosion.

The upper adit, some 60 feet lower in elevation than the outcrop of the vein, was the site of the most recent mining operations. In this adit the vein is crosscut about 100 feet from the portal. The vein, which has a general N. 60° E. strike and a dip of 50° NW., was drifted upon for about 110 feet. The vein is exposed in overhead stopes for 70 feet along its dip. At the northeast face of the drift the vein splits into an 8-inch vein on the hanging wall and a 10-inch vein on the footwall. Near the southwest face of the drift the vein terminates against a major N. 30° W.-trending fault that dips 30° NE. The last 40 feet of the vein is offset to the northwest by three faults that appear parallel to the one that terminates the vein. In an attempt to find the faulted-off segment of the vein in the southwest drift, the operators drove 30 feet beyond the vein in black argillite without encountering the vein. On the northeast end of the drift the vein has been stoped to about 15 feet above the back of the drift; on the southwest end of the vein a 15-foot stope extends 10 feet above the drift. Near the center of the vein a 35-foot stope extends to the surface and appears to be part of the early workings on the vein. Also near the center of the drift, a winze extends to old mine workings that were driven from near creek level.

The Golden Arrow vein, as exposed in the upper workings, consists of white crystalline quartz that ranges from 6 to 24 inches in width. Much of the quartz has been fractured and then has been recemented by secondary silica. Parts of the vein, especially at the southwest end of the drift, exhibit brecciation. In order of decreasing abundance, the quartz contains sparsely disseminated pyrite, sphalerite, galena, and chalcopyrite; a small amount of malachite appears on the surface of some quartz fragments. Free gold is present in the quartz but is not generally visible to the unaided eye. Gourlie (oral communication, 1965) reports that some quartz contained particles of gold that were 2 to 3 millimeters in diameter. Some finely divided sulfide minerals occur in dark parallel bands as much as ½ inch wide in the quartz; these bands tend to parallel the walls of the vein. An assay of this quartz from near the winze in the drift showed 2.00 ounces per ton in gold and 2.50 ounces in silver. This was the highest gold assay on quartz sampled by the writer in the course of this study. Near ground level, fracture surfaces of the quartz vein are rusty brown, due to the oxidation of the iron sulfide minerals.

Little is known by the writer about the quartz vein in the old Tacoma workings at creek level. About 200 feet downstream from where the road crosses Bonita Creek to the Golden Arrow camp, and about 20 feet above creek level, the old Tacoma adit heads N. 70° E. into the west bank of the creek. The vein, as exposed near the portal of the adit, is about 2 feet wide and consists of iron oxide-stained quartz that strikes N. 70° E. and dips 38°-52° N. Fine- to medium-grained pyrite and chalcopyrite are disseminated in the quartz, and malachite occurs sparsely on some fracture surfaces. An assay of this quartz showed only a trace of gold, 1.50 ounces per ton in silver, and 0.50 percent copper. About 100 feet from the portal the vein follows a sinuous course and pinches and swells. A gouge seam 6 to 8 inches wide follows the hanging wall of the vein, and in 18 feet the vein pinches from 28 inches to 6 inches. The iron oxide-stained arkose footwall contains several narrow quartz veins; these parallel the main quartz vein.

Because of the hazardous condition of the lower tunnel, which is due mainly to caving, the writer did not enter it beyond 100 feet. However, E. H. Spafford (oral communication, 1965) reports that the adit follows the vein for about 400 feet. Near the end of this drift a crosscut was driven northwestward for about 500 feet and is barren of ore minerals. Also near the end of the drift, a raise extends to the upper workings, the site of the present mining operations.

Illinois mine

The Illinois claim is one of the patented claims of the Chancellor group, which is owned by the Frank D. Hyde estate, of Berlin, Md. The claim is about ¾ mile southeast of the Indiana claim and is in the NE¼SE¼ sec. 35, T. 38 N., R. 17 E. The property is accessible by a trail from the Mammoth mine, a distance of 1.4 miles, or from Harts Pass by way of the Cascade Crest Trail, which is about 700 feet to the east of the mine workings. The claim is near the headwaters of Benson Creek, at an altitude of about 6,000 feet.

The main underground adit on the property is 400 feet long and follows a general N. 45° E. course into arkose that strikes N. 15° W. and dips 40° SE.; this adit is now caved at its portal. The dump contains numerous fragments of vein quartz. An assay of this quartz showed 0.30 ounce per ton in gold and 18.54 ounces in silver. The quartz resembles ore from the Indiana and Golden Arrow mines and contains narrow black stringers composed of finely divided particles of pyrite, sphalerite, and galena. Mr. Hyde (oral communication, 1946) stated that quartz from the dump assayed around $350 per ton in gold and silver and that high-grade gold ore was shipped from the mine to San Francisco in 1904. Twelve ounces of 852 fine gold was recovered from ¾ ton of ore. Robert Crandall, of Twisp (written communication, undated), reports assays of 201, 422, 5, and 600 ounces per ton in silver from the vein in the mine. Crandall also states that several veins strike northeastward, dip 80° to the northwest, and consist of 3 to 6 feet of quartz that has a slate footwall and a porphry hanging wall.

About 600 feet north of the cabin on the Illinois claim, on the east side of the old wagon road to the Mammoth mine, a 44-inch vein of massive white quartz is exposed. The vein strikes east and dips 74° N.; it can be traced for at least 50 feet on the surface. An adit follows the vein east for about 45 feet, to where the vein pinched to 14 inches and contained marcasite, minor sphalerite, and pyrite (Carithers, field notes, 1944). The adit is now caved at the portal. About 300 feet south of this vein, on the road to the cabin, an open cut exposes a 10-inch quartz vein that is similar to the 44-inch vein.

Indiana mine

The Indiana mine is in Indiana Basin, near the upper drainage of Bonita Creek. It is about 1,500 feet west of the Cascade crest and is in the S½ sec. 26 and the N½ sec. 35, T. 38 N., R. 17 E. A steep mountain road from the camp of Western Gold Mining, Inc., on Bonita Creek, extends to the lower tunnel of the Indiana mine at an altitude of about 6,200 feet. The mine is about 2.5 miles by road from the Slate Creek road.

The Indiana claim was recorded by Peter Bryan on January 12, 1903, and surveyed for patent in 1910. Little is known about the early-day mining operations of the mine except that the Chancellor Gold Mining Co. held four claims, known as the Chancellor group. The claims consisted of the Indiana (M.S. 1001), Grandview (M.S. 1017), Illinois (M.S. 1018), and the Chancellor Mill Site (M.S. 830). From 1935 to 1940 Frank D. Hyde, of Berlin, Md., who was one of the original members of the Chancellor Gold Mining Co., operated the Indiana mine and shipped 120 tons of gold ore to smelters at Kellogg and Tacoma. At present (1966), the Chancellor group is owned by the Hyde estate.

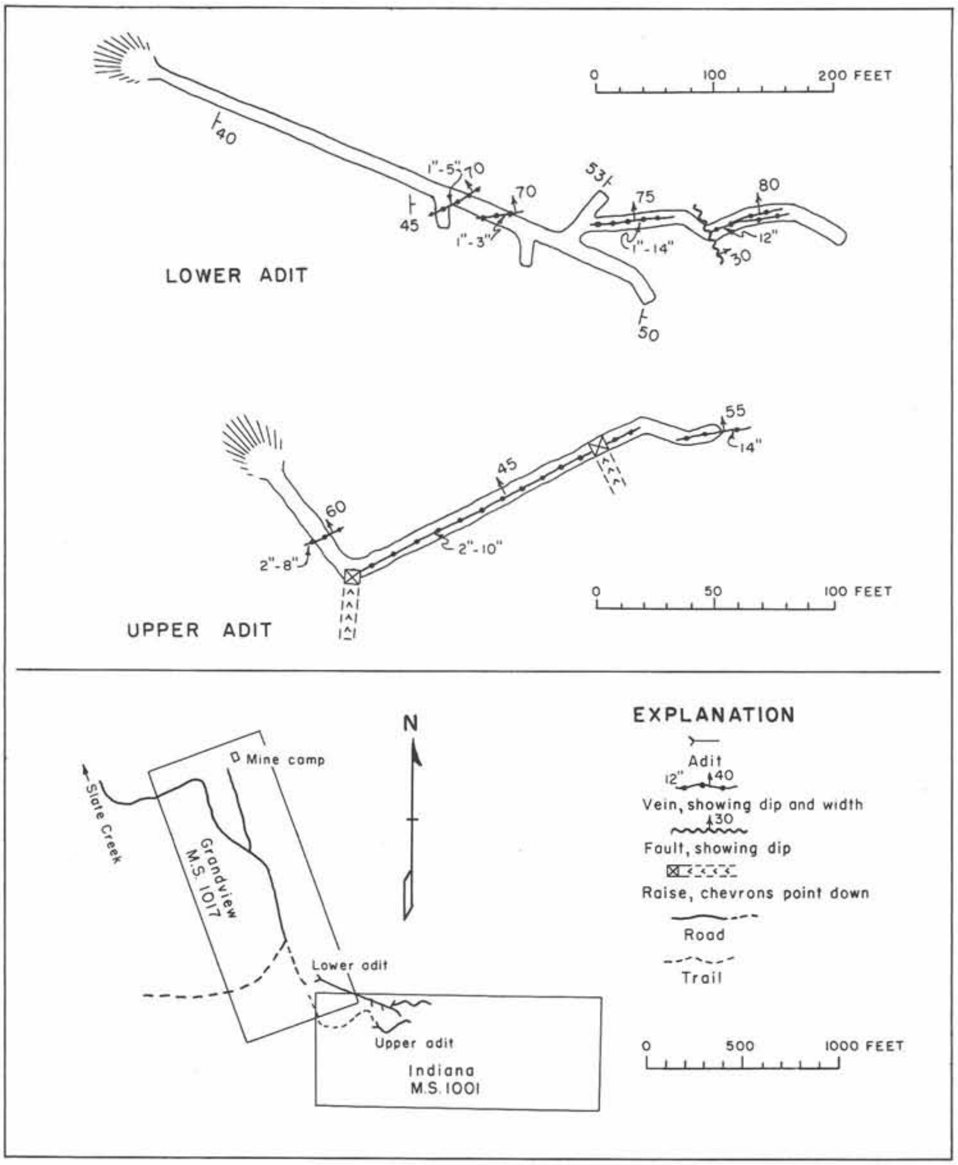

FIGURE 41.—Indiana mine claims and adits.

The country rocks at the Indiana mine are light-gray quartzite, argillaceous quartzite, and shale, all of which strike N. 20°-30° E. and dip 40°-55° SE. These rocks contain several shear zones, some of which contain metalized quartz veins and some that offset the veins. The quartz veins range from 1 to 14 inches in width, strike N. 63°-90° E., and dip 45°-80° N.

The lower adit, the portal of which is on the Grandview claim, contains 800 feet of underground workings (Fig. 41). It heads S. 69° E. into the hillside and exposes the faulted segments of two quartz veins. At 475 feet in the adit the main vein is offset about 20 feet to the south by a N. 25° W.-trending fault that dips 30° NE. In addition to the quartz, the vein contains calcite and a small amount of disseminated pyrite. From 418 to 448 feet in the drift the vein averages 1.7 feet in width and contains 0.33 ounce per ton in gold and 3.25 ounces in silver (Huntting, field notes, 1946).

The upper adit on the Indiana claim is about 400 feet southeast of the lower adit and 135 feet higher in elevation. It is accessible by a trail from the lower adit. The upper adit heads S. 38° E. for 50 feet in argillaceous quartzite, at which point a quartz vein is intersected. This vein, 2 to 10 inches wide, strikes N. 63° E., dips 45° NW., and has been drifted upon for about 135 feet. The vein parallels the bedding of the quartzite wall rock and contains sparsely disseminated pyrite. Near the face of the drift a shear zone that averages 14 inches in width and is 15 feet long contains several narrow quartz stringers. These stringers appear to be an offset segment of the main vein. According to Huntting (field notes, 1946), 125 feet of the vein averages 13 inches in width and contains 0.67 ounce per ton in gold and 2.75 ounces in silver. The 120 tons of ore mined by Hyde from the upper and lower adits averaged $28 to $30 per ton in gold and silver. No work has been done on the claim in recent years, and the adits are caved at the portals. Although it is not known from which part of the mine the ore in the bunker came, the quartz contains fragments of argillite and sulfide minerals. The sulfide minerals are pyrite, sphalerite, galena, and a small amount of chalcopyrite. One small particle of free gold was seen by the writer.

Mammoth mine

This property is in sec. 35, T. 38 N., R. 17 E., on the east side of Bonita Creek ¾ mile north of its junction with Slate Creek. The mine camp is at an altitude of about 5,450 feet, and the Mammoth tunnel is at an altitude of 5,700 feet. The Mammoth group consists of five patented claims surveyed under Mineral Survey 651. These claims are: Mammoth, Iron Cross, Keynote, Hecla, and Gold Leaf. In the past, as many as 60 unpatented mining claims have been included in the Mammoth group; however, these claims are now invalid because of the lack of annual assessment work. Mrs. Virginia Pierson, of Tucson, Ariz., is the owner of the patented claims.

Accessibility.—Access to the property is by way of the Windy Pass road, which begins 2.8 miles west of Harts Pass on the Slate Creek road. The Windy Pass road, a single-track steep mountain road, extends 0.8 mile to the old Mammoth camp. From the camp a steep trail leads eastward up a steep rocky slope to the main levels of the mine. About 0.1 mile beyond the mine camp on the Windy Pass road an old road can also be followed on foot to the mine workings.

History.—The Mammoth vein was discovered by G. C. Mathews et al. in the summer of 1895. Under the management of Charles Ballard and Peter Bryan, a 5-stamp steam-powered concentration mill was erected in 1898. The mill, which was on the corner of the Mammoth claim, received gold ore from the mine by means of an aerial tramway several hundred feet long. At the mill the ore was crushed by stamps to 40 mesh, after which it was passed over amalgamation plates to collect the free gold. The non-amalgamable sulfides that accompanied the gold were concentrated by tabling the tailings. Operations ceased in 1901, after the mine had produced 15,000 tons of ore that averaged $26.50 per ton in gold and silver (Huntting, 1956, p. 178).

In 1901 eastern financial interests acquired control of the mine, and in 1902 a 10-stamp water-powered mill was built near the junction of Bonita and Slate Creeks. A wire-rope aerial tramway extended from the mine to the mill, a distance of 3,800 feet. Because of high costs in the operation of the new mill and tramline, mining and milling operations ceased in 1905. The stamps from the original Mammoth mill are now at the Shafer museum in Winthrop, Wash., and the stamps of the second mill lie rusting beneath rotting timbers of the mill on the north bank of Slate Creek.

In the early 1930's D. W. McArthur, of Bellingham, bought the property at a tax sale and shortly thereafter leased it to Owens Gold Mines, Inc., of Seattle. Examinations of the veins were made and milling tests run on the ore, but mining was not undertaken at that time. In 1936 the Mammoth Gold Mining Co. began mining operations at the lower level, and in 1942 it shipped crude gold ore to the Tacoma smelter. This production was small, as the total gold production for the county in 1942 was only $1,925. Little, if any, work has been undertaken at the mine since 1942, and the buildings and mine workings are in a state of disrepair. The total production from the Mammoth mine is popularly reported to be more than $1,000,000. Huntting (1956, p. 178) reports that 15,000 tons of ore mined before 1900 yielded $397,500 and that a total of 30,000 tons was mined from 1898 to 1942. It is assumed that the 15,000 tons of ore mined after 1900 averaged not less than $15 per ton, the figure given by Phoenix, (as reported by Keffer, 1935, p. 7) who sampled the mine in the 1930's. If the mill recovery had been 65 percent —which amalgamation and tabling tests indicated—the ore would have yielded $147,250. Thus, the total production for the mine would be about $544,750 at the $20 gold price.

Geology.—The underground workings at the mine were not accessible to the writer in 1965, as the portals were caved. However, the upper level of the mine was mapped in 1944 by Ward Carithers, at that time a staff member of the Division of Mines and Geology. Marshall T. Huntting, supervisor of the Washington Division of Mines and Geology, mapped the lower level in 1946. Underground workings, geology, and assays of the Mammoth vein are shown on Plate 13.

The country rocks are alternating beds of slate, quartzite, and arkose of the Pasayten Formation. The beds strike N. 20°-25° W. and dip 45°-50° E. The gold and silver occurs in a quartz fissure vein that strikes N. 70°-80° E. and has a dip averaging 45° N. In several places the vein has been offset as much as 25 feet by faults. These faults strike N. 45°-60° W. and dip 40°-55° NE. In the upper level the vein ranges from 2 to 40 inches in width and averages 20 inches. In the lower level the vein pinches and swells from less than 1 inch to 24 inches.

The quartz vein contains sparsely disseminated pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, and native gold. The sulfide minerals are visible to the unaided eye, but very little gold is seen. However, visible gold was reported in the quartz during early-day mining operations. Although silver is reported in the vein, the writer did not observe any silver minerals in samples of the ore. In most of the vein the sulfide minerals make up less than 5 percent of the vein minerals and occur as euhedral to subhedral crystals 2 to 5 millimeters across. Pyrite and arsenopyrite, which are the predominant sulfide minerals of the vein, also are disseminated in the wall rock. The oxidation of these minerals imparts a reddish color to the wall rock as well as to parts of the quartz vein.

The Mammoth vein has been sampled by Phoenix and Keffer, as reported by Keffer (1935, p. 7). At the upper level, which is known as the Mammoth tunnel, Phoenix reports an average value of 0.680 ounce per ton in gold and 1.212 ounces in silver. Sampling by Keffer shows 0.701 ounce of gold and 0.848 ounce of silver per ton in a vein that averages 20 inches in width. Sampling of the pyritized wall rock showed less than a dollar per ton in gold and silver.

Early reports on the Mammoth mine describe the presence of gold tellurides; however, tests on the ore since 1935 have not revealed any telluride minerals. The U.S. Bureau of Mines (written communication, 1965) reports the presence of 2 parts per million of tellurium in vein quartz from the lower level of the mine, an amount that is insignificant. However, it is possible that the richer, near-surface part of the vein did contain telluride minerals.

Mining and milling.—The Mammoth vein has been drifted upon at 5 levels. Little is known about the lowermost drift, which is about 600 feet north of the mine camp and is below the level of the road. The portal to the drift is caved, and the size of the dump suggests less than a hundred feet of workings. The second level, known as the "D" level, is about 120 feet vertically above the road and 500 feet north-northeast of the camp. This level is the site of the work undertaken from 1936 to 1942 and appears to have been mainly an exploration drift, as stoping was not undertaken. The uppermost levels of the mine were accessible from the Mammoth tunnel, which is at an altitude of 5,700 feet. The tunnel is about 750 feet east of the mine camp and about 250 feet vertically above the old Mammoth mill and the present road.

The Mammoth tunnel was driven eastward for about 995 feet and stoped overhead for most of its length; in several places the stopes reached the surface. About 235 feet from the portal a 94-foot winze extends to a sublevel that is 70 feet vertically below the main level. The extent of this sublevel is not known, but some overhand stoping was undertaken. About 900 feet from the portal, near the face of the Mammoth tunnel, a raise extends upward along the vein for 60 feet to a short sublevel. At this level the vein has been drifted upon for only 40 feet.

The ore from the Mammoth vein that was milled from 1895 to 1905 was mined in the Mammoth tunnel and sublevels. At the time of Carithers' examination in 1944 the upper tunnel was accessible and Carithers (field notes, 1944) reports the following:

> The adit crosscuts about 75 feet where it hit the vein and drifted N. 60° E. for about 900 feet . . . . The vein is quartz following a fracture system through siliceous rocks that strike N. 20°-25° W. and dip 50° NE. The vein thickens and thins with a maximum width of 3.5 feet. The vein is composed of solid quartz in places and smaller parallel stringers elsewhere. Some of the quartz is brecciated and healed by later quartz and sulfides. Sulfides include pyrite, arsenopyrite, and galena.

Carithers' observations (field notes, 1944) in the "D" tunnel are as follows:

> The "D" tunnel was advanced about 1,000 feet northeast to the vein. At the intersection of the vein an upraise is collared and advanced about 70 feet. It is started to connect with the winze of the upper level. The "D" level drifts on the vein for about 75 feet. The lode consists of a series of quartz veins that thicken and thin from 2 to 20 inches through quartzite and argillite and is in a tight shear zone about 10 feet wide, but only a part of this width is mineralized and could be ore.

Carithers noted the presence of pyrite, arsenopyrite, galena, and sphalerite, but he did not sample for assay the vein in the "D" level. An assay on quartz collected by the writer showed only 0.05 ounce of gold and 0.25 ounce of silver per ton.

The percentage of gold recovery from early-day milling operations is not known, but was probably low, inasmuch as amalgamation was the principal means of recovery. Milling tests by Keffer (1935) for Owens Gold Mines, Inc. showed that 89.6 percent of the gold and 70.8 percent of the silver could be recovered by combined amalgamation, flotation, and tabling. Amalgamation recovered 25.1 percent of the gold; flotation, 53.8 percent; and tabling, 10.7 percent. By cyaniding the flotation concentrates, 91.67 percent of the gold and 85.3 percent of the silver were extracted from the concentrate. Only 37 percent of the gold in the tailings was recovered by cyaniding.

Minnesota mine

The Minnesota mine is about 2,000 feet downstream from the junction of Mill and Canyon Creeks and is about 100 feet above creek level on the north side of Canyon Creek. It is in the SW¼ sec. 2, T. 37 N., R. 16 E., at an altitude of about 2,400 feet. About 1,200 feet west of the Mill Creek bridge and on the trail to Ross Lake a trail branches north and then turns west for about 2,700 feet to the old mill building on the north bank of Canyon Creek.

The Minnesota claim was located by W. F. Voight in 1904. Shortly thereafter, the Seattle-St. Louis Mining Co. was organized, and in 1908 a 4-stamp mill, which used amalgamation plates and vanners, was erected on the Minnesota claim. Gold ore was milled at the property in 1911, 1912, and 1913 at the rate of 20 tons per day. The amount of gold production from the mine is not known, and the company was dissolved in 1918. At present (1966), the property appears to be in a state of abandonment. The claims were never patented and were held by possessory title.

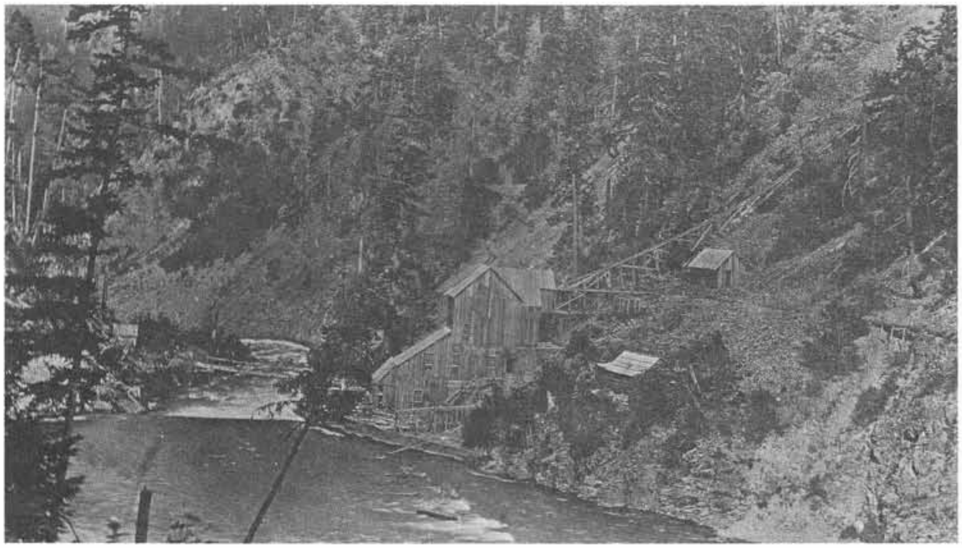

FIGURE 42.—Stamp mill of the Seattle-St. Louis Mining Co., Slate Creek mining district, 1912.
(Photo courtesy of Walter M. Stephen.)

The stamps of the mill are still standing, but the rest of the mill equipment is in ruins. Heavy snows have collapsed most of the buildings, and only a small part of the original mill is still standing (Fig. 42). The ore bunker at the mill contains white quartz that carries medium-grained disseminated pyrite. In several samples the writer noted very fine-grained native gold that was accompanied by fine-grained bornite. A grab sample of the quartz assayed 1.26 ounces of gold per ton and 6.12 ounces of silver.

From the upper level of the mill, remnants of old mine track can be followed eastward for about 300 feet to an adit in a steep rocky gully. The adit, which heads northward into north-trending, steeply dipping quartzite, encounters a northwestward-trending shear zone 40 feet from the portal. The shear zone is 6 to 24 inches wide and has been drifted upon for 445 feet. The shear zone contains several small quartz veins that pinch and swell; however, at the face of the drift a 24-inch-wide quartz vein fills the shear zone (Mortimer Staatz, written communication, 1966). An upper drift, about 300 feet above the lower mine adit, is reported to follow another vein. Also, on the steep rocky slope behind the mill there are remains of what appears to have been a surface tramway. The tracks indicate that another adit is on the hillside above the mill, but the portal is covered by slide-rock. According to early reports (Norman, 1918, p. 201), there are 1,000 feet of underground workings on the property.

New Light group

The New Light group consists of 16 unpatented contiguous claims that are mainly in sec. 27, T. 38 N., R. 17 E., near the headwaters of Bonita Creek. Altitudes at the property range from 5,500 feet at the mill on Bonita Creek to 6,626 feet at the uppermost workings of the mine on Slate Hill.

The New Light group, as well as the Allen Basin group (17 claims) and the Goat group (12 claims), is owned by Western Gold Mining, Inc., of Seattle, of which Harry P. Kramer is president.

Accessibility—From Winthrop, in western Okanogan County, the property is accessible by 40 miles of state, county, and forest access roads. From Harts Pass on the Whatcom-Okanogan county line the Slate Creek road is followed 2.8 miles west to the Windy Pass road, which extends 1.4 miles to the mine mill and camp. From the mine camp on Bonita Creek a steep single-track mountain road leads 1.7 miles to the principal mine workings, which are about ½ mile west of the camp. The camp can be reached by means of conventional vehicles; however, a low-geared vehicle is recommended for travel beyond the camp.

NEW LIGHT GROUP

1.	Grant	11.	Lee
2.	Haida	12.	Echo
3.	Casey	13.	Reno
4.	Jackson	14.	Bonus
5.	Ohio	15.	Rego
6.	Denver	16.	Hugo
7.	Cabin	17.	Manilla
8.	Gordon	18.	Black Jack
9.	Arrow	19.	Walla Walla
10.	Butte		

ALLEN BASIN GROUP

1.	Nephew	8.	Harnessmaker Extension
2.	Aunt	9.	Harnessmaker
3.	Equinox	10.	Uncle
4.	Black Dwarf	11.	Queen City
5.	Captain Jack	12.	Sister Grace
6.	IXL	13.	Maccabee
7.	Solitare	14.	Blue Hen

GOAT GROUP

1.	King	7.	Cougar No. 1
2.	King Spring	8.	Iron Crown
3.	Goat No. 1	9.	Goat
4.	Goat No. 4	10.	Marine
5.	Rust	11.	Gold Shield
6.	Goat No. 2	12.	Cougar

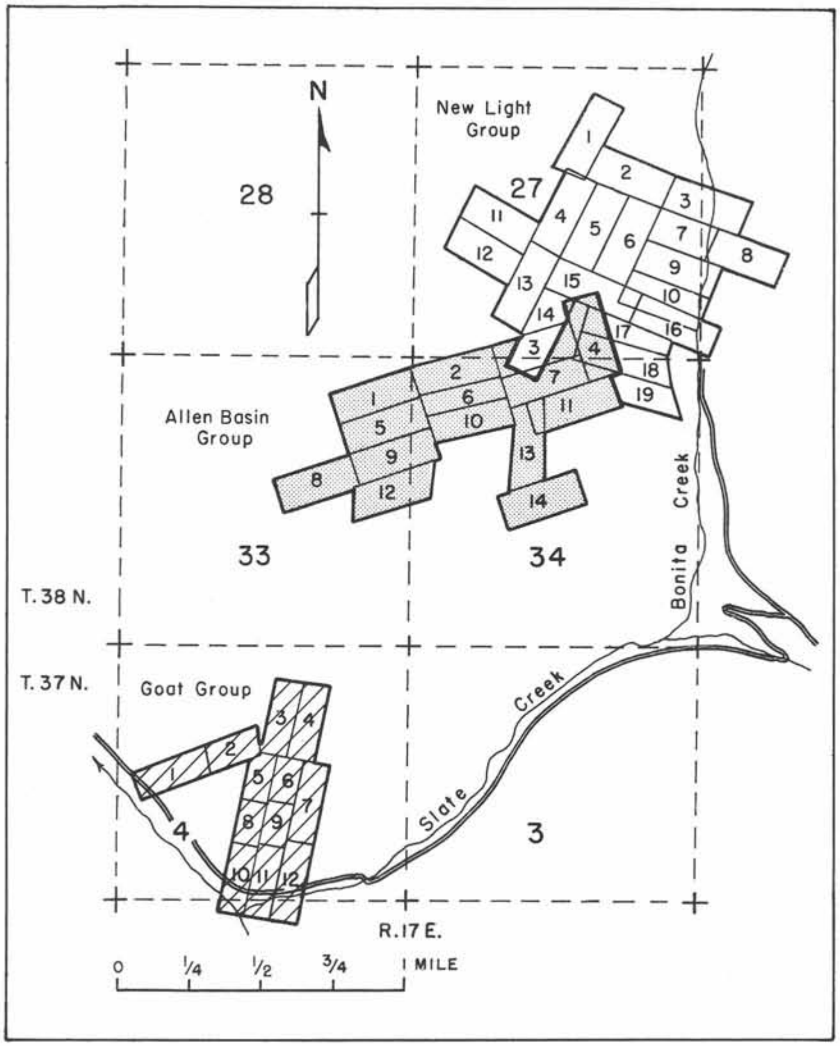

FIGURE 43.—Western Gold Mining, Inc., claim map.

History.—Claims of the New Light group were among the first to be located in the Slate Creek mining district and are part of the original Eureka group of six quartz and two placer claims that were located by A. M. Barron in 1893. The following chronological notes on the history of the property are compiled from the U.S. Geological Survey's annual volumes of Mineral Resources of the United States and from the Minerals Yearbooks of the U.S. Bureau of Mines. Data were obtained also from newspapers, mining publications, and company reports.

1895—Eureka Mining Co., of Anacortes, began sinking a shaft on oxidized gold ore on the Eureka lode. Ore carried $30 in gold and was free milling.

1896—C. D. Lane, of San Francisco, equipped the property with a tramway, a Lane Chilian wheel, and a 10-stamp mill. Glory Hole on the Eureka lode produced $120,000 in gold after 2 years' operation. Original values of $30 per ton dropped to $18 and $10.

1905—Bonita Gold Mining Co., of Snohomish, acquired the property from Lane and developed a new Glory Hole west of the original one. Property consisted of 26 claims.

1907—Bonita Co. worked the 10-stamp mill and a cyanide plant; this was the only producing gold mine in the county.

1915—William Brown, of Everett, acquired the property and developed a large body of low-grade ore that contained $12 to $18 in gold per ton.

1923—Slate Creek Gold Mine, operated by the Brown Development Co., developed a large reserve of low-grade gold ore; more than 8,000 feet of underground workings were on the property. A dispute over electric power from Chancellor curtailed operation.

1933—New Light Gold Mining Co. organized; reported reserves of 2,000,000 tons of $5 to $17 gold ore and 60,000 tons of $25 ore.

1935—New Light Gold Mining Co. completed a 50-ton flotation mill.

1937—Monica Mining Co. took over the property. Ray and Frank Staplin, of British Columbia, had 16 men working at the property.

1938—Mill capacity was increased to 80 tons and mine was worked 140 feet below the Glory Hole; 80 men at the mine worked 2 shifts.

1939—A Montana group installed cyanide equipment at the mill.

1940—Western Gold Mining, Inc. acquired the New Light, Allen Basin, and Goat groups. The property consisted of 46 claims and 13,150 feet of underground workings. Milling tests indicated that 50 to 60 percent of the gold was recoverable as free gold.
1942—Operations were halted during World War II by Government Order L-108.
1947—Western Gold Mining shipped 24 tons of concentrates from development work to the Tacoma smelter.
1948—Diamond drilling and development work were undertaken on four levels.
1956—Capacity of the mill was increased to 120 tons.
1959—Diamond drilling was underway on the No. 2 level.
1960—Company reported 1,500 feet of drilling completed; four holes showed gold values up to $36 per ton.
1961—Harry P. Kramer, president of Western Gold Mining, Inc., reported reserves of 200,000 tons that averaged $11.55 per ton in gold. Mill had 120-ton capacity, utilizing jigs, flotation cells, Wilfley tables, and a cyaniding plant.
1963—Company mined and milled 300 tons of ore; concentrates contained $74.25 to $103.25 per ton in gold.
1965—Company reported 0.005 to 2.6 ounces per ton in platinum was present in the concentrates. Studies were underway to determine the nature of platinum mineralization in the ore.

Accurate figures are not available for the total production of gold from the New Light mine. However, research by the company's president, Harry Kramer, indicates that approximately $350,000 in gold came from the Glory Hole during the first years of operation (1896 to 1905). Huntting (1956, p. 178) reports the production as 60,000 tons in the [early] 1900's and several tons of good-grade ore in 1940 to 1942. In 1947 about 24 tons of concentrates of unknown value were shipped to the Tacoma smelter, and in 1949 about 300 tons of ore was mined and milled. Based on these data, the total production is estimated at around $1,250,000.

Geology.—In the vicinity of the New Light mine the rocks are mainly arkose, quartzite, conglomerate, argillite, and slate of the Pasayten Formation (Lower Cretaceous). The beds strike N. 30° E. to N. 20° W. and dip 20°-40° E. Rocks of the Pasayten Formation have been intruded by a small diorite stock on the northwestern part of the claims, and the underground workings of the mine contain several sill-like bodies of diabase. Well-developed shear zones as much as 10 feet wide have been encountered in the mine workings. These shear zones strike N. 70° E. to N. 70° W. and dip 45° to 90° E. Several shear zones contain gold-bearing quartz veins as much as 5 feet wide. The amount of gold in the quartz veins is erratic, but assays as high as $90 per ton in gold have been reported by the company. In addition to the gold, the quartz contains sparsely disseminated pyrite, galena, and chalcopyrite.

Extensive zones of breccia have been encountered in most underground mine workings. The breccia zones range from 40 to 140 feet in width and are exposed discontinuously over a vertical distance of 1,100 feet. The breccia consists of angular fragments of slate and argillite that are less than 1 inch to as much as 1 foot across. Gold-bearing quartz is the main cementing agent of the breccia and is accompanied by minor calcite. Small amounts of fine-grained pyrite, pyrrhotite, chalcopyrite, and galena occur in a disseminated state and as thin stringers in the breccia. Although the gold is rarely visible to the unaided eye, milling tests indicate that as much as 70 percent of it is present as native gold. Also, a small amount of argentite accompanies the gold. Though the gold is mostly fine grained, particles as much as ¼ inch across have been recovered from the ore. Early-day operators of the mine reported the presence of the gold-silver telluride sylvanite; however, telluride minerals have not been noted in recent mill cleanups. Tests by the U. S. Bureau of Mines (written communication, 1965) show 3.5 parts per million of tellurium present in the breccia ore, and smelter assays of the concentrate show as much as 0.25 percent nickel.

The breccia thus far encountered at the New Light mine is in scattered places over a horizontal distance of 1,600 feet and a vertical distance of 1,100 feet. Sufficient data are not available to establish a structural relation between the different breccia bodies; however, most of the breccia terminates against faults. The breccia appears to have formed during the orogeny that folded and faulted the rocks of the Pasayten Formation. It is possible that brecciation of the incompetent beds occurred at this time. Later, metal-bearing siliceous hydrothermal solutions related to underlying granitic bodies permeated the brecciated rocks, inasmuch as these rocks offered an avenue of escape for the confined solutions. The metalized breccia zone was later complicated by eastward- and northwestward-trending faults that divided it into several fault blocks. Quartz fissure veins occupy several of the eastward-trending faults, which parallel the general strike of most of the quartz fissure veins of the area.

Extensive sampling of the breccia by Western Gold Mining, Inc. indicated an average gold content of 0.33 ounce per ton and an average silver content of 0.137 ounce. Near-surface ore at the Glory Hole contained 1.5 ounces per ton in gold in a 30-foot-wide quartz vein. Recent research work by the company indicates that the breccia contains finely divided sooty grains of platinum. Assays of a mill concentrate showed 0.005 to 2.60 ounces of platinum per ton. Although gold and silver appear to be persistent in the breccia, the richer parts of the breccia occur as pockets or shoots. The gold values in some places are as much as 3 ounces per ton, but the silver rarely exceeds 1 ounce per ton.

Mining and milling.—At the original Eureka discovery the gold-bearing quartz vein did not crop out, but was covered by 4 to 6 feet of overburden that consisted of soil and iron oxide-rich clay. The oxidized part of the lode yielded free gold when washed. Oxidation

FIGURE 44.—Panorama of the Bonita Creek area, Slate Creek mining district. No. 2 Level of New Light mine in foreground.

occurred to 25 feet beneath the surface. In 1895 a 54-foot shaft was sunk upon the 30-foot-wide quartz vein, yielding ore that assayed 1.5 ounces in gold per ton. For more efficient mining of the deposit, a crosscut was started 300 feet east of, and about 125 feet lower than, the collar of the shaft. Two hundred feet from the portal of the crosscut a raise was driven to the ore body. From this No. 1 level a rail tramway delivered ore 2,500 feet to the stamp mill on Bonita Creek. In the years that followed, crosscuts were driven at five lower levels, the lowest being the No. 4 level at an altitude of 5,557 feet, near the level of the mill. The underground workings of the New Light mine are shown on Plate 14. In all, the mine contains about 7,200 feet of underground workings. The tramway is no longer in operation and has been replaced by access roads from the mill to the different mine levels.

The New Light mill (see cover) is the only operational gold mill in Whatcom County (1966) and is rated at 120 tons. A two-stage crushing plant, which consists of an 8- by 15-inch jaw crusher and a No. 18 Intercone secondary crusher, produces a minus ⅜-inch ball mill feed. Grinding is done in a 54 Marcy ball mill to 25 mesh, and the ground rock is discharged over a 1- by 3-foot vibrating screen to remove the coarse barren low-grade rock (+0.202 inches, 3 mesh). The minus 3 mesh ground rock is fed to two 12- by 18-inch Denver jigs before being screened the second time on a 2- by 6-foot vibrating screen. A minus 0.026-inch product is fed to a 4-cell No. 18 Denver flotation machine, and the plus 0.026-inch material from screening is returned to the ball mill. The flotation concentrate is thickened in an 8- by 12-foot thickener before being pumped into three 8- by 8-foot agitator tanks and two 8- by 8-foot solution tanks. The pregnant cyanide solution is then pumped into a seven-compartment zinc box for the precipitation of gold. Power for the mill is furnished by a 187-kv.-a. Westinghouse a.c. generator that is turned by a 222-hp. Atlas Diesel engine. Portable compressors at the portals of the adits supply air for the drills.

Extensive mining and milling tests by Western Gold Mining, Inc. show that the breccia can be mined for about $2 per ton and milled for $2.70 per ton. Trucking costs from mine to mill are approximately $0.75 per ton. Milling tests show that 14 to 44 percent of the gold can be recovered in jigs and 55 to 70 percent of the gold can be recovered through flotation. Milling tests have also been conducted by Monahan (1939). His tests show that 70 percent of the gold in the breccia is native gold and that at an 11.1 to 1 ratio of concentration 90.2 percent of the gold can be recovered by flotation.

North American mine

The North American mine is in sec. 11, T. 37 N., R. 16 E., about 3,000 feet south of the junction of Mill and Canyon Creeks. The mine camp and mill are at an altitude of 4,200 feet. The property can be reached from the end of the road at Chancellor by hiking 4 miles down Canyon Creek to Mill Creek. About 2,500 feet beyond Mill Creek on the main trail to Ross Lake, an old trail can be followed southward for 2 miles to the mine. The property consists of 6 patented claims:

Road across center leads to Indiana Basin and Indiana mine near right center of photo. Distant skyline is in Okanogan County.

Anoka, Anoka No. 2, Anoka No. 4, Iron Cap, Columbia, and Blizzard, all surveyed under Mineral Survey No. 1071. The claims were located by C. H. Clendenin and J. Seigfried between 1895 and 1900. In 1909 the property was deeded to W. A. Wells, who in 1910 deeded the property to the Mountain Top Mining Co., which patented the claims on June 17, 1915. On June 14, 1926, the property was acquired by John E. Wells, of Tulsa, Okla., who presently (1966) owns the property.

Operating under the name of the North American Mining and Milling Co. in the early 1900's, the property was developed by three crosscuts and five drifts that totaled 500 feet in length. The underground workings exposed a 1- to 3-foot-wide quartz vein that contained $3 to $7 per ton in gold at $20 gold prices. In 1907 a 2-stamp amalgamation mill was erected on the Anoka claim. Milling of the ore proved unsuccessful, as not enough native gold was present, and amalgamation recovered only 10 to 15 percent of the gold. From the size of the tailings dump, it appears that only a few hundred tons at the most was ever milled. Some time after 1910 the property was owned by the Mountain Top Mining Co., and in 1923 the company was dissolved because mining proved unprofitable. In 1934 the property was under a 6-year lease to the Velvet Mining Co., which had an option to purchase. Nothing is known about the work undertaken at that time, but there appears to have been no work on the property since 1934.

The rocks in the vicinity of the North American mine are mainly fine-grained gray quartzite, minor argillite, and fine-grained graywacke that strike N. 20°-40° W. and dip 70° NE. to vertical. On the southern end of the claims the rocks have been intruded by a small body of early Tertiary granodiorite. The main body of the intrusion, which is about 0.3 mile wide, extends southeastward from the Blizzard claim for about 1¼ miles. Inasmuch as the mine workings were caved at the portals when the examination for this report was made in 1966, the writer did not see any quartz veins on the property. Grab samples of quartz from an ore dump at the mill contained 0.04 ounce of gold per ton and 2.52 ounces of silver. A small amount of malachite coats some surfaces of the quartz. According to James (1908), an ore shoot on the Columbia claim contains $75 per ton in gold at a $20 gold price, and another body of ore, 7 to 20 feet in thickness, averages about $15 in gold per ton. Most quartz veins are 1 to 3 feet wide and fill eastward-trending shear zones in quartzite.

Spafford (Homestake) prospect

This property is in the SE¼ sec. 22 and the NE¼ sec. 27, T. 38 N., R. 17 E., in the vicinity of Windy Pass, which is on the boundary between Whatcom and Okanogan Counties. E. H. Spafford, of Seattle, holds 11 contiguous unpatented claims: Homestake No. 1 and 2, Glorybe Lodes No. 1 and 2, Ricky Lodes 1 through 6, and Ridge Lode No. 1; Homestake No. 2 is in Okanogan County. From the camp of Western Gold Mining, Inc., on Bonita Creek, a steep mountain road can be followed northward for about 1 mile to the claims and the mine camp.

In the vicinity of Windy Pass the rock consists of well-bedded, fine-grained quartzite that strikes N. 35°

W. and dips 40° NE. About 1,000 feet south of the pass the quartzite has been intruded by a small diorite stock that is about 2,500 feet across.

Most of the work on the claims appears to have been done on the Homestake No. 1 claim, which is 750 feet west of Windy Pass. At this location a 500-foot-long dozer cut exposes a well-developed shear zone in quartzite. The shear zone, which has a general strike of N. 75° E. and appears to dip steeply north, contains an iron oxide-stained lenticular quartz vein. When the writer examined the prospect in 1965, much of the vein was concealed by waste material from trenching operations, but the quartz vein appeared to be at least 150 feet long and as much as 18 inches wide. On the western end of the dozer cut the vein is concealed by a thick cover of overburden, and on the eastern end it appears to have pinched out. Spafford (oral communication, 1965) reports sporadic gold values with lows of about $10 per ton to highs of more than $100 per ton. Typical vein quartz collected by the writer contained 0.06 ounce of gold and 0.66 ounce of silver per ton. Parts of the vein also contain fine-grained disseminated pyrite and sphalerite.

About 100 feet northeast of the end of the dozer cut, an inclined shaft has been sunk 80° W. for at least 50 feet on several narrow white quartz veins that contain abundant pyrite. It is probable that the quartz veins in the shaft represent a continuation of the vein exposed by Spafford in the dozer cut.

Whistler mine

The Whistler group consists of 4 contiguous claims: Jessie, Whistler, Lena, and Homestake, which are owned by Mrs. Victor H. Roth, of Bellingham. The claims are mainly in the SW¼ sec. 10, T. 37 N., R. 17 E., and are about 1 mile southeast of the junction of the South Fork of Slate Creek with Slate Creek. In all probability, the claims were at one time accessible by trail, but due to a steep hillside and rockslides, a trail is no longer visible. The original trail to the mine probably began at the mine camp on the South Fork of Slate Creek, where the road to the Azurite mine crosses the creek. The claims can be reached by climbing southeastward from the junction of the creeks along the ridge to Tatie Peak. United States Land Monument No. 3, which consists of a 10-inch squared tree stump 3 feet high, is about 1 mile from the creeks at an altitude of 6,275 feet. This monument (Pl. 9), which is on the Whistler claim, serves as a reference point for the claims of the group. Altitudes on the claims range from 5,200 to 6,520 feet.

The claims were located by E. C. Bowerman in 1895 and were patented by J. W. Romain and C. I. Roth in 1914. Sporadic development work was undertaken on the claims and an unknown amount of ore shipped in 1936 and 1937.

The rock in the area of the claims is fine-grained gray quartzite that has been intruded by andesite porphyry. Numerous shear zones are present, and disseminated pyrite occurs in much of the quartzite; oxidation of the pyrite imparts a reddish color to the rocks. Some shear zones contain quartz veins as much as 12 inches wide, which for the most part are contorted and pinch and swell. The quartz veins contain gold, silver, and copper. The gold and silver are rarely visible, but copper occurs as disseminated fine-grained chalcopyrite. Sampling of several veins by Roth in 1935 shows the values as follows:

	Gold (ounces)	*Silver (ounces)*	*Copper (percent)*
Homestake claim ..	.03 to .30	.26 to 2.92	....
Jessie claim	.31 to .46	.95 to 14.4	1.2 to 4
Whistler claim	.26 to 1.00	9.0 to 9.9	3.9 to 6.4

Near the center of the Jessie claim two adits are accessible. The upper adit, at an altitude of 5,960 feet, is in the bottom of a steep rocky gulch. The adit heads N. 40° E. for 30 feet into sheared gray quartzite. Thirty feet from the portal a crosscut heads east for 25 feet and another crosscut heads N. 55° W. for 10 feet. Ten feet from the portal the adit follows a 12-inch quartz vein for about 6 feet before the vein is faulted off. The quartz contains only disseminated iron pyrite.

The second adit is about 100 feet southwest of the upper adit and is at an altitude of about 5,900 feet. The adit heads N. 60° E. into highly fractured and iron oxide-stained quartzite and andesite porphyry containing thin stringers of white quartz. One hundred and sixty feet from the portal the adit cuts an 8-inch vein of quartz. One hundred feet from the portal a drift heads N. 30° W. for 70 feet and exposes an 8-inch quartz vein for about 30 feet. This drift appears to have been driven to crosscut a strong shear zone that forms a steep gully on the surface. The shear zone has a few thin stringers of quartz but does not contain ore minerals.

No recent work appears to have been done on the Whistler claims. The cabins on the South Fork of Slate Creek that served as the camp for the mine have long ago been crushed by heavy snowfalls.

Miscellaneous Prospects of the District

The following discussion concerns those prospects about which very little is known. The locations of the patented claims have been verified by the writer; however, the exact locations of many of the unpatented claims have not been determined. The published sources of information on the properties are cited at the end of the descriptions. The locations of the properties are shown on Plate 9.

Alameda prospect

This prospect is ½ mile south of the Anacortes mine and south of Cascade Creek in the NE¼ sec. 26, T. 38 N., R. 16 E. A white quartz vein carries 1.4 to 1.75 ounces of free gold per ton (Hodges, 1897).

B. C. & M. prospect

This gold-silver prospect is 2 miles up Granite Creek from Ruby Creek and is in the SE¼ sec. 17, T. 37 N., R. 16 E. (Huntting, 1956, p. 176).

Beck and Short Grub prospect

These two claims are ¾ mile east of the Mammoth mine and are in the NE¼ sec. 35, T. 38 N., R. 17 E. The claims are patented and are owned by S. W. Shafer, Jr., Alan Shafer, and Paul Duffy, of Winthrop, Wash. The claims can be reached by following the old narrow-gauge wagon road that extends from the upper tunnel of the Mammoth mine to Benson Basin and the Illinois mine. Slate, which has been intruded by porphyry, contains quartz veins 3 to 6 feet wide that assay as much as 2.75 ounces per ton in gold; as much as 51.00 ounces per ton in silver has been reported. On the Beck claim a 132-foot adit follows a 1- to 14-inch quartz vein that strikes N. 85° E. and dips 52° N. In the face of the drift a 10-foot shear zone exposes many small quartz stringers and one large 40-inch-wide quartz vein. About 20 tons of quartz is stockpiled near the portal of the adit. Several short adits are on the Short Grub claim; however, these adits are caved at their portals.

Beebe and Swanson prospect

This claim is 1 mile up Granite Creek from its junction with Ruby Creek and is in the NW¼ sec. 20, T. 37 N., R. 16 E. On the west bank of Granite Creek, 5 to 10 feet above the level of the stream, a short adit follows an aplite dike. This dike supposedly carried values in gold and silver (Bennett, 1939).

Bird and Sawpit prospect

These two patented claims are about 2,000 feet north of the Mammoth mine and are 300 feet south of the mill of Western Gold Mining, Inc., on Bonita Creek. The claims are near the common corner of secs. 26 and 34, T. 38 N., R. 17 E. The owner of this property is John S. Burns, of Redwood City, Calif. On the west end of the Bird claim and about 10 feet below the level of the present road, the dump of a caved adit is visible. The adit was driven on a quartz vein that strikes N. 65° W. and dips 57° NW. The extension of this vein to the southwest is covered by the Black Jack claim (see below). Gold and silver are present in the Bird vein but in only small amounts. Assays of quartz from the dump show as much as 0.12 ounce per ton in gold and 1.20 ounces in silver. No mine workings were noted on the Sawpit claim.

Black Jack prospect

This unpatented claim, which is part of the New Light group, is in the SE¼SE¼ sec. 27 and the NE¼NE¼ sec. 34, T. 38 N., R. 17 E. The claim is on the west bank of Bonita Creek, opposite the original townsite of Barron. Near the east end line of the claim and below the level of the old Bonita Creek road, a short adit heads S. 65° W. on a narrow vein of quartz. The quartz on the dump is iron oxide stained and contains fine-grained disseminated pyrite. The length of the adit is not known, as it is caved at its portal; however, the size of the dump suggests at least 100 feet of workings. The vein appears to be the southwestern extension of the quartz vein on the Bird claim (see above), which is on the east bank of Bonita Creek.

Casa Grande prospect

This claim, which was surveyed for patent in 1902 but never patented, is 1,600 feet west-southwest of the Mammoth mine camp. It is in the SE¼ sec. 34, T. 38 N., R. 17 E., and is now part of the Golden Arrow group. The claim was staked as a gold claim, but little, if any, work was undertaken on the claim.

Chancellor Mill Site

The Chancellor Mill Site is a patented claim of the Chancellor group, which includes the Indiana, the Grandview, and Illinois claims. It is near the junction of Slate and Canyon Creeks near the S. ¼ cor. sec. 30, T. 38 N., R. 17 E. In 1905 a water-operated powerplant was built to supply electrical power to the mines in the Slate Creek area. It operated only during 1905 and 1906, and had a 3-phase powerline that extended 3 miles to the New Light mine on Bonita Creek. The water was carried from Slate Creek through a 2-mile pipe flume that had an 800-foot head. At the powerplant, water was diverted through a Pelton wheel that turned two generators. The large generator was an S.K.C. system of the Stanley Manufacturing Co., Pittsburgh, that furnished 250 kilowatts at 6,600 volts. The smaller generator supplied 3 kilowatts at 120 volts. In 1965, when the writer visited the property, all that remained at the powerplant was the Pelton wheel and the 250-kilowatt generator.

Copper Castle (Helms) prospect

This prospect is ¾ mile west of the confluence of Slate and Bonita Creeks and is in the NW¼ sec. 3, T. 37 N., R. 17 E. A log cabin on the claim is plainly visible from sections of the Slate Creek road between Harts Pass and Benson Creek. According to Harry Tuttle (oral communication, 1966), high-grade gold ore was discovered on the property in the mid-1930's. However, drifting operations on the vein encountered only a small pocket of ore. Although the ore contained as much as several hundred dollars per ton in gold, attempts to recover the gold at a crude mill on the property proved unsuccessful. Mr. Tuttle's description of the ore suggests that the gold occurred in telluride minerals. This would explain why the gold could not be recovered by amalgamation, as gold-silver tellurides are not amalgamable.

Crown Point prospect

This property adjoins the Anacortes group on the west and is in the NW¼ sec. 23, T. 38 N., R. 16 E. A 60-foot adit follows a 4-foot gold- and silver-bearing quartz vein in black slate (Hodges, 1897).

First Find and Ivanhoe prospect

These claims are 2,500 feet east of the Mammoth mine and are in the NE¼ sec. 35, T. 38 N., R. 17 E.;

they are adjacent to the Beck and Short Grub claims. The claims are patented and are owned by Stuart S. Clark, Point Roberts, Wash. On the First Find claim a 30-inch quartz vein, which strikes N. 85° E. and dips 80° N., has been drifted upon for 55 feet. The vein contains pyrite, arsenopyrite, galena, sphalerite, and a small amount of chalcopyrite. The vein is reported to contain gold and silver, and about 20 tons of ore is stockpiled near the portal of the adit. Assays by Keffer (1935, p. 8) on quartz veins of the Ivanhoe claim showed 0.16 to 0.22 ounce per ton in gold and 0.22 to 1.12 ounces in silver.

Gold Ridge prospect

This property is 10 miles from the Canadian border, and the claims are on both sides of the Cascade crest. The claims cover three eastward-trending ledges and four northward-trending ledges that average 0.5 ounce per ton in gold. Exploration and development work consists of 830 feet of tunnels, shafts, and raises (Landes and others, 1902, p. 48).

Good Luck prospect

This prospect is on the Cascade Crest Trail and is about 0.4 mile south of Windy Pass. It is in the SE¼NW¼ sec. 26, T. 38 N., R. 17 E., at an altitude of 6,400 feet.

About 50 feet west of and downslope from the trail, a 50-foot adit has been driven on a quartz vein that strikes east and dips 55° north. The vein ranges from less than 1 inch to 10 inches in width and follows a strong shear zone in highly fractured meta-arkose. Aside from moderate amounts of disseminated pyrite and sparsely disseminated sphalerite, the vein has no visible ore minerals. Near ground level, fracture surfaces of the quartz are stained with iron oxide caused by the oxidation of the pyrite. A representative sample of iron oxide-stained quartz that is stockpiled on the adit dump assayed 0.28 ounce per ton in gold and 1.74 ounces in silver.

Thirty feet upslope from the adit the quartz vein is exposed in a prospect cut. The vein, which is as much as 3 feet wide, pinches and swells along its strike and dip and is vertical. Several tons of iron oxide-stained quartz are stockpiled near the prospect cut. Like the quartz in the adit, this quartz contains a moderate amount of pyrite and minor sphalerite.

Twenty feet above the Cascade Crest Trail the vein is exposed in a shallow prospect pit. The vein strikes east and dips 45° north in quartzite, meta-arkose, and minor argillite. The quartz vein ranges from 4 to 18 inches in width and contains a small amount of pyrite.

Great Northern prospect

This prospect is in the SW¼ sec. 3, T. 37 N., R. 17 E. It is on the south side of Slate Creek ¾ mile above the confluence of the South Fork of Slate Creek and Slate Creek. About 500 feet south of Slate Creek an iron and manganese oxide-stained breccia zone, which is almost 4,000 feet long and 1,000 feet wide, has been explored by means of four adits. The westernmost adit heads S. 30° E. and crosscuts 220 feet of breccia; beyond the breccia the adit crosscuts 80 feet of unaltered quartzite. Except for very fine-grained disseminated pyrite, metallic minerals are lacking in the breccia. Representative samples of outcrops of the iron oxide-stained breccia near the adit assayed 0.01 ounce per ton in gold and 0.70 ounce in silver. Samples of the manganese oxide-stained breccia assayed 0.01 ounce per ton in gold and 0.44 ounce in silver. Random chip samples of the breccia in the adit taken by Noranda Exploration, Inc. showed only a trace of gold, no silver, 0.044 percent copper, and 0.4 percent zinc (Nick Saum, written communication, 1967).

Jim Mountain prospect

This prospect is probably in the SE¼ sec. 9, T. 38 N., R. 17 E. It is on the west slope of Jim Peak, which is 2 miles north of the end of the Bonita Creek road at Windy Pass. The prospect contains three veins of massive pyrrhotite that are 12, 6, and 4 feet wide. Assays show 70 to 80 percent pyrrhotite in the veins (Hunting, 1956, p. 204). This occurrence could not be found by the writer.

Keystone prospect

This claim adjoins the Tacoma claim on the south and the Mammoth claim on the southwest; it is in the NE¼ sec. 34, T. 38 N., R. 17 E. The claim is held by Frank Shell, of Port Angeles, Wash. No mine workings are on the claim, which was surveyed for patent as a gold claim (Huntting, 1956, p. 177).

Mill Creek prospect

This property is on the west side of Mill Creek, about 2 miles above its junction with Canyon Creek. Although the exact location of the property is unknown to the writer, it most likely is in the SW¼ sec. 7 and the NW¼ sec. 18, T. 37 N., R. 17 E. Gold and silver occur in two northeastward-trending parallel quartz veins that average 3 feet in width and are 100 feet apart. The veins have been traced for over 2,000 feet on the surface, and on the south bank of Mill Creek one vein has been crosscut by a 400-foot adit (Adair, 1906).

Murtle prospect

This patented claim is owned by Mrs. John A. Barron, of Anacortes, Wash. The claim is about 1,500 feet east of the Mammoth mine camp and is in the N½NW¼ sec. 35, T. 38 N., R. 17 E. The claim was staked for the gold that occurs in narrow quartz stringers. Other than a few shallow prospect pits, little in the way of exploration and development work has been undertaken (Huntting, 1956, p. 178).

Ninetynine prospect

This property, which at one time consisted of 11 patented claims, is in Ninetynine Basin, at the headwaters of Slate Creek. The claims are at an altitude of 6,800 feet and are on the east-facing slope of a ridge that separates Slate Creek and the South Fork of Slate Creek. The prospect pits and adits are mainly in the NW¼NW¼ sec. 14, T. 37 N., R. 17 E. The property can be reached by a trail that begins 1 mile south of Harts Pass on the road to the Brown Bear mine. This trail leads south into Ninetynine Basin and then heads north and finally west up a steep rocky slope to several caved adits. In places the trail is barely discernible. The main crosscut, which is caved at the portal, is 240 feet long and intersects a 4-foot quartz vein in slate and quartzite. This vein contains free gold and tellurides, which occur along a 2-foot paystreak in the vein (Landes and others, 1902, p. 49). The writer's examination of quartz from the dump revealed about 5 percent disseminated pyrite and sparsely disseminated galena.

Randall (Gold Coin) mine

This property is 200 feet northeast of the Mammoth mine camp and consists of three patented claims: Randall, Good Enough, and Gold Bug. Mr. A. Harding, of Glendale, Calif., is administrator for the property. From the Indiana mine a dozer road can be followed 2,000 feet in a general southwesterly direction to a dozer cut on the Randall claim. The cut exposes iron oxide-stained and highly fractured quartzite that contains two quartz veins. Near the upper edge of the cut a 20-foot adit follows a 15-inch quartz vein that strikes N. 75° E. and dips 55° NW.; the vein is lenticular and is faulted. About 30 feet below the adit a 6-inch vein of quartz that pinches and swells has been followed by means of a short adit for 10 feet. This vein strikes N. 70° W. and dips 40° NE. According to Stoess (1934), the property has a 150-foot adit, and selected samples assayed as high as $1,255.25 in gold. The writer was unable to find this adit.

Red Jacket prospect

This prospect is about 1,500 feet north of Foggy Pass and 80 feet west of the Cascade Crest Trail. It is at an altitude of 6,175 feet and is in the SE¼SE¼ sec. 16, T. 38 N., R. 17 E. On a west-facing hillside a caved adit heads east along a 12-foot-wide zone of fractured and iron oxide-stained arkose. A porphyry dike forms the north wall of the fracture zone. The adit appears to follow a thin iron oxide-stained quartz vein that ranges from 2 to 6 inches in width. Assays of this vein on samples collected by the writer showed 1.10 ounces per ton in gold and 1.68 ounces in silver. The mine dump, the size of which suggests around 200 feet of underground workings, contains several small stockpiles of arsenopyrite-bearing quartz. Some of the quartz contains as much as 30 percent arsenopyrite.

Rockefeller prospect

This property is on Rockefeller Creek and is in the SE¼ sec. 33, T. 38 N., R. 17 E. Rockefeller Creek, a tributary to Slate Creek, is crossed by the Slate Creek road about 8 miles west of Harts Pass. Gold and silver occur in pyrite-bearing quartz veins, which in the early 1900's were explored by means of several short adits and prospect pits (Hodges, 1897).

Seattle prospect

The Seattle group consists of 5 claims that were held under possessory title by the Azurite Gold Co. The claims are 2 miles north of the Azurite mine and about 2½ miles south of the confluence of Mill and Canyon Creeks. Although the exact location of the claims was not verified by the writer, they are probably in the NE¼ sec. 18, T. 37 N., R. 17 E. On the east side of Mill Creek two well-defined white quartz veins have been partly explored by means of 1,000 feet of underground workings. The veins were reported by the Azurite Gold Co. to carry fair values in gold and silver. It is possible that the veins are a part of the vein system of the quartz veins on the Mill Creek property, which is west of Mill Creek.

Shanghai and Nankin prospect

These patented claims are owned by J. L. Yelton, of Bellingham, Wash. Gold, silver, and copper are reported on the claims, but no mine workings could be found by the writer. The Shanghai claim is in the N½ sec. 34, T. 38 N., R. 17 E., and is 2,000 feet west of Bonita Creek. The claim is near the eastern edge of a group of claims in Allen Basin. The Nankin claim is about 1,000 feet northwest of the confluence of Slate and Bonita Creeks and is in the SE¼ sec. 34, T. 38 N., R. 17 E.

Skookum prospect

This prospect, which comprises four unpatented claims and one millsite, is about 1 mile up Canyon Creek from its junction with Mill Creek. The claims are in the NE¼ sec. 2, T. 37 N., R. 16 E., and the SE¼ sec. 35, T. 38 N., R. 16 E., on a steep mountainside that is northwest of Canyon Creek. The claims cover an area of iron oxide-stained argillite and graywacke, the beds of which strike N. 30° W. and dip 50°-70° NE. The iron oxide-stained zone is plainly visible from several places on the Canyon Creek trail. Oscar Cornwall and Charles Erion, of Woodland, Wash., hold the claims by possessory title. According to Cornwall (oral communication, 1966), quartz veins on the claims assay as high as 5.6 ounces in gold. No mining and very little in the way of exploration work has been undertaken on the property.

Trapper prospect

This claim is at the headwaters of Benson Creek, 700 feet west of the crest of the Cascade Mountains, the eastern border of Whatcom County. The claim is south of the Beck claim and north of the Illinois mine, and is in the NE¼ sec. 35, T. 38 N., R. 17 E. The only workings on the property are several caved prospect pits, and in all probability the claim was staked and patented for gold. Bruce M. Archie, Jr., of Tacoma, Wash., is the owner of the claim.

Tripod prospect

The Tripod claim adjoins the Mammoth on the north and is in the NE¼NE¼ sec. 34, T. 38 N., R. 17 E. The owners of the claim are Alan Shafer, S. W. Shafer, Jr., and Paul Duffy, of Winthrop, Wash. The west end of the claim lies roughly along Bonita Creek; here, where the road to the Golden Arrow mine crosses the creek, an adit heads N. 45° E. into the east bank of the creek and follows a 5-foot vein of quartz. The vein dips 70° NW. and contains a 1- to 2-inch seam of gouge on its arkose footwall. The vein is stained reddish brown by iron oxide and contains sparsely disseminated pyrite and sphalerite. An assay on a sample of the vein taken by Keffer (1935, p. 8) at a point 50 feet from the portal showed 0.28 ounce per ton in gold and 0.58 ounce in silver. At present (1966) the adit is caved at its portal.

Walla Walla prospect

This patented claim is in the NE¼NE¼ sec. 34, T. 38 N., R. 17 E., and it adjoins the Tripod claim on the west and the Tacoma claim on the north. The east end line of the claim roughly follows Bonita Creek. The property is owned by Western Gold Mining, Inc., of Seattle, Wash. What little work has been done is on the northwest part of the claim. At an altitude of 6,130 feet a caved adit heads S. 70° W. into greenish-gray quartzite and dark-gray argillite. The dump, the size of which suggests several hundred feet of underground workings, contains pyrite-bearing white quartz. About 250 feet southwest of the adit, open cuts expose an 18-inch-wide vein of iron oxide-stained quartz for about 20 feet. The vein, which contains sparsely disseminated pyrite, strikes N. 70° E. and dips 80° NW. Quartz from the vein assayed 0.01 ounce per ton in gold and 0.18 ounce in silver.

PLACER GOLD MINING

Although currently (1966) there are no active placer gold mining operations in Whatcom County, attempts were made in the past to recover placer gold from streams in the Mount Baker and Slate Creek mining districts. Whatcom County records show that from 1884 to 1937 a total of 1,133 claims were filed for placer gold, and the majority of the claims were in the Slate Creek district. In the western part of the county, placer gold was discovered on the South Fork of the Nooksack River as early as 1860, and in the 1870's placer gold was discovered on Ruby Creek, in eastern Whatcom County. Unlike inactive lode mining operations, which usually retain some evidence of mining at the site of the mine, the workings of small-scale placer mines are soon obliterated. This is mainly owing to the fact that placer mining is usually carried on along banks and bars of active creeks, and after several high-water stages the worked gravels of a placer operation are redistributed along the stream. Indications of bench mining on stream terraces above the normal level of streams persist longer; however, the washed gravels are soon overgrown with brush and the sluice boxes begin to rot away.

Nowhere in the county was placer mining undertaken on a large scale, and gold dredges were not used, as the gravels were shallow and were in steep narrow canyons. Placer operations, for the most part, consisted of running the auriferous gravels through sluice boxes. However, at the Scougale claims, at the mouth of Ruby Creek, small-scale hydraulicking was employed. In recent years part-time and weekend prospectors have used small portable suction dredges to recover placer gold.

In the Ruby Creek area, early-day prospectors recovered gold nuggets as much as 2 ounces in weight; however, most gold ranged in size from dust to small nuggets about the size of a matchhead. The fineness of the gold ranged from 850 to 900, and silver was the alloying metal. There is no record that platinum was associated with the gold.

The production of placer gold in the county was mainly from the Slate Creek mining district, but the total value is unknown. From 1904 to 1947 only $45,809 in placer gold is accredited to Whatcom County. The most productive years were 1904, 1906, and 1907. In 1906 one hydraulic and two sluice mines produced $14,100. In 1907 one hydraulic and four sluice operations produced $13,700, and in 1904 one sluice operation produced $8,000 in placer gold. The production of placer gold as reported by the U.S. Bureau of Mines (U.S. Minerals Yearbooks) for other years is as follows:

Placer gold production, Slate Creek mining district, 1904-1947

Year	*No. of operations*	*Production (dollars)*
1904	1	$ 8,000
1905	1	2,140
1906	3	14,100
1907	5	13,700
1908	4	5,560
1910	1	26
1911	1	189
1915	2	489
1926	1	58
1935	1	77
1941	2	210
1947	1	1,260
	Total	$45,809

The Northwest Mining Journal of August 1908 reported that $2,000,000 in placer gold had been mined in the Slate Creek district prior to 1908. However, this amount cannot be verified and the actual production is probably closer to $200,000. Some gold undoubtedly was sold in other states and to sources other than the United States Mint. Since 1947 the production of placer gold in the county has been insignificant.

In the Slate Creek mining district, Ruby Creek proved to be the most productive creek, especially the area from Mill Creek to Granite Creek. Some gold also was recovered from Slate Creek between Canyon and

Bonita Creeks. Smaller amounts of placer gold were washed from the gravels of Granite, Mill, and upper Canyon Creeks. One of the largest placer mining operations of the district was at the mouth of Ruby Creek. In the late 1890's and early 1900's the Ruby Hydraulic Gold Mining Co. worked claims that extended 2 miles up the creek from its confluence with the Skagit River. Because of the construction of Ross Dam, the area of the claims was flooded in 1947.

In the Mount Baker mining district, placer mining has been carried on sporadically since the 1860's, but not to the extent of the operations in the Slate Creek district. Small-scale placer operations were numerous along the banks of the South Fork of the Nooksack River from Saxon to Howard Creek. The gold was fine grained, but some small nuggets about the size of rice grains were recovered; many miners recovered only 50 cents of placer gold per day. Elsewhere in the district, small amounts of placer gold were recovered from Bell Creek on Sumas Mountain and from Wells, Swamp, and Silesia Creeks north of Mount Baker. Evidence of old small-scale operations also can be found on Ruth Creek and on the North Fork of the Nooksack River north of Mount Shuksan. Some placer gold also was recovered along the upper reaches of the Baker River, as well as along several of its tributaries. A few flakes

TABLE 23.—*Placer mines of the Slate Creek mining district*

Index no. on Plate 2	Property	Location		Remarks	Reference
95	Combination	SW¼ sec. 35 and SE¼ sec. 34, (38-17E)	At confluence of Slate and Bonita Creeks.	Patented claim with some excavations in gravels.	
96	Farrar	Sec. 32, (38-17E)	On Slate Creek between Lime and Darlington Creeks.	Production of up to several hundred dollars per year until 1948.	Huntting, 1955, p. 132.
97	King Tut	Center sec. 3, (37-17E)	On Slate Creek 0.7 mile below Bonita Creek.	Small-scale sluice operation carried out during summer months by Harry Tuttle, Copalis Beach, Wash.	
98	Lazy Tar Heel	Secs. 10, 11, and 12, (37-14E)	On Ruby Creek between Panther and Granite Creeks.	Some production in 1939.	Huntting, 1955, p. 132
99	Nip and Tuck (Tanya)	Sec. 11, (37-14E)	On Ruby Creek above Crater Creek.	5 placer claims with 50¢ per yard material reported.	Huntting, 1955, p. 133.
100	Old Discovery	SE¼ sec. 9, (37-16E)	On Ruby Creek 2 miles above Granite Creek.	Placer gold in old stream channel well above present stream level. Several hundred thousand dollars produced in the late 1800's and early 1900's.	Hodges, 1897; Huntting, 1955, p. 133.
101	Park	NW¼ sec. 34, (38-17E)	In Allen Basin about 1 mile southwest of New Light mine.	Patented claim, no signs of work.	
102	Rose Bud and Snowslide	NE¼ sec. 17, (37-16E)	On Canyon Creek from ¼ to ½ mile above Granite Creek.	Also known as Bice and Wilken claims. Two men averaged $10 per day working claim in crude way.	Adair, 1906.
103	Ruby Creek	Sec. 3, (37-17E)	On Slate Creek downstream from Bonita Creek.	Operated by Granite Creek Mining Co. in 1906 and 1908.	Huntting, 1955, p. 133.
104	Scougale	Sec. 36, (38-13E) and sec. 31, (38-14E)	Claims extend 2 miles up Ruby Creek from confluence with Skagit River.	Gravels 35 to 200 ft. deep containing 25¢ to $1 per yd. in gold. One 80-ft. shaft showed 80¢ per yd. at bottom of shaft. Operated by Ruby Hydraulic Gold Mining in late 1800's. Produced $950 in 6 weeks during 1897.	Hodges, 1897.
105	Wild Goose	NW¼ sec. 32, (38-17E)	On Slate Creek about 1 mile above Canyon Creek.	Small-scale operations by E. G. Fisher, Marblemount, Wash.	
106	Woodrich	Secs. 9 and 10, (37-16E)	On Canyon Creek about 2 miles above Granite Creek.	Gravel bar 5 to 20 ft. thick and 300 ft. long. Operated in the 1930's, and 1½- to 2-oz. nuggets found.	Huntting, 1955, p. 133.

of placer gold can be recovered from most streambeds of western Whatcom County. The source of this gold appears to be the Chuckanut Formation, which contains ancient placer deposits or glacial silts that contain flour gold.

The placer claims of the county that had little, if any, production are too numerous to be discussed individually. As mentioned previously, placer gold production in western Whatcom County has been insignificant, and not all the names of the claims that did produce are known to the writer. However, the streams that were worked for placer gold and the streams that were heavily staked with placer claims are shown on Plate 2. In Table 23 are listed the principal claims of the Slate Creek mining district, as well as the patented placer claims.