STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND EARTH RESOURCES

COAL RESERVES

OF

WHATCOM COUNTY,

WASHINGTON

By

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May 1975

Errata Sheet, COAL RESERVES OF WHATCOM COUNTY, WASHINGTON

P.5 Since this report was written, the leasing policies of the Washington State Department of Natural Resources have changed. Instead of issuing mineral leases on the first-come, first-serve basis that has prevailed in the past, Department of Natural Resources plans to make state land available under a competitive-bid system.

At this writing, policy has not been formulated as full details of the proposed competitive-bid process have not been worked out. Interested parties should write the following address:

Washington State Department of Natural Resources
Division of Land Management
c/o Public Lands Building
Olympia, Washington 98504
Attention: Carl R. McFarland

P.58, line 4 should read R7E instead of R27E

P.78, 6th-line from bottom should read T38N instead of T36N

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PREFACE

Within the past 12 to 18 months, the small, almost unknown Middle East countries have vividly demonstrated to the rest of the world only a fraction of the political power available to them by banding together to control petroleum supplies and prices. By Presidential mandate a program has been embarked upon to make this nation self-sufficient in energy within 25 years.

Among the various alternate energy sources is coal. Due to handling inconveniences and stricter clean-air standards, the use of coal as an energy source plays a lesser role than do gaseous and liquid petroleum fuels However, on a uniform Btu basis, domestic coal resources of the United States are greater than those of petroleum, natural gas, oil shale, and bituminous sandstone combined. When viewed in this perspective, coal has come into sharper focus as a source of not only energy, but for synthetic lubricants as well.

A survey of known coal reserves here in Washington (1961) indicates at least 2,750 million tons of measured coal, although at present there are but two working mines in the state. Clearly, a vast reserve of energy lies at our feet, as yet untapped.

The following compilation of available data regarding the various coal mining areas of Whatcom County was made in response to the search for new and exploitable sources of energy. Of particular interest at the present (May 1975) is the anthracite deposit near the town of Glacier in Whatcom County and also the Hamilton-Cokedale area in northern Skagit County. Corporations involved in the promotion of these properties have announced plans to begin drilling and developing coal reserves. Consistent with the findings, production from operating coal mines in the two locations could be of a commercial volume within 5 years.

INTRODUCTION

Whatcom County's 2,082 square miles is contained in a roughly rectangular parcel, which measures 100 miles east to west and 25 miles north to south. It is bounded on the north by the Canadian-United States boundary, on the east by Okanogan County, on the south by Skagit County and on the west by San Juan County and the Strait of Georgia. The eastern two-thirds of the county is within the Mount Baker National Forest. The remaining western one-third is the area under investigation in this report and is shown in figure 1. The economic base of western Whatcom County is best described as diverse. Petroleum products are produced from both the Mobil and Arco refineries, and aluminum ingots are produced at the Intalco Corporation. These three "heavy" industries are located in close proximity to one another, west of Ferndale. The Georgia-Pacific Corporation in Bellingham produces pulp and paper products. Uniflyte, Inc. is known in maritime circles for its commercial and pleasure boats.

Near optimum conditions in the Whatcom lowland has allowed development of an extensive dairy-farming industry, while agriculture, fishing and lumbering are also important contributors. Moen (1969) notes in times past that mineral production has exceeded the value of logging, but present economic trends may indicate a future reversal of present patterns. An increasing number of mining and exploration companies have spent considerable sums in recent years in both metallic and nonmetallic mineral explorations.

ACCESS

Whatcom County is accessible by rail, ship, auto and air travel. Interstate 5 connects Bellingham, the county seat, with both Vancouver, B.C. to the north and the Seattle-Tacoma-Everett population centers to the south.

The Burlington Northern railroad serves the western part of Whatcom County; railroad access to the eastern part extends as far as Maple Falls on the Nooksack River.

Bellingham, Washington is a deep-water port with excellent cargo handling facilities and spacious berthing facilities for deep-draft vessels.

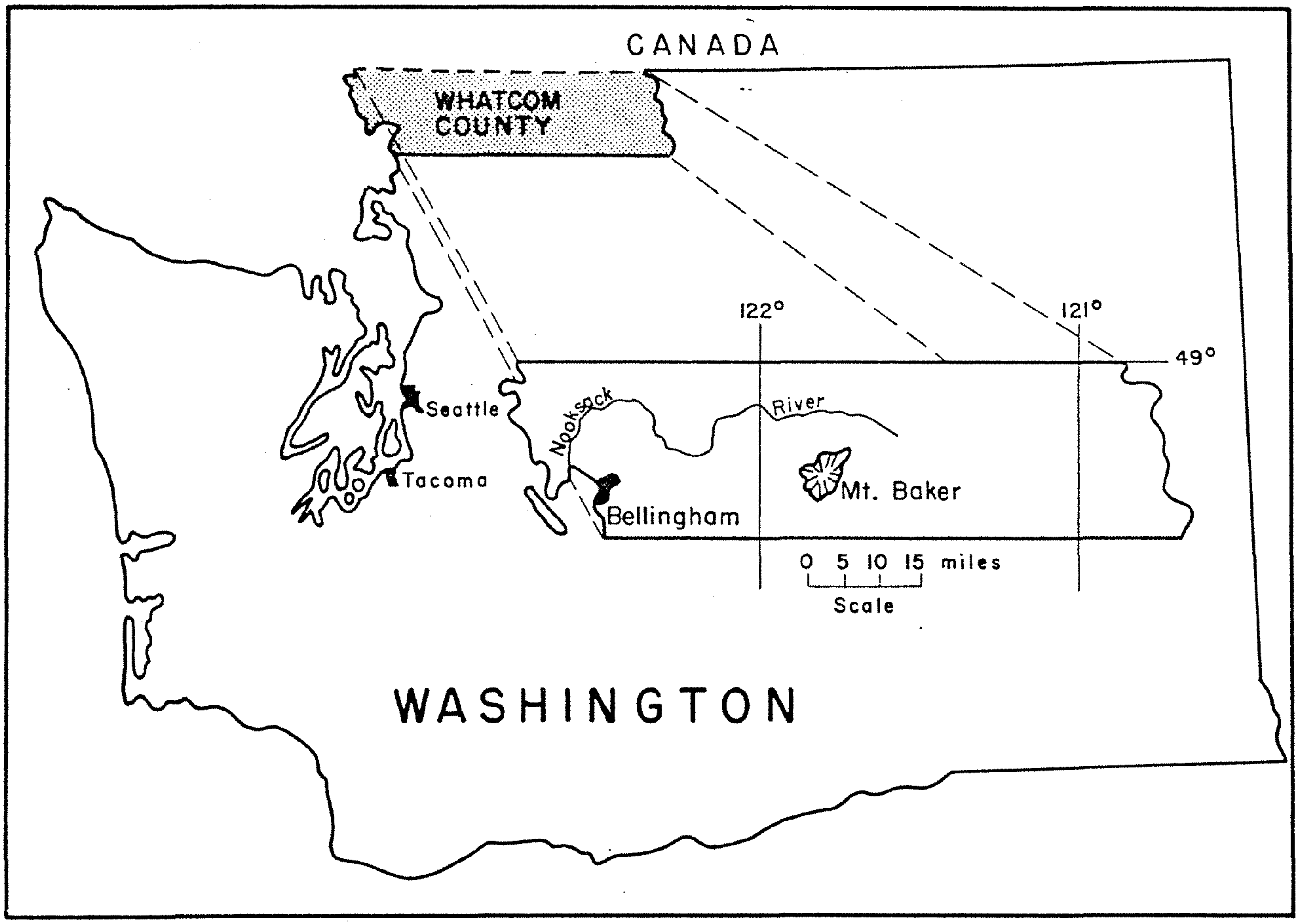


FIGURE 1.—Area of report.

Bellingham International Airport is a lighted and hard-surfaced 5,000-feet facility and will handle up to, and including, medium-size turbine and conventional aircraft.

PHYSIOGRAPHY AND CLIMATE

Whatcom County is composed of two major physiographic provinces. The western one-fourth of the county is dominated by the Whatcom lowland, a northerly extension of the Puget Lowland physiographic province. Within the Whatcom lowland, the Nooksack River has developed a broad alluvial plain. This plain in punctuated by low, gently rolling hills which nowhere exceed 600 feet in elevation above sea level. The Nooksack and its tributaries drain both Canadian and American soil, totaling over 1,000 square miles in areal extent.

To the east, the Cascade Mountains comprise the remaining 75 percent of the county's area; relief is moderate to extreme and access is limited to occasional logging roads and river valleys. The highest points are Mount Baker (10,778 feet) and Mount Shuksan(9,127 feet) and occur near the center of the county. From Mount Baker to the Cascade crest, the average summit is between 6,000 and 7,000 feet in elevation; the terrain is very mountainous and is generally accessible only by trail (figure 2).

Whatcom County enjoys a modified marine climate. Summer temperatures average less than 80°, while winter temperatures average greater than 20°. In the Whatcom lowland, winters are mild and summers are warm and fairly dry. Most of the 35-inch mean annual precipitation in the Whatcom lowland occurs as rain during the spring and fall months.

Farther east, precipitation as high as 140 inches per year falls on the mountains. This precipitation serves to form a deep snowpack that is present into late summer above 4,000 feet; on the higher mountains, this moisture is stored permanently in the form of glacial ice.

LAND OWNERSHIP

The area under consideration in this report consists of roughly 750 square miles of land. Of this, approximately 82 percent is under private ownership and

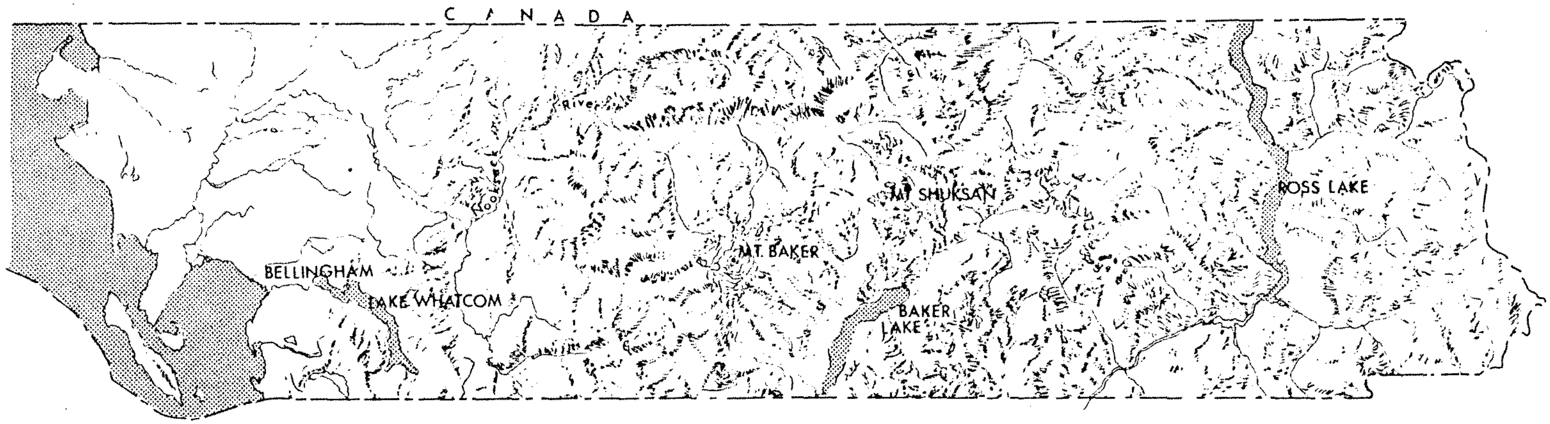


Figure 2 - Relief Map of Whatcom County, Washington

18 percent is owned by the state. Less than 1 percent is federally owned land. Included within the private land category are both individuals and timber companies.

The overall definition of state-owned land includes the following categories:

1. School lands
2. University lands
3. Highway rights-of-way
4. State forest lands
5. Deeded lands
6. State parks
7. Institutional lands
8. Tidelands
9. Offshore lands
10. Navigable streams and lakebeds
11. Land under management of the Departments of Fisheries and Game

On the accompanying map (plate 1), Washington State land ownership in Whatcom County is shown. Data for this map were gathered in March, 1975 and is accurate only insofar as the parent documents are concerned. Since land ownership is constantly changing, the map should be used only as a general guide, and all questions regarding state land ownership should be referred to the State Commissioner of Public Lands, Department of Natural Resources, Olympia, WA 98504.

All state-owned land is open to coal prospecting and exploration under the terms set forth in Chapter 79.01.652 - 79.01.692 RCW. Briefly, individuals who contemplate drilling or open-pit explorations are required to apply for a coal option contract. This lease is good for 2 years from date of issue and allows the lessee access to state-owned land for exploratory work and prospecting necessary to determine the presence of coal. The area under lease must be less than 1 section (640 acres) and more than one-sixteenth section (40 acres).

Assuming the lease-holder is successful in his efforts to find coal, he may (prior to lease expiration) present proof of required development work and apply for a coal mining lease. This lease is good for twenty years from date of issuance. Under the terms of the lease, the holder pays a royalty per long-ton (2,240 lbs.) of coal, ranging from 10 cents per ton for lignite grade to 20 cents or more for anthracite grade coal. A minimum royalty of $1 per acre to a maximum royalty of $10 per acre is stipulated. In addition, the lessee gives the state unrestricted examination and inspection privileges over operations, workings, and records and also deeds timber and sand-and-gravel rights to the state for its disposal.

The most accurate and up-to-date source of private-land-ownership information is the county assessor plat books, usually found in the county assessor's office in the county court house (Bellingham is the Whatcom County seat). These plat books are kept as up to date as possible, since they are used in tax-determination purposes.

They are a part of the public record and free access to them is allowed, although they are not for sale. Individual sheets showing land ownership within a county may be purchased from either of the two most popular sources: the Metzker Map Co. or the Kroll Map Co., both of Seattle, Washington.

For a more rigorous treatment of land ownership and leasing information, the reader is referred to Information Circular No. 36, "Mineral Rights and Land Ownership in Washington," by W. S. Moen, and to a pamphlet entitled "Rules and Regulations for the Management of Mineral Resources" by the State Department of Natural Resources.

ZONING CONSIDERATIONS

Zoning restrictions, as they would effect exploration drilling and mine development, appear to be nonexistent in the majority of the areas covered in this report. For the most part, areas under consideration in this report are part of unclassified districts; these districts are referred to as "General Protection Districts" by the Whatcom County Planning Commission. Any mining activities contemplated in General Protection Districts would be considered individually under a Conditional Use Application and would be subject to certain unique restrictions commensurate with present property uses.

Those exceptions to the General Protection classification include property along the southwest shore of Lake Whatcom (Rocky Reach area, Manley's Camp area), which is zoned generally as residential area, and the area north of Ferndale (Enterprise reserve). Zoning restrictions in these areas have permanently halted mining activities of any sort (Jim Chin, Whatcom County Planning Commission, oral communication, April 1975).

Contemplated mining activities within the Bellingham city limits (such as reactivation of Bellingham No. 1 mine) would be subject to city and county zoning restrictions. The northern and westernmost extent of Bellingham No. 1 workings end at McLeod and Bennett Roads (respectively) and roughly coincide with present-day city limits. Development and subsequent mining outside of these limits would, however, not be subject to the General Protection District regulations, since the county land in discussion is considered Precisely Zoned Areas. Presumably, more stringent regulations are in effect in areas such as these, (Bob Anderson, Bellingham City Planning Commission, oral communication, April 1975).

A further in-depth treatment of both city and county zoning regulations and restrictions is beyond the scope of this paper. The interested reader is referred to the respective planning commission offices for more detailed answers to zoning-related questions.

PREVIOUS WORK

The rocks of the Chuckanut Formation were assigned to the Puget Group by White (1888), who studied the coal measures of the Puget Sound basin. Willis (1886) and Landes (1902) studied the stratigraphy and structure of the Puget rocks from a coal-mining aspect.

I. C. Russell (1899) was the first to report on selected areas within Whatcom County. A geological reconnaissance by Smith and Calkins (1904) traversed the Cascade Mountains from east to west and gained much geologic information in the process. Woodruff (1914) described the Glacier anthracite deposit on the eastern border of the coal measures. Jenkins (1923) undertook a rigorous and detailed work of the Whatcom County coal measures; his work, although dated, is perhaps the most complete description of Whatcom County coal geology thus far. McClellan (1927) first used the term "Chuckanut Formation" and assigned an Eocene age, but subsequent work by Pabst (1968, posthumous) showed that the Chuckanut Formation was time-transgressive from Cretaceous to Paleocene. Glover (1935), in addition to measuring two type sections south of Bellingham, also retained the usage of the term "Chuckanut Formation" and did extensive work on the structural features of the formation in Whatcom and Skagit Counties. Weaver (1937) determined the areal extent of the Chuckanut Formation and, remeasuring the type sections established by Glover, found a probable formation of approximately 12,000 feet in thickness.

Beikman and others (1961) reviewed the findings of previous workers and estimated coal reserves by township and range for those areas of the county underlain by coal-bearing rocks.

Miller and Misch (1963) studied the structural relationships and concluded that an angular unconformity existed at the front of the Cascade foothills. Subsequent reinterpretation of salient structural features, aided by pollen determinations (Fisher, written communication, 1961) strongly suggests the presence of a two-fold sequence of coal-bearing rocks north and east of Bellingham.

Glaeser (1958, 1960, 1962) reporting on the results of an exploratory drilling program, noted an additional 2.08 million tons of coal otherwise unreported by previous workers. Moen (1969), using data from Glaeser (1962), calculated an additional 6.03 million tons of reserves.

ACKNOWLEDGMENTS

The writer, in making this present compilation of data, is indebted to those previous workers who concerned themselves with Whatcom County geology and coal occurrences. These workers are given due credit where their contributions are mentioned.

The writer also thanks the staff of the Division of Geology and Earth Resources for their cooperation and many helpful comments during drafting of the manuscript.

GEOLOGY

GEOLOGIC SETTING

The geology of Whatcom County is fairly complex with classic examples of large-scale faulting and folding. Geologic time units, while not all-inclusive, range from Devonian to Eocene.

In general, younger rocks crop out in the western part of Whatcom County while outcrops of older rock units are restricted mainly to those areas of greater relief in the more easterly part of the county.

Beginning at the eastern border of Whatcom County, the most dominant rock unit is a sequence of Lower Cretaceous marine rocks that crop out between the county line and Ross Lake. These rocks are part of the Dewdney Creek Group and the Pasayten Formation and consist mainly of sandstones, shales, phyllites, and arkoses, with minor conglomerates. This area has been intruded by granodiorite and quartz diorite plutons, which are genetically related to emplacement of the Chilliwack batholith of Tertiary age.

Superimposed on the western border of Dewdney and Pasayten rocks in an overthrust relation is a klippe of older Paleozoic with interbedded cherts, argillites, and tuffs of the Hozomeen Group.

Farther west, the dominant unit is the pre-Upper Jurassic Skagit Gneiss. The unit is exemplified by a variety of hornblende, biotite, and quartz dioritic gneisses (many migmatitic), locally intruded by small granitic plutons. The northwest extreme of the unit has been massively intruded by Tertiary granitic rocks of the extensive Chillawack batholith.

Adjoining the Skagit Gneiss and the Chilliwack batholith to the west are the eastern margins of two metamorphic thrust sheets. The first includes a narrow band of slates, metasediments and minor limestones of the Darrington Phyllite, while the second, of greater area, is composed of greenschist and schistose metaconglomerates. The impressive and often-photographed Mount Shuksan massif is composed almost entirely of this largest schist unit.

The Darrington Phyllite again crops out to the west and becomes one of the dominant rock units of south-central Whatcom County. An erosional window or fenster has developed within the Shuksan thrust sheet, exposing marine sediments and volcanics of the Chilliwack Group. In the center of the fenster, porphyritic andesites, tuffs and agglomerates have been extruded onto Darrington Phyllite to form the Quaternary stratovolcanic cone of Mount Baker. On the north, Baker volcanics lap unconformably upon marine sediments, low-grade metamorphics, and occasional basic volcanics of the Jurassic-Cretaceous Nooksack Group, in turn overthrust to the north upon sediments of the Permian-Carboniferous Chilliwack Group.

To the southwest of Mount Baker lies the spectacular Twin Sisters range. It is the largest known mass of olivine on the North American continent, with some 12 cubic miles of exposed volume (Moen, oral communication).

On the southwest border of Whatcom County are found unnamed sediments and metasediments, with attendant cherts and greenstones, of pre-Tertiary age. North of this area lies the Whatcom basin, a structural low composed of moderately folded Chuckanut sandstones plunging generally northwest. The Chuckanut sandstone is one of two coal-bearing formations of Whatcom County; it crops out in a diagonal band running northeast-southwest and underlies and area of approximately 500 square miles.

Weaver (1937) describes the Chuckanut Formation as:

> . . . essentially a massive cross bedded to stratified, medium- to coarse-grained grayish-brown to brownish-gray sandstone. There are subordinate amounts of sandy shales, varying in color from gray to light and dark-brown. Conglomeratic lenses reach thicknesses that locally exceed 100 feet.

A type section measured by Weaver along Chuckanut Drive showed a thickness approaching 12,000 feet; a section measured along the west shore of Lake Whatcom showed a thickness of 8,930 feet at that location.

Deposition of the Chuckanut Formation was within a rapidly subsiding geosynclinal trough where the rate of subsidence kept pace with, or was slightly ahead of, deposition. The structural continuity of the geosynclinal trough at one time across the present Cascade Range has been demonstrated by various individuals. The Chuckanut Formation was mapped farther to the southeast by Vance (1957) as the Swauk Formation. A belt of continental sediments extends northwest from the Swauk type locality in north-central Washington. The lower portions of the Guye Formation near the Snoqualmie Pass area are correlative with the upper Swauk, according to Foster (1955). Vance (1957) also noted the presence of Swauk sandstone near the summit of Jumbo Mountain in eastern Snohomish County and on Mount Higgins in northwest Snohomish County. Present outcrop patterns thus delineate the Swauk as a formation with one of the largest regional extents in the Cascade Mountains.

The source area for the Swauk-Chuckanut sediments was thought to be a granite upland, since detrital quartz and plagioclase are predominant in the unit (Vance, 1957). Mackin and Cary (1965) favor the Wenatchee area as a provenance for the sediments and suggest the name Weaver Plain for the low coastal plain of deposition.

The Chuckanut Formation is strongly folded, but the folds are regular and regionally open. Local overturning is noted by previous workers (Jenkins, 1923). Most of the folds plunge away from the Northern Cascades in a northwesterly direction.

Differential warping of the crust within the depositional area produced changes in the gradients of all the streams, with a resultant overlapping and coalescing of adjacent alluvial fans. Ponding was widespread and irregular shaped lakes within the area accumulated stratified sandy clays together with the remains of semitropical vegetation.

Pabst (1968) studied the fossil flora of the Chuckanut Formation and determined the age to be time-transgressive from the Cretaceous Period to the Eocene Epoch.

The second coal-bearing formation of Whatcom County is the Huntingdon Formation, considered by Miller and Misch (1963) to be middle and(or) upper Eocene in age. It is similar to the Chuckanut Formation in that it displays medium-grained arkosic sandstones, sandstones, siltstones, and shales of an entirely terrestrial provenance. Thus, outcrops of both Huntingdon and Chuckanut rocks appear almost identical. Apparently, earlier workers were deceived by the similarities, for the two formations were mapped as Chuckanut as late as 1960.

Miller and Misch (1963) recognized the existence of an angular unconformity of early Eocene age between the Huntingdon and Chuckanut Formations. This unconformity is roughly coincindental with the obvious topographic break that exists between the Whatcom lowland on the north and the more hilly areas to the south (see plate 2).

Convincing lines of evidence have been presented for the existence of the unconformity between Chuckanut and Huntingdon rocks. The best exposures are visible on the west side of American Sumas Mountain (SE$\frac{1}{4}$ T. 39 N., R. 4 E.) (Miller and Misch, 1963).

1. Dip angles near the unconformity become noticeably steeper than those farther north of the contact. This phenomenon is best shown on the north side of Squalicum Mountain (secs. 11 and 12, T. 38 N., R. 3 E.), where dip angles change as much as 45° in less than one-quarter of a mile, and on the hill in T. 38 N. and T. 39 N., R. 4 E. (known locally as Lookout Mountain but unnamed on U.S. Geological Survey quadrangle).
2. A marked discordance is noted when dominant regional structural fabric and degree of deformation within the two rock units is compared. Folds within the Chuckanut are noticeably tighter with attendant steeper dips and trend generally northwest-southwest (Chuckanut Mountain T. 37 N., R. 3 E.), while folds in the Huntingdon are broad and open with dips averaging 10° to 15° in the area north of the unconformity (Goshen-Fazon Lake area, T. 39 N., R. 3 E.).
3. Spore and pollen analyses of cuttings from wells drilled in the Whatcom lowland suggest the presence of a section of Huntingdon Formation of approximately 2,500 feet in thickness. According to Fisher (1961), analyses below that level indicate an Eocene-Cretaceous age and suggest the presence of the Chuckanut Formation below the Huntingdon in that area (table 1).

Misch (1966) notes the presence of the pre-Huntingdon, post-Chuckanut Boulder Fault, which trends generally northeast and southwest. Truncation of the Chuckanut folds by this fault leads Misch to suggest a displacement of some 5,000 vertical feet along the fault which he considers to be a tectonic boundary between the upthrust Coast Range block to the north and the downdropped Nanaimo-Chuckanut block to the south (Miller, Misch, 1963). Huntingdon sediments cover the fault trace to the west, but no displacement has been observed along the basal contact between Huntingdon and Chuckanut rocks.

Structural relationships near the city of Bellingham and immediately north remain somewhat obscure and the location of the unconformity is known only approximately.

TABLE 1.—Spore and pollen determinations on selected well samples Whatcom County, Washington[1/]

Well name and location	Lithology-depth	Age	Formation
Chamber of Commerce No. 5 SW. cor. sec. 27, T. 39 N., R. 2 E.	Coal, depth unknown	Eocene	
Ferndale Community No. 1 SW¼NE¼ sec. 5, T. 39 N., R. 1 E.	726- 746	Barren	
	1150-1562	Barren	
	1990-2000	Barren	
	2455-2471	Eocene	Huntingdon
	2896-2900	Eocene-Cretaceous	Chuckanut
	4069-4074	Eocene-Cretaceous	
	4354-4359	Eocene-Cretaceous	
Hillebrecht No. 1 NW¼SE¼ sec. 6, T. 39 N., R. 3 E.	Coal, shale; depth unknown	Eocene	Huntingdon
King No. 1 SE¼SW¼ sec. 27, T. 39 N., R. 2 E.	Coal 70-120	Eocene	Huntingdon
	Coal, shale 845-860	Eocene	
	Coal 1085-1090	Eocene	
	Coal, shale 1135-1145	Eocene	
Lange No. 2 SE¼NE¼ sec. 28, T. 39 N., R. 2 E.	Coal, 1700	Eocene	Huntingdon
Pelican Dome No. 1 SE¼, sec. 32, T. 38 N., R. 3 E.	Shale, 540-545	Eocene-Cretaceous	Chuckanut
	Coal, shale 4065-4075	Eocene-Cretaceous	
Peoples No. 1 SW¼NW¼ sec. 27, T. 39 N., R. 2 E.	Coal, shale 900-910	Eocene	Huntingdon
Peoples No. 2 NW¼NE¼ sec. 34, T. 39 N., R. 2 E.	Coal 470-475	Eocene	Huntingdon
	Sandstone, coal 994-998	Eocene	
	Sandstone, coal 1350-1355	Eocene	
Peoples No. 6 SW¼SW¼ sec. 28, T. 39 N., R. 2 E.	Coal, 560	Eocene	

TABLE 1.—Spore and pollen determinations on selected well samples Whatcom County, Washington[1/] - Continued

Well name and location	Lithology-depth	Age	Formation
Russler No. 1 NW¼SW¼ sec. 13, T. 39 N., R. 3 E.	Coal, shale, sandstone 600	Eocene	Huntingdon
	Coal, sandstone 1150-1160	Eocene	Huntingdon
	Shale, coal 2600-2610	Eocene-Cretaceous	Chuckanut
	Shale, coal 3340	Eocene-Cretaceous	
	Coal 3460	Eocene-Cretaceous	
	Shale, coal 3588-3590	Eocene-Cretaceous	

1/ Determinations made by John C. Fisher, Union Oil Company; unpublished communication dated July 31, 1961.

PRE-PLEISTOCENE TOPOGRAPHY

Water and gas well logs from the Whatcom lowland show that moderate relief had been developed on the topography prior to advances from the north by Pleistocene glaciers. Bedrock encounters in drilled wells in northern and northwestern Whatcom County have demonstrated that Pleistocene fill there extends far below sea level. Easterbrook (1962) mentions that Chuckanut(?) sandstone was encountered northwest of Ferndale at 320 feet. To the east at Enterprise, a well was drilled that encountered bedrock at 545 feet below sea level. A well in Blaine was drilled to a total depth of 746 feet without reaching bedrock. Four miles southwest of Blaine at Birch Bay, the Pleistocene sediments total less than 200 feet in thickness.

In Bellingham some buildings have foundation footings cut directly into Chuckanut sandstone. Bedrock in north Bellingham was encountered at 158 feet below sea level after drilling through 230 feet of Pleistocene material. Just 2 miles to the north, King Mountain, a strike ridge of resistant Huntingdon sandstones and conglomerates, rises to an elevation of 550 feet above sea level.

Bedrock outcrops north of the Anderson Creek-Fazon Lake area have allowed workers to delineate the Goshen anticline, while occasional bedrock outcrops between Everson and Goshen indicate that a pre-Pleistocene topographic high is also present in that area.

More recently, Hall and Othberg (1974) used oil and water well logs to establish data points for an isopach map depicting thickness of unconsolidated sediments for the Puget Lowland. That portion of the map that deals with Whatcom County is of a generalized nature and is shown in figure 3.

COAL DATA

CHARACTERISTICS OF COAL

Coals are classified by rank according to the percentage of fixed carbon they contain and their heat content. Calculations are on a mineral-matter free basis, as seen in table 2. As coal is metamorphosed—through thermal and(or) mechanical means—from lignite through low-volatile bituminous to anthracite, the percentage of fixed carbon within the coal increases, while moisture and volatile material content decrease. These changes are a function of time, compaction, depth

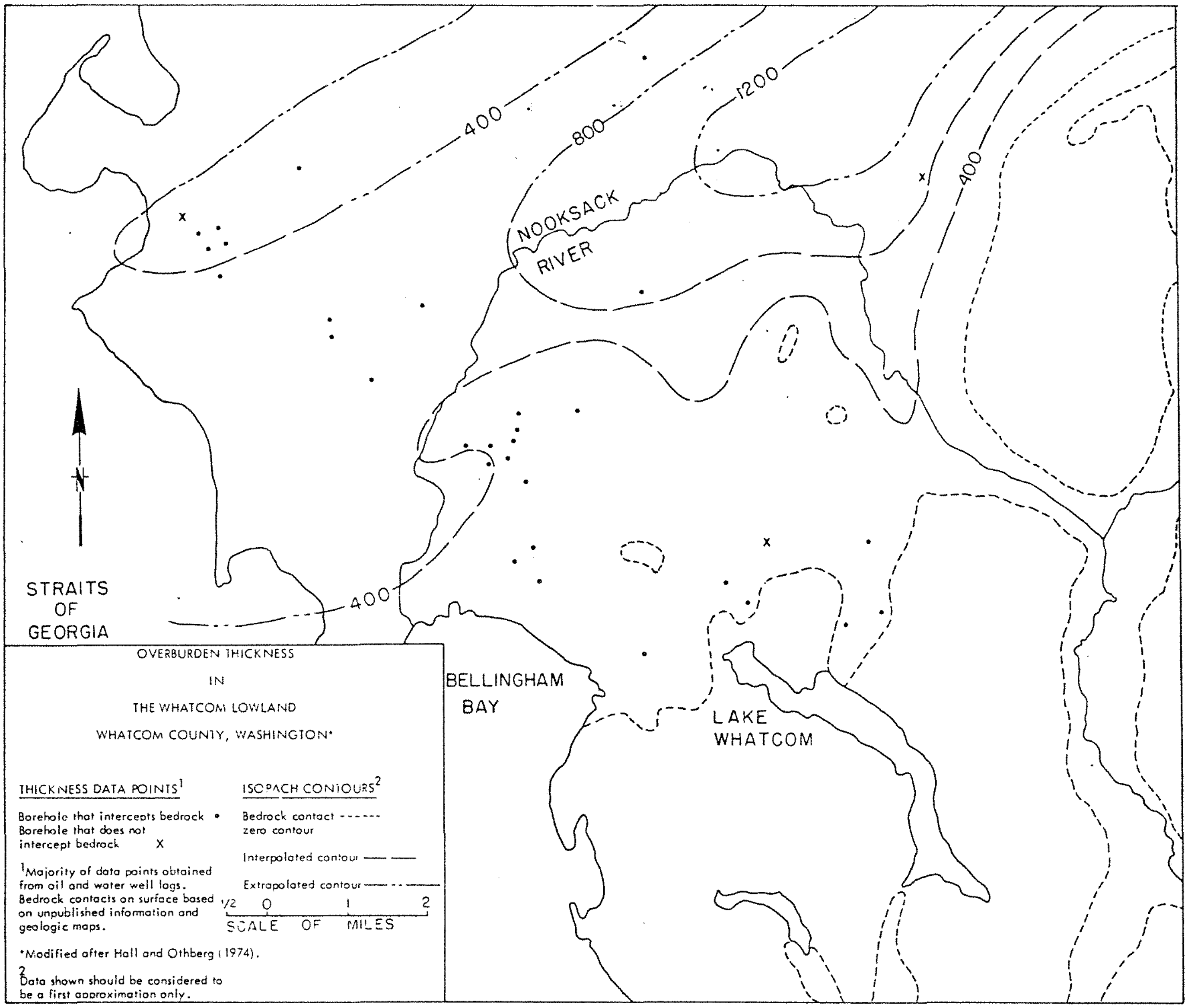


FIGURE 3.—Isopach map of Whatcom County.

Table 2.--Classification of coals by rank*

Explanation: FC, fixed carbon; VM, volatile matter; Btu, British thermal units.

This classification does not include a few coals that have unusual physical and chemical properties and that come within the limits of fixed carbon or Btu of the high-volatile bituminous and subbituminous ranks. All these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

[From American Society for Testing Materials (1951, p. 75)]

Class	Group	Limits of fixed carbon or Btu mineral-matter-free basis	Requisite physical properties
I. Anthracitic	1. Meta-anthracite	Dry FC, 98 percent or more (dry VM, 2 percent or less)	
	2. Anthracite	Dry FC, 92 percent or more and less than 98 percent (dry VM, 8 percent or less and more than 2 percent)	
	3. Semianthracite	Dry FC, 86 percent or more and less than 92 percent (dry VM, 14 percent or less and more than 8 percent)	Nonagglomerating 1/
II. Bituminous 2/	1. Low-volatile bituminous coal	Dry FC, 78 percent or more and less than 86 percent (dry VM, 22 percent or less and more than 14 percent)	
	2. Medium-volatile bituminous coal	Dry FC, 69 percent or more and less than 78 percent (dry VM, 31 percent or less and more than 22 percent)	
	3. High-volatile A bituminous coal	Dry FC, less than 69 percent (dry VM, more than 31 percent); and moist 3/ Btu, 14,000 4/ or more	
	4. High-volatile B bituminous coal	Moist 3/ Btu, 13,000 or more and less than 14,000 4/	
	5. High-volatile C bituminous coal	Moist Btu, 11,000 or more and less than 13,000 4/	Either agglomerating or nonweathering 5/
III. Subbituminous	1. Subbituminous A coal	Moist Btu, 11,000 or more and less than 13,000 4/	Both weathering and nonagglomerating
	2. Subbituminous B coal	Moist Btu, 9,500 or more and less than 11,000 4/	
	3. Subbituminous C coal	Moist Btu, 8,300 or more and less than 9,500 4/	
IV. Lignitic	1. Lignite	Moist Btu, less than 8,300	Consolidated
	2. Brown coal	Moist Btu, less than 8,300	Unconsolidated

1/ If agglomerating, classify in low-volatile group of the bituminous class.

2/ It is recognized that there may be noncaking varieties in each group of the bituminous class.

3/ Moist Btu refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

4/ Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

5/ There are three varieties of coal in the high-volatile C bituminous coal group, namely, variety 1, agglomerating and nonweathering; variety 2, agglomerating and weathering; variety 3, nonagglomerating and nonweathering.

* From Beikman and others, 1961, p. 3.

of burial, heat, and the amount of structural deformation the area has been subjected to. Rank, then, is another way of describing a particular coal in terms of the metamorphic forces it has been subjected to.

Since coals of varying rank have different uses, rank of coal within a given area is a major factor taken into consideration when determinations of remaining and available coal resources are made. No adjustments are made for Btu values, since the pattern would change due to lower heat values of lignite and subbituminous. Instead, reserves are calculated on a tonnage basis only. The standard coal classification chart accepted throughout industry is shown on table 2.

Grade of coal is another parameter by which coal is classified. Grade takes into account both sulfur and ash content, plus other constituents that would have an effect of lowering the desirability of a particular coal as a fuel.

Sulfur is considered to be an undesirable element. Forty to 80 percent of the sulfur occurs as either pyrite FeS_2 or its isomorph, marcasite. It lowers the quality of coke and lends brittleness to iron and steel products. Sulfur also accelerates corrosion and allows a buildup of boiler deposits if the coal is used to generate steam. Sulfur, present in stack gases as SO_2, allows the formation of sulfuric acid when in contact with moisture and ultimately increases the chances for pollution of water supply. The sulfur content of Washington coals is low, varying between 1 and 4 percent on the average.

Grading of various coals by sulfur content is fairly standard, but a satisfactory classification scheme strictly on the basis of ash content has not been proposed due to the various parameters involved. The majority of ash content of a given coal is a result of sediments present in the depositional environment at the time the parent material was accumulated. Since sedimentation characteristics may vary considerably over a very short distance, so too will the ultimate ash content of a coal also vary, (Averitt, 1973).

CHEMICAL PROPERTIES OF COAL

In addition to those characteristics of coal previously mentioned, samples are subjected to chemical procedures and tests to further classify them according to their properties.

Probably the least involved and least time-consuming method of illustrating general characteristics of coal is the proximate analysis. Typically, the parameters determined in a proximate analysis include the following:

Moisture content.—Since heat is required to evaporate the moisture contained within the coal, the thermal efficiency of a coal is affected by the amount of moisture. When a coal is considered for a commercial purpose such as steam generation, moisture content becomes important. When the coal is of lower rank, relative moisture compared to caloric value is greater, and moisture content becomes of even greater importance. Moisture content generally decreases with an increase of rank, although a slight rise of $1\frac{1}{2}$ to 2 percent may occur between high rank bituminous and anthracite coals.

Volatile content.—Volatile content indicates the gas and tar yield of a coal and also gives indications of certain combustion characteristics. In coal gasification, a process receiving heavy study in light of the present cost of natural gas, the desirable volatile content is usually over 30 percent (Mitchell, 1943). There is no clear-cut relation between volatile content and rank of coal in the lower ranks, such as peat and lignite, due to compositional differences in the original vegetable matter (Trotter, 1954). In the high bituminous and anthracite rank, it becomes of much greater importance.

Ash content.—Ash is that incombustible material remaining after a coal has been burned to a constant weight. It is an important parameter when fuel value and combustion characteristics are considered; ash disposal is also a problem when large volumes of coal are consumed in industrial and commercial heating applications.

Fixed carbon content.—The fixed carbon content in a proximate analysis is determined by subtracting the moisture, volatile and ash content from 100. Fixed carbon content, as determined in a proximate analysis, also includes small amounts of oxygen, nitrogen, and sulphur and thus does not express true combustible carbon present in a coal. Fixed carbon content increases with the rank of coal.

Caloric value.—Caloric value is determined by measuring the heat rise of a known volume of water in which a bomb calorimeter containing the coal sample has been placed. Oxygen under pressure is then used to fire the sample and the resultant heat rise is measured. The caloric value is expressed in British Thermal Units (Btu), or that quantity of

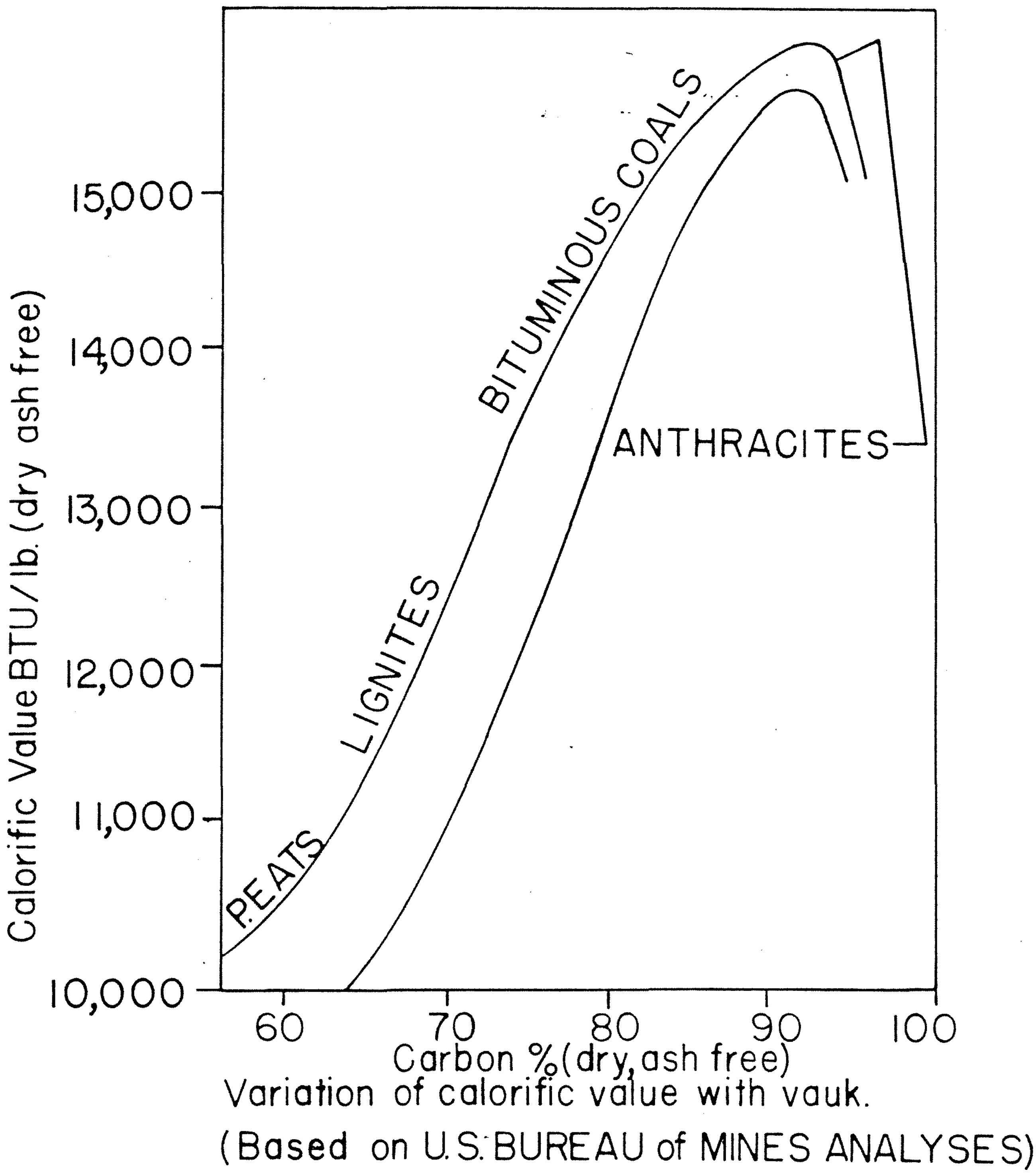


FIGURE 4.—Relationship of caloric value to carbon content in coal.

heat required to raise a pound of water through 1 °F. The relationship of caloric value to carbon content is demonstrated in figure 4.

Sulfur.—Sulfur content has already been discussed in an earlier section as an undesirable element present in coal. Wandless (1959) has shown that microscopic pyrite is freely distributed throughout coals, especially within those coals overlain by marine sediments. Thiessen (1920) feels that some pyrite has an organic origin and is a result of precipitation by bacterial action.

(Moisture, volatile, ash, and sulfur content are all expressed as percentages of the sample weight.)

The ultimate analysis is a more painstaking procedure, in which relative percentages of combustible carbon, oxygen, hydrogen, nitrogen, and sulfur present in the coal are determined.

According to Hickling (1927) . . .

> the oxygen content changes inversely with the rank of coal, varying from over 30 percent in the lower ranks to less than 1 percent in the anthracites. Hydrogen content reaches approximately 6 percent in the bituminous coals and then undergoes a progressive decrease to below 3 percent in the anthracites.

Also taken into consideration are the exclusion of such elements as noncombustible carbon (present in carbonate partings) and the clay minerals, illite and kaolinite, which form a significant proportion of the ash content. Other elements may be noted when they could be deleterious to a manufacturing process (phosphorus) and could pose an environmental and(or) a health hazard (chlorine and arsenic).

The reader is directed to Standard Specification for Classification of Coals by Rank, (American Society for Testing Material Standards 1964, Pt. 8 pp. 1078-83; Designation: D 388-38) for a more rigorous discussion of analytical scheme.

RESERVES

Most of the reserve figures calculated for Whatcom County coals were done by Beikman and others (1961). Certain assumptions regarding Washington coals were incorporated in the calculations. Those assumptions are discussed briefly as follows:

Rank of coal.—Table 2 presents the standard ASTM method used by Beikman and others in classifying coals by rank.

Weight of coal.—Calculations are based on the following values where precise data were not available:

1. Anthracite and semianthracite, 2,000 tons per acre-foot.
2. Bituminous, 1,800 tons per acre-foot.
3. Subbituminous, 1,770 tons per acre-foot.

Bed thickness.—For anthracite and bituminous coals, the following bed thicknesses were applied:

1. Thin, 14 to 28 inches in thickness.
2. Intermediate, 28 to 42 inches in thickness.
3. Thick, 42 inches or over in thickness.

Beikman notes that anthracite and bituminous beds less than 14 inches thick and subbituminous beds less than 30 inches thick are generally considered to be too thin to mine on a profitable basis and thus neglected in final estimates.

Overburden thickness.—For coal mined underground, the reserves presented are divided into the following categories: 1 to 1,000 feet, 1,000 to 2,000 feet, and 2,000 to 3,000 feet. Beikman neglected coal below 3,000 feet in depth as being uneconomical to mine; final estimates do not reflect coal below that depth.

Abundance of reliable data.—Three categories of reserves have been calculated, based on different degrees of reliability.

1. Measured reserves

   Tonnage computed from outcrops revealed in trenches, wells, mine workings, and drill holes.

   Points of observation no more than one-half mile apart.

   Thickness and extent of coal bed defined to point where tonnage is shown to be within ±20 percent of actual tonnage.

2. Indicated reserves

   Tonnage computed partly from specific measurements and partly from projection of reliable data for a reasonable distance. Points of observation generally 1 mile apart but may increase to $1\frac{1}{4}$ miles for beds of known continuity.

3. Inferred reserves

   Tonnages based on a broad knowledge of geologic nature of individual coal beds.

   Good geologic evidence for assumed continuity of coal bed.

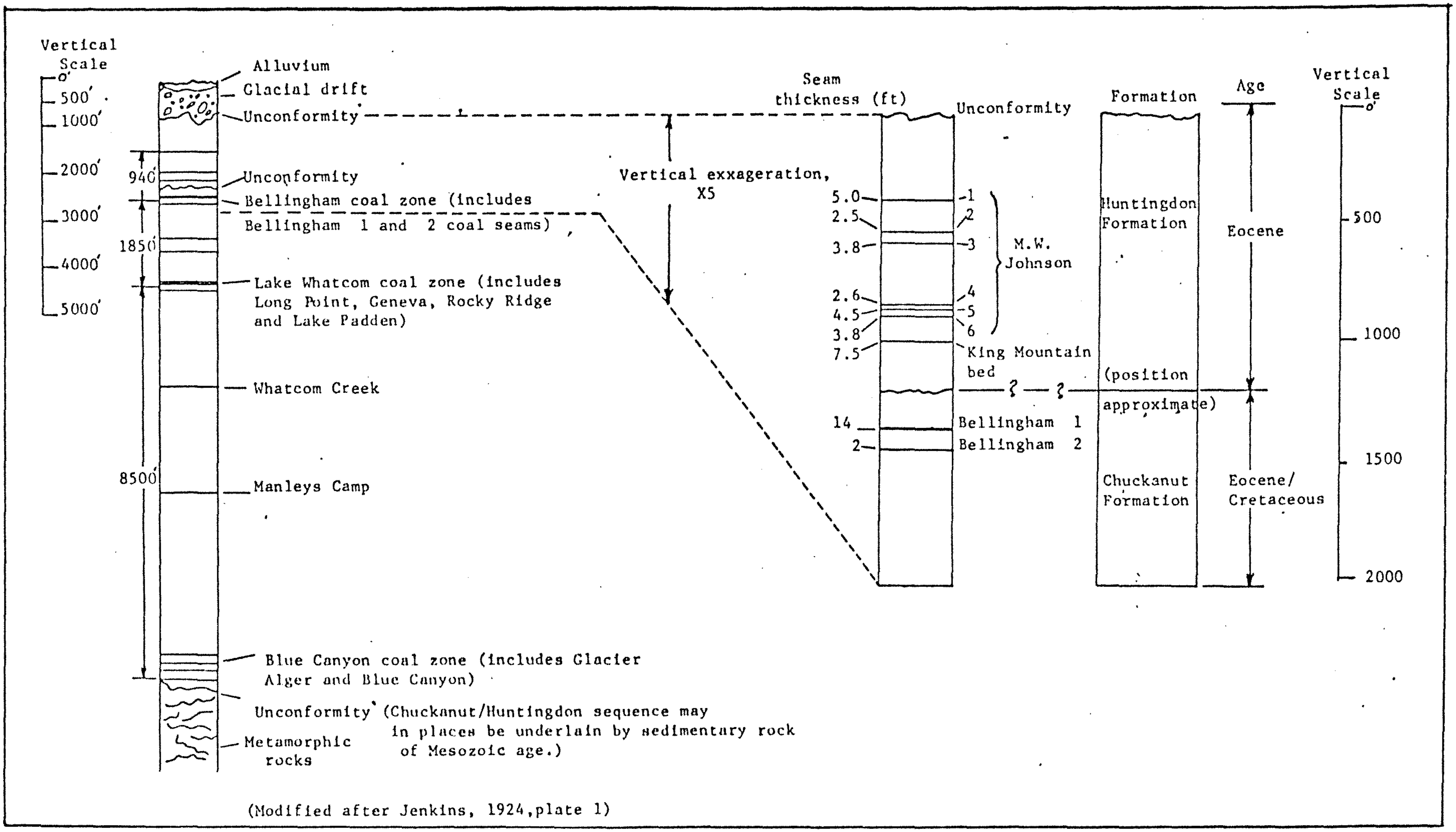


Figure 5. Generalized stratigraphic section of coal-bearing rocks, Whatcom and Skagit counties, Washington.

Beikman notes that there is a scarity of drill-hole, subsurface, and outcrop data within the state. As a result, she suggests that those measured reserves probably comprise less than 10 percent of the total reserves. The combined estimates of both "measured" and "inferred" coal in Whatcom County could no doubt be increased substantially by modest programs of exploration and drilling.

Beikman computed reserves on a township basis. Where total reserves computed for a township apply to only one coal field or coal mine, those figures are considered meaningful and are presented as reserves for that area.

On the other hand, some township figures combine two or more prospects or mines. To separate the reserve figure into component parts according to the map area of mines or prospects in most cases would not be meaninfgul due to questionable accuracy of the map area limits shown. Where two or more coal areas occur within one township, the reader is referred to the summary of coal reserves in table 6.

COAL MINES AND PROSPECTS IN WHATCOM COUNTY

BELLINGHAM COAL MINE

Coal was discovered near the present town of Bellingham in 1852. It was the first discovery in the state and predated the next coal discovery (in Lewis County) by 4 years. Stratigraphic relationships within Whatcom County are generalized in figure 5.

In 1853, the Bellingham Coal Co. was formed to mine the coal. The original opening was made on a coal seam striking N. 75° E. and dipping 70° N. at the present intersection of Railroad Avenue and Myrtle Street. Production figure during the earlier years are not available but a contemporary town writer noted that by October 1867, 1,400 tons a month were being produced (Jenkins, 1923).

Later in the same year, a mine fire caused by spontaneous combustion broke out. Water from Bellingham Bay was used to flood the mine and put the fire out. The mine was pumped out after a year's lapse, but fire broke out again. The mine was flooded and pumped out a second time. Apparently the spontaneous combustion problem had finally been overcome, for the mine was reopened and produced coal for another 11 years. In 1868 the mine was closed permanently.

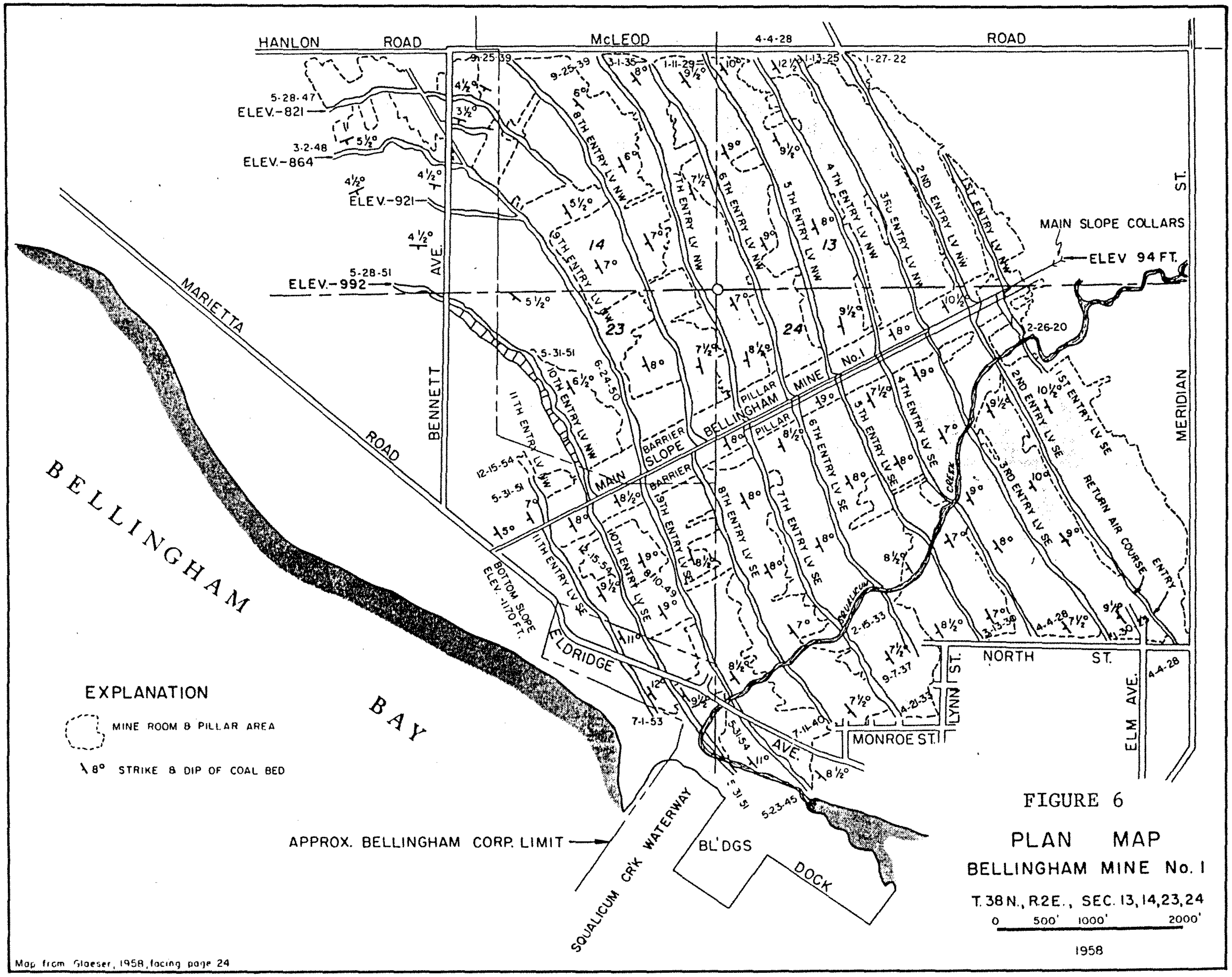


FIGURE 6

PLAN MAP

BELLINGHAM MINE No. 1

T. 38 N., R.2 E., SEC. 13, 14, 23, 24

1958

Bellingham coal had a widespread reputation as a good steam fuel, and the bulk of production tonnage went to San Francisco.

In 1892, R. B. Symington, a mining engineer was employed by the Bellingham Bay Improvement Company to ascertain the existence of the coal seam 2 miles to the northwest of the original mine. An extension of the original coal seam was intersected at a depth of 410 feet below the surface. Mining operations were commenced in September 1918.

With few exceptions, the mine was in continuous production until 1951. The mine was closed only briefly in that year, but was reopened under the management of Northwest Improvement Company in 1952, using continuous mining machinery. Mining was carried on until 1955, when the mine was closed down permanently. Available production figures for the Bellingham coal mine are listed in table 3. During its productive years, this mine contributed a large part of the total tonnage of coal mined in the state. Today, a few concrete abutments located several hundred yards northeast of the intersection of Birchwood and Northwest Avenues in Bellingham are all that remain of the mine structures. A plan map of the Bellingham mine, showing areal extent and relation of its boundaries to the present Bellingham street system, is shown in figure 6.

Beikman and others (1961) note that there are reserves of approximately 50 million tons of measured coal, and another 20 million tons of reserves inferred. Even under the present renewal of interest in coal as an energy source, the prospects for reopening the mine appear to be dim. W. S. Moen (personal communication) notes that the area has undergone rapid urban development and that attempts to start the mine again could be thwarted by environmentally oriented legislation and zoning regulations.

TABLE 3.—Production statistics for Bellingham coal mine, 1918-1955 [1]

Year	Tonnage	Year	Tonnage
1918	914	1937	213,341
1919	42,103	1938	164,670
1920	114,264	1939	227,973
1921	186,237	1940	175,789
1922	163,877	1941	189,153
1923	187,015	1942	230,435
1924	197,701	1943	160,300
1925	273,698	1944	123,453
1926	236,161	1945	110,400
1927	288,171	1946	105,369
1928	266,673	1947	154,500
1929	213,917	1948	136,240
1930	223,906	1949	123,625
1931	164,512	1950	96,742
1932	118,765	1951	65,003
1933	2,741	1952	23,586
1934	97,873	1953	91,824
1935	122,341	1954	75,538
1936	227,123	1955	2,049

[1] Source: Washington State Mine Inspector 1918-1955, Annual coal production report: Washington State Department of Labor and Industries.

Proximate analyses of the Bellingham No. 1 mine were calculated using samples of coal collected by Jenkins during field examinations of the Bellingham No. 1 Mine.

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

Sample[1/]		M	Proximate (percent) VM	FC	Ash	Sulfur	Btu
I	A	4.26	35.67	40.78	19.29	1.01	10,872
	B	....	37.26	42.59	20.15	....	11,356
II	A	4.16	34.62	44.67	16.55	.68	11,467
	B	....	36.12	46.61	17.27	....	11,965
III	A	4.70	35.11	47.73	12.46	.94	11,657
	B	....	36.84	50.01	13.15	....	12,232

A = As received; B = Moisture-free basis.

[1/] Sample locations:

I: Taken across face of room No. 8 3rd level north, 30 feet up from entry, approximately 1,530 feet northeast of main slope. (Measured stratigraphy of the face is presented in the next section.)

II: Taken across face of 4th north entry 1,150 feet northwest of main slope. A 7'9" section from roof to floor was exposed. The 4-inch-thick brown shale parting mentioned previously occurred 1 foot above the floor, and was excluded from the sample.

III: Taken across face of 4th south entry, 660 feet southeast of air course. A 7 ft 2 in section was sampled and the 4-inch-thick brown shale parting was excluded.

(Data from Jenkins, 1923)

According to the coal classification scheme presented earlier in table 2, the Btu values of the above analyses place them in the high volatile "C" category of the bituminous class.

The Bellingham seam was entered on a 30° slope, approximately 550 feet in length. The coal seam was encountered 20 feet stratigraphically below the overburden-sandstone interface; overburden thickness was approximately 265 feet at this point.

A measured stratigraphic section at the face of Room No. 8, 30 feet from the entry of the third level north on the upper portion of the seam, shows the following:

	Stratigraphic thickness	
Roof	ft	in
Bony coal		6
Brown shale		2
Coal	1	
Shale		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		2-4
Coal	1	4
Total (approximately)	9	2
Mine floor		

The horizon listed as "brownish yellow shale, coaly" is a fairly persistent marker bed throughout the mine and is noted in the logs of bore holes Nos. 6 through 10 of the 1892 Symington project. The lower 1½ feet of coal was not economical to mine and the shaly parting signaled the lowermost extent of mining prior to 1952. A change at that time to continuous mining methods allowed addition of the lower seam to the total section mined.

A smaller 2-foot-thickness of coal is found approximately 100 feet below the main coal sequence. The vertical section between the two coal beds is composed largely of shale with some sandstones and conglomerate. It was not economical to mine this lower coal seam, but a proximate analysis shows it to be of the same general quality of the main coal seam.

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

Proximate Percent				
M	VM	FC	Ash	Btu
5.47	39.99	43.36	11.16	11,048

In the general vicinity of the mine portal, dips were on the order of 10° S. on strata striking N. 22° W. At lower stratigraphic levels, the dip decreases to between 5° to 7°. Near the northern extent of the workings, the strike shifts from northeast to slightly south of west. Thus, the Bellingham coal seam appears to be situated on the northeast limb of a small structural basin, open to the southeast. The nearest bedrock east of the mine is two-thirds of a mile away in Cornwall Park. Here, beds strike N. 65° W. and dip 20° S. Farther to the northeast, on King Mountain, similar sediments form a sharp northwest-striking anticline and then dip northward into the broad Van Wyck syncline.

The local geologic setting is unique, in that the dips in the area of the Bellingham mine are much shallower and the folds are more open than the dips found in the more tightly folded and steeper-dipping southeasterly portion of the Chuckanut Formation. It was noted earlier that an angular unconformity is known to exist between the Chuckanut Formation and overlying Huntingdon sediments, but the position of the unconformity in relation to the Bellingham field is not known. If the general conditions of structure exist here as they do in previously examined areas, then the gentle dips and broad open folds strongly suggest the Bellingham field is part of the Huntingdon Formation rather than the Chuckanut Formation.

Reserves for Bellingham Coal Field
(reserves in millions of tons, in beds of thickness shown)

Bed	Overburden (ft)	14-28 (in)	28-42 (in)	42+ (in)	Total
(Measured and indicated)					
Bellingham No. 1	0-1,000			33.96	33.96
Bellingham No. 2	0-1,000	14.13			14.13
Total measured and indicated reserves					48.09
(inferred)					
Bellingham No. 1	0-1,000			22.97	22.97
Bellingham No. 2	0-1,000	6.35			6.35
Total inferred reserves					29.32
Total all reserves					77.41

VAN WYCK SYNCLINE

(central Whatcom lowland)

In 1929 and 1930, three holes were drilled by the MacKay Land Company with the hope of proving the existence of a northwestward extension of the main Bellingham coal field (Jenkins, 1923). This drilling was done prior to the time the present northern limit of the Bellingham field had been reached. Results of the MacKay drilling showed that while several coal seams were intercepted they diminished in thickness and became of such poor quality that they would be uneconomical to mine. Development subsequent to the drilling by MacKay showed that the strike of the basin changed from northwest and then west to a point southeast of the location of the MacKay holes.

The most recent discovery of additional coal reserves in Whatcom County is located approximately 6 miles north and slightly east of the city of Bellingham. The area lies within the limits of the structural low known as the Van Wyck syncline and is contained in T. 39 N., Rs. 2 and 3 E.

Glaeser (1958) made a survey of potential coal reserves with the objective of using the coal to supply a coal-fired thermoelectric power plant. He noted that, although the ends and bottom of the Bellingham mine workings had not changed in size or quality at the time the workings had been closed down, most of the area developed had been mined out. The Bellingham mine had been closed permanently 3 years prior (noted earlier) and would probably have been expensive to reopen and operate. Glaeser noted the information contained in the MacKay logs and reasoned that if the main Bellingham seam was continuous to the northwest, it must also diminish in thickness to the point where mining would be uneconomical. Therefore, Glaeser felt it was mandatory to develop new reserves exclusive of the main Bellingham field.

Jenkins (1923) noted that coal had been intercepted in several wells dug in the Van Wyck syncline. Most of the well logs available were concerned with water or natural gas and lacked the detail required to construct and correlate stratigraphic sections drawn in other coal-bearing areas.

Of particular interest were four wells enclosing an area of some 12 square miles (figure 7). Sections of coal varying from 13 feet in the Sinnes well to over 30 feet in the Hillebrecht well indicated that coal reserves were present and needed development. With the exception of the intercept in the Sinnes at -465 feet (thought possibly to be a bedrock "high" within the basin), the general plunge of the seam is to the northwest

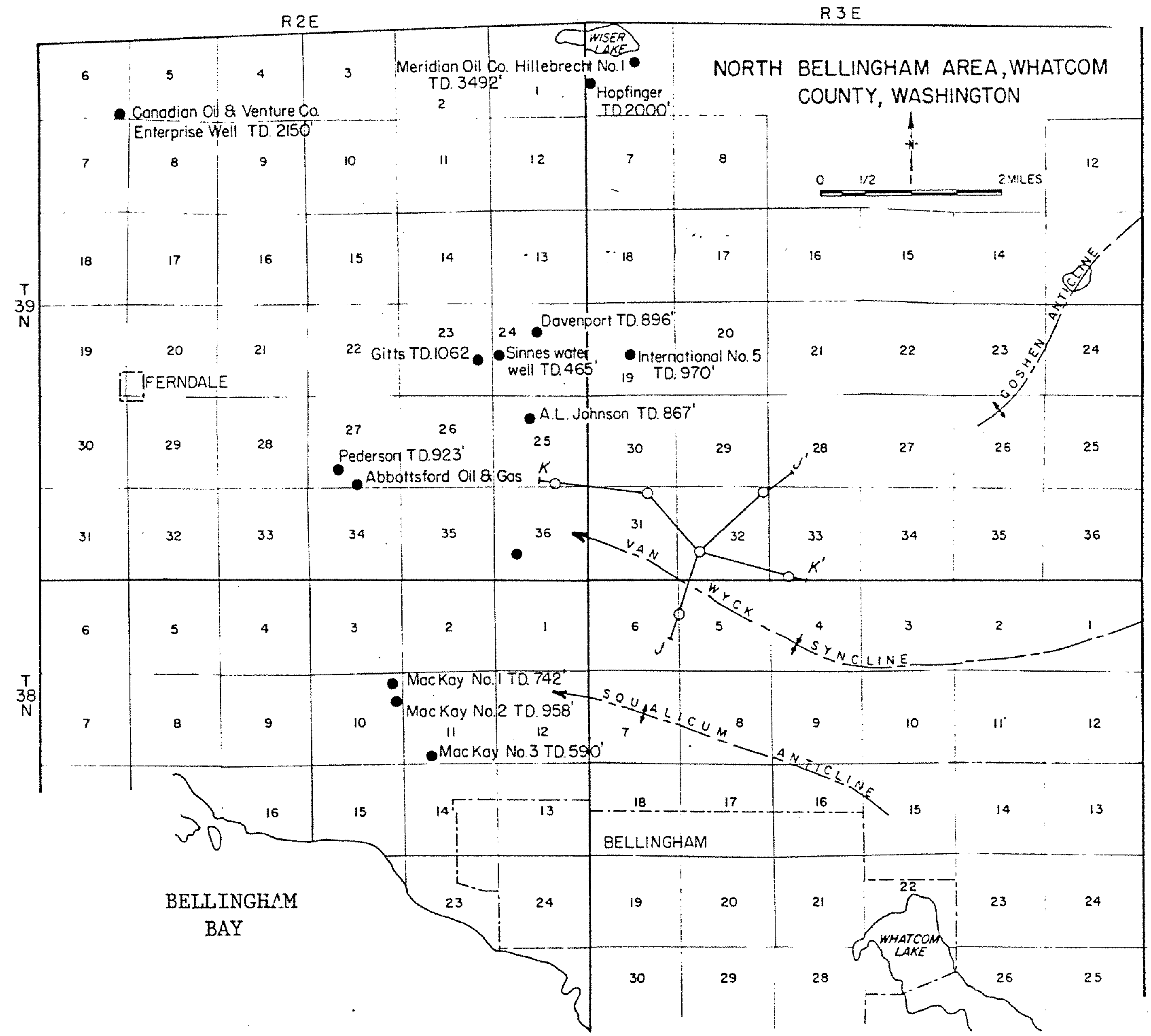


Figure 7. Map of well locations in Van Wyck syncline.

and was in general agreement with findings of earlier workers, although Glaeser acknowledged that considerable structural relief could exist between the respective wells.

Eight additional exploration holes totaling about 11,000 linear feet were drilled between 1959 and 1961 in selected areas with the principle in mind of developing a reserve of at least 100 million tons with a 50 percent recovery factor (figure 7) that would lend itself to mechanized mining techniques.

Coal samples in each hole were collected and subjected to standard analyses; proximate data are presented below in summary form for each hole.

Proximate analyses of drill hole cores, as received

Ray Davenport No. 1

Total depth: 846 feet

Location: SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 24, T. 39 N., R. 2 E.

Predominant rock type penetrated: Shale and sandstone, shale predominent

Bedding dips: Variable, horizontal to 5°

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
581.0-583.0	2.0	6.33	46.25	30.70	16.72	0.28	8,746
583.0-586.0	3.0	5.49	30.52	50.03	13.96	0.23	5,656
603.7-608.2	4.5	5.56	28.29	42.08	24.07	0.48	6,909
798.0-802.2	4.2	4.76	38.25	26.12	30.87	0.26	9,591

A. L. Johnson No. 1

Total depth 867 feet

Location: NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 25, T. 39 N., R. 2 E.

Predominant rock type penetrated: Shale and sandstone

Bedding dips: Variable, horizontal to 7°

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
733.0-739.4 1/	6.4	4.38	--	--	--	0.32	4,658

1/ Several coal beds were cored in this hole, but samples from only one were submitted for proximate analysis.

Proximate analyses of drill hole cores, as received - Continued

Nick Gitts No. 1

Total depth: 1,062 feet

Location: NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 23, T. 39 N., R. 2 E.

Predominate rock type penetrated: Shale and sandstone of equal proportions

Bedding dips: Variable, horizontal to 10°

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
970.0-972.1	2.1	5.65	27.33	64.09	2.93	0.11	3,871
972.1-976.3	4.2	5.1	39.96	25.70	29.24	0.28	9,752
970.0-976.3 1/	6.3	5.3	35.30	39.85	19.54	0.22	7,584

1/ Weighted average.

Alyce Pederson No. 1

Total depth: 923 feet

Location: SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 27, T. 39 N., R. 2 E.

Predominant rock type penetrated: Shale and sandstone, shale proportionally greater

Bedding dips: Variable, horizontal to 5°

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
853.6-858.0	4.4	5.24	35.39	24.50	34.87	0.46	9,821

Proximate analyses of drill hole cores, as received - Continued

J. V. Hopfinger No. 1

Total depth: 2,000 feet

Location: NW¼SW¼ sec. 6, T. 39 N., R. 3 E.

Predominant rock type penetrated: Shale and sandstone, minor conglomerate

Bedding dips: Variable, horizontal to 10°; more flat-lying near bottom of hole

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
622.3-629.1	6.8	5.70	37.50	42.80	14.0	2.60	6,867
1352.7-1358.2	5.5	3.58	26.16	62.63	7.63	0.29	2,288
1428.8-1431.0	2.2	4.45	31.76	40.71	23.08	0.54	7,338
1457.7-1461.2	3.5	4.72	36.14	25.70	33.44	0.29	9,747
1936.7-1942.0	5.3	4.78	34.71	22.87	37.64	0.34	10,068

M. W. Johnson No. 1

Total depth: 1,725 feet

Location: NW¼SW¼ sec. 32, T. 39 N., R. 3 E.

Predominant rock type penetrated: Calcareous shales and sandstones; interbedded conglomerates below 1,325 feet

Bedding dips: Variable, horizontal to 10° with minor faulting

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
478.0- 483.0	5.0	5.78	39.26	26.28	28.68	0.35	9,582
908.3- 910.8	2.5	5.15	35.03	15.58	44.24	0.39	11,105
995.8- 999.5	3.7	5.36	35.08	24.86	34.70	0.54	9,473
1206.8-1209.3	2.5	4.15	35.19	27.37	33.29	0.48	9,389
1295.8-1300.3	4.5	4.88	35.92	22.19	37.01	0.56	9,878
1392.0-1395.8	3.8	4.73	36.05	19.36	39.86	0.43	10,284
1684.8-1692.3 1/	7.5	5.32	34.53	27.08	33.07	0.47	9,059
1692.3-1693.7	1.4	4.69	17.55	72.18	5.58	0.22	2,480

1/ King Mountain coal bed.

Proximate analyses of drill hole cores, as received - Continued

Clare Fleming

Total depth: 1,517 feet

Location: 60 ft S., 250 ft W., NE. cor. sec. 32, T. 39 N., R. 3 E.

Predominant rock type penetrated: Shale and sandstones, evenly proportioned

Bedding dips: Variable, horizontal to 8°

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
678.4- 683.5	5.1	3.3	28.3	41.3	27.1	0.35	7,099
878.0- 881.0	3.0	3.8	35.3	16.4	44.5	0.44	10,856
961.7- 965.5	3.8	3.7	31.6	27.9	36.8	0.63	8,998
1146.0-1149.3	3.3	4.0	26.4	48.0	21.6	0.44	6,158
1244.5-1247.7	3.2	4.4	35.4	18.8	41.5	0.40	10,456
1335.8-1338.9	3.1	4.3	33.9	21.1	40.7	0.40	10,135

Halli Gudmundson No. 1

Total depth: 1,992 feet

Location: 500 ft S., 1,850 ft W., NE cor. sec. 31, T. 39 N., R. 3 E.

Predominant rock types penetrated: Shale, minor sandstones

Bedding dips: Uniform, 5°

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

Drill hole intercept	Thickness (feet)	Proximate (percent) M	VM	Ash	FC	Sulphur (percent)	Btu
592.5- 595.5	3.0	5.2	32.8	35.8	26.2	0.30	7,474
669.5- 673.5	4.0	5.3	30.3	34.1	30.3	0.40	7,142
743.0- 745.5	2.5	4.2	26.8	46.2	22.8	0.41	6,193
745.5- 748.5	3.0	5.1	35.6	20.9	38.4	0.34	9,825
748.5- 754.0	5.5	4.7	31.6	32.4	31.3	0.37	8,177 (composite)
961.0- 965.1	4.1	5.2	35.9	34.3	24.6	0.46	7,910
1200.5-1203.1	2.6	4.2	39.0	20.7	36.1	0.41	10,001
1595.9-1600.0	4.1	3.9	37.0	16.0	43.1	0.30	10,995
1683.3-1685.9	2.6	3.8	34.4	22.9	38.9	0.33	9,877
1970.2-1970.7	0.5	3.2	24.4	56.2	16.2	1.07	4,915
1970.7-1971.2	0.5	3.6	33.5	22.9	40.0	0.45	9,886 1/
1971.2-1971.9	0.7	1.9	24.3	73.7	00.1	0.13	*
1971.9-1974.0	2.1	3.3	34.6	25.9	36.2	0.38	9,538
1974.0-1976.0	2.0	3.9	37.3	10.2	48.6	0.33	11,691
1976.0-1978.0	2.0	3.2	33.0	31.2	32.6	0.81	8,645
1978.0-1978.5	0.5	2.9	31.1	39.8	26.2	1.17	7,522
1978.5-1979.7	1.2	2.2	21.1	66.5	10.2	0.30	3,524
1979.7-1981.6	1.9	Gray shale, not sampled					
1981.6-1982.3	0.7	2.3	21.5	65.9	10.3	0.68	3,591
1982.3-1983.3	1.0	2.2	20.7	68.3	8.8	0.71	3,163
1983.3-1983.9	0.6	2.4	27.4	45.5	24.7	1.22	6,654
1983.9-1985.4	Not sampled because of poor quality						

Of particular interest were four wells enclosing an area of some 12 square miles (figure 7). Sections of coal varying from 13 feet in the Sinnes well to over 30 feet in the Hillebrecht well indicated that coal reserves were present and needed development. With the exception of the intercept in the Sinnes at -465 feet (thought possibly to be a bedrock "high" within the basin), the general plunge of the seam is to the northwest and was in general agreement with findings of earlier workers, although Glaeser acknowledged that considerable structural relief could exist between the respective wells.

Eight additional exploration holes totaling about 11,000 linear feet were drilled between 1959 and 1961 in selected areas with the principle in mind of developing a reserve of at least 100 million tons with a 50 percent recovery factor (figure 8) that would lend itself to mechanized mining techniques.

Coal samples in each hole were collected and subjected to standard analyses; proximate data are presented below in summary form for each hole.

Discussion of Drilling Results

Glaeser considered a 5-foot thickness of coal as the minimum that could be minable and, therefore, placed emphasis only on the 1936.7 to 1942.0 interval which analyzed 10,068 Btu in the Hopfinger hole, and on the 478.0-483.0 interval in the Johnson hole, which analyzed 9,582 Btu. In addition, the King Mountain bed, present between 1684.8 to 1692.3 and analyzing 9,059 Btu in the M. W. Johnson hole, was considered to be well over the minimum thickness of 5 feet that could be adaptable to mechanized mining processes.

The USSRAM (U.S. Smelting, Refining, and Mining Co.) drilling program confirmed predictions of earlier workers (Jenkins, 1923) that coal reserves of substantial tonnages are present in the Van Wyck syncline. Exploitation of the coal should present few if any structural problems. Bedding dips for the most part are less than or equal to 15°, and appears to be amenable to mechanized mining.

Considerable structural information on the Van Wyck syncline was gained from the battery of drill holes sunk. Drilling information confirms that the Van Wyck syncline is of an asymmetrical nature, with shallow dips nowhere exceeding 15° on the north limb. The Van Wyck syncline plunges northwesterly at an angle averaging 4°. Cross-section K-K' (figure 8) correlates some of the beds between the Gudmundson and the Johnson holes. The King Mountain bed and other beds are projected to the west and southeast; without the control afforded by additional borings, they should be considered as only tentative, although minimal faulting and structural disturbances are noted in other drill holes. Based upon the above information, it should be safe to assume that additional coal reserves are present and that cautious projection of the respective seams could give a general first approximation of those reserves.

Coal Reserves

Glaeser (1962) conservatively computed coal reserves for the King Mountain bed in a trapezoidal shaped area between the Gudmundson, Fleming, and W. M. Johnson holes. According to Glaeser, reserves of approximately 2.08 million tons underlie the outlined area. The Btu value is estimated at 8,859 Btu per pound, with 28.5 percent ash.

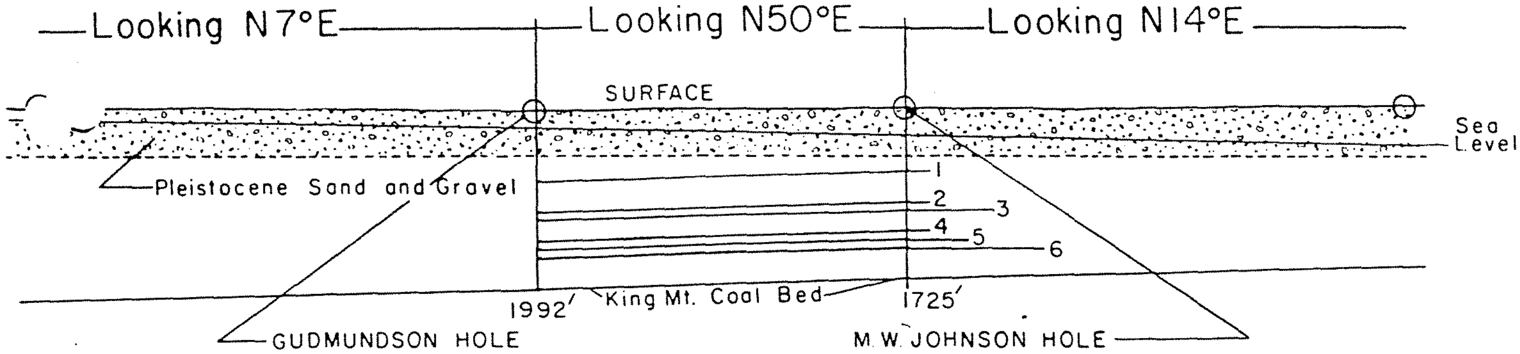
The six coal seams lying above the King Mountain were not considered in the reserve computations made by Glaeser. Moen (1969) took into account the six beds present in the M. W. Johnson hole when he calculated reserves for this area.

Strippable Reserves

Depths of overburden in the Van Wyck syncline would appear to make the area uneconomical to strip mine. Averitt (1968) notes that in some "ideal" areas, strip mining is economically feasible where stripping ratios of as high as 30:1 are being encountered. Using the ultra-liberal 30:1 stripping ratio and the 475 ft. overburden depth, the coal seam most amenable to strip-mining (Johnson No. 1) would have to display at least sixteen feet (instead of the present 5.0 ft) in thickness before a strip mining operation could be considered feasible.

In reality, slope stability, ground water conditions, presence of alluvium in creek valleys, potential reserves, etc., would no doubt drastically reduce the economic stripping ratio. As an example, the maximum stripping ratio allowable (but still considered to be economic) at the states only large-volume strip mine near Centralia is considered to be 8:1. (Roger Paul, Washington Irrigation and Development Corporation, Centralia, personal communication.)

Applying the more realistic factor of 8:1 to the Van Wyck syncline area, a thickness of 60 ft. would be required in the Johnson No. 1 bed before economic justification of a stripping operation could occur.

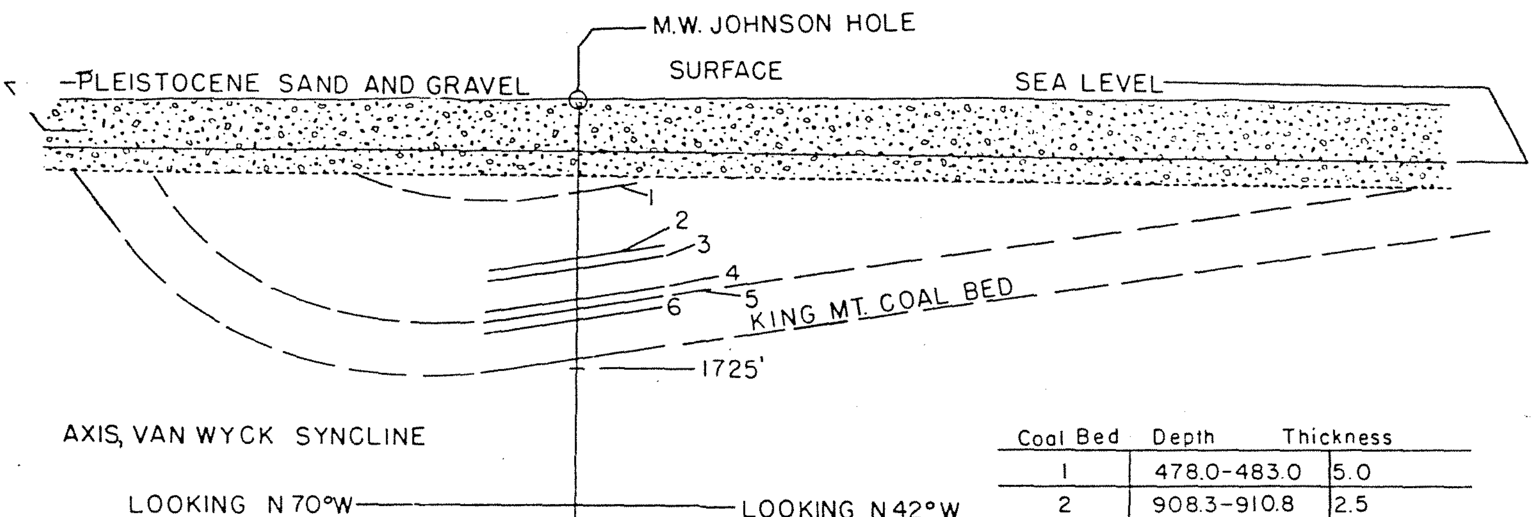


Coal Bed	Depth	Thickness
1	743–748.5	5.5
2	1200.5–1203.1	2.6
3	Not Sampled Too Thin–Poor Quality	
4	Not Sampled Too Thin–Poor Quality	
5	1595.9–1600.0	4.1
6	1683.3–1685.9	2.6
KING MT.	1970.2–1978.5	8.3

Coal Bed	Depth	Thickness
1	478.0–483.0	5.0
2	908.3–910.8	2.5
3	995.7–999.5	3.8
4	1206.7–1209.3	2.6
5	1295.8–1300.3	4.5
6	1392.0–1395.8	3.8
KING MT.	1684.8–1692.3	7.5

GEOLOGIC SECTION K-K'

Gudmundson hole and M. W. Johnson hole
Whatcom County, Washington
Scale: 1 inch = 1,000 feet
Modified after Glaeser, 1962



Coal Bed	Depth	Thickness
1	478.0–483.0	5.0
2	908.3–910.8	2.5
3	995.7–999.5	3.8
4	1206.7–1209.3	2.6
5	1295.8–1300.3	4.5
6	1392.0–1395.8	3.8
KING MT.	1684.8-1692.3	7.5

GEOLOGIC SECTION J-J'

Thru VAN WYCK Syncline
Whatcom County Washington
Scale: 1"=1000'

Modified after Glaeser (1960)

FIGURE 8.—Cross section of Van Wyck syncline.

Reserves for Van Wyck Coal Zone [1]
(reserves in millions of tons, in beds of thickness shown)

Bed	Overburden (ft)	14-28 (in)	28-42 (in)	42+ (in)	Total
	(Measured and indicated)				
Unnamed	0-1,000		8.17		8.17
King Mountain	1,700-2,000			2.08	2.08
Johnson No. 1	478			1.58	1.58
Johnson No. 2	908		.79		.79
Johnson No. 3	955			1.17	1.17
Johnson No. 4	1,206		.79		.79
Johnson No. 5	1,295			1.42	1.42
Johnson No. 6	1,684			1.20	1.20
Total measured and indicated reserves					17.20
	(inferred)				
Unnamed			18.55		18.55
Total inferred reserves					18.55
Total all reserves					35.75

[1] After Beikman (1961) and Moen (1969); listed reserves confined to T. 39 N., R. 3 E.

GOSHEN

Various bedrock exposures occur near Goshen, sec. 19, T. 39 N., R. 4 E., but unfortunately most of the outcrops are badly weathered. A number of coal showings have been reported but most appear to be of minor importance.

Apparently 1951 was the last year that the Goshen area gave any evidence of mining activity. In that year, the annual report of coal mines (Washington State Mine Inspector, 1951) states "a new mine was being opened" and that "fifty feet of gangway and 43 feet of shaft had been driven." Since no production figures for the ensuing years are available, it is assumed that activity on a volume-production basis failed to materialize.

The most important aspect of geologic significance is the change in structure between this area and those areas previously discussed. As seen on the map (plate 1), regional strike is markedly different from the previously-noted northwest-trending fold of the Chuckanut Formation. Dip angles are nowhere more than 10°, a departure from the steeper dips typically found farther south. In addition, folds are commonly broad and open.

Moen (1969) considers observations at Goshen to be indicative of structural conditions found in the Huntingdon Formation and not the Chuckanut Formation.

BLUE CANYON

The Blue Canyon coal deposit was first discovered in 1887 near the extreme south end of Lake Whatcom (secs. 15 and 22, T. 37 N., R. 4 E.), about ten miles from present downtown Bellingham (plate 1). The Blue Canyon Coal Mining Company was formed for purposes of extracting the coal and underwent final incorporation in 1890.

The coal was mined by two separate underground workings (see figure 9, Location A). The first was terminated in late 1892 when a gravity-induced thrust fault within the basal portion of the Chuckanut Formation was encountered. The second working was started at a lower elevation (figure 9, Location B) and remained in production until the mine closed.

In 1894, a mine explosion caused the death of 23 miners, making it the worst mine disaster in the state that far. The coal mines within the Chuckanut Formation all had the reputation of being very gassy; the condition was due to the high volatile

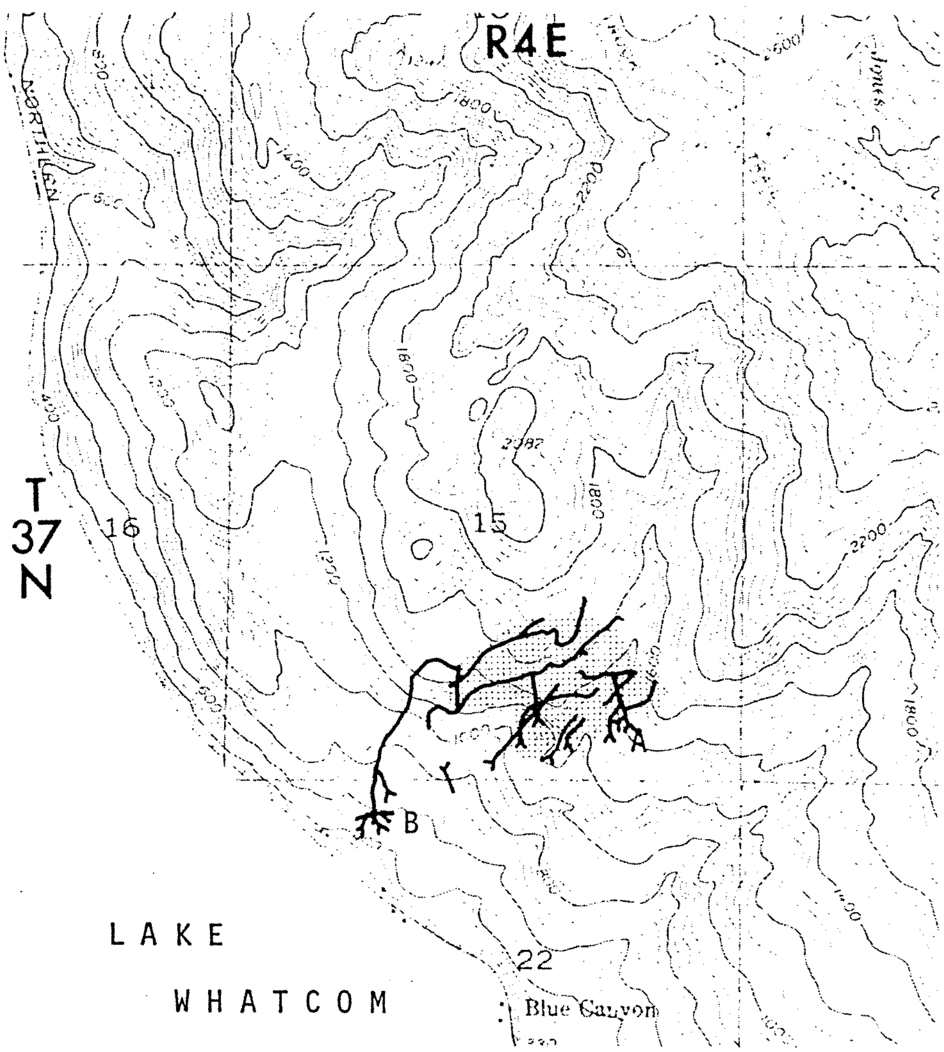


FIGURE 9.—Underground workings of Blue Canyon mine.

content of the coal.

Numerous gas wells have been driven in the area north of Bellingham. Here, gas emanating from the underlying sediments is pocketed and trapped by overlying impervious Pleistocene clays. Although the gas is not present in quantities to support continued large-scale commercial production, owners of property on which gas wells occurred had the gas piped to their homes for heating and cooking purposes (see Glover, 1935).

From 1904 to 1907, the mine was worked by William Lawton, and then leased to J. M. Walter. After refinancing the mine as the Whatcom County Coal Mining Co., Walter continued production until 1919, at which time the mine was closed down. Several key buildings were destroyed by fire in 1920, and the area subsequently fell into disuse. U.S. Bureau of Mines records indicate that the mine produced less than 350 tons in 1933, the last year of reported production.

There is no record of the coal being exported, although some of it was used to fuel the U.S. Navy's Alaskan Fleet shortly before the turn of the century. Navy officials found the heating value to be higher than the coals used prior to that time. Apparently, the largest market was in the demands of homeowners and businesses in the Bellingham, Whatcom County area.

Coal Production, Blue Canyon Mine

Year	Tons 1/	Year	Tons
1891	7,200	1899	6,650
1892	26,675	2/ 1900	48,200
1893	26,000	1901	8,200
1894	no report	3/ 1902	6,010
1895	28,764	4/ 1918	3,689
1896	12,000	1919	543
1897	5,853	1933	333
1898	6,300		

1/ 1 ton equals 2,000 pounds.

2/ 1891-1900 figures from D. R. Owen letter to C. A. Stewart dated March 27, 1923.

3/ 1901-1902 figures from Landes, 1902.

4/ 1918 and subsequent from USBM annual reports for year shown.

Proximate analyses by various individuals and agencies give the following data:

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

Proximate (percent)				Sulphur (percent)	Btu
M	VM	FC	Ash		
1/ 1.79	31.48	62.74	3.68	.31	11,910
2/ 1.60	41.30	55.0	2.20	1.1	11,919
3/ 1.68	30.97	54.21	13.14	---	---

1/ Jenkins, 1923 (Navy Dept. analysis)
2/ Beikman, 1961
3/ Tarr, 1909

Based upon the above figures, the coal at Blue Canyon is classified by Beikman as being high-volatile C bituminous in rank. Tarr (1909) noted the coal "burns freely, but with considerable black smoke."

A cross-section of the Blue Canyon coal seam, as measured by Landes (1902) shows the following characteristics:

Hanging walls—(sandstone)	Thickness (ft)	Thickness (in)
Coal	4	8
Clay		1
Coal	8	6
Clay		2½
Bone		4
Coal	4	6
Bone		5
Coal	1	10
Clay		2
Slate	1	7
Footwall (sandstone)		

According to Landes (1902), the main seam in the mine averaged 7 feet, but was reported to pinch and swell from nothing to as much as 40 feet in thickness. Because of the highly disturbed and fractured character of the beds, the size fractions of the coal were quite small. The coal was mined from a tight north-northwest-plunging syncline with surface dips averaging 30° but steepening to over 50° at depth. In some places, the coal was separated from the underlying metamorphic rocks by a thin basal conglomerate; in other places, this conglomerate was absent and the coal lay in fault contact with the metamorphic rocks.

ROCKY RIDGE

The Rocky Ridge coal deposit is located on the south shore of Lake Whatcom (SW¼, sec. 31, T. 38 N., R. 4 E.). A mine was started on the property in 1898 by Harry Moore, but little is known about the history of its operation and production statistics are obscured. The operation was quite small, and the coal that was extracted was stockpiled at the west end of Lake Whatcom for local consumption.

A proximate analysis of the Rocky Ridge mine showed the following characteristics:

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

	Proximate (percent)				Sulphur	
Sample	M	VM	FC	Ash	(percent)	Btu
A[1/]	4.97	31.51	23.70	39.82	.88	7,232
B[2/]		33.16	24.94	41.90		7,609

(From Hansen and Stewart analysis in Jenkins, 1923).

1/ A equals as-received

2/ B equals moisture-free

According to the coal classification chart (table 2), the coal at Rocky Ridge would be considered lignitic.

Although five coal seams were exposed, only the last three were mined. Vein No. 3 yielded the preponderance of the coal extracted; a 6-foot thickness in No. 1 slope was reported, but no stratigraphic measurements are available. Measurements made in the No. 3 vein (No. 2 slope) give the following cross section:

Hanging wall (sandstone and black shale)	Thickness (ft)	(in)
Coal		17
Coaly shale		18
Clay		18
Coal	(covered)1/	
Footwall (covered)2/		
Total	6	5

1/ Reported to be 2 feet.
2/ Reported to be shaly sandstone.

With the high ash content and relatively low heating value when compared to other coals available around the Bellingham area, it is probably safe to say that the Rocky Ridge coal was noncompetitive when considered on a commercial-volume basis.

GLEN ECHO

The Glen Echo Coal Mining Co. was organized by M. L. Dickerman, and the Glen Echo mine was opened in 1920 at the common corner of sec. 5 and 9, T. 38 N., R. 4 E. Jenkins (1923) reports that approximately 1,000 tons of coal of fairly high quality was extracted prior to 1921. Apparently, the working tunnel intercepted the overlying Pleistocene sediments, which mantle much of the bedrock of the region. Operations were temporarily ceased and the mine was closed in 1921.

The company was reorganized and mining continued from 1927(?) to 1948, with production sporadic and fitful at first and becoming more consistent in later years. Structural complexities within the locally contorted sandstones led to the ultimate closure of the mine in 1948. The company was dissolved later in that year with no further production reported. According to Moen (1969), Mr. J. A. Jussel of Bellingham now owns the majority of the Glen Echo assets.

Production figures for Glen Echo coal mine[1]

Year	Tonnage	Year	Tonnage
1920	1,000	1940	9,376
1932[2]	18	1941	986
1933	762	1942	3,344
1934	2,201	1943	4,548
1935	350	1944	3,461
1936	4,142	1945	4,920
1937	9,177	1946	4,005
1938	8,164	1947	1,266
1939	8,833		

1/ Reorganized and known in later years as West Coast Coal Mine.
2/ Production records 1927-1931 (inclusive) not available; no reported production from 1921 to 1927.

The coal of the Glen Echo mine was analysed and found to display the following characteristics:

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

Sample	Proximate (percent)				Sulphur (percent)	Btu
	M	VM	FC	Ash		
A[1]	6.82	33.98	34.48	24.72	.52	9,254
B[2]		36.46	37.00	26.46		9,930

1/ A equals as-received
2/ B equals moisture-free
(Hansen and Stewart analysis, In Jenkins, 1923).

On the basis of heating value, the analyses suggest that the coal could be considered a subbituminous B grade.

The main coal workings were reported by Jenkins (1923) to be concentrated in the No. 1 seam. Mining was by the room and pillar method. It is not known whether this seam gave sustained production through 1947 or whether another tunnel or opening was made elsewhere. A generalized stratigraphic section on the No. 1 seam shows the following:

Hanging wall (lithology unknown)	Thickness (ft)	(in)
Hard bony coal		6
Clean coal		18
Carbonaceous rock		4
Clean coal		14
Bony rock		2
Coal		6
Footwall (lithology unknown)		

In addition to the previous sequence, a measured section stratigraphically above the No. 1 seam shows the presence of four other coal seams:

	Thickness (feet)
No. 5 coal seam	?
Sandstone	?
No. 4 coal seam (coal & bony coal)	3½
Sandstone	75
No. 3 coal seam (coal & shale)	3
Sandstone	50
No. 2 coal seam (coal & shale)	4
Sandstone	60
No. 1 coal seam	5

The general geology of the Glen Echo area is rather unique in that the mine is situated on the northwest limb of an anticline. Typically, the other coal deposits within the Chuckanut Formation are found in syncline areas, where their structurally lower position has afforded greater protection from erosional forces.

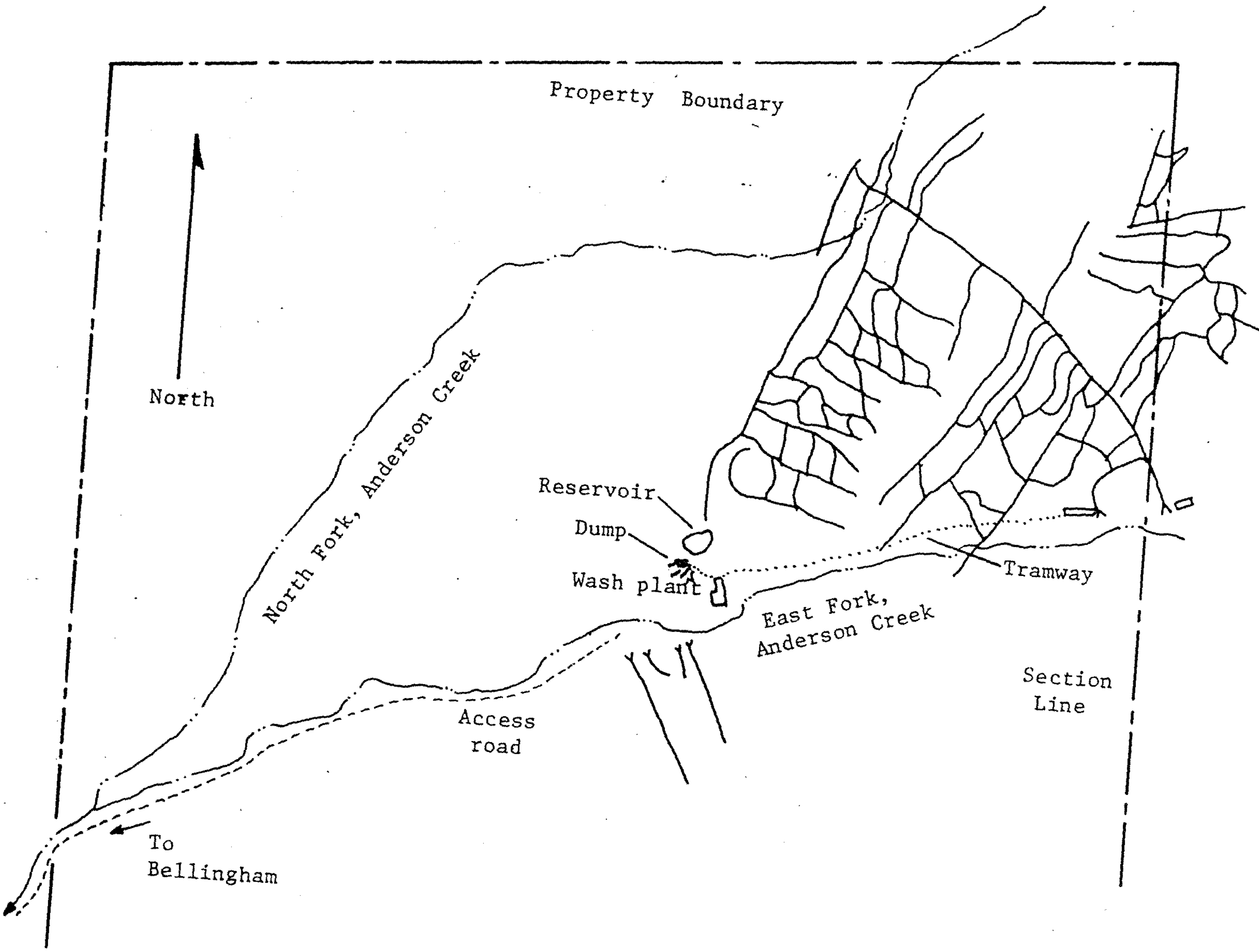


Figure 10. Mine workings, Glen EchoCoal Mine, ca. 1942 (T38N, R4E, secs. 4,5,8,9)

Here at Glen Echo, Anderson Creek has eroded a deep valley through the fractured and weakened rocks at the crest of the anticline; the mine is located in sediments that strike N. 60° E. and dip 75° to 80° N., very near the bottom of the creekbed. Across the creek valley, a prospect in the form of an inclined shaft follows the same coal seam down beds that strike N. 84° E. and dip 37° S. A consultant's report in 1945 expressed the opinion that the coal south of the creek was of little economic value due to steep dips and the likelihood of the coal being badly crushed. (Hill, written communication, 1945.)

As shown on the accompanying map, the Glen Echo mine is located very near the unconformable contact between the Huntingdon and Chuckanut Formations. Hill mentions the presence of a small thrust fault within the workings, but also observes that faulting in general was not a large problem. A general map of the mine workings is shown in figure 10.

According to Jenkins, the original Glen Echo mine was located 1 mile north of the site under discussion near the extreme northwest corner of sec. 4. Here, a 300-foot tunnel was found to cut three seams of coal that were thought to be correlative with the three higher coal seams at Anderson Creek. These three "original" beds would lie well north of the contact and are thus considered to be part of the Huntingdon Formation. An unnamed diamond drill hole in SE$\frac{1}{4}$ sec. 6, T. 38 N., R. 4 E. shows five coal seams intercepted between 291 and 875 feet in depth. It is clear that a more detailed stratigraphic study of the area should be the first step taken in a further investigation of the Glen Echo coal mine.

SILVER BEACH

The Silver Beach coal mine was started in the early 1920's by the Pacific Atomized Fuel Co. It was located in the NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 22, T. 38 N., R. 4 E., at what is now the community of Silver Beach. This mine should more properly be termed a prospect, since little development was done and no records of production existed at the time of Jenkins' inspection (1921). No subsequent production figures were found during a perusal of U.S. Bureau of Mines annual coal mine reports.

Jenkins (1923) reports that at least 6$\frac{1}{2}$ feet of coal in five separate horizons were cut in a tunnel some 360 feet long. The last 4$\frac{1}{2}$ feet of coal was the largest encountered and was termed a "burnt" coal. The significance of the "burnt" coal is not explained. The writer questions the term, since a true burning of the coal, assumedly started by spontaneous combustion, should produce local areas of low-grade thermal alteration on each side of the burnt seam. Altered material in the form of brightly colored "clinker" is discussed by Rogers (1918); more recently clinker thickness was used in exploration and as indicators of coal-bed quality and thickness in the northern Powder River Basin of Montana (Matson and Blumer, 1974).

No heating values of the coal at Silver Beach are included in Jenkins' discussion.

Jenkins measured a 210-foot stratigraphic section near the shore of Lake Whatcom and found five separate coal seams within that distance.

(South end)	Approximate stratigraphic thickness (feet)
Covered, sandstone continues to the south	----
Sandstone, conglomeratic phases	30
Conglomeratic sandstone	3
Coal, decomposed, with clay underneath (No. 5 seam)	3
Sandstone	3
Smut, with clay (No. 4 seam)	3
Sandstone	3
Clay and sandstone	5
Gray sandstone	4
Clay and sandstone	7
Coal, decomposed, and a little clay (No. 3 seam)	5
Clay and a little fire clay	2
Fine-grained gray sandstone	22
Water-bearing iron-stained clay	3
Sandstone	23
Shaly sandstone	5
Coal, decomposed (No. 2 seam)	2
Sandstone, clayey	3
Sandstone, dense	2
Thick-bedded sandstone with shaly sandstone	16
Coal, decomposed, with clay (No. 1 seam)	9
Gray fire clay	6
Soft, fine-grained clayey sandstone	8
Sandstone and conglomerate with $\frac{1}{4}$-in pebbles	40

(Northern end)

Correlation between the lakeshore section and the beds cut in the mine indicates that Nos. 1, 2, and 3 seams were cut in the mine while the last two went undiscovered. According to Jenkins, the tunnel was stopped a short distance past the No. 3 bed.

Jenkins felt that the stratigraphic section at Silver Beach is generally correlative with the section at Rocky Ridge; with the lack of a more detailed section, this correlation should be regarded as only tentative.

The Chuckanut Formation at this point strikes generally east and west and local dips average 40° S.; this area is situated on the north limb of the west-plunging Lake Whatcom syncline.

GENEVA

The Geneva coal mine was opened by Otho Williams in 1921 under the name of the Pacific Atomized Fuel Company. It is located 1 mile south of the western end of Lake Whatcom (NE¼SW¼ sec. 34, T. 38 N., R. 3 E.).

Production figures for the years 1921 and 1922 show a total of 350 tons mined; no subsequent production figures are available. All coal was consumed locally, including some used at Silver Beach coal mine.

A proximate analysis of coal sampled from the stratigraphically lower of two beds yields the following information:

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

	Proximate (percent)					
Sample	M	VM	FC	Ash	Sulphur (percent)	Btu
A 1/	5.52	32.70	24.80	36.98	1.12	7,161
B 2/		34.67	26.35	39.04		7,579

1/ A equals as-received
2/ B equals moisture-free
(from Jenkins 1923; analyst(s) unknown)

According to table 2, Geneva coal would be classified as lignitic.

The majority of the coal was extracted from a 360-foot-long tunnel driven on-strike in a coal seam striking N 10° E and dipping 21° to 25° S. A crosscut drift 174 feet in length is reported to have cut several smaller seams of coal of lesser quality. A stratigraphic section measured by Jenkins was reported to contain the following:

	Approximate stratigraphic thickness (ft)	(in)
Black coaly shale; hanging wall		
Coal (main seam)	2	4
Bone		few
Sandstone, clay, and greenish shale, interbedded	7	8
Coal		6
Clay shale	1	4
Bony coal	1	10
Clay shale		5
Bony clay		10
Bony coal		8
Clay shale	1	4
Coaly shale		8
Clay shale	1	4
Coal (lower 6 in. clayey)	2	3
Greenish clay shale) Sandstone (Clay)	50	
Coal		6
Clay		9
Sandy clay		

(The previous proximate analysis was taken from the 2-ft-4 in-thick main seam.)

Another tunnel some 70 feet topographically lower than the first, but 40 feet higher stratigraphically, was again driven on beds striking N. 30° E. and dipping 24° S. A section measured by Jenkins (1923) showed the following:

Hanging wall; impure fire clay	Approximate stratigraphic thickness (ft)	(in)
Coal	1	7
Coaly clay		3 or 4
Coal		10
Clay shale with coal	1	6
Footwall of massive clay shale		

The Geneva coal workings are located on the southwest limb of a syncline whose axis plunges generally northward. Dips encountered within the area are relatively gentle when compared to other mines of the area. Based upon stratigraphic data, the two tunnels contain at least a 6-foot total thickness of coal. A correlation by Jenkins suggests that the Geneva coal may be at or near the same stratigraphic level that contains the Rocky Ridge-Silver Beach coal seams. Sufficient data to support the hypothesis are lacking and the correlation is therefore regarded as tentative.

The location of the mine and the relatively gentle dips may warrant further exploration and development consistent with local zoning restrictions of this long-inactive mine.

Alger

Jenkins notes that a structural basin of at least 2 square miles in extent exists just north of the town of Alger in Skagit County. Near the basal contact between Chuckanut sandstone and underlying metamorphic rocks in the general area of SE¼ sec. 36, T. 37 N., R. 3 E., he reports a tunnel between 200 and 300 feet in length, which cuts a contorted coal seam. The seam is found in rocks that generally strike N. 82° E. and dip 70° N. in a locally disturbed area.

A stratigraphic section (Jenkins, 1923) measured farther up the hillside shows the following relationship:

	Stratigraphic Thickness	
	ft	in
Gray sandstone and sandy shale		
Black coaly shale		8
Black coal and some shale		8
Shale	1	3
Weathered coal.	2	2
Coaly shale		8
Coal with clay, decomposed. . . .		10
Gray shaly sandstone		

The writer made a reconnaissance trip to the area. He learned that at one time a coaling station was located just below Squires Lake. This coaling station was an intermediate stop for steam-powered freight trains northbound over the Samish Pass grade to Bellingham (Ralph Squires, personal communication).

This prospect is at the base of the southern extension of Lookout Mountain and is situated very near the axis of a gently plunging major syncline, which trends variously north to northwest; this syncline is traceable from Alger all the way north to the flanks of Squalicum Mountain and beyond.

Beikman (1961) includes the Alger area in the Blue Canyon coal zone. The structural setting in this location is the same as that encountered at Blue Canyon, although the dips on Lookout Mountain appear to be less steep than at Blue Canyon. Lack of geologic data precludes a more precise assessment of structural conditions. A modest exploration program in this area would add greatly to the structural and stratigraphic knowledge and would allow a confirmation of the 5.4 million tons measured by Beikman and others (1961).

Reserves, Alger Coal Area[1/]

(reserves in millions of tons, in beds of thickness shown)

Bed	Overburden (ft)	14-28 (in)	28-42 (in)	42+ (in)	Total
(Measured and indicated)					
Alger	0-1,000		2.43		2.43
	1,000-2,000		1.62		1.62
	2,000-3,000		1.31		1.31
Total measured and indicated reserves					5.36
(inferred)					
Alger	0-1,000	.67	1.01		1.68
	1,000-2,000	.63	.94		1.57
	2,000-3,000	.45	.67		1.12
Total inferred reserves					4.37
Total all reserves.					9.73

1/ After Beikman and others (1961); listed reserves confined to T. 36 N., R. 4 E.

Author's note: Federal assistance in starting a small exploration program was requested and received. At the time of this writing a core drilling plan is being formulated.

Glacier coal field

The only known occurrence of anthracite-grade coal in Whatcom County is near the town of Glacier, approximately 45 miles east of Bellingham on State Highway 542 (figure 11). The coal field was discovered by a hunting party in 1907 near Steep Creek (E½ sec. 29, T. 39 N., R. 27 E.).

The first worker who made a detailed geologic investigation of the immediate area was Woodruff (1914) although Smith and Calkins (1904) made the earliest report on the region in conjunction with a cross-Cascade reconnaissance roughly paralleling the Canada-Washington border. Since that time, the area has received considerable attention from promoters, speculators and would-be developers. Mine and prospect locations are shown in figure 12.

The first commercial venture was embarked upon by the Bellingham Bay and British Columbia Mine in 1902, but operations were terminated soon after.

In 1908, Alex Paulson obtained the leases on much of the property. From then until 1914, the Hoquiam lumberman spent considerable sums of money on the property, driving some 6,000 feet of tunnel and diamond drilling various areas. Through poor business practices involving unfulfilled obligations stipulated within the lease contracts, several lawsuits were filed against Paulson, and ownership and development became ensnared in a maze of litigation.

In 1916, Alex Tozier and E. R. Peoples gained control of the original leases and upgraded much of the original shaft timbering. A main adit was started from near Glacier normal to the strike of the coal beds to intercept all the coal-bearing veins. The tunnel was a failure, as no coal in commercial quantities was tapped as late at 1932, when the adit had been driven 2 miles into the mountain.

Tozier and Peoples formed the Peerless Coal Co. in 1920, but no recorded production occurred. Another attempt to mine the coal by the Anthracite Coal Corp. in 1927 resulted in insolvency soon after that venture was started.

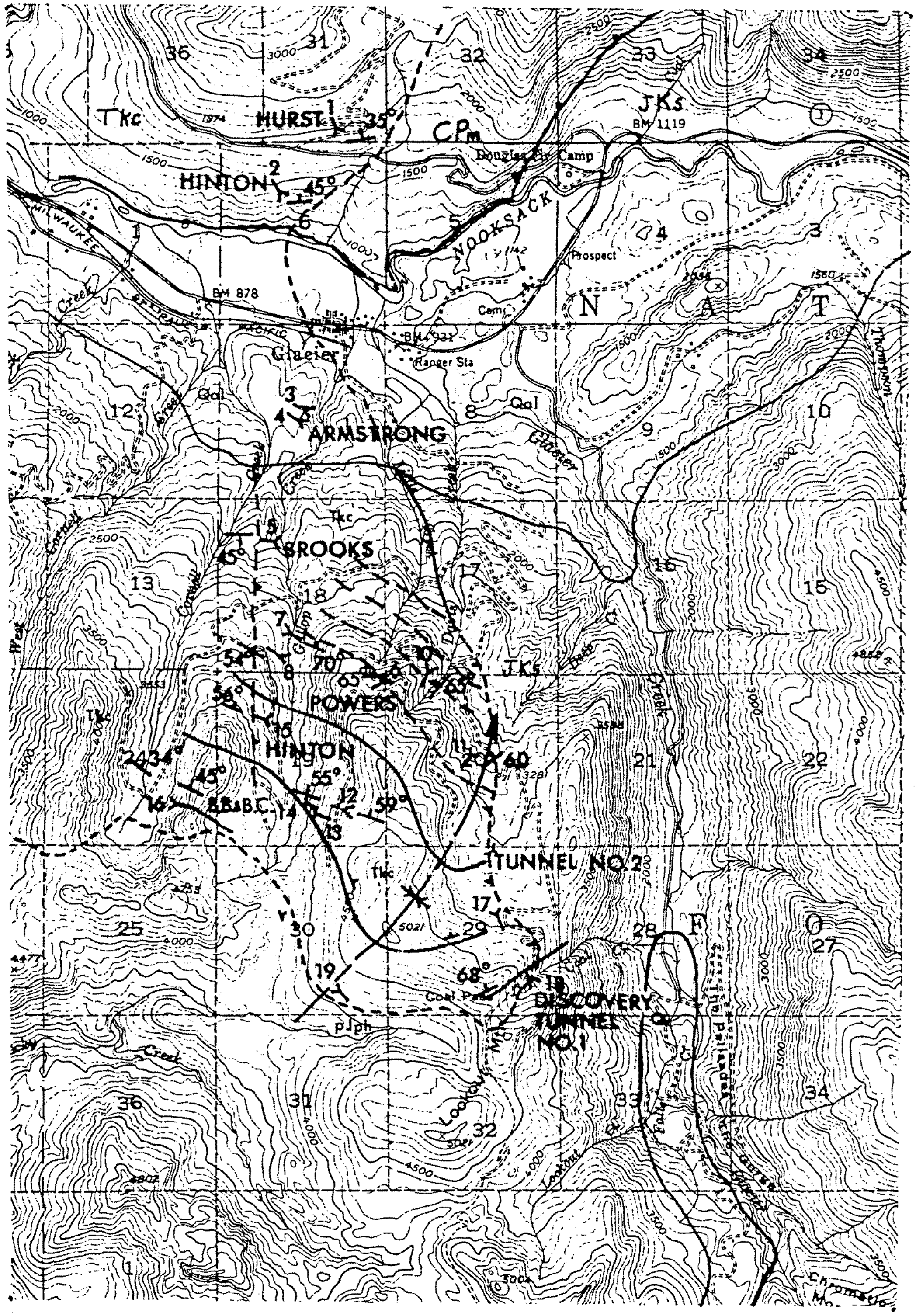


Figure 11. Geologic map of Glacier coal field, showing mine and prospects locations.

(Geology after Woodruff, 1914 and State of Washington (1961))

Qal	Alluvial sediments, Nooksack River
Qv	Quaternary andesites, Mt. Baker
TKc	Coal-bearing arkose, Chuckanut Formation
JKs	Marine sediments, Nooksack Group
pJph	Low-grade metamorphic rocks, Darrington phyllite
CPm	Marine sediments and volcanics, Chilliwack Group

- Fold-axis, showing plunge
- Thrust-fault Saw-teeth on upper plate
- Anthracite coal-seam
- Bituminous coal-seam
- Formational contact (dashed where inferred)

The Washington State Mine Inspector's Annual Report of Coal Mines (1929) shows that the Old Dominion Coal Co. had been doing some exploration work. The same report, somewhat optimistically, says:

> The United Collieries Coal Company, Glacier, has in the course of the year started reopening and enlarging the rock tunnel driven some years ago on the outskirts of the town of Glacier. This tunnel is driven to tap and develop some twelve or thirteen seams of coal, and most of the seams are purported to be anthracite coal of very high quality and if the claims made by officers of the company materialize, this development will ultimately comprise one of the most important mines of the state. The tunnel is now in about 2,000 feet and the furthermost seam reported and proposed to be reached is 12,000 feet from the portal.

The tunnel had been driven two miles by 1932, but only a small fraction of the reported reserves were mined; the Washington State Mine Inspector's Annual Report of Coal Mines (1932) shows only 870 tons of coal produced that year.

In 1940, Consolidated Coal Mines was formed to exploit the coal but no mining operations were started.

During the initial years, numerous claims were challenged in court by the U.S. Forest Reserve, on the grounds that the 200 million board feet of harvestable timber was worth much more than were the coal reserves underlying the property. All court decisions were made in favor of coal-mining interests after a number of apparently competent and well-qualified geologists gave pro-mining testimony under oath.

Woodruff (1914) found the character of the coal to range in quality from subbituminous to anthracite. Previous writers have cited the transformation of the more basal coal measures to anthracite as a result of regional metamorphism associated with folding of the Chuckanut Formation. Moen (1969) points out that coal seams in other areas of the Chuckanut exhibit as much, if not more, deformation, and are not considered to be anthracitic. A more plausible explanation proposed by Moen suggests the transformation from bituminous to anthracite as a result of nearby Mount Baker volcanics and associated shallow intrusions baking the surrounding area at sustained temperatures. Coals from Crested Butte and Los Cerrillos (New Mexico) were thought to have been reduced in volatiles and upgraded to anthracites through lit-par-lit igneous intrusion into coal-bearing sediments (no known example of this relationship exists between Chuckanut sediments and Mount Baker volcanics).

Coal samples were collected by Campbell and Clark (1916) near the base of the Chuckanut Formation in this area and subsequently analyzed by the U.S. Bureau of Mines. They show only that area near the Discovery opening (SW¼ sec. 29, T. 39 N., R. 7 E.) was deemed to hold anthracite; other samples analyzed appear to vary from bituminous to semianthracite.

Sample Locations and Notes[1/]

Discovery tunnel - Washington Anthracite Co.

Sample No. 19722

SE¼ sec. 39, T. 39 N., R. 7 E.

Sample slightly damp

Coal beds vary considerably in thickness; dip 68° N.

Stratigraphic section

	Thickness (ft)	(in)
Coal (sampled).	2	5
Coal, soft, laminated		4
Shale, carbonaceous	1	6
Coal (sampled).	5	10
Total	10	1

Discovery tunnel - Washington Anthracite Co.

Sample No. 19723

300 feet from entry

Coal slightly weathered and covered with dirt

Stratigraphic section

	Thickness (ft)	(in)
Coal, impure, laminated.	1	6
Coal, hard (sampled).	14	5
Coal, impure, laminated.	2	1
Total	18	0

[1/] Analyses made by U.S. Bureau of Mines. In Campbell and Clark (1916).

Sample Locations and Notes[1/]

Smith tunnel - Washington Anthracite Co.

Sample No. 19724

SE¼ sec. 30, T. 39 N., R. 7 E.

200 feet from entry

Weathered sample

Dips about 20° N. (strike not given)

Stratigraphic section

	Thickness (ft)	(in)
Coal (sampled).	5	6
Coal, soft, laminated	2	6
Total	8	2

Prospect

Sample No. 19725

SE¼ sec. 24, T. 39 N., R. 6 E.

20 feet from mouth

Weathered sample

Dip 51° N. (strike not given)

Stratigraphic section

	Thickness (ft)	(in)
Coal (sampled).	.5	9
Bone.		11
Coal, soft, laminated	.2	7+
Total	9	3+

Sample taken from open cut

Sample No. 19726

SW¼ sec. 24, T. 39 N., R. 6 E.

Dip 30° to 40° N.

Poorly exposed

Sample badly weathered, crushed, and squeezed

Stratigraphic section

Represents approximately 3 feet.

TABLE 4.—Proximate analyses of Glacier coal field

Laboratory No.	Air-drying Loss	Form of Analysis*	PROXIMATE: Moisture	PROXIMATE: Volatile Matter	PROXIMATE: Fixed Carbon	PROXIMATE: Ash	ULTIMATE: Sulphur	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	HEATING VALUE: Calories	HEATING VALUE: British Thermal Units
19722	2.6	A	4.4	7.4	76.0	12.23	0.96	2.97	77.75	0.98	5.11	6,995	12,590
		B	1.8	7.7	78.0	12.55	.99	2.76	79.79	1.01	2.90	7,180	12,920
		C	...	7.8	79.4	12.79	1.00	2.60	81.30	1.02	1.29	7,315	13,170
		D	...	8.9	91.1	.....	1.15	2.98	93.23	1.17	1.47	8,390	15,100
19723	3.2	A	5.5	6.9	77.7	9.9	1.02	....	.....	....	....	7,115	12,810
		B	2.4	7.1	80.3	10.2	1.05	....	.....	....	....	7,345	13,230
		C	...	7.3	82.2	10.5	1.08	....	.....	....	....	7,530	13,550
		D	...	8.1	91.9	....	1.21	....	.....	....	....	8,415	15,150
19724	4.7	A	5.8	8.1	77.1	9.0	.91	....	.....	....	....	7,205	12,970
		B	1.2	8.6	80.8	9.4	.96	....	.....	....	....	7,560	13,610
		C	...	8.6	81.8	9.6	.97	....	.....	....	....	7,650	13,770
		D	...	9.6	90.4	....	1.07	....	.....	....	....	8,455	15,220
19725	3.6	A	4.3	9.0	77.2	9.5	1.06	....	.....	....	....	7,415	13,350
		B	.7	9.3	80.1	9.9	1.10	....	.....	....	....	7,695	13,850
		C	...	9.4	80.7	9.9	1.11	....	.....	....	....	7,755	15,960
		D	...	10.4	89.6	....	1.23	....	.....	....	....	8,610	15,500
19726	7.6	A	10.7	13.1	68.8	7.4	.94	....	.....	....	....	6,610	11,900
		B	3.6	14.1	74.3	8.0	1.02	....	.....	....	....	7,140	12,850
		C	...	14.6	77.0	8.4	1.05	....	.....	....	....	7,405	13,330
		D	...	16.0	84.0	....	1.15	....	.....	....	....	8,080	14,540

*A. Sample as it comes from the mine.

B. Sample after it has been dried at a temperature of 86° to 95° F.

C. Sample after all moisture has been eliminated.

D. Sample after all moisture and ash have been theoretically removed.

C and D are recalculated from A and B

The Glacier coal field is structurally more complex than the previously examined areas in the western part of Whatcom County. A north-south low-angle thrust fault of minor displacement places Chuckanut sandstone on top of Nooksack slates to the east, and on top of phyllitic rocks to the south.

The trace of the fault (plate 2) passes under Glacier townsite to the north and then curves northwest, placing Chuckanut sediments first on volcanics and then on marine sedimentary rocks of the Chilliwack Group, and finally the marine sediments of the Bald Mountain Formation.

Farther west, another low-angle thrust fault within the Chuckanut Formation forms the western limit of a small thrust sheet within which the anthracite is apparently contained. Both faults are attributed by Misch (1966) to shearing and sliding of massive, more structurally competent blocks along glide planes composed of structurally weaker rocks. This decollement or shearing-off phenomena was recognized by Buxtorf in the Jura Mountains of western Europe, where early Mesozoic shales and salt beds serve as basal slip planes.

Decollement phenomena were also recognized by Miller and Misch (1963) on Sumas Mountain. Faulting there and at Glacier is thought to be contemporaneous with, and in response to, folding and deformation within post-depositional times.

Basal exposures of the fault plane south of Glacier show that westward dips are less than 15° average. At the sole of the thrust plate, minor deformation of the underlying Nooksack indicates local movement in this area to be from west to east (Misch, personal communication).

Woodruff (1914) found tectonic forces have caused local swelling and pinching of the less structurally competent beds (that is, coal and shale) within the Chuckanut Formation has allowed the coal to take on a fractured and crushed habit. Lateral variation in thickness along the strike of a given coal seam is great.

Generally, dips in the area are steep, averaging 45°. Locally steeper dips exceeding 65° are found on the west edge of the field. Regional dip is generally to the north, but shows the presence of a small synclinal flexure just west of Glacier Creek (Woodruff, 1914).

Throughout the history of the Glacier anthracite field, numerous geologists from both the Northwest and as far away as Pennsylvania have examined the area and published their interpretations. Hughes (1970) noted the lack of systematic exploration that had been done and also noted the possibility of north- and northwest- trending transverse fault patterns having a very significant impact upon minable coal and potential versus actual reserves.

Large differences of opinion exist between the various mining engineers and geologists regarding reserves present at Glacier. On the one hand, estimates of reserves as high as 250 million tons have been proffered although most estimates average between 40 and 50 million tons. More recent evaluation of the field by Beikman and others (1961) suggests reserves of approximately 5 million tons.

Reserves for Glacier Coal Field 1/
(reserves in millions of tons, in beds of thickness shown)

Bed	Overburden (ft)	14-28 (in)	28-42 (in)	42+ (in)	Total
	(inferred)				
Glacier	0-1,000	.67	1.81	.50	2.98
	1,000-2,000	.33	1.49		1.82
Total inferred reserves					4.8
Total all reserves					4.8

1/ After Beikman and others (1961) listed reserves confined to T. 39 N., R. 7 E.

Woodruff (1914) conservatively advises that, due to the apparent discontinuity of the beds and also the pinching and swelling of the coal due to deformation, ordinary prospecting or diamond-drilling cannot be used as an accurate means, since results gained in one hole cannot be considered to be the norm for other areas in near proximity. On the other hand, Hughes (1970) states that a complete stratigraphic study of the coal measures of the Glacier area ought to be considered the key to prospecting.

A study was undertaken by Klemgard (1953) with the objective of converting Glacier anthracite to metallurgical grade electrode carbon. According to Klemgard, approximately one-half pound of carbon electrode is consumed in the production of one pound of aluminum and comprises between 12 and 19 percent of the net cost.

Washington State produced 1.17 million tons of primary aluminum in 1974, or 24 percent of the entire national output (U.S. Bureau of Mines Preliminary Mineral Industry Surveys.) Based on Klemgard's figures, electrode carbon costs in this state for the 1974 production period totaled approximately 100 million dollars. Klemgard, using 1953 prices, notes that the projected cost of coke produced from Glacier anthracite was on the order of $50 per ton compared with petroleum-produced coke at $39 per ton. Present-day coke production cost estimates from Glacier anthracite are not available, although present day prices for metallurgical grade electrode carbon is on the order of $175 per ton (Tom Briggs, International Aluminum Corporation, personal communication.)

Despite the presence of steep dips and probable lack of continuously minable horizons as barriers to developing reserves, a commercial mining venture may yet become profitable at some time in the future at Glacier.

Author's note:

At the time of this writing (April, 1975) a privately sponsored core-drilling program has been embarked upon. It is anticipated that between 3 and 4 thousand feet of NX-size core will ultimately be available for establishment of stratigraphic standards. The detailed geologic mapping program intended to accompany the drilling phase of the project should sort fact from fiction in the many conflicting statements that have been made in the past regarding this property.

Other Prospects

Numerous prospects within the area around Glacier townsite have been made (figure 11). A short summary of those prospects follows, although it should be kept in mind that many of them are on the order of at least fifty years in age; steep slopes developed on Pleistocene material coupled with 70" per year rainfall invite large-scale sliding and subsequent obliteration of adits.

TABLE 5.—Summary of Coal Prospects, Glacier Area 1/

Location 1 Hurst prospect - SE¼ sec. 31, T. 40 N., R. 7 E.

Prospect tunnel 200 ft in length, 75 ft slope ending in noncoal-bearing rock; tunnel possibly faulted off.

Slope cut in mainly shale, with some coal interbedded.

Coal occurrence extremely irregular, occurring as lenses between hanging wall and footwall of thick-bedded sandstone, dipping 35° N.

Bituminous coal found in lense 6 in thick and 10 ft long.

Abandoned at exam time.

Location 2 Hinton prospect - NW¼ sec. 6, T. 39 N., R. 7 E.

Prospect tunnel 250 ft in length through thick-bedded sandstones, including 8 ft of soft slickensided shale.

Shale contains bituminous coal 4 in thick, less than 10 ft in length.

Bed attitude: strikes N. 75° E. dips 45° N.

Abandoned at exam time.

Location 3 Unnamed - middle of sec. 7, T. 39 N., R. 7 E.

Prospect tunnel penetrates surface material to depth of 125 ft and terminates in highly distorted shales containing a bituminous coal 5 ft 2 in thick.

Location 4 Armstrong - Extreme NE¼SW¼ sec. 7, T. 39 N., R. 7 E.

Prospect tunnel penetrated unconsolidated material to 75 ft in depth and terminates 2 ft-thick bed of carbonaceous shale, with no coal being found.

1/ From Woodruff, 1914.

Location 5 Brooks prospect - SW. cor. $NE\frac{1}{4}NW\frac{1}{4}$ T. 39 N., R. 7 E.

125-foot entry on a coal bed between beds of sandstone dipping 45° S.

(Hanging wall of sandstone)

Badly crushed carbonaceous shale 4 ft, 5 in

Badly crushed coal - 1 ft, 8 in

Footwall of sandstone

Field test of ash content showed 54 percent impurities.

Coal occurs as discontinuous lenses.

High impurities and difficult access probably preclude systematic and economic mining.

Location 6 Powers prospect - Common cor. secs. 17, 18, 19, and 20, T. 39 N., R. 7 E.

Entry 115 ft long in strata dipping 65°.

Very pockety and crushed character of coal exemplified here. Slickensided, carries 35 percent ash. One bed decreases in thickness from 23 in.down to 13 in. in 7 ft.

Location 7 Unnamed - SE.cor. $NE\frac{1}{4}SW\frac{1}{4}$ sec. 18, T. 39 N., R. 7 E.

Prospect tunnel 250 ft long exposes 18-in bed of shale with some crushed coal.

Location 8 Unnamed - Center $SE\frac{1}{4}SW\frac{1}{4}$ sec. 18, T. 39 N., R. 7 E.

125 ft prospect tunnel shows a 6 in thickness of badly crushed coal, 20 ft in length.

Both hanging wall and footwall are thick sandstone.

Location 9 Unnamed - Approximately 350 ft south of the center of section line between sec. 17 and sec. 20 T. 39 N., R. 7 E.

Diamond drill hole sunk 500 ft vertically into beds dipping 25° W.; actually tested 210 ft of noncoal-bearing strata.

Location 10 Unnamed - Middle of north line of $NW\frac{1}{4}$ sec. 20

Prospect tunnel running SW. for 100 ft, and then 150 ft SE.

Encountered two lenses of black carbonaceous shales and one 2-in seam of lignite-bearing coal in a carbonaceous shale.

Location 11 Unnamed - center of sec. 11, T. 39 N., R. 7 E.

Prospect tunnel 50 ft in length in sandstone.

A carbonaceous shale, locally altered to impure graphite, is reported just inside the tunnel. 100 ft SW. of this location occurs sheared and crushed bed of bituminous coal carying between 3 in and 36 in along the strike.

(Authors note: According to the geologic map of the Glacier area, figure II, the previous two prospects appear to be located wholly within the non-coal-bearing shales of the Nooksack Formation of Jura-Cretaceous age. The findings and locations are therefore suspect.)

Location 12 Unnamed - SE$\frac{1}{4}$ sec. 19, T. 39 N., R. 7 E.

Exposed section.

Massive gray arkose with leaf imprints.

Slickensided carbonaceous shale - 1 ft 2 in.

Black shale and sandstone - 1 ft 2 in.

Location 13 Unnamed - NE. cor. SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 19, T. 37 N., R. 7 E.

Entry of 45 ft in depth.

Bed of carbonaceous shale swells to 3 ft at 36 ft and eventually goes to zero thickness at 45 feet. Thickest coal is bituminous and is on order of 4 in but appears to be very pockety.

Location 14 Unnamed - NE$\frac{1}{4}$NW$\frac{1}{4}$ of sec. 19, T. 39 N., R. 7 E.

40-foot tunnel diagonally cuts a bituminous coal bed of widely varying thickness. Coal is badly slickensided, having been crushed between walls of massive sandstone. Field analysis showed 74 percent ash.

Location 15 Hinton prospect - Center of NW$\frac{1}{4}$ sec. 19, T. 39 N., R. 7 E.

Two entries, one 50 ft above the other. Slickensided coal between two massive sandstone walls varies to 6 in. in thickness. No coal reported in other 50 ft in length.

Location 16 Bellingham Bay and British Columbia mine - NW. cor. NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 24, T. 39 N., R. 6 E.

1,000-ft tunnel driven along strike

Location 16 Bellingham Bay and British Columbia mine - (Continued)

Section at portal

Massive sandstone

Shattered shale	2'0"
Bituminous coal, slickensided	1'5"
Crushed shale	3'6"
Bituminous coal, slickensided	6"
Crushed shale	

Woodruff (1914) reports no coal was found 50 ft or 150 ft from the portal. Although the coal had a field ash analysis of only 5.3 percent, it is reported that the bed was lenticular in shape, for the width diminished to zero less than 300 ft above the portal.

Location 17 Tunnel 2 - SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 29, T. 39 N., R. 7 E.

Tunnel is reported to be 700 ft in length. In the first 325 ft, the beds are highly fractured and crushed and have been locally metamorphosed. Conditions varied so much that a measured section did not represent true conditions 150 ft away. Bright anthracitic coal was observed at the 325 ft mark but no samples were taken for analysis. Dip measurements were said to be roughly 70°.

Location 18 Discovery Tunnel - Center SW$\frac{1}{4}$ sec. 29, T. 39 N. R. 7 E.

Tunnel reported to extend over 750 ft in length and is said to be most promising of all locations.

Hanging wall - slate

Coal	2'2$\frac{1}{2}$"
Bone	1'1"
Coal	6'9"

Footwall - slate

The anthracite coal is badly crushed and slickensided in this area. 100 ft above the tunnel the coal thins markedly, and a mile west at Location 19, very little coal is found. The area where the section was measured is thought to be only a locally thick lens of coal.

Location 19 Smith Tunnel - Center SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 30, T. 39 N., R. 7 E.

Prospect tunnel 300 ft in length through badly distorted sandstones. A coal bed, generally 6 in or less in thickness, is associated with shale varying from 48 in to less than 1 in across 100 ft.

MISCELLANEOUS COAL PROSPECTS

There are many other instances of coal discoveries in western Whatcom County - most of them must be classified as prospects. There are few, if any, indications that they produced coal on a commercial-volume basis.

Long Point Prospect

(SE¼SW¼ sec. 25, T. 38 N., R. 3 E.)

Two obvious promontories on opposite shores of Lake Whatcom, 2½ miles from the west end, are made up of crossbedded sandstones and resistant conglomerates of the Chuckanut Formation. Strata on the north promontory (Long Point) strike N. 45° W. and dip 68° S. and lie stratigraphically above the coal seam. Strata on the south point (Strawberry Point) strike N. 30° W. and dip 20° S., and are stratigraphically lower. A vein of coal "several feet wide" and of "very good grade" was reported to exist between the two resistant beds, but no samples were taken for subsequent analysis and no stratigraphic sections were measured. Jenkins (1923) feels that the stratigraphic sequence found here may correlate with those at Rocky Ridge and at Silver Beach. The correlation must remain tentative, as the entire sequence is only partially exposed.

Both Long Point and Strawberry Point are presently (1975) dotted with beach homes; observable geology today is likely restricted to beach and near-shore areas.

Manley's Camp Prospect

Remains of once-active coal bunkers mark an area near SE¼SE¼ sec. 1, T. 37 N., R. 3 E., where, according to Jenkins (1923), coal was mined in the early 1900's. No outcrops are exposed and local dips in this area are fairly steep to the northwest. One mile west, near NE¼NW¼ sec. 2, T. 37 N., R. 3 E., a drift is reported to follow a coaly bed, which strikes N. 55° E. and dips 35° N.

Correlations of coal-bearing horizons at this location, Rocky Ridge and Geneva are possible because of the proximity to one another but must be regarded as tentative at this time.

Deming Prospect

On the south side of Mount Baker highway, SW¼SW¼ sec. 35, T. 39 N., R. 4 E., two tunnels were cut in vertical strata that strike essentially north and south. The coal occurs in association with a two-foot bed of fireclay; a green shale is found stratigraphically above and below the coal and fire-clay. Coal samples taken by Jenkins (1923) on a weathered surface prospect show evidence of severe deformation. A proximate analysis of this coal gives the following data:

(M--Moisture; VM--volatile matter; FX--fixed carbon; Btu--British thermal units)

Sample	Proximate Analysis (percent) M	VM	FC	Ash	Sulphur (percent)	Btu
A1/	6.47	24.24	30.80	38.40	1.94	7541
B2/		25.91	33.03	41.06		8062

1/ A equals as received basis
2/ B equals moisture free
(Jenkins, 1923; analyst unknown)

A tunnel was driven 65 feet into the hill, again in vertical strata striking north-south. A stratigraphic section at the tunnel face shows the following information:

Wall (east to west)	Thickness (in)
Shaly sandstone	16
Coaly shale, squeezed into flakes	3
Clay	18
Coaly flaky shale	3
Clay	10
Coaly clay	12
Coal, squeezed into flakes	18
Bony coal	?
Wall	

A second tunnel nearby was reported to have cut a 3-foot seam of coal, but no stratigraphic or analytical data are available.

Jenkins also reports that one-half mile east, a 2-foot-thick coal seam exists in strata that strike No. 50° E. and dip 32° S.

Considerable variation of bedding attitudes within a very short distance in this area suggests major structural changes; it is quite possible that this local deformation is related to the unconformable nature of the contact between the Huntingdon and Chuckanut Formations. Clearly, more precise geologic information is needed before stratigraphic correlations are attempted.

Lake Padden Prospect

A 3-foot-thick seam of coal is reported to exist near the Galbraith Lookout road in NW¼SW¼ sec. 10, T. 37 N., R. 3 E. Here, sandstone beds of the Chuckanut Formation strike N. 25° W. and dip 80°. A slope was driven down-dip for an unknown distance, but little else is known about the location.

Chuckanut Creek - Samish Lake Road Prospects

Two prospects have been driven on the south valley wall of Chuckanut Creek, in the vicinity of NE¼ sec. 21, T. 37 N., R. 3 E. The strata in this area strike N. 80° E. and lie between the prominent Chuckanut anticline to the south and the Padden syncline to the north. Dips vary between 50° and 70°.

The first tunnel is alleged to follow the strike of a 3-foot-thick coal seam, but the purported thickness remains unsubstantiated. A stratigraphic section measured by Jenkins (1923) shows the following data:

	Thickness (ft)	(in)
Clayey shale (hanging wall)	10	0
Shale with thin coal seams	3	
Coal		6
Clay and shale with coaly streaks	2½	
Coal		3
Shale with coal streaks	1	3
Coal		1
Shale and coal streaks	2	
Shale (foot wall)		

The second tunnel, one-half mile east, was driven across the tip of a sequence striking N. 20° E. Jenkins reports that two seams crop out above the tunnel portal and one or two are exposed in the tunnel.

Jenkins suggests that these two prospects may lie within the same general stratigraphic horizon as those occurrences at Lake Padden and at Geneva. It is tempting to correlate this area and the Lake Padden occurrence, but it has been demonstrated previously that incompetant beds (shales, clays, coal) tend to pinch and swell in response to forces exerted upon them by enclosing more competent beds of sandstone. A correlation with the Geneva beds should be tentative at best; considerably more information is required before a definite association can be made.

As in previous attempts to correlate coal-bearing sequences, the geologist is thwarted by lack of consistent marker beds and the presence of Pleistocene over-burden which masks important structural features.

Coal on Chuckanut Drive

Numerous small veins of coal and shaley coal can be observed along Chuckanut Drive. The strata in this area are tightly folded and dips are fairly steep in most places. Jenkins notes the occurrences of some prospects near tidewater on both Samish and Chuckanut Bays, but no known geologic data has been collected.

The contact between the Chuckanut sandstone and underlying metamorphic rock is exposed at Oyster Creek on Chuckanut Drive, (Skagit County), but the area stratigraphically above the contact is covered by alluvium and landslide material and no known prospects occur in this area.

Other Prospects

An apparent prospect tunnel exists on the Van Zandt Dike (sic), a section of east-west-striking Chuckanut sandstone in which dips are commonly between 45° and 60° N. (Sec. 3, 10, 16, 17, T. 38 N., R. 5 E.). The basal contact between Chuckanut formation and underlying metamorphic rocks trends to the northeast across secs. 21, 22 and 14; it is not known if the same general stratigraphic and structural conditions exist here as they do 9 miles southwest at the Blue Canyon area. (O.P. Jenkins, field notes)

A prospect south of Maple Falls (general area of Slide Mountain, NW¼, T. 39 N., R. 6 E.) is also mentioned by Jenkins (O.P. Jenkins, field notes, unpublished). Here, steep northerly dips and local reversals of structure suggest possible complications in future geologic interpretation. More complete and detailed structural treatment by other workers is unknown to the writer.

Moen (1962) notes that "coal seams of the northern half of the Van Zandt quadrangle are small and have not proven to be of economic value. All past attempts to develop these seams have failed". (A summary list of coal prospects appears at the end of the paper.)

CONCLUSIONS

Livingston (1974) notes that, with few exceptions, most of the coal in the state is not considered at the present time to be in economic abundance. Limited quantities in fields of variable composition, with steeply dipping beds covered by thick overburden, all tend to complicate mining conditions and thus contribute to higher-than-average costs in mining Washington coals.

As an example, at 1972 prices, Washington coal cost $8.21 per ton to mine. This equals a 165 percent increase over the national average of $4.99 per ton. Cheaper coals from Utah, Wyoming, and Montana strip mines tend to confound the state's coal producers. Montana coal, for example, cost $2.18 per ton to mine, or a decrease of 40 percent below the national average.

In a discussion of strip-mining efficiency, Averitt (1968) notes that man-day output, using stripping methods, is approximately 100 percent higher, recovery rates are approximately 60 percent higher, and operating costs are as much as 30 percent lower than in underground mining. It is therefore easy to understand why strip mining activity has steadily increased from only 1 percent of overall mining activity in 1917 to almost 10 percent in 1966, when coal output from eight states came solely from stripping activities.

Significant progress has been made abroad utilizing hydraulic techniques in underground mining (Boyd, 1959); one coal mining company in the Wilkeson-Carbonado district southeast of Seattle is operating under a grant to seek ways of making hydraulic mining less costly. Hopefully, those efforts will bring state mining cost per ton closer to the $5.00 per ton figure suggested by Livingston and allow state coal producers to be more competitive in the national and international marketplace.

The National Coal Association projects coal demand to reach some one billion tons per year by 1985, with the bulk of that demand being consumed through thermo-electric generation. Although only one such plant exists in the state now, Livingston anticipates that future state demands on coal will align themselves with national priorities.

It would indeed be ironic to erect a thermo-electric generating plant near a coal field with a guaranteed 40-year reserve, only to find, at some point in the future, that out-of-state coal was more economic (from both transportation and heating-value standpoints) to burn than native coal. With larger and (presumably) more efficient strip-mining equipment leaving the drawing board every day, it follows that the future of underground mining in the state may hinge on whether or not hydraulic mining techniques can be refined to the point of being profitable when applied to Washington coal.

Beikman and others (1961) have summarized reserves of coal within Whatcom county, totaling some 333 million tons, or approximately 5 percent of the estimated 6 billion tons of coal reserves for the entire state.

Numerous prospects have been driven in various localities in Whatcom county and coal occurrences are present in most all of the prospect pits mentioned, but it appears that only a few of these areas have enough reserves to warrant further serious consideration in light of the aforementioned economic factors surrounding Washington coal.

Three sites within Whatcom county coincidental with state-owned land have been identified and are considered to hold enough potential to warrant further exploratory work.

The first area lies partially in Skagit and partially in Whatcom counties, just north of the small town of Alger (see plate 1). Here, a small north-plunging syncline lies under some 720 acres of state-owned land. The syncline is continuous to the north and appears to be the same depositional basin in which the Geneva coal appears. Previous workers have shown this area to be part of the Blue Canyon coal zone and have estimated reserves to be 5.4 million tons. 1/

The second area of potential coal reserves underlying state land is in T. 38 N., R. 5 E. The area comprises roughly five square miles, but no known stratigraphic or exploratory information is known to the writer. It is considered potentially coal-bearing due to its stratigraphic proximity to the basal portion of the Chuckanut Formation (same stratigraphic horizon as at Blue Canyon). Available geologic data indicates that large-scale deformation at the surface is absent, although dips are fairly steep.

The third area is located in sec. 16, T. 36 N., R. 6 E. near the Clearwater Creek area. Little geologic information is available other than that shown on plate 1. No drill holes are known to exist in the area and no prospects have apparently

1/ As of this writing, federal funds have been granted to begin exploratory drilling in this location. It is anticipated that the results of the drilling will be available sometime during the 3rd quarter of 1975.

been made. Basal Chuckanut sandstone has been folded into a northwest-trending syncline in this area; geologic conditions here thus parallel those in other areas of Whatcom County with known coal occurrences.

State land is located in the northern half of sec. 15 and all of sec. 10 of T. 37 N., R. 4 E. This area lies just to the north of the old Blue Canyon mine location. Steep dips and thrust faulting known from previous mining activities at Blue Canyon would complicate present mining attempts and would no doubt add considerably to mining expenses.

From the standpoint of reserves and ease of mining, the most promising coal field in Whatcom County is in the Van Wyck syncline. Unfortunately, state-owned land within the known limits of the Van Wyck syncline comprises less than 600 acres.

TABLE 6.—*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				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	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.

(From Moen, 1969)

Summary of Coal Occurrences

Whatcom County, Washington

Property Name	Map Symbol Plate 1	Location
Alger	Al	SE¼ sec. 36, T. 37 N., R. 3 E.
Blue Canyon	Bc	SE¼ secs. 15 & 22, T. 37 N., R. 4 E.
Bellingham Coal Mine	Be	SE¼ sec. 13, T. 38 N., R. 2 E.
Boulder Creek	Bo	SW¼ sec. 22, T. 40 N., R. 6 E.
Coal Creek	Cc	Sec. 4, T. 39 N., R. 5 E.
Chuckanut Creek - Samish Lake Road	Cs	NE¼ sec. 21, T. 37 N., R. 3 E.
Deming	De	SW¼ sec. 35, T. 39 N., R. 4 E.
Glen Echo	Ge	NW¼ sec. 9, T. 38 N., R. 4 E.
Glacier	Gl	Sec. 19, T. 39 N., R. 7 E. (See separate listing & map in text)
Geneva	Gn	Sec. 19, T. 39 N., R. 7 E.
Goshen	Go	SW¼ sec. 19, T. 39 N., R. 4 E.
Lake Padden	La	SW¼ sec. 10, T. 37 N., R. 3 E.
Long Point	Lp	SW¼ sec. 25, T. 38 N., R. 3 E.
Manley's Camp	Mc	SE¼ sec. 12, T. 37 N., R. 3 E.
Maple Falls	Mf	NW¼ T. 39 N., R. 6 E.
Rocky Ridge	Rr	SW¼ sec. 31, T. 38 N., R. 4 E.
Silver Beach	Sb	SW¼ sec. 22, T. 38 N., R. 4 E.
Saar Creek	Sc	SW¼ sec. 17, T. 40 N., R. 5 E.
Van Zandt Dike	Vz	Sec. 16, T. 38 N., R. 5 E.
Van Wyck syncline	Vw	T. 39 N., R. 2 E. & R. 3 E.
Small Creeks		Sec. 9, T. 39 N., R. 5 E.

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BELLINGHAM QUADRANGLE
WASHINGTON STATE PUBLIC LANDS
1:100 000-SCALE SERIES (PLANIMETRIC)

OFR 75-9

DEPARTMENT OF NATURAL RESOURCES MANAGED UPLANDS
DECEMBER 1979

- 01 - State Forest Board - Transfer
- 02 - State Forest Board - Purchased
- 03 - Common School, Indemnity, and Escheat
- 04 - Agricultural School
- 05 - University - Transferred
- 06 - CEP and RI
- 07 - Capitol Building
- 08 - Normal School
- 10 - Scientific School
- 11 - University - Original
- Administrative

(PT. ANGELES)

Mapped, edited, and published by the Geological Survey

Compiled in 1975 from USGS 1: 24 000 and 1:62 500-scale topographic maps dated 1962–1973.

Planimetry revised from aerial photographs taken 1973 & 1976
Revised information not field checked
Tracts less than 40 acres are usually omitted because of map scale.
50 000-foot grid ticks based on Washington coordinate system, north zone
1927 North American datum

SCALE 1:100 000

KILOMETRES
MILES
FEET

SPOT ELEVATIONS IN METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
To convert meters to feet multiply by 3.2808
To convert feet to meters multiply by 0.3048

Revised and reprinted by the Washington State Department of Natural Resources

Roads Updated From Aerial Photography Taken In Year Indicated

1976

- DNR recreation site
- Village or locality
- Landmark building
- Perennial stream, lake
- Intermittent stream, lake
- Public park or recreation area
- U.S. National forest
- Other public area or military or Indian reservation
- Washington Dept. of Game

ROAD CLASSIFICATION

- Primary highway, hard surface
- Secondary highway, hard surface
- Light-duty road, hard or improved surface
- Unimproved road, or street
- Trail
- Interstate Route
- U.S. Route
- State Route

BELLINGHAM, WASH.
NE/4 VICTORIA (NM 10-11) 1:250 000-SCALE MAP
N4830–W12200/30x60
1973

Produced by the Geological Survey

Compiled from USGS 1:24 000 and 1:62 500-scale topographic maps dated 1952–1969. Planimetry revised from aerial photographs taken 1974, 1975 & 1979 and other source data. Revised information not field checked. Map edited 1979
Tracts less than 40 acres are usually omitted because of map scale
50 000-foot grid ticks based on Washington coordinate system, north zone. 1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines 22 meters north and 91 meters east
Dashed red lines indicate protracted land lines
Boundaries as shown represent the proclamation or designated areas
There may be private inholdings within these boundaries

OFR
75-9
Plate 1


PLATE 2, GEOLOGIC MAP OF COAL-BEARING ROCKS, WHATCOM COUNTY, WASHINGTON
1 1/2 0 1 2 miles
Scale 1:62,500
N
EXPLANATION
FOLD AXIS, SHOWING PLUNGE
STRIKE AND DIP OF BEDS
APPROXIMATE LIMIT OF HUNTINGDON FORMATION; DASHED WHERE INFERRED
APPROXIMATE LIMIT OF CHUCKANUT FORMATION; DASHED WHERE INFERRED
AREAS OF ESTABLISHED COAL RESERVES, SHOWING ABBREVIATION OF FIELD (PAGE 81 OF TEXT)
LOCATION OF PROSPECT OR FORMER MINE
THRUST FAULT, SAWTEETH ON OVERTHRUST PLATE
FAULT, SHOWING RELATIVE MOVEMENT
MINE ADIT OR PROSPECT
GEOLOGY AFTER JENKINS (1923); GLOVER (1935); GLAESER (1960); AND MILLER AND MISCH (1963)
(BASE MAP: USGS TOPOGRAPHIC QUADRANGLES, 15')
BELLINGHAM COAL ZONE
LAKE WHATCOM COAL ZONE
BLUE CANYON COAL ZONE
GLACIER COAL ZONE
BOULDER FAULT
VAN WYCK SYNCLINE
GOSHEN ANTICLINE
SQUALICUM ANTICLINE
WHATCOM SYNCLINE
WHATCOM CREEK ANTICLINE
LOOKOUT MOUNTAIN SYNCLINE
PADDEN ANTICLINE
SAMISH SYNCLINE
CHUCKANUT ANTICLINE
BELLINGHAM BAY