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Department of Conservation and Development

D. A. SCOTT, Director

DIVISION OF GEOLOGY

S. SHEDD, Supervisor

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(Geological Series)

Geological Investigation

OF THE

Coal Fields of Western Whatcom County, Washington

BY

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LETTER OF TRANSMITTAL

Hon. D. A. Scott, Director, Department of Conservation and Development, Olympia, Washington.

SIR: I have the honor to submit herewith the manuscript of a report on the Coal Fields of Western Whatcom County and recommend that it be published as a Bulletin of the Department of Conservation and Development and designated as Geological Series No. 28.

Very respectfully,

S. SHEDD,

Supervisor, Division of Geology.

College Station,
Pullman, March 24, 1923.

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ABBREVIATIONS USED IN THIS REPORT

N.—north.

S.—south.

E.—east.

W.—west.

NW.—northwest.

NE.—northeast.

SE.—southeast.

SW.—southwest.

R.—range.

T.—township.

Sec.—section.

NW¼—northwest quarter.

W½—west half.

Dip 60°—dip is 60° from the horizontal.

N. 40° W.—bearing is north, 40 degrees to the west.

INTRODUCTION

PURPOSE

The object of this investigation was to make a careful study of the coals of western Whatcom County, Washington, from a geological standpoint. Particular attention was therefore focussed upon the structural features of the rocks and upon the occurrence and correlations of the coal seams, as well as upon the value of the coals from the standpoint of quality, quantity, and location.

Although limited time and appropriation prevented the mapping of the whole of western Whatcom County during the summer of 1922, the principal features were completed of a certain significant area, and one especially important conclusion was reached, which, it is hoped, may result in the discovery of another coal basin not far from Bellingham.

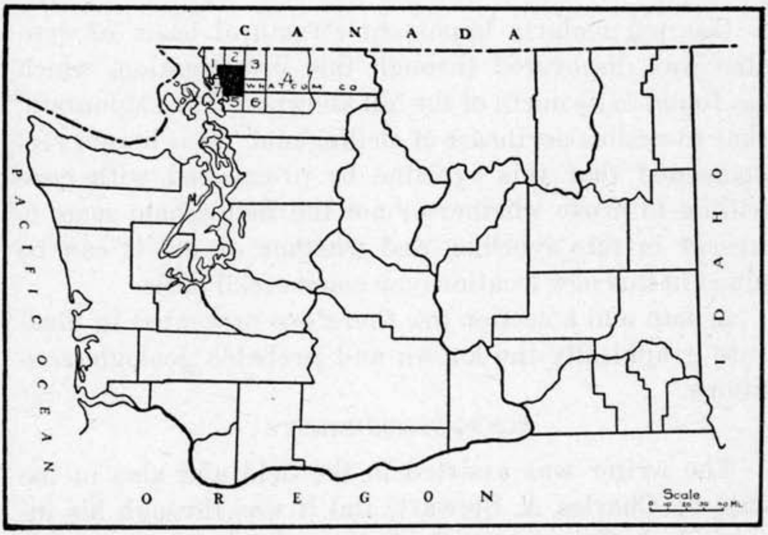

FIG. 1. Index map showing the relative positions of the topographic and geodetic maps, and the area covered in detail by this report. The numbers, 1, 2, 3, 4, 5, and 6, refer to U.S.G.S. topographic quadrangles, Blaine, Sumas, Van Zandt, Mt. Baker, Samish Lake, and Wickersham respectively. No. 7 refers to the U.S. Coast & Geodetic chart, Bellingham Bay (6378). The black portion represents the principal area covered by this report.

AREA COVERED

The investigation necessitated a hurried reconnaissance of the whole situation, but special care was given to the study of the region in the extreme western part of Whatcom County. This part includes the area reaching from the coast of Samish, Chuckanut, and Bellingham bays to the north shore of Lake Whatcom, and northwestward through Squalicum Mountain and to the more level drift covered region beyond Bellingham. An endeavor was made to secure all the information possible regarding the surface and underground conditions of the area north of Bellingham. It was considered especially essential to study this region in consideration of the possible extension of the Bellingham coal seam, which at the present time is the only seam in the county mined on a commercial basis.

RESULTS

One particularly important structural basin or syncline was discovered through this investigation, which was found to lie north of the hill known as King Mountain, some five miles northeast of Bellingham. It is herein recommended that this syncline be prospected with core drilling to prove whether or not the Bellingham seam is present in this syncline, and whether or not it can be mined in this new location on a commercial basis.

A map and a section are therefore presented to illustrate graphically the known and probable geologic conditions.

ACKNOWLEDGEMENTS

The writer was assisted in the field and also in the office by Charles A. Stewart, and it was through his interest and efficient help that much of the data were collected and compiled.

Many citizens of Whatcom County gave much material assistance. To all of them the writer is greatly indebted

for their courtesies. Among these persons should be mentioned in particular John C. Eden and J. H. Pasco of the Bellingham Coal Mines; J. J. Donovan and Andrew Ecklund, who gave information concerning Blue Canyon and Glen Echo; Otho Williams and James Gilfilen, who were interested in properties about Lake Whatcom; and C. F. Livermore, who gave much data concerning the water wells of the county. In addition to these the kind attention of the officers of the Bellingham Bay Improvement Company is gratefully acknowledged, especially in reference to the use of the old records of the diamond drilling previously carried on by that company in Bellingham.

A report by George Watkin Evans, made to the Bellingham Coal Mines, on the problem of withdrawing pillars was lent by that company to the writer for perusal. It was found both interesting and instructive, especially since it contained a geological section of the mine.

The maps presented in this present report were drawn by Cedric E. Denman. Both A. C. Hansen and Charles A. Stewart made analyses of several samples of coal collected.

TOPOGRAPHIC AND MINE MAPS

In the field the topographic maps issued by the United States Geological Survey, which cover practically the whole area studied, were used for plotting geologic data and for the determination of structural geologic features. The index map (Fig. 1.) shows the positions and the names of these "topographic quadrangles", as they are called.

In addition to these quadrangles, other maps were found useful. The chart of Bellingham Bay, No. 6378, issued by the United States Coast and Geodetic Survey, was found indispensable for parts of the coast line not covered by other maps. A map of the city of Bellingham, prepared by C. M. Adams, 1907, was also used extensively for detailed work within the city limits. The Bellingham Coal Mines property has been well surveyed, and a map, made by E. C. Lyle and brought up to date, shows all the important underground workings of Mine No. 1, as well as the surface features.

A map of the Blue Canyon mine, dated 1908 and signed by J. H. Walter, partly compiled from an earlier map of the older mine workings, prepared by R. E. Helms, in 1892, shows clearly the conditions of that area.

PRODUCTION[1] OF COAL IN WASHINGTON BY COUNTIES, IN 1921

COUNTY	Short Tons	Number of Producing Mining Companies	
		Those Over 1,000 Tons	Those Under 1,000 Tons
Kittitas	1,392,813	9	1
King	340,015	17	3
Thurston	256,218	2	0
Whatcom	187,005	3	2
Lewis	142,084	9	2
Pierce	102,538	4	1
Skagit	1,433	1	0
Total	2,422,106	45	9

[1]Statistics taken from the State Mine Insp ector's reports.

PRODUCTION OF COAL IN WHATCOM COUNTY, WASHINGTON

Year	Short Tons	Year	Short Tons
1891	7,200	1907	3,160
1892	26,675	1908	18,963
1893	26,000	1909	14,632
1894	....	1910	12,415
1895	28,764	1911	3,476
1896	12,000	1912	6,523
1897	5,853	1913	7,325
1898	6,300	1914	6,602
1899	6,650	1915	6,255
1900	48,200	1916	5,983
1901	8,200	1917	4,841
1902	6,010	1918	4,603
1903	600	1919	42,886
1904	....	1920	114,264
1905	....	1921	187,005
1906	....	*1922	81,239

* First half.

The production of coal from Whatcom County for the years 1891 to 1917, inclusive, was entirely from the Blue Canyon mine, which also produced 3,689 tons in 1918, and 543 tons in 1919. The rest of the production was from Mine No. 1 of the Bellingham Coal Mines, with the exception of 240 tons produced in 1919 from the Glen Echo mine, and 618 tons in 1921 from the same mine, and also 150 tons by the Pacific Atomized Fuel Company from the Geneva mine in 1921. These statistics were taken from the State Mine Inspector's reports. The Report of 1891 has the following notation: "Bellingham Bay mine in Whatcom County has the first mine of note developed in Washington. This mine has not been in operation for several years and is now filled with water. Coal was shipped from this mine in 1860. The mine yielded some 250,000 tons in all." This old mine does not exist now, but the present Mine No. 1 of the Bellingham Coal Mines is undoubtedly located on a continuation of the same seam of coal.

TABLE OF PROXIMATE ANLYSES OF COALS FROM VARIOUS WESTERN MINES PRESENTED FOR COMPARISON

LOCALITY			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B.T.U.	Reference
State	County	Place							
Washington	Whatcom	Bellingham	4.16	34.62	44.67	16.55	0.68	11,467	This report.
Washington	Kittitas	Roslyn	3.08	35.60	50.05	11.27	0.41	12,848	U.S.B.M., Bull. 22, p. 213 (No. 9460).
Washington	Thurston	Hurn (Hanniford No. 1)	22.2	31.5	37.2	9.1	0.35	8,565	Same, p. 221 (No. 9941).
Washington	Lewis	Chehalis	30.50	34.94	29.61	4.95	1.25	7,934	Same, p. 214 (No. 9941).
Washington	Pierce	Burnett	3.61	36.83	45.47	14.09	0.38	12,370	Same, p. 217 (No. 9889).
Washington	King	Renton	17.97	35.13	39.12	7.78	0.43	10,006	Same, p. 207 (No. 2456).
Wyoming	....	Rock Springs	8.53	35.60	50.39	5.48	0.78	11,833	Same, p. 312 (No. 5358).
Utah	....	Sunnyside	5.96	38.68	48.77	6.59	1.73	12,841	U.S.B.M., Bull. 85, p. 103 (No. 12632).
B. C.	....	Nanaimo	1.1	39.3	49.2	10.0	0.4	13,160	C.G.S., Memoir 51, p. 97 (No. 3).

HISTORY OF COAL MINING IN WHATCOM COUNTY

EARLY DEVELOPMENTS OF THE BELLINGHAM COAL SEAM

Coal was first discovered[1] in Whatcom County on Bellingham Bay in the year 1852. This was four years later than the first discovery in the state, which was of a poor grade of lignite in Cowlitz Valley. The first coal mine in the State was consequently opened on this Bellingham seam. The dip of the seam is reported as being about 35°, bearing northwest.

An interesting account of the early history of the Bellingham Bay coal mine is given by Edward Eldridge[2], and this has been freely drawn upon in the present writing. A Captain Pattle, who was cutting piles on San Juan Islands and transporting them by boat to San Francisco, was informed by the Indians that coal existed on Bellingham Bay. Acting upon this information Pattle visited the outcroppings over which now stands the City of Bellingham, and then went away to get companions to locate claims with him. He later returned with two men named Morgan and Thomas, and the three located claims which now form a part of Bellingham and South Bellingham, once known as Fairhaven. The present City of Bellingham really includes South Bellingham, however, and is composed of what were first known as the towns of Whatcom, Sehome, and Fairhaven.

In 1835, two men named Hewitt and Brown discovered a seam of coal at Sehome[3]. They were logging for a mill on Whatcom Creek and found the seam exposed in a hole where a tree had been upturned. Some of the coal was

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[1]George Otis Smith; Pacific Coast Coal Fields, U. S. Geol. Survey, 22d Ann. Rept., Pt. 3, 1902, p. 492.

[2]History of Whatcom County, Bellingham. Herald's History of Northwestern Wash., Supplement to Bellingham Herald.

[3]Henry Landes; The Coal Deposits of Washington. Wash. Geol. Survey, Vol. 1, Ann. Rept. for 1901, p. 257.

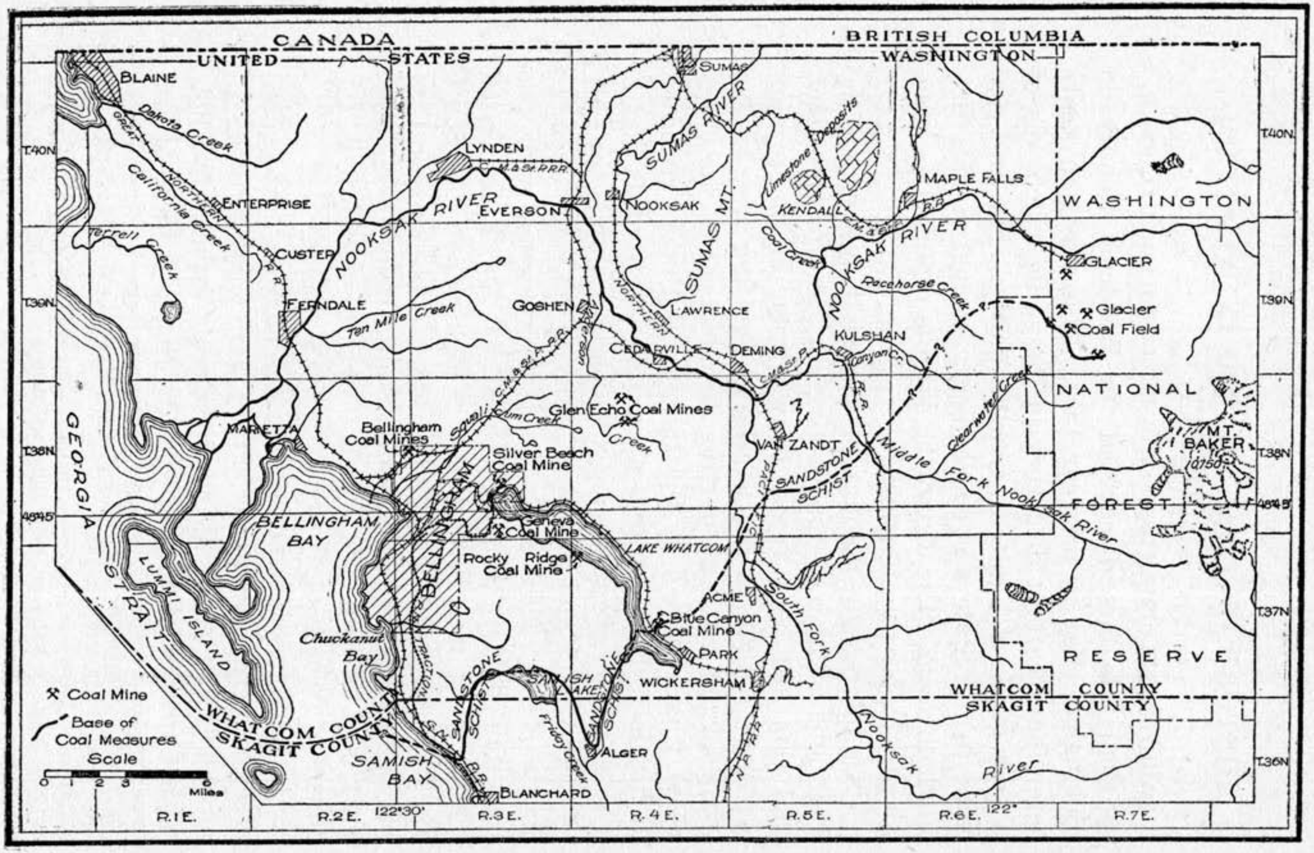


FIG. 2. General map of the western half of Whatcom County, showing in particular the locations of the important coal mines and prospects and the contact line between the coal measures and the underlying schist.

sent to San Francisco to be tested, and a company was formed which purchased the claims from Hewitt and Brown for $20,000. Edmund C. Fitzhugh was then put in charge of the property. This was the beginning of the old Bellingham Bay mine.

In the meantime a company consisting of Sam Brannan, Charles Minturn, and others, was formed to open and mine the Pattle property. This company leased claims for a period of three years and was to pay $75 a month for each claim, and a royalty for each ton of coal taken from the mine. A party under the superintendency of a certain Captain Howard arrived in the fall of 1853 to open and work the mines. This enterprise failed for various reasons, one of which was the lack of mining experience on the part of the operators.

In 1859 the Bellingham Coal Company leased its property to partners named Moody and St. Clair. It was reported that these men made $300,000 during their first year of operation, and that they purchased 2,000 additional acres of adjoining land.

The success of these men induced a man by the name of Richards of Whatcom to try mining on a claim known as the Morrison Donation claim. The claim was purchased for $3,000, a company was formed with Richards at the head, and about $40,000 was spent in development work. This enterprise was a failure. Two or three cargoes were gotten out and then the work was stopped and never resumed.

The coal seam of the Bellingham Coal Company, according to Eldridge, dipped at an angle of about 45°, the angle gradually decreasing with depth. The seam was reported as being thick and containing several streaks of slate. A slope several hundred feet long followed the seam down the dip. Three hundred feet down the slope, a gangway was cut with just enough rise to allow the water to drain to the slope and so that loaded cars could be easily drawn out. After the gangway was driven some distance, rooms were opened in order to mine the coal. Twenty feet of coal next to the slope were left to support the ground, then a room of 60 feet was worked out, then another 20 foot piller was left, the work continuing in this manner.

In 1867 the lease was re-purchased from Moody and St. Clair by the stockholders, and the mine was placed under new management. Soon after this change, fire, caused by spontaneous combustion of debris, broke out in the mine. In order to extinguish the fire, the mine was filled with water from the bay.

It was nearly a year before the water was pumped out and mining again resumed. Later, fire broke out once more and the mine had to be flooded again. Although somewhat discouraged, the company again pumped the water out and continued to work the mine until 1878, when it was shut down, and never reopened.

Bruce Cornwall[1] says, regarding the old Bellingham mine:

"In the early fifties the Bellingham Bay Company was organized.

"In spite of fire, production increased and in 1867, from January until October, production advanced from 262 to 1400 tons per month. In January, 1868, fire broke out. . . . work was resumed in June.

"The mines at Bellingham Bay were not developed to any great degree, owing to the fire and to the increased cost of transportation, and the company found itself with 5000 acres of land unnecessary for mining."

[1]Bruce Cornwall; Life Sketch of Pierre Barlow Cornwall, 1906.

After a very early exploring expedition, Blake[1] published the following report:

"Coal from this locality was in use in the city in 1854 for burning in grates and for cooking, and gave general satisfaction. It is a compact and perfectly black bituminous coal, breaking with a brilliant conchoidal surface, and, in large masses, much resembles the Carboniferous coal mined at Pittsburgh, Pa. It burns freely, and leaves a fine, white ash which appears to be very abundant, but may not be present in such quantity in the better or interior parts of the vein. Through the kindness of Lieutenant W. P. Trowbridge, of the United States engineers, who has examined the region, I am able to present the following extracts from a manuscript report made by him in August, 1853:

" 'The coal strata exposed to view on Bellingham Bay are situated in latitude 48° 43′, and occur in a series of stratified rocks, which dip at an angle of 70° from the horizon, and strike E. 15° N. The thickness of the series being about two thousand feet . . . the coal beds enter the bank at right angles to the shore-line, and rise with a gradual slope to the height of about three hundred and fifty feet, at the distance of half a mile from the shore, where they are broken in a direction oblique to that of the beds, and fall off in abrupt ledges to their original level. . . . From the sections it will be seen that there are ten workable seams of coal, interstratified with six or seven heavy beds of sandstone, and numerous strata of bituminous shale, slate, clay, iron-stone, and thin beds of sandstone. In two thousand feet the coal occupies about one hundred feet; the thick beds of sandstone about seven hundred, and other rocks about twelve hundred. . . . The workable veins are, respectively, 20, 6, 6, 12, 25, 5, 5, 18, and 13 feet in thickness—making an aggregate of 116 feet.

" 'Bellingham Bay here offers a fine harbor and good anchorage for vessels of all kinds; and by constructing a wharf a few hundred feet in length, coals can be brought down from the pits in cars, and dropped into the vessels, without the employment of any other power than their own weight.'

"The following descriptive section is also given by Lieut. Trowbridge. The measurements are on a horizontal line; the real thickness of each stratum is therefore 94/100 of that stated.

[1]W. P. Blake; Pacific Railroad Reports, Vol. 5, 1856, pp. 285-287.

SECTION OF COAL-BEARING STRATA, BELLINGHAM BAY

		Feet
1.	Sandstone (thickly bedded), about	150
2.	Coal	20
3.	Shale	6
4.	Argillaceous sandstone	6
5.	Clay shale	10
6.	Slate filled with impressions of leaves	2
7.	Clay and bituminous shale	14
8.	Slate filled with impressions of leaves	4
9.	Clay	55
10.	Bituminous shale	25
11.	Bituminous shale and clay	178
12.	Sandstone (thickly bedded), about	200
13.	Coal	6
14.	Shales	35
15.	Coal	6
16.	Sandstone and shale	25
17.	Coal	6
18.	Clay, iron-stone, clay, and shale	145
19.	Coal (impure)	4
20.	Clay	40
21.	Coal (impure)	4
22.	Clay and shale	40
23.	Sandstone	35
24.	Coal	12
25.	Bituminous shale (probably will work into coal)	14
26.	Coal	25
27.	Clay	24
28.	Sandstone (thickly bedded), about	100
29.	Clay	30
30.	Stratified argillaceous sandstone	50
31.	Coal	5
32.	Clay and shales	200
33.	Coal	5
34.	Shales and slates	150
35.	Coal	18
36.	Clay	20
37.	Sandstone (thickly bedded), about	200
38.	Coal	13
39.	Clay	15
40.	Sandstone (thickly bedded).	

"It is possible that some of the many distinct beds of coal described by Lieutenant Trowbridge are not perfectly pure; they may contain seams of bituminous shale, or earthy matter, which, in the rough and unworked outcrops, might be considered as good coal. The number and thickness of the beds, as given in the section, show that the formation is very remarkable and extensive, and excites a desire to know more of the geology of the region[1]. An extended and careful

[1]"It is not impossible that these beds of coal are so much plicated that the same series is included more than once in the section as above given. I am assured, however, that the measurements were made with great care."—W. B. Blake.

survey is exceedingly desirable, not only for the geological results that may be expected, but as preliminary to the exploration of the beds.

"The imprints of leaves and twigs occur in the shales of the locality; but the specimens procured by Lieutenant Trowbridge were too obscure and imperfect to permit their specific characters to be made out.

"I learn from one of the officers that accompanied the United States Coast-Survey steamer *Active* on a recent trip to Puget Sound (1854), that the Bellingham Bay coal was used on the steamer a part of the voyage. The furnaces of this steamer are provided with 'drop and return flues'; but notwithstanding this construction, the flame from the furnaces would generally pour out of the top of the smoke-stack for ten or twenty feet. This is sufficient evidence of the existence of a very large amount of volatile matter in the coal; and it shows that the fire was not properly managed, or that the furnaces were not adapted to the peculiarities of the coal. This coal produced a large amount of very fluid slag, and it was necessary to rake the fires every twenty minutes. It was regarded as inferior to the coal from Vancouver's Island, which was also used on the steamer.

"The wharf at the mine on Bellingham Bay was not completed when the steamer left, and it was necessary to take the coal off to the vessel by lighters. Even these small vessels were obliged to take advantage of the tides in order to reach and leave the dock. The excavation into the hill, on the course of the coal-bed, did not extend over twenty feet; a large part of the coal at that time must, therefore, have been of very inferior quality, in consequence of long exposure to the weather and the infiltration of impurities.

"A block of sandstone obtained from the vicinity of the coal-bearing strata by Lieutenant Trowbridge very much resembles, in its lithological characters, the sandstone of San Francisco and its vicinity. The color is nearly the same; and it likewise contains small disseminated scales, or films, of a dark color, very much like those seen in the sandstone from Yerba Buena and Benicia. It also contains two thin fragments of coal, the remains of coal-plants, and one round fragment looking like a rounded or water-worn mass. Two well-preserved shells of the genus Pecten are contained in the same block. The synchronism of the stratum from which this block was taken with the sandstone of San Francisco is more than probable."

The year following Blake's report, Newberry[1] wrote as follows:

"This coal is found interstratified with sandstones and shales on the shores of Bellingham Bay. Lieut. W. P. Trowbridge, U. S. A.,

[1] J. S. Newberry; Coal of Bellingham Bay, Pacific Railroad Reports, Vol. 6, Pt. 2, 1857, pp. 53-68.

while superintending the construction of lighthouses on that part of the coast, made a careful measurement of the strata of the section in which the beds of coal are exposed, of which the results have been published in the geological report of Mr. W. P. Blake, contained in Vol. 5, U. S. P. R. R. Reports.

"The section exposed, when measured by Lieut. Trowbridge, consisted of about 2,000 feet of shales, sandstones, and coal, of which the coal presented the enormous aggregate of 110 feet. It is possible, however, that the series is, in part, composed of repetitions of the same members, as the strata are inclined at a high angle, and are much convoluted and disturbed in all that region.

"Many of the shales are fossiliferous, and vegetable impressions are particularly abundant. These consist, for the most part, of the impressions of dicotyledonous leaves, and are similar in general character; and some of them specifically identical with those collected on Frazer's River by the United States Exploring Expedition, under Capt. Charles Wilkes. Among them are species of *Platanus*, *Acer*, *Alnus*, etc., as yet undescribed. There is also a *Taxus*, or *Taxodium*, and a *Juniperous*. It is probable that all the dicotyledonous species there represented are extinct. The *coniferae* may not be so. A sufficient number of well marked specimens has, however, not yet been collected to determine this question.

"The flora of the coal deposits of Bellingham Bay is remarkably like that of the lignite beds of the upper Missouri, the genera being nearly all represented on the Missouri, and some of the species are identical.

"The lignite beds of the Missouri are undoubtedly Miocene, and it is very difficult to distinguish some of the species found in them from those of the Miocenes of Austria and of the Island of Mull.

"The strata exposed on Bellingham Bay, both in their lithological character and their fossils, are closely related to the sandstones and shales of the Columbia and Coose Bay, and are, probably, portions of the great San Francisco group, which forms the most striking feature of the geology of the coast mountains.

"The mines at Bellingham Bay were among the first opened on the western coast, and have already furnished a large quantity of coal for the San Francisco market.

"*Physical and chemical characters.* While having much the appearance and character of that from Coose Bay, this coal is harder and better, and more resembles the carboniferous coals of the Mississippi Valley. Several analyses give me for its composition:

Fixed carbon	47.63
Bitumen	50.22
Ashes	2.15

"Its economical value and adaptation to the different purposes for which coal is used are very similar to those of the Coose Bay coal, but commands a somewhat higher price in market. When I was in San Francisco, coal from Bellingham Bay was selling for $22 per ton."

In mentioning this mine, Willis[1] says that it was opened "on an isolated outcrop surrounded by a region of forest covered drift beds." He further states that the mine was first opened in 1851, shipped 20,500 tons of coal to San Francisco in 1859, and finally closed down in 1878.

The results of some experiments made on the Bellingham Bay coal in 1871 at the Mare Island navy yard, are reported by Isherwood[2], who gives the chemical composition of the Bellingham Bay coal, in units of weight as follows:

Carbon	49.60
Hydrogen	3.39
Oxygen	8.96
Nitrogen	0.83
Sulphur	1.22
Hygrometric moisture	12.52
Ash and clinker	23.48
	100.00

Isherwood also makes the following statements:

"The specific gravity of the Bellingham Bay coal was 1.350.

"Of the earthy matter remaining after combustion, and composed of ash and clinker, 72.35 per centum were ash, and 27.65 per centum clinker. The specific gravity of the clinker was 1.794.

"One cubic foot of this brown coal in the merchantable state, weighed 60.70 pounds, of which bulk the solid matter occupied 72.07 per centum and the interstitial space 27.93 per centum. To stow one ton of this coal, 36.90 cubic feet are required.

"One cubic foot of the ash weighed 39.00 pounds, and one cubic foot of the clinker weighed 32.00 pounds."

The results of tests made by the Navy Department on the economic and potential vaporization of the coal of

[1]Bailey Willis; Report on the coal fields of Washington Territory. 10th Census U. S., Vol. 15, Mining Industries, Washington, 1886, pp. 759-771.

[2]B. F. Isherwood; Letter from the Secretary of the Navy, Forty-Second Congress, Second Session, House of Representatives, Executive Document, No. 206, 1872, pp. 23-28.

Bellingham Bay are tabulated in this early report of Isherwood's as follows:

	Maximum Combustion	Medium Combustion	Slow Combustion
Date of commencing experiment	June 20, 1 P. M.	Sept. 1, 2:30	June 29, 1 P. M.
TOTAL QUANTITIES—			
Duration of the experiment, in hours	24	24	17
Cubic feet of water vaporized from temp. of feed water	627	434.377	187.320
Pounds of water vaporized from temp. of feed water	39,018.243	27,023.811	11,642.389
Pounds of coal consumed	10,225	5,520	2,326
Pounds of ash from the coal	1,774	787	509
Pounds of clinker from the coal	733	272	168
Pounds of clinker and ash from the coal	2,507	1,059	667
Pounds of combustible consumed	7,718	4,461	1,649
Per centum of the coal in ash	17.35	14.26	21.88
Per centum of the coal in clinker	7.17	9.92	7.22
Per centum of the coal in ash and clinker	24.52	19.18	29.10
PRESSURES AND TEMPERATURES—			
Temp. in degrees Fahrenheit, of external atmosphere	62.1	63.4	61.3
Temp. in degrees Fahrenheit of the boiler room	75	74	78
Temp. in degrees Fahrenheit of the feed water	75	77	83.5
Height of the barometer in inches of mercury	30	30.50	29.94
Steam pressure in boiler, in fraction of lb. per square inch above atmosphere	0.106	0.031	0.026
Steam pressure in boiler, in pounds per square inch above zero	14.83	15	14.72
RATE OF COMBUSTION—			
Pounds of coal consumed per hour	426.042	230	136.824
Pounds of combustible consumed per hour	321.583	185.875	97
Pounds of coal consumed per hour per square foot of grate surface	23.452	12.661	7.532
Pounds of coal consumed per hour per square foot of heating surface	1.039	0.561	0.334
Pounds of combustible consumed per hour per square foot of grate surface	17.704	10.232	5.339
Pounds of combustible consumed per hour per square foot of heating surface	0.784	0.453	0.237
VAPORIZATION TOTAL—			
Pounds of water vaporized from temperature of 100 degrees Fahrenheit	39,924.264	27,601.133	11,820.875
Pounds of water vaporized from temperature of 212 degrees Fahrenheit	44,594.676	30,835.135	13,202.268
ECONOMIC—			
Pounds of water vaporized from 100 degrees Fahrenheit by 1 lb. of coal	3.905	5	5.082
Pounds of water vaporized from 100 degrees Fahrenheit by 1 lb. of combustible	5.173	6.187	7.169
Pounds of water vaporized from 212 degrees Fahrenheit by 1 lb. of coal	4.361	5.586	5.677
Pounds of water vaporized from 212 degrees Fahrenheit by 1 lb. of combustible	5.778	6.912	8.006

From experiments on the rapidity of combustion of various coals Isherwood reports the following results:

Kind of Coal	Maximum Rate of Combustion	
	In pounds of combustible portion of coal per hour per square foot of grate surface	Relatively
Anthracite of Pennsylvania	13.122	1.0000
Welsh anthracite	13.450	1.0250
Coke from Nanaimo coal	13.600	1.0304
Mount Diablo brown coal	15.027	1.1451
Semi-bituminous coal of Maryland	15.693	1.1959
Nanaimo brown coal	16.124	1.2288
Australian brown coal (second sample)	17.266	1.3158
Bellingham Bay brown coal	17.702	1.3490
Australian brown coal (first sample)	18.133	1.3819
Rocky Mountain brown coal	18.862	1.4374
Coos Bay brown coal	21.761	1.6584
Seattle brown coal	26.396	2.0116

Analyses of two samples of "Fairhaven" coal, made at the U. S. Navy Yard, Washington, D. C., are recorded by George Otis Smith[1] as follows:

Moisture at 110° C.	0.310	2.98
Volatile matter other than H_2O	22.265	35.03
Fixed carbon	62.395	59.98
Ash	14.885	2.01
Sulphur	0.145	2.02
Phosphorus	0.245	....
Increase in weight at 250° F.	....	.867

Landes[2] records the following tests of "Fairhaven" coal, made at the Mare Island Navy Yard:

Coal consumed per hour per square foot of grate surface	11.178
Water evaporated per pound of coal	6.853
Equivalent evaporations from and at 212° per lb. of coal	8.05
Refuse	19.95

Information has not been found showing the entire amount of coal taken from the old Bellingham Bay mine, but a map made by R. B. Symington, in a report to the Bellingham Bay Improvement Company, shows that a

[1]U. S. Geol. Survey, 22nd Ann. Rept., Pt. 3, 1902, p. 490.

[2]Washington Geol. Survey, Ann. Rept. for 1902, Vol. 2, p. 266.

considerable area was mined from beneath the city. Since the mine was operated, though by no means continuously, over a period of 25 or 26 years, with frequent yearly production of over 20,000 tons, a considerable tonnage of coal must have been removed. The chief outside market for the coal was San Francisco.

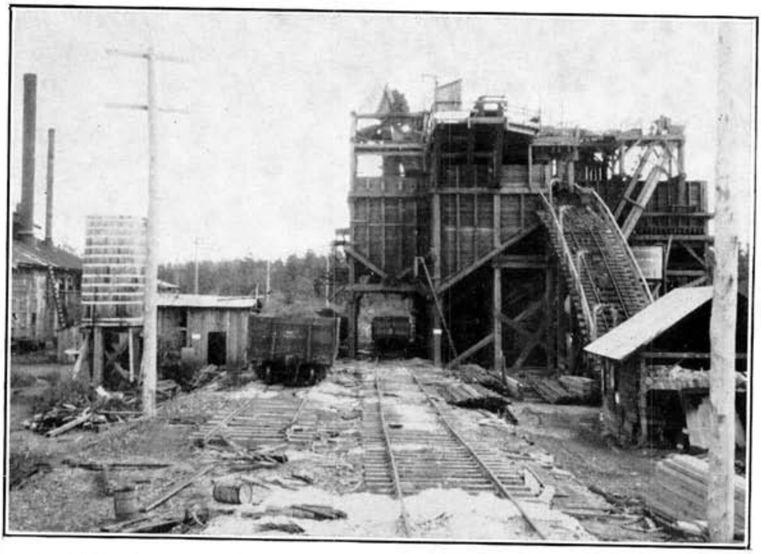
The old mine was opened at the intersection of Myrtle Street with Railroad Avenue. Following the direction of Railroad Avenue, an area over two blocks wide was mined out, this width continuing to a little beyond Maple Street, where the underground workings are narrowed to a little over half this width. The mine followed the strike of the coal bed, which was found to gradually swing from northeast to more nearly north. Since then, however, the strike has been discovered to turn towards the northwest. The mine extended to the point where Champion Street, Unity Street, and Dock Street intersect. At this point the strike is a little east of north.

There has been considerable trouble with caving of the surface over this undermined area. It has been found necessary to construct concrete arches, or some other means of support, over this space in establishing foundations for buildings. This caving has been especially noticeable in the southeast corner of the block at the intersection of Railroad Avenue and Holly Street.

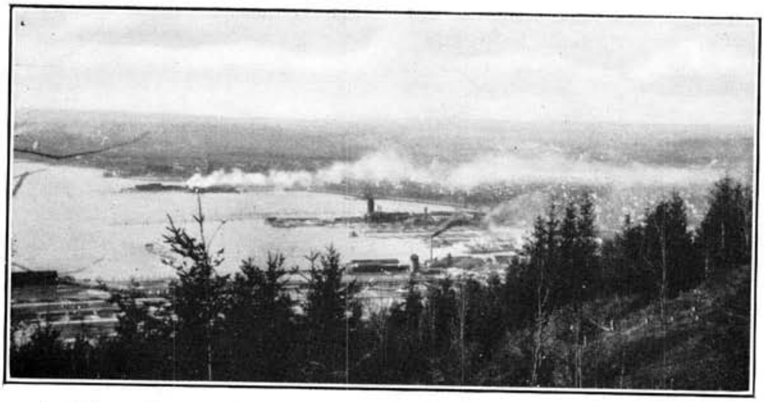
LATER DEVELOPMENTS OF THE BELLINGHAM COAL SEAM

At present the only operating coal mine in Whatcom County is Mine No. 1 of the Bellingham Coal Mines Company. This is located just within the northwest city limits of Bellingham on the Northwest Diagonal road, a pavement running from Bellingham to Blaine.

The position of the coal seam, which apparently is a continuation of the same seam that was worked by the old Bellingham Bay Coal Mining Company, was found by core drilling. In 1892 a mining engineer, R. B. Syming-



a. Mine No. 1 of the Bellingham Coal Mines, which produces from 500 to 1,000 tons of coal per day. Photograph taken September, 1921, before the construction of the concentrator which has since been installed to the right of the incline.



b. View of a portion of Bellingham Bay and the City of Bellingham. Looking north from the Normal School hill. Most of the city shown here and the area in the distance overlies the main Bellingham coal seam.

ton, was employed by the Bellingham Bay Improvement Company to do this drilling. Following the extension of the line of outcrop as it was at the old mine, holes number 1, 2, 3, and 4 were put down, but the main seam was not found. Going farther west Symington put down number 5 hole and struck a two foot seam of coal which was thought to be the same as a two foot seam which was known to underlie the big coal seam formerly mined. Accordingly, he went farther to the west and put down holes number 6, 7, 8, 9, and 10, all of which cut the big seam upon which the present mine is now working. The strike of the formation swings from northeast to northwest, but this feature was apparently not determined from surface outcroppings which are now exposed to view in places.

Investigations to develop the coal were begun in 1917 by John C. Eden and his associates. The coal was to be used by the Superior Portland Cement Company, located at Concrete, Skagit County, Washington. Actual operations began in September, 1918, and production commenced and steadily increased until it was over a thousand tons a day, making this the largest mine operating on a strictly commercial basis in the State.

The mine was closed, however, in April, 1922, on account of a nation-wide strike, for a period of about two months, but was opened in May with non-union labor. One shift a day was being used during the summer of 1922, with a daily output of about 500 tons of coal.

BLUE CANYON

In 1887 a prominent coal seam was discovered in Blue Canyon, which is located one mile west of the settlement of Park, on the northeastern shore of Lake Whatcom. The coal outcrops in sections 15 and 22, T. 37 N., R. 4 E., not far from the Northern Pacific Railroad. The Blue Canyon Coal Mining Company was incorporated in 1890 and mined coal from this deposit from the spring of 1891 until 1904. The date of reaching the northeast end of the levels, from the First Opening is given on the mine map as December 12, 1892. Of this company, M. E. Downs of Bellingham was president, J. J. Donovan, one of the present-day prominent business men of Bellingham, and now a trustee of the mine, was engineer, and D. Y. Young was superintendent. In 1894 an explosion occurred, caused by the ignition of mine gas from the firing of a shot in its presence. The concussion caused by the explosion killed 23 miners. From the standpoint of gas, this mine was at that time regarded as the most dangerous in the state.

In 1904 the company shut down the mine, which was then leased by William Lawton, who operated it for two or three years. In 1907 J. M. Walter leased it, raised $50,000 in Seattle, with which to commence operations, and ran the mine from August 1, 1907, to May 1, 1908. The Second Opening, located on the line between sections 15 and 22, and about 1750 feet west of the First Opening, was made in 1907. The mine went into the hands of receivers, however, and was held in receivership by Andrew Ecklund of Bellingham for one year.

Then the Whatcom County Coal Mining Company was organized by J. M. Walter, and this company, with Andrew Ecklund as superintendent, operated the mine continuously for 12 years, closing down in 1919. In 1920 the idle bunkers and other buildings which stood near the Northern Pacific Railway tracks, caught fire from a train in the night and were burned. Since then mountain landslides and local caving have made the openings inaccessible.

During the period in which this last company was operating the Blue Canyon mine, coal was taken out at the rate of 50 to 75 tons per day. The United States

Government used this coal for the Alaskan fleet during the years of 1894, 1895, and 1896, and it is said that the coal was at first objected to by engineers of the fleet on account of it being in such a finely divided state. By feeding it on the fire a little at a time, however, it was found to give better fuel value that other coals previously used.

The following analysis was made by the Navy Department[1] in 1893-1898 of the Blue Canyon coal:

	Per Cent.
Moisture	1.790
Volatile matter other than H_2O	31.479
Fixed carbon	62.744
Ash	3.679
Sulphur	0.308
Phosphorus	0.006

When tested for steam heating efficiency at the Mare Island Navy Yard in 1895-1897, it was found to evaporate 6.597 pounds of water for each pound of coal.

Boiler tests were made on the U. S. S. Yorktown and are given by Landes[2] as follows:

Name of Coal	Coal Burned Per Hour (Pounds)	Burned Per H.P. Per Hour (Pounds)	Refuse (Percentage)	Knots Per Ton of Coal	H.P.
Fairhaven	2,575	3.40	20	9.4	756
Blue Canyon	2,599	2.53	16	10.2	1,025
Blue Canyon	2,336	2.50	27	9.3	934

The production of the Blue Canyon mine, as given by Landes in this early report, was 8,200 tons in 1901, and 6,010 tons in 1902. The seam, he says, averaged 7 feet in thickness and dipped to the northwest 50 to 60 degrees, and the coal was used to supply the demand of the cities and towns around Bellingham Bay. He describes the vein as lying at the base of the coal measures, sepa-

[1]G. O. Smith; The Coal Fields of the Pacific Coast. U. S. Geol. Survey, 22nd Ann. Rept., Pt. 3, 1902, pp. 490, 492.

[2]The Coal Deposits of Washington, Wash. Geol. Survey, Vol. 2, Ann. Rept. for 1902, pp. 266, 174.

rated from the schist in most places by a thin layer of conglomerate and in other places lying directly on the schist.

A cross section of the Blue Canyon seam is given by Landes[1] and also by R. P. Tarr[2] as follows:

Walls, sandstone	Feet	Inches
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

He also gives the following analysis of the Blue Canyon coal, remarking that the coal "burns freely, but with considerable black smoke":

	Per Cent.
Moisture	1.68
Volatile	30.97
Fixed carbon	54.21
Ash	13.14

ROCKY RIDGE

Coal at Rocky Ridge, on the south shore of Lake Whatcom, was first mined about 25 years ago by a man named Harry Moore. Although some coal was removed from this mine, it was never an important producer and very little of its history is obtainable.

Five openings were made on three different seams, but coal was mined from only one of these, known as Slope No. 2 on No. 3 vein, which dips 41°, bearing S. 38° W. The coal was brought out of the mine on cars and dumped into a chute which carried it down to the bunkers near the shore of the lake. From here it was transported by way of Lake Whatcom to distributing points.

[1]Wash. Geol. Survey, Vol. 1, 1901, Pl. XXV.

[2]The Coal Resources of Washington. Mines and Minerals, Vol. 30, 1907.

GLEN ECHO

The Glen Echo Coal Mining Company was organized with M. L. Dickenson as president and Andrew Ecklund as superintendent. The mine, located at the cornering of sections 5 and 9, T. 38 N., R. 4 E., was opened in 1920, operating until 1921. About 1,000 tons of good quality of coal were taken out during that time. The mine was closed because of encountering glacial gravel, which cut off the vein.

About a mile to the north of the Glen Echo Mine, and near the corner of section 4 is a tunnel with some old slacked coal and coaly shale on the dump. This is said to be the original Glen Echo Mine, sometimes called the Raper Mine.

GENEVA

In August, 1921, the Geneva coal mine was opened by Otho Williams under the supervision of the Pacific Atomized Fuel Company. The mine is located just outside of the city limits of Bellingham. About 150 tons of coal were removed from this mine in 1921, and about 200 tons in 1922, all of which was used locally. Some of this was used by the company in their work at the Silver Beach mine.

SILVER BEACH

In December, 1921, prospecting was started at Silver Beach at the west end of Lake Whatcom. The work has been in charge of Otho Williams, and under the supervision of the Pacific Atomized Fuel Company of Bellingham. An incline and tunnel have been driven for a total distance of about 360 feet, but so far coal of commercial quality and quantity has not been found.

PROSPECTS OF MINOR IMPORTANCE

Numerous other outcrops of coal have been prospected during the past years in Whatcom County, and some are being worked at the present time. Most of these are described in another chapter of this report.

GLACIER COAL FIELD

The Glacier coal field was discovered some years ago and excited considerable interest on account of containing anthracite coal. It is located south of the town of Glacier, the terminus of a railroad (formerly the Bellingham Bay and British Columbia Railroad, but now owned by the Chicago, Milwaukee & St. Paul Railway Company) running from Bellingham.

Since E. G. Woodruff's report[1] was published, a few tunnels have been driven in this field and some diamond drilling carried on, but no mines have been put on a commercial basis. One new tunnel, which has its entrance near the town of Glacier, is reported to be a quarter of a mile long. There has been much litigation over the properties but it is thought that development work and prospecting will be continued. The irregularity of the form of the coal deposits and the disturbance of the formations containing the coal, together with mountain landslides, faults, etc., have always made the development work extremely difficult and trying.

ANALYSES OF COALS FROM THE GLACIER FIELD

The following information is quoted from the United States Geological Survey[2]:

19722. Anthracite coal from Discovery tunnel of Washington Anthracite Coal Co., in SE¼ sec. 29, T. 39 N., R. 7 E., 4 miles south of Glacier, terminus of Bellingham & Northern Railroad, a branch of Chicago, Milwaukee & St. Paul Railway. Coal bed, Tertiary (Eocene) age; Puget group; dips 68° NW. Sample slightly damp; cut at end of 750-foot entry July 31, 1914, by M. R. Campbell. Coal

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[1]The Glacier Coal Field of Whatcom County, Washington, U. S. Geol. Survey, Bull. 541-I, 1914, pp. 389-398, containing a map, Plate XXIII.

[2]M. R. Campbell and F. R. Clark; Analyses of Coal samples from various parts of the United States, U. S. Geol. Survey. Bull. 621, 1916, pp. 327-328, 369. (Analyses made by the U. S. Bureau of Mines.)

bed varies considerably in thickness, owing to the intense pressure developed when the rocks were folded. Section at point sampled is as follows:

	Feet	Inches
Coal (sampled)	2	5
Coal, soft, laminated		4
Shale, carbonaceous	1	6
Coal (sampled)	5	10
	10	1

19723. Anthracite coal from same mine as No. 19722. Coal bed, Tertiary (Eocene) age; Puget group. Sample cut 300 feet from mouth of drift July 31, 1914, by M. R. Campbell. Coal slightly weathered and covered with some dirt. Section at point sampled is as follows:

	Feet	Inches
Coal, impure, laminated	1	6
Coal, hard (sampled)	14	5
Coal, impure, laminated	2	1
	18	0

19724. Anthracite coal from Smith tunnel of Washington Anthracite Coal Co., in SE¼ sec. 30, T. 39 N., R. 7 E., 4 miles south of Glacier, terminus of Bellingham & Northern Railroad, a branch of Chicago, Milwaukee & St. Paul Railway. Coal bed, Tertiary (Eocene) age; Puget group; dips about 30° NE. Sample weathered; cut in first right entry 200 feet from mouth of tunnel August 1, 1914, by M. R. Campbell. Section at point sampled is as follows:

	Feet	Inches
Coal (sampled)	5	6
Coal, soft, laminated	2	6
	8	0

19725. Semi-anthracite (?) coal from prospect in SE¼ sec. 24, T. 39 N., R. 6 E., 3 miles southwest of Glacier, terminus of Bellingham & Northern Railroad, a branch of Chicago, Milwaukee and St. Paul Railway. Coal bed, Tertiary (Eocene) age; Puget group; dips about 51° NE. Sample weathered; cut from east end of drift, 20 feet from mouth, August 2, 1914, by M. R. Campbell. Section at point sampled is as follows:

	Feet	Inches
Coal (sampled)	5	9
Bone		11
Coal, soft, laminated	2	7 plus
	9	3 plus

19726. Semi-anthracite (?) coal from open-cut prospect in SW¼ sec. 24, T. 39 N., R. 6 E., 3 miles southwest of Glacier, terminus of Bellingham and Northern Railroad, a branch of Chicago, Milwaukee and St. Paul Railway. Coal bed, Tertiary (Eocene) age; dips 30°—40° N.; poorly exposed. Sample badly weathered, crushed, and squeezed; taken from open cut August 2, 1914, by M. R. Campbell; represents about 3 feet of coal.

Laboratory No.	Air-drying Loss	Form of Analysis*	Proximate				Ultimate					Heating Value	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	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	7.4	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.

GEOGRAPHIC FEATURES OF WESTERN WHATCOM COUNTY

LOCATION AND GENERAL FEATURES

Whatcom County is situated in the extreme northwest corner of the United States and of the State of Washington. It is 110 miles long by 24 miles wide, its greatest length lying east and west. British Columbia lies to the north of the county, Bellingham Bay and the Strait of Georgia to the west. Okanogan County extends along its mountainous eastern side, longitude 123° 19′, while to the south, along parallel 48° 39′, Skagit County adjoins it.

Two physiographic or topographic provinces are represented in Whatcom County, Puget Sound Basin and the Cascade Mountains. Mt. Baker stands nearly in the center of the county, so that the western half of Whatcom County may be considered to lie to the west of this mountain. The Puget Sound Basin province, however, lies in the extreme western part of the county.

One outstanding feature is a long spur of the Cascade Mountains which extends clear to the coast in the southern part of Whatcom County, so that even part of Bellingham is located on the hills of this spur.

CLIMATE AND VEGETATION

The climate of western Whatcom County is quite mild and equable. The annual precipitation of this area is from 30 to 42 inches.

As in the rest of the Puget Sound country, the surface of the ground, whether plain or hillside, is covered, where it is not cleared, with a dense growth of vegetation. Trees, shrubs, and underbrush entangle each other into a jungle-like mass. Even where the ground is cleared the vegetation takes only a short time to spring up again if not constantly cut down. Geologic work or prospecting is greatly handicapped by the presence of this vegetation. In places it may take hours or even days to acquire only a small bit of geologic data, while into other places it may be practically impossible to penetrate. Fortunately, however, there are many roads, railroads, trails, and lakes which serve as means of entry into the parts of the country important from a geological standpoint.

TOPOGRAPHY

Whatcom County has a very uneven coast line. Starting with the northwestern corner of the county, and going southwest the prominent bays are Drayton, Birch, Lummi, Bellingham, Chuckanut, and Samish. There are a number of islands, of which Lummi Island is the largest, which form part of the county. The white dome of Mt. Baker, known to the Indians as *Koma Kulshan,* rising to an elevation of 10,750 feet, stands as the most prominent topographic feature of Whatcom County. The rough and mountainous neighboring region extends as far west as Sumas, on the north, to Bellingham, and thence to the Skagit County line on the south. Black Mountain, Red Mountain, and Vedder Mountain all lie in the northern part of the county. Sumas Mountain, Slide Mountain, and Van Zandt Dike are situated in the central part, while Lookout Mountain, lying between lakes Whatcom and Samish, and Chuckanut Mountain between Samish Lake and Chuckanut Bay, form marked features of the topography of the southwestern section of the county. At the north end of Lake Whatcom and west of Bellingham, Squalicum Mountain reaches an elevation of 1,525 feet, covering an area of about eight square miles. With the exception of a hill known as King Mountain, the northwestern area, north of Bellingham and Squalicum Mountain, and west of Sumas Mountain, contains no mountains. The surface is in general, either of a hummocky nature or a level plain, a result largely of glaciation.

The Nooksak River is by far the most important stream of western Whatcom County. With its tributaries it drains the larger portion of this part of the county. Squalicum Creek, which flows through the mining district in Bellingham, and Whatcom Creek, which drains the lake by the same name and flows through the heart of the City of Bellingham, are two of the more important minor streams.

Lakes Whatcom, Samish, and Padden all lie within a few miles of Bellingham and all are probably the result of glaciation. They are in length respectively twelve, three, and one-half miles.

TRANSPORTATION LINES

Bellingham Bay is an excellent natural port and is large enough to accommodate hundreds of ships at one time. It is advantageously situated for Alaskan and Oriental trade and is reached by many steamers plying on Lower Puget Sound.

Three transcontinental railway companies are represented in Whatcom County; namely, the Northern Pacific, Great Northern, and Chicago, Milwaukee, and St. Paul. In addition, the Pacific Northwest Traction Company operates an electric line between Bellingham and Mt. Vernon, Skagit County, and between Everett and Seattle, the connection between Mt. Vernon and Everett being made by limousine motor stages. The total length in Whatcom County of steam and electric railways is about 222 miles. Practically every city and town in western Whatcom County is reached by at least one of these lines.

In pavements, western Whatcom County is very well supplied, for there are at present nearly 125 miles in all. The Northwest Diagonal, the Guide Meridian, and the Northeast Diagonal roads extend from Bellingham and connect in such a manner as to reach Blaine, Lynden, and Sumas respectively, as well as many other towns, such as Ferndale and Deming. Chuckanut Drive, famous for its scenic beauties, extends along the precipitous southern coast line and connects Bellingham with points in Skagit County and beyond to Seattle. In addition to the pavements there are at least 600 miles of other roads. Most of the points in the mountains are accessible only by trails and old abandoned skid roads, formerly used in logging activities. Fire trails such as that which connects the mouth of Oyster Creek on Samish Bay with the west end of Samish Lake, often serve as means for entering the rough forested regions.

DISTRIBUTION OF POPULATION

The population of Whatcom County is given by the 1920 census as 50,600 inhabitants, while the total land area is 1,132,480 acres, of which 177,742 acres are in farms. About 70 per cent of the county is mountainous and heavily timbered, and maintains very few inhabitants.

According to the 1920 census the population of the principal cities and towns of Whatcom County are as follows:

Bellingham	25,585
Blaine	2,254
Lynden	1,244
Sumas	854
Ferndale	759
Wickersham	300

It is said, however, that South Bellingham with a population of about 6,000 was not included in the census for the whole city.

On account of the lumbering and mining industries there are many industrial camps in this region, such as those at Park, of the Bloedel-Donovan Lumber Company, and at South Bay, Lake Whatcom, where the Wood-

Knight Lumber Company is now at work. There are also many old and abandoned logging and mining camps throughout the region.

INDUSTRIAL OUTLOOK OF WHATCOM COUNTY

Lumbering has been in the past the principal industry of the county and is still of major importance, but the acreage of timber suitable for lumber is fast diminishing, so that this industry will soon take a minor position. Fishing has always been one of the most important industries, with several large canneries at Bellingham and Blaine. At the present time, however, it is at a low ebb because the fish have been removed faster than they have propagated. This industry can, however, be resumed with proper restocking measures and with international regulations.

Agriculture has made rapid progress within the last ten years. The main branches followed are dairying, poultry raising, horticulture, and seed production. Logged-off lands are fast being turned into producing farms. The climate of the region is well suited to agriculture, and the farmers are quite industrious and up-to-date.

Manufacturing is rapidly assuming an important place in the county, the principal center being the city of Bellingham. The 1920 census has on record for this city 110 manufacturing establishments, employing 3,520 people, and having a capital investment of $13,581,000.

Whatcom County has a variety of mineral resources. Coal mining, however, occupies first place in the mining industry and with the development of the Bellingham Coal Mines has assumed considerable importance.

Deposits of limestone near Sumas have caused a great development of the lime and cement industry. The International Lime Company operates kilns near Sumas at a place called Limestone. The Olympic Portland Cement

Company, although it gets its products from quarries situated between Kendall and Sumas, has a plant on Bellingham Bay, just northwest of the city of Bellingham.

With the waning of the lumber and fishing industries, coal mining should be welcomed as an industrial savior. The opening of new mines should be looked upon as a credit to the community.

The quarrying of sandstone for building stone was at one time important, but has not been carried on of late years. The well known Chuckanut sandstone was quarried south of Bellingham on Chuckanut Bay.

GEOLOGIC FEATURES OF WESTERN WHATCOM COUNTY

GENERAL STATEMENT

In the study of the coal beds of Whatcom County there are several significant geological features which must be considered. These may be summarized as follows:

1. The character of the sedimentary rocks, sandstones, and shales in which the coal seams are interstratified.
2. The character of the underlying formation, which, as far as we know, is largely made up of an old, twisted, metamorphosed series of schists.
3. The stratigraphic character, and position of the coal seams and their correlation one to another.
4. The geologic structure of the sedimentary series containing the coal beds, and especially the position of synclines, where erosion has not removed as much of the series as in the case of anticlines.
5. The relation of the geologic structure to the character of the coal.
6. The covering effect of surficial formations.

ROCKS OLDER THAN THE COAL MEASURES

THE SCHIST COMPLEX

At Blue Canyon the coal formerly mined was found to lie directly on talc schist or on a thin bed of conglomeratic sandstone, which in turn rests upon the schist. This same feature is found, to a certain extent, in the anthracite coal field near Glacier. The contact, therefore, between the sedimentaries and the underlying basement rocks is of economic as well as scientific or stratigraphic interest.

A bare surface exposure across this contact was not found during this particular investigation, because of the loose material in the form of landslide talus, mantle rock, soil, and glacial deposits, one or all of which generally cover the particular exposure of interest. The contact, however, was sketched in the field on the topographic maps with a fair degree of accuracy, for schist was found in place on one side and the sandstones, with their interbedded layers of shales, containing imprints of leaves, within a very short distance on the other side.

The schist is a softer formation than the sandstone, but contains innumerable veins of white quartz. It is often exposed as a white or gray, talcose, crumpled material, but in many other places it is quite black and graphitic. The laminated and plicated character indicates an origin of thinly bedded shaly sediments, whose subsequent history has been that of compression and deformation, together with the action of heat, pressure, and infiltration of solutions resulting in the formation of veins.

Occasionally there are found within the schist formation masses of serpentine, having the appearance of a metamorphosed form of an old basic igneous intrusive rock whose minerals have been changed by hydrothermal alteration to a material resembling, in some respects at least, the schist itself.

Between Samish and Blanchard there are evidences of the original sedimentary character of these basement rocks. The contact evidently runs through part of Samish Lake, for schist is well exposed on the south side, while the sandstone series is present on the northern shore.

Defined ridges are not prominent in the schist, as they are where produced by the edges of dipping sandstone strata. Usually the area just back of the contact of schist with the coal measures is eroded to a valley or depressional form of some sort or another.

The contact was followed through the Samish Lake topographic quadrangle, but in the Wickersham and Van

Zandt sheets, only points were taken on it northeast as far as the Middle Fork of the Nooksak River. It probably follows in a direction somewhat as shown on the general map (Fig. 2) to the point in the Glacier field, where its position indicated is taken from a map by Woodruff[1].

SERPENTINE

There are a number of places where serpentine is present. There is one exposure a mile south of Acme beside the road. In another place, not nearly so accessible, on the west side of Sumas Mountain (Sec. 35, T. 40 N., R. 4 E.) there is a body of serpentine or peridotite, weathered on the surface to a ferruginous laterite deposit[2]. Here a basal conglomerate of the coal measures overlies the eroded and weathered surface of the serpentine. The conglomerate dips westward at an angle of 47 degrees.

LIMESTONE

At a point one mile northwest of Kendall the Olympic Portland Cement Company quarries limestone from the side of a mountain. Also on the opposite side of the valley on the face of Red Mountain, the same company is opening a new large quarry in limestone which is a direct continuation of the deposit operated by the International Lime Plant[3]. This limestone is an old metamorphic recrystallized rock and contains numerous marine fossil remains. In most cases the fossils are in silicified form, embedded within the rock, recognizable only where they stand out as rough, resistant forms on old weathered surfaces. Crinoid stems, bryozoa, and a few brachiopods were found present. The formation is undoubtedly much older than the coal measures and of marine rather than

[1]U. S. Geol. Survey, Bull. 541-I, Pl. XXIII.

[2]Jenkins and Cooper; A Study of the Iron Ores of Washington, Div. of Geol., Dept. of Cons. & Dev., Bull. 27, 1922, pp. 105-107.

[3]S. Shedd; Cement Materials and Industry in the State of Washington. Wash. Geol. Survey, Bull. 4, 1914, pp. 208-220.

fresh water origin. The relation in age between the limestone and the old schist complex was not determined, but probably the schist is the older.

The areal extent of these formations in this part of the county has not yet been determined. The coal measures have been found on the east as well as the west flank of Sumas Mountain, serpentine also on the west side, and these limestones on the northeast extension. Apparently a complicated bit of geology awaits determination from future endeavors.

CRETACEOUS[1] ROCKS

On some of the islands west of Bellingham, Cretaceous sandstones and shales are exposed. A good collection of marine shells of Cretaceous age was made during this examination from the well-known fossil locality on Sucia Island. Cretaceous fossils have been reported from some of the rocks in the vicinity of Mt. Baker[2], and undoubtedly rocks of this age are present throughout the northern Cascades[3]. It is quite possible that the Cretaceous rocks of the region may in places be mistaken for the sandstones of the coal measures, which they somewhat resemble.

THE COAL MEASURES

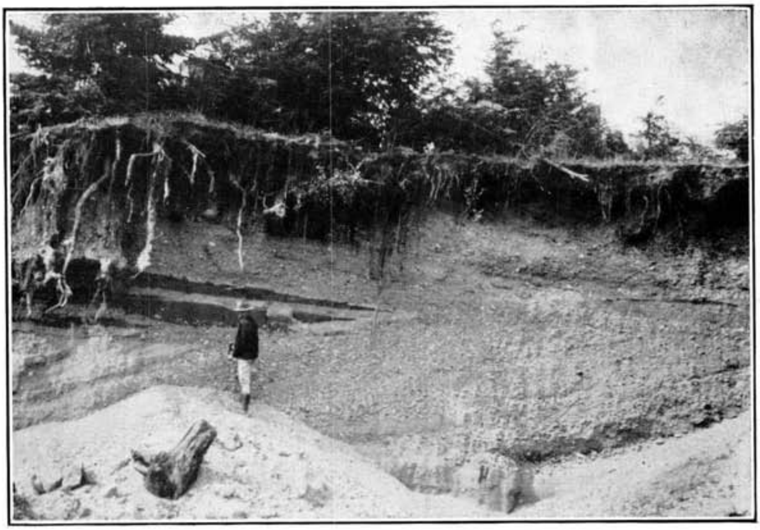
GENERAL FEATURES

Although the coal seams of Whatcom County are generally interlayered between shaly beds, the bulk of the coal measure series is composed of sandstones and conglomeratic phases of these sandstones. The strata have been tilted from this original horizontal position into various types of structural forms. Toward the

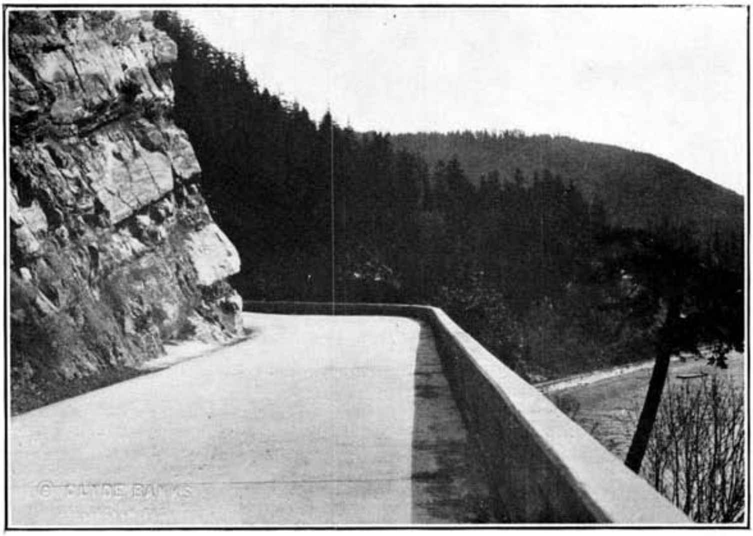
[1]Smith and Calkins; A Geological Reconnaissance across the Cascade Range near the Forty-ninth Parallel. U. S. Geol. Survey, Bull, 235, 1904, pp. 28-30.

[2]E. J. Woodruff; The Glacier Coal Field, Whatcom County, Washington. U. S. Geol. Survey, Bull. 541-I, p. 15.

[3]I. C. Russell; Geology of the Cascade Mountains. 20th Ann. Rept. U. S. Geol. Survey, Pt. 2, 1900, pp. 114-117.



a. Glacial outwash gravel, roughly sorted. The kind of material that covers as a mantle many of the surface geological features. Exposure occurs on roadside near Kendall.



b. Exposure of sandstones and interbedded coaly shales along Chuckanut Drive where many excellent specimens of fossil leaves may be collected.

northwest these sedimentary beds appear to flatten out, while to the southeast they are intensely folded. The axes of these folds run in a general northwest-southeast direction, but the series as a whole has been tilted in such a manner that the axes plunge to the northwest. This movement, together with the profound action of erosion, has caused the beds in the southeastern region to be stripped clean from the old basement schistose rocks, now exposed south of Blue Canyon and Samish Lake.

STRATIGRAPHIC FEATURES

It is apparent from data which are included later in this report that the Blue Canyon coal seam is at the base of these coal measures and that the Bellingham coal seam is in the upper layers that lie between these geologic horizons. It is not apparent, however, just how thick these sediments are; that is, the stratigraphic thickness of the beds from the oldest to the youngest. Rough estimates are very likely to exaggerate the measurements because the strata have been folded so many times, and, besides, the exposures along roads, railroad cuts, lakes, etc., are nearly all more or less parallel with the strike of the formation instead of at right angles to it.

Beginning with the uppermost layers and working down, the stratigraphic section may be compiled from various data which appear elsewhere in this article in a manner, illustrated as follows, which should give results of at least a fair degree of accuracy:

(1) The deep well at Enterprise (according to geologic evidence) probably enters the youngest layers of the coal measures of which we have record in the region, and probably pierces them almost at right angles to their bedding planes. These beds are entered at 615 feet below the surface and at 2,165 feet a coal seam is cut through, which may possibly be correlated with the main

Bellingham seam. If this correlation is correct it gives a record of the measures above this seam of 1,550 feet.

(2) In Mine No. 1 of the Bellingham Coal Mines there is a prospect shaft which cuts through 100 feet of strata, disclosing an underlying 2-foot coal seam below.

(3) Drill hole No. 5 passes through this lower 2-foot seam, 176 feet from the surface, and reaches another coaly layer at a depth of 637 feet. Considering the dip of the formation, this coaly layer would be 430 feet, stratigraphically, below the 2-foot seam.

(4) This lower coaly layer which underlies sandstone and conglomerate may be correlated with a similar horizon in drill hole No. 4, which encountered it at a depth of 306 feet.

(5) It is quite probable that this last horizon may be correlated with another similar horizon in drill hole No. 1 at the depth of 68 feet.

(6) Drill hole No. 1 reaches a greater stratigraphic depth than any of the other drill holes. A coal seam, one foot thick, was reached at 457 feet, and another at 828 feet. Considering the dip of the formation and the above correlation, these thin coal seams would be placed at 920 and 1,180 feet, respectively, below the main coal seam. Besides this thickness, drill hole No. 1 pierced 100 feet more of strata below.

(7) Considering the dip of the formation and the general structure determined through field evidence, the surface of the ground south of King Mountain (which is the crest or axis of an anticlinal fold in the underlying rocks) would be stratigraphically about 2,700 feet below the main coal seam. That is, 2,700 feet of sedimentary rocks were eroded at this point after the coal seam and its overlying strata were removed by the same process.

(8) According to geologic field evidence, the crest of an anticline which crosses Whatcom Creek is 5,450

feet stratigraphically below the main Bellingham seam, but the coal exposed in that creek, since it lies at a higher geologic horizon than the strata at the crest of the anticline, would be only 4,050 feet below the main seam or 1,400 feet above the crest of this anticline.

(9) Although data are not sufficient for determining the exact position of the Silver Beach coal seams, they probably lie in a higher geologic horizon than the Whatcom Creek coal; or approximately 1,850 feet below the main Bellingham coal seam, according to the present evidence in the nature of dips, etc.

(10) Assuming for the present that the Silver Beach coal seams are in the same stratigraphic horizon as those of Geneva and Rocky Ridge, a section may be worked out from structural evidence in the region of Manley's Camp. The crest of the anticline in the northern half of section 12 (T. 37 N., R. 3 E.) would be, according to these measurements, about 4,500 feet stratigraphically below the general horizon of these coal seams. There is a coal horizon near this point.

(11) Judging from field evidence, this last horizon is approximately 4,000 feet above the schist formation, which underlies the coal measures at Blue Canyon and elsewhere.

Summarizing these data, the approximate geologic column may be compiled as follows:

	Stratigraphic Thickness in Feet
Strata in Enterprise well above the main Bellingham coal seam..........	1,550
Strata below main seam to lower 2-foot seam	100
Strata below 2-foot seam to lower 1-foot seam	820
Strata below 1-foot seam to second lower 1-foot seam	260
Strata below second 1-foot seam to Silver Beach coal horizon (including Geneva and Rocky Ridge)..	670
Strata below Silver Beach horizon to Whatcom Creek Coal..............	2,200
Strata below the Whatcom Creek coal horizon to the coal horizon in Sec. 12, T. 37 N., R. 3 E..	2,300
Remaining strata to the schist contact or Blue Canyon coal, probably about	4,000
Total, about..	11,900
Approximately	12,000

DESCRIPTION OF THE STRATA OF THE FORMATION

General characters. Accuracy in the exact determination of stratigraphy and geologic structure is hampered because of the lack of constancy in the thickness of the individual strata of the coal measures. The beds not only are lenticular in shape but seem to vary from place to place in character and composition. Sandstone is the predominating rock, but conglomerates of many varieties occur in many places. Shales generally form partings between sandstone strata, and are also associated with the coal beds, but only occasionally form the principal surface rock.

Conglomerates. Many of the sandstone beds have conglomeratic phases, or at least contain very coarse grained layers. The most prominent conglomerate beds of the district lie in the hills southwest of Manley's Camp. This consolidated coarse gravel formation is used as a road material in the region about Geneva.

Sandstones. The sandstones are generally gray or olive in color. The greenish tinge is generally more or less lacking on the weathered surface of the rocks. Most of the strata are distinctly bedded, with shaly layers lying between. Cross-bedding is a common feature to be found within the layers themselves. The sandstones are generally arkosic and vary in clayey content and in fineness of grain, from argillaceous sandstones to conglomerates. Excellent exposures of these rocks are present along Chuckanut Drive. In one place, south of Inspiration Point (Sec. 13, T. 37 W., R. 2 E.) is the site of the old Chuckanut sandstone quarry, where good building stone was once removed and handled on a commercial basis. Several important buildings constructed of this sandstone are located in Bellingham. The following quotation[1] describes the rock from this quarry:

[1] S. Shedd; Building and Ornamental Stones of Washington, Wash. Geol. Survey, Ann. Rept., for 1902, Vol. 2, pp. 62-65.

"The Chuckanut sandstone is a fine grained, dark colored, well cemented stone. The deposit that has been worked here is about 40 feet thick, and below this a shale occurs the thickness of which is not known as it has not been prospected. The strike of the deposit is N. 10° W. The stone is broken down in large masses by blasting and then worked into dimension stone by wedging and sawing. Three distinct grades of stone are found in this deposit, two of which are due simply to the size of the sand grains which have been cemented together, while the third is known as flagging stone on account of the fact that it splits easily in certain directions, giving good flagging blocks. This stone is somewhat harder than the Tenino stone, but at the same time it is not so hard but that it is easily worked.

"Tests made by Ordnance Department, U. S. A., show the stone to have an ultimate strength of from 10,276 to 12,790 pounds to the square inch.

"There is a medium sized mill connected with the quarry in which are two gang saws 14 feet by 7 feet. The power for driving these saws is furnished by a 40 horse power boiler and engine. The quarry is also supplied with steam hoist and derricks for handling the stone in the yard.

"Sections of the sandstone from Chuckanut examined under the microscope show it to be composed essentially of small grains of quartz and that these grains are very angular and sharp cornered, having been rounded but little as a general thing. The individual sand grains vary but little in size, are a little smaller and perhaps a little less rounded than those of the Tenino stone.

"The small grains of silica in this sandstone are quite firmly bound together by a ferruginous cement. There are two grades of stone quarried here as far as texture is concerned, the coarser being about the same or perhaps a little coarser than the Tenino stone, while the other is much finer. This very fine texture or grain of the Chuckanut stone makes it a very good stone for carved and ornamental work, giving good, sharp edges and perfect outlines.

"The following chemical analysis shows the Chuckanut stone to have practically the same chemical composition as the Tenino stone:

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

". . . The samples which were tested on the bed—that is, where the pressure was perpendicular to the bedding planes—showed a crushing strength of 10,740 and 11,070 pounds to the square inch, while the one tested on the edge—that is, where the pressure is parallel to the stratification planes—showed a crushing strength of 5,340 pounds to the square inch. The modulus of elasticity of the samples tested on the bed was 1,517,000 and 1,158,000 pounds to the square inch, and of the one on the edge 871,500 pounds to the square inch.

"Samples of this stone were alternately frozen and thawed each day for a period of twenty days and the loss in weight of the samples carefully determined, and . . . the loss in weight was .076 of 1% of the entire weight of the sample. The stone has a specific gravity . . . of 2.727, and a sample weighing 65.168 grammes absorbed 2,927 grammes of water, or 4.47% of the weight of the sample, and the percentage of pore space or porosity is 10.91% of the entire mass of the stone.

"Samples were tested to show the effects of extreme heat and sudden cooling by placing them in a muffle furnace and gradually heating them to a temperature of 800° F. Some of the samples were cooled suddenly by being taken from the furnace and while at a temperature of 800° they were put into cold water and allowed to remain until cooled, and they were apparently unaffected by this sudden change even, as the samples would not crumble even on the edges, as the samples from the other localities did. Samples were also heated to temperatures of 1200° F. and 1600° F. and allowed to cool in the open air and the samples then tested, and it was found that the strength of the samples that had been at a temperature of 1600° F. was somewhat weakened. The weakening was principally along the bedding planes, however, and caused the samples to split along these planes more readily than before being heated, but it did not cause them to crumble. The samples that were heated to 1200° F. and then cooled were apparently uninjured and appeared to be as strong as they were before being heated. The color was changed by the heat to a dark red.

"The first stone quarried around Chuckanut Bay was in the early seventies and for a number of years the quarries were not operated continuously, but at intervals when orders for stone were received. The last few years, however, the quarries have been operated on a larger scale, and at the present time stone from here is being used in a number of new buildings that are being constructed in Seattle. This stone has been used in such buildings as the U. S. Custom House, Port Townsend; U. S. Custom House, Portland, Oregon; Dexter-Horton building, Seattle; Thurston County courthouse, Olympia; and many other of the important buildings in the larger cities of Washington."

It is not uncommon to find carbonaceous remains in the sandstones, such as portions of tree trunks and limbs, as well as leaves of palms and other plants. In practically every case these plant remains are in the form of coal, even though they may be only chunks of small size.

Shales. Just north of the Chuckanut sandstone quarry is the plant of the Coast Clay Company, not at present in operation. This concern used shale from steeply dipping beds, interstratified with this same series of sandstone rocks. The shale, however, is in the main rather sandy.

There are many other shaly bands throughout the coal measures. The most prominent shale belt was found on Coal Creek on the eastern side of Sumas Mountain. Here the shales appear to be at least as abundant as the sandstones. They contain many thin coal seams and much fossil vegetation.

Fossil leaves are very abundant in many of the shale beds of the entire coal measure series. Carbonaceous layers are also frequent, varying in composition from peat and lignite to bituminous coal, and even, in metamorphosed areas, to anthracite.

Coal layers. The interstratified coal layers are nothing more nor less than packed and compressed fossil vegetation carbonized. Some of the layers still retain the peaty form; others are lignitic in character; while still others carry true bituminous coal with cubical cleavage. These coal layers are abundant throughout the whole formation. The thicker layers, or at least those which have been prospected, are described more fully in this report under the description of mines and prospects.

The stratigraphic positions of these coal seams are of particular interest in this study, especially when one realizes that the two principal seams are over 10,000 feet apart. The Blue Canyon seam lies at the base of the coal measures and the Bellingham seam near the top.

Metamorphic action. The farther east one goes to study this formation, the more complex the structure of the rocks is found, because the earth disturbances have been greater in the region nearer the axes of the mountain ranges. The rock beds, therefore, become more altered in appearance. The clays become more shaly, the softer sandstones become harder sandstones, until one reaches Maple Falls and the town of Glacier. Here these same rocks become slaty and more quartzose. Likewise, the softer coals become changed to coals of a higher carbon content, until even anthracite is found in a metamorphosed and badly broken and sheared series of rocks of the Glacier coal field.

AGE OF THE COAL MEASURES

Although collections were made of fossil leaves of the coal measures from several localities in Whatcom County during this investigation, they have not yet been submitted to a paleobotonist for determination. Previous work along this line, however, has evidently proved fairly well that these Whatcom County coal measures are of Eocene age and belong to the Puget formation. Smith and Calkins[1] make the following statements:

"A sedimentary series, possibly in part correlative with the beds of Skagit Valley, is exposed about the confluence of the forks of the Nooksak and also in the valley of the North Fork of the Nooksak below Glacier Creek. Professor Landes has also collected from these beds near Keese, obtaining some excellent material, which was submitted for examination to Doctor Knowlton, who reports that much of this material is identical with or similar to forms from vein XII at Franklin, thus correlating the beds at Keese with the Puget formation, which is of Eocene age.

"Lithologically the material constituting the Tertiary series of Nooksak Valley is chiefly sandstone, generally of light olive or gray color, containing considerable amounts of feldspar and rock fragments. Some shale and conglomerate also enter into the constitution of the series. The character of the rocks shows that shallow-water conditions prevailed during the entire period of their deposition.

[1] G. O. Smith and F. C. Calkins; A geological reconnaissance across the Cascade Range near the forty-ninth parallel. U. S. Geol. Survey, Bull. 235, 1904, pp. 34, 97.

"There are productive coal mines in the extreme northwestern part of Washington at Cokedale and at Blue Canyon. In Skagit Valley near Hamilton there are also coal prospects in beds the age of which, according to fossil leaves determined by Dr. F. H. Knowlton, is the same as that of the beds at Cokedale, but no development has been accomplished at that locality."

The climatic conditions during the time of deposition of the original sands and clays must have been, as J. P. Smith[1] says, "subtropical and very rainy", for such plants as palms, sequoias, willows, poplars, and ferns are recognizable all together in the same geological horizon. The sands and clays were evidently deposited in lakes and swamps and so also was the excessive vegetation which later was transformed into coal.

STRUCTURE OF THE STRATA

General features. In order to understand where to prospect and how to mine a coal seam, it is necessary to know where and how the seam is lying in the earth. Since we know that the seam is interbedded with the other strata of the sedimentary series a knowledge of the underground structure of these strata will give us a relative idea of where the coal seams may be buried, and, if they are present, their form, extent, and position underground. The sandstones and shales outcrop at the surface in many places, but the coal seams are sparingly exposed, owing to their less resistant character towards weathering, therefore more abundant information is to be had on the more resistant strata which "sandwich" the coal beds.

Sedimentary beds—like sandstones, shales, and coal seams—were originally deposited in water on the floor beneath that body of water. Originally the beds were laid down in approximately a horizontal position, and

[1]Ancient Climates of the West Coast, Popular Science Monthly, May, 1910, p. 485.

any change from this horizontality has been caused by subsequent earth movements.

The attitude of a sedimentary bed is all important, for this position gives the structure of the layers of the formation for that particular place. The tilting of a stratum is recorded by measuring its *dip* and *strike* and by locating this information accurately upon a map. In this particular investigation the topographic quadrangles were used as field maps and information of this sort was recorded upon them. The *strike* is a level line on the face of a rock bed, such as a coal seam or shale layer. The *dip* is taken at right angles to this and measured down the surface of the tilted bed—the angle of dip being measured from the horizontal plane. The bearing of the dip is the direction of the dip in reference to north or south.

Two prominent structural features are: the *anticline,* or structural arch in which the rocks dip away from the crest or *axis;* and the *syncline* or structural trough, in which the rocks dip toward another axis. The axes of the synclines, therefore, lie between the axes of the anticlines, and vice versa.

Another type of structure is the *fault* or rock displacement, where, along a certain line or plane, strata on one side abut against different strata because they have been broken and displaced by earth movements.

Anticlines and synclines. In western Whatcom County it was found that a great upwarp of the earth in the general region of the boundary between Skagit and Whatcom counties caused the sedimentary beds to be tilted northwestward and this action, together with continual erosion, has caused the old underlying schists on the southern side to be exposed. In addition to this tilting, the beds were laterally compressed into a series of folds, whose axes dip or *plunge* northwestward. The reason that the mountains and valleys trend in this direction also, is not that they represent anticlines and synclines, but that they are caused by differential weathering and erosion of the harder and softer strata whose upturned edges strike in this direction.

As a matter of fact some of the depressions represent anticlinal structures and some of the mountains, synclinal structures. Chuckanut Mountain is formed by the upturned edges of rocks, forming a syncline on the west and an anticline to the east. A great syncline passes just east of Lookout Mountain and its dipping, upturned sandstone ledges stand out as great ridges, resisting the forces of weathering and erosion. The structure in the region of Samish Lake and the upper end of Lake Whatcom is more anticlinal than synclinal, but at the lower end of Lake Whatcom an axis of a syncline passes right through the lake. Geologic structure should, therefore, not be confused with topographic relief. Rock structure has to do with the "lay" of the rocks, beneath the surface of the earth, not with the surface features.

The significant feature in regard to anticlines and synclines, is that on the anticlines the under layers of the rocks are more generally found exposed, uncovered by erosive carving of the great arch, while in the synclines more of the upper strata are preserved. In other words, where coal beds are interstratified, the synclines represent the coal basins.

On the accompanying detailed map the axes of the principal anticlines and synclines have been drawn, together with the recorded dips of the rocks. The dips are quite accurate. The positions of the axes are necessarily only approximate, for they have been determined through the scattered data secured on dips. A study of this map should reveal more than a verbal description can give. The map should be studied in connection with the topographic sheets issued by the United States Geological Survey, which were used originally in locating and plotting this information. The synclines should be given special consideration in view of prospecting for coal.

For sake of convenience in reference, the most pronounced anticlines and synclines have been given names, taken from names of surface features nearby. These are as follows:

Goshen anticline	Whatcom Creek anticline
Van Wyck syncline	Samish syncline
Squalicum anticline	Padden anticline
Lake Whatcom syncline	Padden syncline
Austin anticline	Chuckanut anticline
Lookout Mountain syncline	Chuckanut syncline

Faults. Although a few minor faults are present in the coal measures of western Whatcom County, they were not found to exist on a very large scale or to be as prominent as the folding of the beds. Faults apparently were a disturbing feature in the Blue Canyon mine. One distinct fault is exposed in the cliffs along the western side of Lake Whatcom in section 9 (T. 37 N., R. 4 E.). In two places along Chuckanut Drive, one near Grandview and the other near Wildcat Cove, are probably local faults. Farther eastward there is undoubtedly much more faulting in these sedimentaries, such as in the Glacier coal field. It is not to be expected, however, that faulting of a very profound character will be found in the extreme western and northwestern area. The most disturbed zone, as far as mining is concerned, is in the beds immediately overlying the schist which lies below the base of the coal measures.

SURFICIAL DEPOSITS

General features. Nothing is more distracting in prospecting than to have the surface of bed rock covered with a loose mantle of rocky and earthy material. This is the condition which is met, to a greater or lesser extent, in nearly all of western Whatcom County. The steeper slopes generally maintain bed rock exposures and some of these are very clear indeed, but a large area, especially that north of Bellingham, is nearly all covered with gravel, sand, and silt. A few scattered outcrops, however, have told much concerning the underlying structure of the coal measures. Although it is with these data that we are most concerned, it is necessary that a thorough understanding be grasped of the surficial deposits.

Three forms of surficial material, having three different origins, are present. One is a marine deposition of silt, filling some of the irregularities of the old preglacial surface and interbedded with the glacial deposits themselves. The second is of glacial origin and consists of various kinds of glacial deposits—such as unstratified moraines, left as loose material of the melting ice, and as outwash gravels, stratified and sorted only in a rude fashion by local streams from the old ice front. The third is of recent stream fillings of alluvium, which consist very largely of re-worked glacial material. This does not cover as widespread an area as the deposits of glacial origin, and is, therefore, only of local importance. The old river channels which existed before and during the glacial epoch, however, may, in some cases, be now occupied by some of the present streams. In such cases the total deposition of alluvium would be of great depth and the rock surface beneath would be, therefore, far below the surface, and consequently the interbedded coal seams might be partly or completely washed away through this pre-glacial erosion.

The first of these deposits (marine clays, largely) contains in places shells of marine origin, clams, etc., but is not consolidated to any great extent. From some of the water wells recent marine fossils have been brought to the surface, according to various reports. The clays of this type of deposit serve as impervious strata, in many places, and divert the flow of the ground water.

The second class is most widespread and enters into the problems of mining operations as well as into those of prospecting. For the reason of its importance—even though of negative value—extracts are quoted below from a bulletin entitled, "Glaciation of the Puget Sound Region", by Harlen Bretz.[1]

"*The Whatcom County Moraines.* The plain region of Whatcom County lies west of the Cascades and north of the spur of mountainous hills which . . . . [interrupt] the Puget Sound basin. It is included in the Blaine and Sumas quadrangles of the U. S. Geological Survey, and its topography is almost entirely determined by ground moraine and by the post-glacial alluvial deposits of the Nooksak River. A few areas exist where the glacial till has been left in true frontal moraine ridges, among the first to be built in the retreat of the Puget Sound Glacier after those of Pierce and Thurston counties.

"A moraine ridge begins southeast of Ferndale and extends northeastward for five miles, passing just south of Laurel. Another moraine ridge lies immediately east of this. Other moranic areas, somewhat scattered, occur along the Bellingham Bay and British Columbia Railroad, [now owned by the Chicago, Milwaukee, and St. Paul Railway], near Wahl and Goshen, and also close to Clearbrook and Sumas. Yet other areas of similar character lie between Nooksak and Geary School (Damtown).

"The Laurel moraine is the one of most interest. Its orientation affords a clue to the form of the Puget Sound Glacier's front on withdrawal from the mountainous interruption of the basin. The moraine's ground plan describes a curve, with its concavity to the north. The heavy frontal moraine deposits on the eastern face of the large interglacial hill west of Ferndale, together with the Laurel moraine, give a complete outline for this portion of the front of the glacier. It indicates that the ice was moving almost directly from the north when the deposits in question were formed.

"Corroborative evidence for this conclusion is secured from glacial groovings on the Chuckanut sandstone in the southern part of the city of Bellingham, the trend of which is magnetic north and south. An element of doubt remains as to exact direction of movement because it could not be determined whether the edges of outcropping strata were responsible for the exact direction taken. In general,

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[1]Wash. Geol. Survey, Bull. 8, 1913, pp. 76-78, 170-171, 229-231, and 233-234.

however, the ice must have moved approximately south in production of the groovings.

"Another item of considerable interest attaching to the Laurel moraine is the fact that marine shells occur in it. An isolated moraine hill two miles west and one mile south of Laurel was opened some years ago under the impression that it was a drift covered rock outcrop, with the hope of finding coal which exists in the Tertiary sedimentaries of the region. The tunnel which was driven penetrated a stony hardpan so firm that no timbering was required. Clam shells were reported as occurring in large numbers in this till. The writer picked up a few fragments of barnacle shells from the old dump of the tunnel.

"Half a mile south of Laurel, a gravel pit has been opened in the same moraine. The section thus made shows about three feet of Vashon till at the top, very like that near the surface in the most southern deposits of the Puget Sound Glacier. Below it is three feet of a stony clay, different from the overlying till. It contains sand and gravel, but has no foliation like the overlying till. Instead, it is cut by roughly vertical, crudely conchoidal joints, along which the clay parts on drying. These surfaces are stained a dull purplish-brown by percolating water, the clay elsewhere being gray. Besides their prevailing verticality, these joints also radiate to a minor degree in all directions from the larger pebbles in the mass. A sharp line of contact exists between the till and this clay. In the clay were found a number of fragile marine shells, some with the valves still attached.

"Beneath the shell-bearing clay is stratified sand, and beneath this in turn is the gravel for which the pit was opened. The gravel is undoubtedly of Vashon age. It shows foreset beds which dip to the south and southwest. The upper surface of these beds was irregularly eroded by running water before deposition of the overlying sand. All these evidences indicate that the moraine was subaerially deposited, and the included marine shells of the peculiar clay apparently must be explained as having been plowed up by the glacier. The shell bearing clay, therefore, is a fill of peculiar facies. . . .

"*Glacial Lake Whatcom.* Lake Whatcom occupies the valley of the northward-flowing stream of pre-Vashon age, eroded in the northern slope of the diagonal mountain spur of the basin. The retreating Vashon glacier left a heavy moraine deposit in the mouth of this valley, causing the present lake.

"There are two broad drift-filled valleys opening northward to the low plain of Whatcom County from the northern end of the lake. They are separated by Squalicum Mountain. Either of them is oriented favorably for the continuation of the preglacial valley, but without data on the depths of drift in them, the question cannot be settled. The lake extends farther into the western valley and discharges through it. Whatcom Creek, carrying the outflow, crosses bed rock close to the lake, but is so far over to one side of the filled valley that the rock in the stream bed is probably only a portion of the preglacial valley slope on which the stream has been superposed.

"During the retreat of the Vashon ice across this region the glacial front formed a dam too high for northward flow and glacial Lake Whatcom was formed, with discharge from the southeast tip to a tributary of Samish River. The coal in the outlet valley lies just north of Mirror Lake at an altitude of 375 feet. A drift filling here has been incised to a depth of 30 feet.

"The valley which carried discharge of the glacial lake unites with a larger one at Wickersham. High terraces of glacial gravel occur in this larger valley. At Prairie, three miles south of Wickersham, these terraces are 340 feet in altitude and farther south of here they widen out into a broad plain which leads to the Skagit River.

"This train which floors the valley to which Glacial Lake Whatcom discharged, came down the main valley from the north. Its extent north of Wickersham has not been studied.

"After the margin of the ice had withdrawn from Squalicum Mountain, and after Glacial Lake Whatcom had ceased to discharge over the Mirror Lake col, the gravel train was largely eroded by the diverted South Fork of the Nooksak River, which for some time after the disappearance of Glacial Lake Whatcom, was blocked by ice at the north and forced to be tributary to the Skagit. Its course at this time was southwest from Prairie to the present Samish, emerging on the Skagit Delta three miles north of Burlington.

"At the inception of standing water at the south end of Lake Whatcom valley, the southwestern arm contained a small independent lake with outlet to Samish River about three miles below Samish Lake. The outlet channel lies on the north side of the drift-filled valley connecting the Whatcom and Samish valleys, with an altitude of about 415 feet. . . .

"*The Squalicum Delta.* A marginal river formed along the edge of the Puget Sound Glacier as it withdrew northward from Squalicum Mountain, east of Bellingham. Its channel is followed by the Bellingham Bay and British Columbia Railroad between Noon and Bellingham, and descends westward to open out toward the bay in a broad flat of sand and gravel in the northern part of the city of Bellingham. Extensive excavations and railroad cuts in the valley of Squalicum Creek expose the structure of this delta, but the stratification is not in any way comparable to the beautiful structure of some of the Lake Russell deltas.

"Strata dipping seaward are common, though of no great length or thickness. Such foreset beds possess no definite upper limit by which the sea level may be determined. Stream-bedding occurs conspicuously at the top, bearing sandy strata with fine cross-bedding dipping seaward. But gravels with rude horizontal stratification occur beneath the foreset beds, at a vertical distance from the sand too great to fall within the tidal range of Bellingham Bay. Beneath the whole is an eroded surface of sand, which is as fresh as the gravel above, and doubtless belongs to the same deposit. In the upper part of the gravel is a persistent clay stratum one to three feet thick.

"Obviously, this is the deposit of a heavily loaded stream which flowed through the Squalicum channel. The plain caused by this delta-like deposit has an altitude of 75 feet. From this must be subtracted the variable thickness of the topset beds to obtain the height of the sea at the time of deposition. This was perhaps 50 feet above present sea level. Horizontal and foreset bedding both are to be found within 30 feet of present mean tide.

"The sea cliffs of the northern portion of the Squalicum delta plain show 10-20 feet of clay at the top. Since this is at the same level as the sandy and gravelly portions, it must be contemporaneous. It may be explained as part of the delta which during the last stages of growth was not reached by distributary currents, the clay settling in the still water. This conception demands, however, an altitude of 75 feet for the sea level.

"The Squalicum Delta plain is bounded on the north by ground moraine which rises 30 feet above it. Sea cliff sections show foreset gravel beneath the till. The till is probably the result of a slight readvance of the Vashon ice, while the delta was being built.

"The conclusion drawn from the Squalicum Delta regarding sea level during Vashon retreat is that this plane lay somewhere between 30 and 75 feet above present mean tide.

"*Shell-bearing Till of Whatcom County.* . . . . The shell-bearing stony clay, overlying the Laurel moraine at an altitude of 100 feet, is essentially the same as this till of the Bellingham Bay sections. If the latter is a till sheet of Vashon age, produced by two successive advances, little hesitancy need be felt in explaining similarly the marine shell-bearing stony clay of the Laurel moraine, five and a half miles north. The shells of the Laurel moraine, 100 feet above tide, therefore, do not enter our present problem of the height of the sea level during Vashon retreat. . . .

"*Beach Ridges of Whatcom County.* The broad plains of post-glacial marine and fluvial aggradation which constitute the fertile farming country of Whatcom County in places bear beach ridges recording the former marine submerges. Such beaches are conspicuous on the plain north and west of Laurel. They are somewhat irregular in crest, and inclined to be duney, and hence are not used for ridge roads. Some are very low and scarely to be detected. They are composed of clean brown sand with rounded grains. Numerous thin, wavy seams or strata of clay occur in them, but no shell remains were found in them.

"The largest ridge observed trends northeast to southwest along the edge of a terrace, the ridge being 20 feet above the plain on the northwest, and 10-12 feet above that on the southeast. This ridge is cut in three places by the road between Ferndale and Laurel, and once by the Pacific Highway north of Laurel. The course of Tenmile Creek is parallel to the ridge.

"Beach ridges are numerous between Lynden and Sumas, and are commonly composed of fine gravel. A section afforded by one of these showed strata dipping westward, obviously produced by accretion on the seaward face of the beach.

"The highest known occurrence of beach sand on the Whatcom County plain is east of Everson at an altitude of about 100 feet. It does not have the form of a ridge, but from its surficial position and freedom from clay, it is best explained as a shore deposit on the ground moraine. It contains a peaty layer in a position in entire harmony with beach origin but difficult to explain otherwise."

RECORDS OF DRILL HOLES AND WELLS

DIAMOND DRILL RECORDS

SYMINGTON'S REPORT

Through the courtesy of the Bellingham Bay Improvement Company, and of the Bellingham Coal Mines, the old records of diamond drilling were secured which give valuable data on the stratigraphy, as well as the coal record of the region.

A mining engineer, R. B. Symington of San Francisco, was employed some thirty years ago to determine the position of the old Bellingham Bay coal seam. It was not, however, until 1917 that this information was put to practical use in mining, when John C. Eden initiated his activities which led to the development of the Bellingham Coal Mines.

The original report of R. B. Symington, it is said, was destroyed in the San Francisco fire, but a copy of a portion of it, fortunately, was left in Bellingham. Symington showed in his later report, of 1912, however, the probable position of the outcrop of the coal seam and the dip of it by means of a map. A section also was included, graphically representing the position of the main coal bed, the lower two-foot coal seam, the position of the overlying and underlying sandstones and shales, and the position of the glacial drift covering the surface. Besides these illustrations, special graphic sections were drawn to scale, showing those portions of bore holes Nos. 6, 7, 8, 9, and 10 which cut the main coal seam.

The following extracts are taken from the report of R. B. Symington made to the Bellingham Bay Improvement Company, in 1912, in connection with a plan for generating electricity:

"In the year 1892 I was employed to find by diamond drilling the position of the great coal vein in the property of the Bellingham Bay

Improvement Company lying north of the city of Bellingham which had been worked in the Company's land on the south side of the city in the sixties and seventies of last century. The result of my work is shown in the accompanying map and sections.

"As there was no exposure of the strata on the tract between the old mine and the territory to be explored, the assumption was that the outcrop of the coal would be somewhere near the extension of the line of outcrop developed by the old workings, and Bores Nos. 1, 2, 3, and 4, as shown on the map, were accordingly put down in conformity with this theory. They tested the strata for a thickness of 2,000 feet, but found no coal of any workable thickness. The cores got from the drill showed the strata dipping about 20 degrees to the southwest. It was thus evident that the outcrop lay farther to the west and Bore No. 5 was put down which found a coal about 2 feet thick at a moderate depth. It was known that such a vein lay about 200 feet below the main coal, and I therefore went 1800 feet southwesterly and in No. 6 Bore found the great vein 14 feet, 10 inches thick at a depth of 425 feet. This showed that the line of outcrop had changed, and instead of running northerly, had curved to the left and was northwesterly. It was then an easy matter to trace out the location of the coal, and Bores Nos 7, 8, 9, and 10 each found the coal of a similar thickness dipping at the rate of about 10 degrees to the southwest.

"The map shows the position of each of the bores, and the depth at which the coal was found. The details of thickness and character of each portion of the vein and the intervening banks of fire-clay and shale are given in the sectional diagrams and show that the total thickness ranges from 14 feet 6 inches in No. 7 Bore to 15 feet 11 inches in No. 9 Bore, and has an average of 15 feet, made up as follows:

Good coal	9 feet 4 inches
Inferior coal	4 feet 6 inches
Shale and fire-clay bands	1 foot 2 inches
Total thickness	15 feet 0 inches

"The shale and fire-clay are usually in bands of two to four inches thick. The bores also show that west of the Meridian Road the stratified measures are covered with gravel for a depth of from 150 to 280 feet, increasing towards the northwest, but this rapidly diminishes east of the Meridian Road. The accompanying section or profile shows the overlying gravel and the consequent cutting off of the coal and other stratified measures at a depth of 150 to 280 feet from the surface.

"There are 940 acres of land belonging to the Bellingham Bay Improvement Company lying to the west of this proved line of outcrop, and as the dip flattens toward the west, the maximum depth to the coal will not probably exceed 1200 feet, and after allowing 40 per cent for waste, there should be 13,000 tons per acre, or over 12,000,000 tons in this coal-bearing tract.

"The merchantable value (not the intrinsic value) of a coal depends very much on the absence of bands of shale or streaks of inferior quality such as prevail in this vein, and as the owners of this land were then operating a coal-field singularly free from this drawback, nothing was done to open up this tract.

"The former operations in this vein were confined to selecting the best three or four feet of any particular section, and this added enormously to the cost per ton, but perhaps was necessary because inferior coal is unsalable, yet when used by the owner of the mine at the mine, it has an efficiency of about 75 per cent of the selected quality, the drawback being in the disposal of the extra quantity of ash.

"This leads me to suggest the value of this coal for the generation of electricity utilizing the whole thickness of the vein.

"The good coal has the following average composition, as ascertained by many analyses made by me at the time of drilling.

Moisture	5.2 per cent
Volatile matter	34.2 per cent
Fixed carbon	55.6 per cent
Ash	5.0 per cent
	100.0 per cent

"The inferior coarse coal showed an average of

Moisture	4.7 per cent
Volatile matter	27.2 per cent
Fixed carbon	41.8 per cent
Ash	26.3 per cent
	100.0 per cent

"The whole vein, including the shale and clay bands, gives

Moisture	5.0 per cent
Volatile matter	28.7 per cent
Fixed carbon	47.3 per cent
Ash	19.0 per cent
	100.0 per cent

"This is equivalent to 11,000 B. T. U., which, with a 70 per cent boiler efficiency, would evaporate 8 pounds of water per pound of fuel, and one ton is equal to 3½ barrels of oil.

"Most of the old workings were near the surface where the superincumbent pressure is not great, and it consequently took a long time before the final caving took place, and it would then form holes on the surface. When the depth exceeds 200 feet, the subsidence takes place very soon, but is gradual and does not show holes or any break on the surface, and this is especially true, when as here, there is a thickness of 200 feet of gravel above the stratified measures. Very little subsidence would show on the surface as it would be mostly distributed through the gravel."

The following records of bore holes, numbers 1, 2, 4, and 5, have been compiled from section diagrams copied from the original drawings. Number 3 bore hole was not found with the rest of the records. The thickness and depth of each stratum have been scaled off from the sectional diagrams, and may therefore not be in every case the exact original measurement.

Records of bore holes numbers 6, 7, 8, 9, and 10 were secured through the courtesy of the Bellingham Coal Mines Company, who had copies of the logs on file. These logs, however, were not in every case complete, for in checking against the diagrams of the sections of the coal seams in Symington's report of 1912, a few important features were found wanting. A compilation of the two reports is given herein, with the hope that the result is fairly accurate.

The drill holes were apparently driven straight down, cutting dipping strata. Drill holes 5, 6, 7, 8, 9, and 10 all entered strata dipping about 10° from the horizontal, while drill holes 1, 2, 3, and 4 entered beds whose dip is about 20°. This feature should be taken into consideration when measuring the stratigraphic thickness of the formation or any part of it.

Bore Hole No. 1.

Location: SE¼, SW¼, Sec. 18, T. 38 N., R. 3 E.
Commenced drilling October 27, 1891.
Finished drilling January 2, 1892.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
	Soil	3		....	
1 to 15	Sandstone, streaks of shale	63		66	
16	Dark fire clay	2	6	68	6
17–18	Fire clay	3	6	72	
19	Coaly streaks	2		74	
20 to 22	Fire clay	7	6	81	6
23	Dark fire clay	5		86	6
24–25	Fire clay	6	6	93	
26	Dark fire clay	3		96	
27	Fire clay	3		99	
28–29	Claystone	3	6	102	6
30	Dark fire clay	2	6	105	
31	Claystone	1	6	106	6
32	Dark fire clay	2		108	6
33	Claystone	1		109	6
34	Fire clay	7		116	6
35	Coaly streaks	1	6	118	
36–37	Fire clay	11	6	129	6
38 to 40	Dark fire clay	5		134	6
41	Fire clay	4		138	6
42	Claystone	3	6	142	
43 to 45	Fire clay	13		155	
46	Sandstone, streaks of fire clay	10	6	165	6
47 to 49	Coaly streaks in shale	9		174	6
50–51	Fire clay	12		186	6
52	Coaly streaks	1		187	6
53	Fire clay	8		195	6
54	Sandstone, streaks of fire clay	4	6	200	
55	Fire clay	6		206	
56	Sandstone, streaks of fire clay	5		211	
57	Coaly streaks	2		213	
58	Fire clay	7		220	
59	Shale	2	6	222	6
60	Fire clay	5		227	6
61	Fire clay	2		229	6
62	Dark fire clay	6	6	236	
63	Fire clay	3	6	239	6
64	Sandstone, streaks of fire clay	7	6	247	
65	Coaly streaks in dark fire clay	5		252	
66	Fire clay	2	6	254	6
67	Dark fire clay	2		256	6
68	Fire clay	3		259	6
69	Sandstone, streaks of fire clay	16		275	6
70	Sandstone	3	6	279	
71	Sandstone	9		288	
72	Conglomerate	9		297	
73	Coarse conglomerate	2		299	
74	Sandstone, streaks of fire clay	8	6	307	6
75	Fire clay	3		310	6
76	Sandstone, streaks of fire clay	4		314	6
77	Coaly streaks in fire clay	9	6	324	
78	Fire clay	10		334	
79	Fire clay	15	6	349	6
80	Sandstone, streaks of fire clay	5		354	6
81	Fire clay	1		355	6
82	Sandstone	7		362	6
83–84	Fire clay	7		369	6
85	Claystone	9	6	379	
86	Fire clay	16		395	
87	Coaly streaks	4		399	
88	Sandstone, streaks of fire clay	12		411	
89	Fire clay	4		415	
90	Coaly streaks	4		419	
91	Dark fire clay	3		422	

Bore Hole No. 1.—Continued.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
92	Fire clay	15	6	437	6
93	Dark fire clay	1	6	439	
94	Fire clay	9		448	
95	Fire clay	8		456	
96	Coal	1	3	457	3
97	Fire clay	8	3	465	6
98	Sandstone	9	6	475	
99	Fire clay	5		480	
	Sandstone, streaks of shale	10		490	
100	Sandstone	2	6	492	6
101	Dark fire clay	5	6	498	
102	Sandstone, streaks of fire clay	7		505	
103	Coaly streaks	3	6	508	6
104–105	Fire clay	22		530	6
106–107	Shale	14		544	6
108	Claystone, fire clay streaks	5		549	6
109–110	Coaly streaks	3	6	553	
111	Claystone	8		561	
112–113	Fire clay	9		570	
114	Sandstone, fire clay streaks	19		589	
115	Shale	3	6	592	6
116	Sandstone, fire clay streaks	6		598	6
117	Coarse sandstone	6	6	605	
118	Sandstone, streaks of shale	14	6	619	6
119	Very coarse sandstone	10		629	6
120	Sandstone	10		639	6
121	Sandstone, streaks of shale	4	6	644	
122	Fire clay	2		646	
123	Sandstone, streaks of fire clay	11	6	657	6
124	Shale	2		659	6
125	Fire clay	8		667	6
126	Claystone	2		669	6
127	Dark fire clay	3	6	673	
128	Fire clay	7		680	
129	Shale	8		688	
130	Fire clay	5	6	693	6
131–132	Coaly streaks in shale	8		701	6
133–134	Coal		6	702	
135	Sandstone, streaks of fire clay	8		710	
136	Coaly streaks in shale	6		716	
137	Sandstone, streaks of shale	16		732	
138	Sandstone, streaks of fire clay	1		733	
139	Sandstone	5		738	
	Coal	1		739	
140	Shale	4		743	
141	Fire clay	13		756	
142	Claystone	8		764	
143–144	Fire clay	6	6	770	6
145	Ribs of coal in shale	9		779	6
146-147-148	Sandstone, streaks of fire clay	19	6	799	
149–151	Sandstone	19		818	
152	Conglomerate	4		822	
153	Sandstone	5		827	
	Coal	1		828	
154	Fire clay	5		833	
155	Sandstone	10	6	843	6
156	Fire clay	10		853	6
157	Sandstone, streaks of shale	7	6	861	
158 159 to 161	Fire clay Coal and shale, fire clay, shale	7		868	
162–164	Fire clay	30		898	
165	Claystone	2		900	
166	Sandstone, streaks of shale	4		904	
167–169	Sandstone	27		931	

Bore Hole No. 2.

Location: E½, SW¼, Sec. 18, T. 38 N., R. 3 E.
Commenced shaft, January 13, 1892.
Commenced casing, January 21, 1892.
Commenced diamond drill, February 11, 1892.
Finished diamond drill, March 9, 1892.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
	Gravel				
	Sand				
	Gravel				
	Clay				
	Clay and gravel				
	Sand				
	Sand and clay				
	Clay				
	Clay and gravel				
	Boulder				
	Boulder				
	Fine gravel				
	Coarse gravel				
	Fine gravel				
	Gravel				
	Sand			195	
	Sandstone	4		199	
	Fire clay	3		202	
1	Fire clay	14		216	
2	Shale and coal streaks	1	6	217	6
3–11	Fire clay and dark fire clay	42		259	6
12	Coal streaks	2		261	6
13–14	Fire clay	11	6	273	
15–16	Sandstone, bands of shale	19		292	
17–18	Sandstone				
19	Conglomerate sandstone	24		316	
20	Conglomerate sandstone				
21–22	Sandstone				
23–25	Fire clay	21		337	
26–27	Fire clay (This fire clay swelled and caused stoppage of bore)	11		348	
28–30	Fire clay and dark fire clay	15		363	
31	Sandstone	4		367	
32	Sandstone, bands of shale	6		373	
33–36	Sandstone	24		397	
37–40	Fire clay and dark fire clay	30		427	
41–42	Sandstone	9		436	
43	Shale	1	6	437	6
44–47	Fire clay	30		467	6
48	Shale	2	6	470	
49–50	Fire clay	16		486	
51	Sandstone	1	6	487	6
52	Fire clay	7		494	6
53	Conglomerate sandstone	38		532	6
54	Bituminous rock	4		536	6
55	Dark fire clay	3	6	540	
56	Shale	1		541	
57	Fire clay	10		551	
58–61	Bone and coal, and fire clay	7		558	
62	Sandstone	11		569	
63	Shale	2		571	
64–65	Fire clay, and dark fire clay	12		583	
66	Sandstone, bands of shale	17		600	

Bore Hole No. 4.

Location: E½, NW¼, Sec. 19, T. 38 N., R. 3 E.
Commenced shaft, 1892.
Commenced diamond drill, May 11, 1892.
Finished diamond drill, June 1, 1892.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
....	Clay and stones, sand, and gravel........	99		....	
....	Fire clay—end of casing....................	4		103	
1	Light sandstone..............................	5		108	
2	Bluish sandstone with dark streaks........	6		114	
3	Bluish sandstone............................	7		121	
4-5	Conglomerate sandstone.....................	17		138	
6	Argillaceous sandstone......................	1		139	
7-8-9	Sandstone with dark streaks...............	10		149	
10	Conglomerate sandstone.....................	17		166	
11	Sandstone with dark streaks...............	11		177	
12	Sandstone with coaly streaks.............	4	6	181	6
13	Sandstone	15		196	6
14	Fine grained sandstone with streaks......	9		205	6
15-16	Fine grained sandstone with coal streaks and clay bands................	9		214	6
17	Coarse bluish sandstone with dark grains	27		241	6
18-19	Hard sandstone..............................	7		248	6
20	Conglomerate sandstone.....................	3		251	6
21	Hard sandstone with coal streaks..........	10	6	262	
22	Hard sandstone..............................	9		271	
23-24	Coarser sandstone..........................	25	6	296	6
25	Conglomerate sandstone.....................	8	6	305	
26	Dark fire clay...............................	1	6	306	6
27	Shale and threads of coal..................	1		307	6
28	Light fire clay..............................	4	6	312	
29	Fire clay bands..............................	4		316	
30	Dark shale and fire clay....................	7		323	
31	Fire clay not so dark.......................	29		352	
32-33	Argillaceous sandstone......................	25		377	
34-37	Shale, bone and coal threads..............	11		388	
38	Light fire clay..............................	5		393	
39	Argillaceous sandstone......................	6		399	
40	Shale and coal threads......................	1		400	
41-42	Sandy fire clay and coal threads..........	5		405	
43	Fine grained sandstone.....................	5		410	
44	Shale and coal threads......................	3		413	
45	Fine grained hard sandstone...............	2		415	
46	Shale	2		417	
47	Sandstone and fire clay bands.............	8		425	
48	Hard light fire clay.........................	1	6	426	6
49	Dark fire clay, shale and coal threads.....	8		434	6
50	Light fire clay..............................	6		440	6
51-52	Sandstone and fire clay bands.............	15	6	456	
53-55	Shale, fire clay, and coal threads..........	6		462	
56	Light sandy fire clay........................	6		468	
57	Dark fire clay...............................	1		469	
58	Light fire clay..............................	5		474	
59	Fine grained sandstone and fire clay bands	15		489	
60	Bluish sandstone and dark grains.........	2		491	

Bore Hole No. 5.

Location: On east side of Guide Meridian, W½, NW¼, Sec. 19, T. 38 N., R. 3 E.

Commenced drilling, June 8, 1892.

Finished drilling, July, 1892.

Dip, S. 50° W., 14°.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
		....		172	
....	Fire clay and shale	1	9	173	9
....	Coal	2	3	176	
....	Fire clay	29	6	205	6
....	Argillaceous sandstone	3		208	6
....	Fire clay	23	6	232	
....	Sandstone	3		235	
....	Light fire clay	10		245	
....	Sandstone and fire clay, dark fire clay	4		249	
18-19	Sandstone and fire clay	4		253	
20	Fire clay	6		259	
21	Sandstone	3	6	262	6
22	Fire clay and sandstone	13		275	6
23-25	Dark fire clay	100		375	6
26	Bone	1		376	6
27	Shale and bone	3		379	6
....	Dark fire clay	5		384	6
28	Sandstone and fire clay	10		394	6
29-30	Sandstone	39	6	434	
31	Conglomerate	4		438	
32	Sandstone	6		444	
33-34	Sandstone mixed with conglomerate	36		480	
35-36	Sandstone	45		525	
37	Coarse sandstone	10		535	
38-39	Sandstone and conglomerate	15		550	
40	Fine grained sandstone	10		560	
41	Sandstone and conglomerate	43	6	603	6
42	Argillaceous sandstone	4	6	608	
43-44	Sandstone and clay bone	6		614	
45	Fire clay and shale	3		617	
46-48	Dark fire clay, shale, and bone	9		626	
49	Shale and coal streaks	11	6	637	6
50-51	Sandstone and fire clay bone	12		649	6
52	Sand and fire clay	4	6	654	
53	Sandstone and fire clay bone	11		665	
54-55	Bone and shale	10		675	

Bore Hole No. 6.

Location: Center of S½, NE¼, Sec. 24, T. 38 N., R. 2 E.
Finished drilling, September 22, 1892.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
....	Soil, etc.	....		6	
....	Gravel	21		27	
....	Gravel and soft clay	156		183	
1	Fine clay	5		188	
2	Fine clay	2	6	190	6
3	Fine clay	8		198	6
4	Fine sandstone	3	5	201	11
5	Fine sandstone	8		209	11
6	Fine sandstone	9		218	11
7	Small streak dark shale	10		228	11
8	and black at 240 feet	8	10	237	9
9	Small streak dark shale	10	4	248	1
10	Dark shale at 272 feet	9	8	257	9
11	....	10		267	9
12	....	9	4	277	1
13	....	10		287	1
14	....	10		297	1
....	Fine sandstone at 308 feet	11	1	308	2
15	Fire clay	6	3	314	5
15	....	5		319	5
16	Dark shale	10	2	329	7
17	....	8		337	7
18	....	9	10	347	5
27	....	9	8	357	1
		5	7	362	8
		6	4	369	
		3		372	
....	Chopping shale at 369 feet	4	1	376	1
29	Struck clay at 379 ft. 7 in.	5	2	381	3
30	Fire clay	2	2	383	5
....	Hard fire clay	....		....	
....	Struck coal 410 ft. 10 in. September 14, 1892.				
....	Coal, coarse	1	4	412	2
....	Shale		2	412	4
....	Coal	1		413	4
....	Fire clay		1	413	5
....	Coal	1		414	5
....	Fire clay		2	414	7
....	Coal		8	415	3
....	Coal		3	415	6
....	Bone		6	416	
....	Coal	1	3	417	3
....	Coal		4	417	7
38	Bone or shale		2	417	9
39 to 47	Coal	1		418	9
48	Coal		3	419	
....	Clay		5	419	5
49 to 50	Coal	1	4	420	9
51	Coal		4	421	1
....	Clay band		4	421	5
64	Coal		8	422	1
65	Clay		4	422	5
66 to 79	Coal, coarse	1	8	424	1
80 to 88	Coal and bone		9	424	10
89 to 91	Bone and coal		6	425	4
92	Fire clay		3	425	7
93	Bone		3	425	10
94	Fine sandstone	1	3	427	1
95	Coarser sandstone	3	3	430	4
96	Finer sandstone	2	4	432	8
97	Fine clay		6	433	2
98	Fine clay	3	4	436	6
99	Fine sandy clay		10	437	4
100	Fine sandstone	18	8	456	
101	Conglomerate, coarse sand, etc.		6	456	6

Bore Hole No. 6.—Continued.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
102	Conglomerate	10		466	6
....	Conglomerate	3		469	6
....	Conglomerate chopped	4	4	473	10
103	Fine sandstone and gravel	1		474	10
....	Fine sandstone and gravel	1		475	10
....	Fine sandstone and gravel	1		476	10
....	Chopped	4	2	481	
104	Fire clay		5	481	5
105	Conglomerate		7	482	
....	Conglomerate chopped	1	5	483	5
....	Fire clay		6	483	11
106	Fire clay		7	484	6
....	Fire clay	1		485	6
107	Fire clay	2		487	6
108	Bone and shale	2	11	490	5
109	Fire clay	2		492	5
110	Bone		3	492	8
111	Bone		10	493	6
112	Fine sandstone	3		496	6
113	Fine sandstone with dark streaks	2		498	6
114	Little coarser sandstone	5		503	6
115	Very fine sandstone	3		506	6
116	Little coarser	1		507	6
117	Sandstone with bands	4		511	6
118	Fire clay	5		516	6
119	Coal with little bone	4	6	521	
120	Dark fire clay	3		524	
121	Fine clay	2	6	526	6
122	Very fine sand with clay	5		531	6
123	Fire clay	5		536	6
....	Fire clay	3		539	6
124	Sandy fire clay	3		542	6
125	Fire clay	4		546	6

Bore Hole No. 7.

Location: W½, NE¼, Sec. 24, T. 38 N., R. 2 E.
Finished drilling October 18, 1892.

Core	Material Encountered	Thickness Feet	Thickness Inches	Depth Feet	Depth Inches
....	Soil, etc.	3		....	
....	Fine sand	6		9	
....	Coarse gravel	9		18	
....	Soft clay	56		74	
....	Gravel and sand	26		100	
....	Gravel and sand	6		106	
....	Soft clay and gravel	20		126	
....	Soft clay	34		160	
....	Sand and boulders	1	6	161	6
....	Soft clay and gravel	4	6	166	
....	Soft clay	3		169	
....	Fine sand	4		173	
....	Soft clay	9	6	182	6
....	Soft clay	10		192	6
....	Sand and gravel	36		228	6
....	Clay and gravel	9		237	6
....	Bed rock at 237 feet 6 inches	....		237	6
....	Fire clay	3	6	241	
....	Bottom 3 in. casing	....		....	
....	Sandstone	1	6	242	6
....	Sandstone		10	243	4
....	Clay		2	243	6
1	Sandstone with clay	2		245	6
2	Rotten sand moved with clay	1		246	6
3	Sandy fire clay	2	3	248	9
....	Sandy fire clay	8	6	257	3
....	Sandy fire clay	3	7	260	10
....	Sandy fire clay	9	6	270	4
4	Dark bone and coal	1		271	4
5	Fine rotten sand	7	4	278	8
5	Fine rotten sand	3		281	8
6	Sandstone with bands	6	6	288	2
6	Sandstone with bands	5	4	293	6
7	Very hard sandstone	4		297	6
8	Soft sandstone	10	8	308	2
9	Fire clay	2		310	2
10	Fine sandstone	1	4	311	6
10	Fine sandstone	2		313	6
....	Fine sandstone	2		315	6
....	Sandstone with hard pebbles	4	6	320	
		2	9	322	9
		2	6	325	3
....	8-inch core fine sandstone got		8	325	11
		5	10	331	9
		2	8	334	5
		2	1	336	6
....	Core	3		339	6
		1		340	6
....	Core	8		348	6
....	Core	3		351	6
....	Core	4	10	356	4
....	Chopped	4		360	4
....	Fire clay	3	5	363	9
....	Shale	1	7	365	4
....	Coal	1	1	366	5
....	Shale		1	366	6
....	Coal		9	367	3
....	Shale		5	367	8
....	Coal	1	7	369	3
....	Coal	2	10	372	1
....	Fire clay		5	372	6
....	Coal	2	8	375	2
....	Coal, coarse	3	4	378	6
....	Coal	1	4	379	10
....	Bone		3	380	1
....	Fire clay	....		....	

Bore Hole No. 8.

Location: SE¼, Sec. 13, T. 38 N., R. 2 E.
Finished drilling, November 10, 1892.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
....	Still and timbers	3		....	
....	Gravel and sand	11		14	
....	Clay	1		15	
....	Sand	6		21	
....	Light clay	2		23	
....	Dark clay	2		25	
....	Gravel	6		31	
....	Gravel and sand	14	4	45	4
....	Mud and soft clay	6		51	4
....	Light blue clay	48	8	100	
....	Clay, mud, gravel, and sand	63		163	
....	Bottom of 5 in. casing	....		....	
....	Clay, mud, etc.	82		245	
....	Hard sand	7		252	
....	Sand	3		255	
....	Bottom of casing	....		....	
....	Soft clay and gravel	9		264	
....	Shale and bone		4	264	4
....	Coal	1	6	265	10
....	Bone		2	266	
....	Coal	1	4	267	4
....	Coal	....		267	4
....	Coal	....		267	4
....	Chopped coal		5	267	9
1	Coal and bone	1		268	9
....	Coal	1	3	270	
....	Bone and clay		3	270	3
....	Coal		6	270	9
....	Coal		3	271	
....	Shale		3	271	3
....	Coal	1	8	272	11
....	Fire clay		4	273	3
....	Coal and bone	1	8	274	11
....	Coarse coal		10	275	9
....	Coal	1	2	276	11
....	Coal and bone	1	9	278	8
....	Clay and coarse coal		3	278	11
....	Clay and coarse coal	1	2	280	1
....	Clay	1	8	281	9
....	Fine clay	2		283	9
....	Fine sandstone	8		291	9
....	Fire clay	1	3	293	
....	Sandstone	8	9	301	9
....	Sandy	4		305	9
....	Fire clay	6		311	9
....	Fire clay	4		315	9
56	Sandstone (dark)	6		321	9
57	Fine sandstone	10		331	9
....	Fine sandstone	2		333	9
58	Bone and shale	1	10	335	7
59	Dark bone	1		336	7
60	Iron stone		2	336	9
61	Fire clay	2	2	338	11
62	Dark bone	2		340	11
63	Sand with fine clay bands	1	6	342	5
....	Sand with fine clay bands	9	8	352	1
....	Sand with fine clay bands	10	8	362	9
64 to 70	Coal	1	10	364	7
71	Coal	1		365	7
72	Coal	10	1	375	8

NOTE: The record of this last coal as being 10 feet thick is undoubtedly incorrect for it is recorded in other drill holes and in a prospect shaft within the mine as being only about 2 feet thick, lying about 100 feet below the main seam.

Bore Hole No. 9.

Location: Center of east line, SW¼, SE¼, Sec. 13, T. 38 N., R. 2 E.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
....	Timbers	....		4	
....	Fine sand........	2		6	
....	Small gravel........	4		10	
....	Sand	1		11	
....	Light sticky clay........	2		13	
....	Soft fine sand........	1		14	
....	5-inch casing........	....		....	
....	Commenced driving........	3		17	
....	Gravel and sand........	18	4	35	4
....	Light blue clay soft........	8		43	
....	Light blue clay, some gravel........	28		71	4
....	Gravel	12		83	4
....	Gravel	8		91	4
....	Gravel	17		108	4
....	Clay	29	8	138	
....	Gravel	3		141	
....	Sandy clay........	3		144	
....	Bottom 5-inch casing........	20		164	
....	Clay	27		191	
....	Gravel	12		203	
....	Clay	25		228	
....	Gravel	12		240	
....	Clay, gravel, and sand........	22		262	
....	Clay, gravel, and sand........	12	2	274	2
....	Bed rock 274 ft. 2 in........	1	4	275	6
....	Sandstone		11	276	5
....	Sandstone	2	4	278	9
1	Fine sandstone........	7		285	9
2	Dark sandstone........	11	4	297	1
....	With clay bands........	5		302	1
3	With clay bands........	1	11	304	
		2		306	
4	....	8		314	
		13	3	327	3
5	....		4	327	7
6	Ironstone		7	328	2
7	Dark clay........		4	328	6
8	Coal		5	328	11
9	Bone		2	329	1
10	Coal	1	10	330	11
11	Bone or shale........		1	331	
12	Coal	2	10	333	10
13	Shale		2	334	
14	Coal	1	8	335	8
15	Shale		4	336	
16	Coal	1	6	337	6
....	Coal		3	337	9
....	Coal	1		338	9
....	Shale		3	339	
....	Coal		6	339	6
....	Coal		10	340	4
....	Brown sand........		3	340	7
....	Coal	1		341	7
....	Shale		6	342	1
....	Coal		3	342	4
....	Bone shale and coal........	2		344	4
....	Sandy fire clay........	18	6	362	10
....	Sandy fire clay........	4		366	10
....	Medium sandstone........	2		368	10
....	Fine hard sandstone........	4		372	10
104	Sandstone	12		384	10
105	Conglomerate	2	7	387	5
....	Chopped conglomerate........		9	388	2
106	....	2		390	2
107	....	8		398	2
108	Fire clay........	5		403	2
109	Bone	1	10	405	

Bore Hole No. 9.—Continued.

Core	Material Encountered	Thickness Feet	Thickness Inches	Depth Feet	Depth Inches
110	Clay bone and soapstone	1		406	
111	Bone and coal mixed	2	2	408	2
112	Bone		6	408	8
113	Fire clay	2		410	8
114	Shale and clay		8	411	4
115	Sandstone mixed with clay	6	10	418	2
....	Sandstone mixed with clay	10		428	2
....	Sandstone mixed with clay	8	6	436	8
....	Shale	1	6	438	2

Bore Hole No. 10.

Location: NE¼, NW¼, Sec. 24, T. 38 N., R. 2 E.

Core	Material Encountered	Thickness Feet	Thickness Inches	Depth Feet	Depth Inches
....	Timbers	....	....	2	
....	Soil	1		3	
....	Sand	13		16	
....	Clay	4	6	20	6
....	Sand	22	6	43	
....	Clay	31		74	
....	Clay	10		84	
....	Sand	11		95	
....	Clay	9		104	
....	Sand	35		139	
....	Sand	22	6	161	6
....	Clay	116	6	278	
....	Gravel	4		282	
....	Bed rock fire clay	1	6	283	6
....	Brown shale	1		284	6
....	Bottom of 4-inch casing	....	....	....	....
1	Shale		6	285	
2	Bone		6	285	6
3	Bone		6	286	
4	Bone		6	286	6
5	....	6		292	6
6	Dark bone	2		294	6
7	Fire clay	2		296	6
8	....	5	8	302	2
9	Ironstone		4	302	6
10	Fire clay	1		303	6
11	Shale	5	6	309	
12	Firestone	1	6	310	6
13	Sandy fire clay	10	10	321	4
14	Very hard stone	1	6	322	10
15	Fine sandstone	5	1	327	11
16	Coarse sandstone	2		329	11
17	Sandy fire clay	6	8	336	7
18	Rotten shale	2	10	339	5
....	Rotten shale	1	6	340	11
19	Bone and shale	1	3	342	2
20	Dark shale	2	4	344	6
21	Shale bone	1	3	345	9
22	Sandy clay	1		346	9
23	Sand, clay, and bone	2		348	9
24	Sandstone		8	349	5
....	Sandstone	3	3	352	8
25	Bone and coal		10	353	6
26	Shale		6	354	
27	Bone and shale	1	3	355	3
28	Fine sandstone	5	6	360	9

Bore Hole No. 10.—Continued.

Core	Material Encountered	Thickness		Depth	
		Feet	Inches	Feet	Inches
29	Fine sandstone, crumbly	9	4	370	1
30	Fire clay	3	6	373	7
31	Sandstone with bands	5	4	378	11
....	Sandstone with bands	10	3	389	2
32	Sandstone	10		399	2
....	Sandstone	23		422	2
		10		432	2
		10		442	2
33	Fire clay	4	10	447	
....	Fire clay	6	6	453	6
....	Ironstone		6	454	
34	Bone		2	454	2
35	Coal	1	2	455	4
36	Sandstone		2	455	6
37	Coal	1	6	457	
38	Bone		1	457	1
39	Coal	1	8	458	9
40	Coal and bone		6	459	3
41	Coal	1	5	460	8
....	Ironstone		4	461	
....	Coal	1	1	462	1
....	Clay band		3	462	4
....	Coal	1	5	463	9
....	Coarse coal	4	3	468	
....	Coal	1		469	
....	Fire clay	....		....	

Drove 5-inch casing 176 ft. 1 in.
Drove 4-inch casing 284 ft. 6 in.

DEEP WELL NEAR ENTERPRISE

A quarter of a mile east of the station of Enterprise on the Great Northern Railway (SE¼, SE¼, Sec. 19, T. 39 N., R. 2 E.) there is an old broken down derrick lying over a well which is discharging some water and bubbles of gas. A few diamond drill cores were found nearby which were composed largely of sandstone and shaly sandstone with coaly streaks and some fossil leaf impressions. The rock formation underground must have been found lying in a nearly horizontal position, for the cores show little dip, other than cross-bedding.

It is reported that this well was first drilled by the National Oil and Gas Company of Vancouver, and that it went down 1,300 feet. Then the Canadian Oil and Venture Company (Stone Brothers of Spokane, drillers) drilled down to 3,500 feet. It is reported that the first part of the well was diamond drilled with a standard rig, while the last part was diamond drilled.

The following data have been taken from a blue print made by F. H. Whipple:

CANADIAN OIL AND VENTURE COMPANY

Log of Well No. 1.

(Elevation above sea level, 710 feet)

STRATA	Thickness in Feet	Depth in Feet
Quicksand	30	30
Blue sand strata	70	100
Quicksand gravel	95	195
Blue clay	390	585
Water sand	30	615
Rotten shale and clay	225	840
Flour sand—coarse sand	295	1,135
Conglomerate	20	1,155
Gray sand	15	1,170
Blue clay	30	1,200
Fine gray sand	20	1,220*
Coal	5	1,225
Gray sand	5	1,230
Blue clay	10	1,240
Shale	30	1,270
Clay	65	1,335
Brown shale	30	1,365
Sharp white sand	15	1,380
Brown rotten shale	20	1,400
Rotten shale	60	1,480
Sandy shale	10	1,490†
Brown shale gas	60	1,550
Light sandy shale	95	1,645
Brown rotten shale	50	1,695
Light sandy shale	5	1,700
Brown shale	65	1,765
Shale gas	1	1,766
Blue clay	49	1,815
Dark gray sand	5	1,820
Blue clay	40	1,860
Sharp white sand	20	1,880
Blue clay	12	1,892
Coal	3	1,895
Gray sand	2	1,897
Blue clay	18	1,915
Sharp gray sand	43	1,958
Coal	2	1,960
Blue clay	25	1,985
Sharp gray sand and small streaks of clay	55	2,040
Shale gas	2	2,042
Blue clay	50	2,092
Brown shale, gas	48	2,140
Limestone	5	2,145
Hard shale, sandstone overlying	5	2,150
Coal with yellow clay caving badly	15	2,165
Hard shale	5	2,170‡
Blue shell	65	2,235
Fine sand	10	2,245
Limestone shell	2	2,247
Shale	3	2,250
Fine sandstone	15	2,265
Sandstone shell	2	2,267
Coal, some gas	10	2,277
Dark blue shale	5	2,282
Black shale	8	2,290
Fine sand, some gas	10	2,300
Hard sandstone	3	2,303
Sandstone fine, light gas	50	2,353
Blue shale and black shale, heavy gas	58	2,411

* End of 8-inch casing. † Hard shale overlying. ‡ Salt water.

Remarks: In the above log there are several coal horizons which may be summed up as follows:

Coal (5′)	down to 1,225
Coal (3′)	down to 1,895
Coal (2′)	down to 1,960
Coal with yellow clay, caving badly (15′)	down to 2,165
Coal, some gas (10′)	down to 2,277

It is quite probable that one of these may be the continuation of the big Bellingham seam. The 15 foot bed of "coal with yellow clay" may be the main seam, with the underlying 10 foot coal bed, 115 feet below, representing the continuation of the 2 foot seam found 100 feet below the main seam in the Bellingham Coal Mines. It is quite probable that the figure, 615 feet, marks the depth of the surficial material, glacial drift, etc., encountered at this point.

WATER WELL RECORDS

The following information was obtained largely through personal interviews with C. F. Livermore, well driller, whose father was also a driller, from the owners of some of the wells, and from other interested people. Although far from complete, it is considered by the writer to be of value in connection with this geological report, especially as it assists in the determination of the depth of the surficial material, glacial drift, etc., which overlies the coal measures. In some cases, actual data on underlying coal beds are listed.

WELLS IN THE REGION ABOUT GOSHEN AND WAHL

Dug water well. NE¼, SE¼, Sec. 24, T. 39 N., R. 3 E.

Surface	
Soil	3 feet
Coal, decomposed	10 inches
Shale	2 inches
Coal and shale	8 inches
Shale	3 feet
Coaly seam	3 inches
Shale and water	

(Measurement by writer.)

Water well, drilled by Livermore. NE¼, NW¼, Sec. 24, T. 39 N., R. 3 E.

Depth	74 feet
To bed rock	11 feet

Water well drilled by Livermore, SW¼, SW¼, Sec. 13, T. 39 N. R. 3 E.

Depth	100 feet
To solid rock	12 feet
Coal at	70 feet

Water well, drilled by Livermore, NW¼, NW¼, Sec. 24, T. 39 N., R. 3 E.

Depth	62 feet
To sandstone bed rock	5 or 6 feet

Last part is blue shale, with a little coal under sandstone.

Water well drilled by Livermore, on Mrs. S. L. Shell farm. SW¼, SW¼, Sec. 12, T. 39 N., R. 3 E.

Depth	100 feet
Soil and dirt	8 feet
Coal, 3 feet thick, at	70 feet

Rest of well is sandstone.

Old abandoned mill well on Geo. Hemmi land. SE¼, SW¼, Sec. 14, T. 39 N., R. 3 E.

Depth, 93 feet.
Dug to 33 feet, drilled from there on.
To sandstone, 24 feet.
Coal, approximately 4 feet, at about 70 feet.

Water well on Geo. Hemmi place. NE¼, NE¼, Sec. 22, T. 39 N., R. 3 E.

Well contains coal.

Water wells in hill in NE¼, Sec. 26, T. 39 N., R. 3 E.

Depth to sandstone, according to Livermore, about 30 feet.

Water well drilled by Livermore, near school house.

Depth, 166 feet.
Sandstone streak 18 inches thick at 152 feet.
Blue clay down to 105 feet, then sandy formation.
The well sucked air.

Water well drilled by Livermore near school house. SE¼, SE¼, Sec. 35, T. 39 N., R. 3 E.

Depth, 198 feet.
Gray sand with washed coal at 195 feet.
No bed rock.

WELLS IN THE REGION ABOUT LAUREL

Water well drilled with churn drill by C. F. Livermore on L. J. Sinnes farm. NW¼, SW¼, Sec. 24, T. 39 N., R. 2 E.

	Thickness in feet	*Depth*
Quick sand	35	...
Blue clay	19	54
Quick sand	24	78
Blue clay	162	240
Cement sand and gravel (hard rock begins below this)	85	325
Blue shale	140	465
Coal	5	470
Blue shale and coal	8	478
Coal	2	480
Blue shale	12	492

(6 inch casing down to 317 feet. First water crevice at 385 feet. This well gave some gas.)

Remarks: It is just possible that the coal encountered in this well is the continuation of the main Bellingham seam.

Water well drilled by Livermore. SW¼, NW¼, Sec. 30, T. 39 N., R. 3 E.
Depth, 138 feet.
Clay and hard pan formation down to 108 feet.
Then quick and flour sand, 30 feet.

Water well drilled by Livermore. NW¼, NE¼, Sec. 31, T. 39 N., R. 3 E.
Depth, 97 feet.
All loose boulders, no water.

Water well drilled by Livermore. NW¼, NW¼, Sec. 31, T. 39 N., R. 3 E.
Depth, 84 feet.
Clay and loose gravel and sand.

Water well drilled by Livermore. SW¼, NW¼, Sec. 31, T. 39 N., R. 3 E.
Depth, 86 feet.
Clay down to 45 feet.

Water well drilled by Livermore. SW¼, NW¼, Sec. 31, T. 39 N., R. 3 E.
Clay and gravel, 8 feet.
Boulders and clay.
Drilling now. (Aug. 17, 1922.)

Water well drilled by Livermore. SW¼, NW¼, Sec. 31, T. 39 N. R. 3 E.
Depth, 92 feet.

Water well drilled by Livermore. NW¼, SW¼, Sec. 31, T. 39 N., R. 3 E.
Depth, 96 feet.
Clay down to 60 feet.
Sand, gravel, and clay.
Water at 90 feet.

Water well drilled by Livermore. SW¼, SW¼, Sec. 28, T. 39 N., R. 3 E.
Depth, 176 feet.
Blue Clay, 50 feet.
Sand and gravel.
Last 18 feet, gray sand.

Water well drilled by Livermore. NW¼, NW¼, Sec. 33, T. 39 N., R. 3 E.
Probably over 100 feet deep.
Blowing and sucking well.

Water well drilled by Livermore. SE¼, NW¼, Sec. 26, T. 39 N., R. 2 E.
Depth, 65 feet.
Brackish water.

Water well drilled by Livermore. NW¼, Sec. 36, T. 39 N., R. 2 E.
Depth, 100 feet.
Water salty, like bay (unusual occurrence).
No bed rcck.

WELLS IN THE REGION ABOUT KING MOUNTAIN

Water well drilled by Livermore. NE¼, SW¼, Sec. 6, T. 38 N., R. 3 E.

Depth, 157 feet.

Clay all the way.

Water well drilled by Livermore. SE¼, NW¼, Sec. 7, T. 38 N., R. 3 E.

Depth, 60 to 80 feet.

Brackish water with clam shells.

Water well drilled by Livermore. SW¼, NW¼, Sec. 7, T. 38 N., R. 3 E.

Depth, 67 feet.

Sea shells, clam and snail, in blue clay at 30 or 40 feet.

WELL IN VICINITY OF FERNDALE

Besides the well at Enterprise, whose log is given elsewhere in this paper, it is reported by J. J. Donovan that in the early days the Great Northern Railway, through Stockett Brothers, drillers, sunk a well, in the vicinity of Ferndale, nearly 2,000 feet in depth. It is reported that nothing but silt was encountered with an occasional buried log. It was thought that the Frazier River, in past geologic ages, came down through Ferndale and eroded a great canyon which was later filled with silt by the encroachment of the ocean upon the land.

WELLS IN THE REGION ABOUT MARIETTA

Water well drilled by Livermore. NW¼, SW¼, Sec. 15, T. 38 N., R. 2 E.

Bed rock at 245 feet.

Water well drilled by Livermore. NE¼, Sec. 7, T. 38 N., R. 2 E.

Depth, 475 feet.

River wash, 36 feet, with salt water.

All blue clay.

WELL IN SEC. 14, T. 38 N., R. 2 E.

It is reported that in the early days the Great Northern Railway sunk a hole in this locality, but no records of it are known now.

WELLS WITHIN THE CITY OF BELLINGHAM

Water well drilled by Livermore from dock. Corner of Maple and H streets, east of Central Whatcom.

Depth, 270 feet.

To bed rock, 170 feet.

Sandstone and shale, with a little fresh water at 100 feet.

Water well drilled by Livermore. Chestnut and I streets, Block 45. One foot above tide.

Depth, 113 feet.

Brackish water, not very salty.

No bed rock.

Water well drilled by Livermore on J. N. Nelson's place near lumber mill. SW¼, Sec. 33, T. 38 N., R. 3 E.
Depth, 98 feet.
Soft dirt, 12 feet.
Sandstone down to 32 feet.
Coal, 2 feet thick, at depth of 32 feet.
Trace of coal at bottom of well.

Water well drilled by Livermore. NW¼, Sec. 33, T. 38 N., R. 3 E.
Depth, 93 feet.
All blue clay, no coal.

WELLS IN THE REGION ABOUT VAN WYCK

Water well drilled by Livermore. NE¼, SE¼, Sec. 9, T. 38 N., R. 3 E.
Depth, 114 feet.
No bed rock.
Water.

Water well drilled by Livermore. SW¼, Sec. 10, T. 38 N., R. 3 E.
Depth, 175 feet.
Bed rock at 104 feet.
Very hard sandstone, then blue shale.

Water well drilled by Livermore. SW¼, SW¼, Sec. 2, T. 38 N., R. 3 E.
Depth, 28 feet.
Water and gas in it.

Water well drilled by Livermore SW¼, SE¼, Sec. 2, T. 38 N., R. 3 E.
Depth, 152 feet.
Blue clay, 110 feet.
Gravel, 9 feet, at 142 feet, with water.
Blue clay.

WELLS IN THE REGION ABOUT ANDERSON CREEK

Water well drilled by Livermore. SE¼, SW¼, Sec. 31, T. 39 N., R. 4 E. Artesian well.
Depth, 99 feet.
Blue clay.
Fine black sand.

Water well drilled by Livermore. NE¼, NW¼, Sec. 6, T. 38 N., R. 4 E. Artesian well.
Depth, 156 feet.
A little bit of gas.
Reddish water.

Water well driven by Livermore. SW¼, SE¼, Sec. 7, T. 38 N., R. 4 E.
Depth, 93 feet.
All blue clay.

WELLS IN THE REGION ABOUT CEDARVILLE

Water well drilled by Livermore. NW¼, Sec. 33, T. 39 N., R. 4 E.
Bed rock at 74 feet.

Well drilled for oil and gas. NE¼, NW¼, Sec. 23, T. 39 N., R. 4 E. Derrick standing today. Bradley, driller. Hole, 4 inch.
Depth, 72 or 74 feet.
Soil, 8 or 10 feet.
Blue clay with gas.

Mr. John McCush of Bellingham reports that he was burned by ignited gas from this well.

WELLS IN THE REGION ABOUT SILVER BEACH

Water well drilled by Livermore. Location is only approximate. Near center of Sec. 23, T. 38 N., R. 3 E. 180 feet above Lake Whatcom.

Depth, 108 feet.

Encountered some coal.

Water well drilled by Livermore. Location is approximate. NW¼, Sec. 23, T. 38 N., R. 3 E.

Depth, 70 feet.

Blue shale, gravel, and clay streaks.

No coal.

WELLS IN THE REGION EAST OF BLAINE

Water well drilled by Livermore near Dakota Creek Mill. NE¼, Sec. 8, T. 40 N., R. 1 E.

Depth, about 600 feet. Drilled with 2 inch pipe.

No bed rock.

Water well drilled by Livermore, 3 miles east of Blaine. SE¼, Sec. 33, T. 41 N., R. 1 E. 4 wells in a string, 40 feet apart. All flowing wells.

Average depth, 50 feet.

All blue clay down to water.

No bed rock.

WELL EAST OF NOOKSAK

No definite location given.

Depth, 350 feet.

All blue clay.

No bed rock.

COAL MINES AND PROSPECTS IN WESTERN WHATCOM COUNTY

BELLINGHAM COAL MINES, MINE NO. 1

LOCATION

Mine No. 1, at present the only mine of the Bellingham Coal Mines Company, is located within the northwest corner of the city limits of Bellingham. The coal deposits, below 200 feet of the surface, are leased from the owner, the Bellingham Bay Improvement Company. The underground area leased, consisting of 940 acres, lies in sections 13, 14, 23, and 24, T. 38 N., R. 2 E.

The city is situated on Bellingham Bay, a northerly extension of Puget Sound, and therefore has ready access to oceanic navigation. The Great Northern Railway connects Bellingham with Seattle and with British Columbia, the latter by way of Blaine. The Northern Pacific Railway connects Bellingham with Wickersham, which, in turn, is on the line between Seattle and Sumas. The Chicago, Milwaukee and St. Paul Railway Company owns a railroad running from Bellingham to Glacier by way of Sumas. The Pacific Northwest Traction Company, an electric interurban, connects Bellingham with Seattle. Besides these various ways for transportation, the city, and likewise the mine, is connected with the other coast towns with a wonderful network of concrete pavements, probably the finest of their kind in existence.

PHYSICAL FEATURES

In the early times the region, where the mine is at present located, was a dense forest. Now the land has been cleared to a considerable extent, so that even the gravelly surface of the ground is exposed to view in many places.

The mine is situated on a fairly flat, or rolling, glacial outwash region, a sort of local plain. The main entrance of the incline is 93.73 feet above sea level and within a mile and a quarter of the shore of Bellingham Bay. Squalicum Creek, which flows along the south side of the mine, supplies water for the mine washers. The Northwest Diagonal pavement passes directly along the west side of the mine, to the city, one mile away, on a nearly level surface. Below this pavement, over 400 feet underground, is the second mine level which follows under this road for over a mile. Many new and modern residences are being constructed in this region on all sides of the mine and over the underground workings. It is an attractive residence section of the town, and the mine is kept orderly, so that one would hardly realize that a coal mine was even in existence within the city limits.

GEOLOGIC FEATURES

The principal formation exposed in the region of the mine is in the form of sand and gravel of stream deposition, and of the deposition from the earlier outwash of the melting and retreating ice sheet. The nearest exposure of the underlying rocks of the coal measures is in Cornwall Park, two-thirds of a mile east of the mine, where beds of sandstones dip 20° from the horizontal, bearing S. 25° W. From drill hole data it has been shown by R. B. Symington that this dip decreases westward until at the mine it is only about 10°, S. 62° W. Farther to the northeast the dip increases until King Mountain is reached, 2 miles away to the northeast, and here the rocks bend over and dip steeply in the opposite direction, forming a structural fold, an anticline in the strata of the coal measures. Beyond this point the beds are again covered with glacial outwash material, and other superficial deposits.

The superficial deposits vary in thickness from place to place, as noted in the various drill holes and well records. It has been found that generally blue clay overlies the coal measures, below the glacial outwash gravelly material. Thus impervious beds seal off to a greater or lesser extent, circulation of some of the near-surface ground water from the coal measures beneath. In places it has been found that these underlying clays contain marine shells of recent origin, showing a pre-glacial bay deposition over the old underlying surface of the sandstones.

UNDERGROUND CONDITIONS

The mine is entered by means of a 30° slope, which passes through the superficial layers of gravel, sand, and clay for a distance of about 550 feet, where it encounters the coal seam. This point lies 285 feet below the surface of the ground.

The log of this slope to the coal seam has been recorded by the company as follows:

	Stratigraphic Thickness
Sand and gravel	35 feet
Water bearing sand and gravel	15 feet
Clay, impervious to water	104 feet
Fine sand and water	10 feet
Sand, clay, gravel, and water	26 feet
Boulders and gravel	6 feet
Fine gravel and sand, quicksand	8 feet
Large gravel	8 feet
Clay, large gravel boulders	30 feet
Sandy, some gravel, little water	24 feet
Sandstone	about 10 feet
Shale	about 4 feet

The coal seam with its interbedded shaly layers, has an average total thickness of 14 feet, but only the upper 7 or 8 feet are being worked at the present time, as this contains the better quality of coal. The seam dips 10° in a direction which averages S. 62° W. A section was measured at the face of Room No. 8, 30 feet from the entry of third level north, on the upper commercial portion of the seam, with the following results:

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

Throughout the mine there is one very persistent shale layer, a few inches thick, which is shown here as "brownish yellow shale, Coaly". In most cases the coal mining is not carried very far below this shale parting.

Sections of the entire seam are best given in the records of the drill holes (presented elsewhere in this report), at the following positions in the holes:

	DEPTH	
	From	To
Bore hole No. 6	410′10″	425′4″
Bore hole No. 7	364′ 4″	380′1″
Bore hole No. 8	264′ 4″	280′1″
Bore hole No. 9	328′ 6″	344′4″
Bore hole No. 10	454′ 2″	469′

It must be borne in mind, however, that these sections are cut vertically on a bed dipping 10° from the horizontal, so that the actual thickness of the seam would be a little less than that recorded.

An underground prospect shaft was sunk below the coal bed and is recorded as follows:

(Location, near No. 10 Bore Hole, between entries of numbers 2 and 3 levels.)

	Stratigraphic Thickness
Shale	22 feet
Sandstone and conglomerate	29 feet
Fine grained sandstone	11 feet
Shale	14 feet
Sandstone	10 feet
Sandstone and coal streaks	8 feet
Shale and sandstone	2 feet
Coal	22 to 24 inches

An analysyis of this 2-foot coal seam, lying 100 feet below the main seam, was obtained from the Bellingham Coal Mines. It was given as follows:

Moisture	5.49 per cent
Volatile matter	39.99 per cent
Fixed carbon	43.36 per cent
Ash	11.16 per cent
B. T. U.	11,048

MINING OPERATIONS

After reaching the coal, the slope was continued on the dip of the bed, until on February 8, 1922, it had reached a length of over 2,300 feet on the 10° slope.

The difference in elevation between this point and the surface at the entrance of the mine, which is practically the depth of this point underground since the surface is nearly level, is 709 feet.

About 200 feet beyond the point on the slope where the coal was first encountered, the first northwest entry was turned, following practically the strike of the seam on a one per cent grade. This first level lies at a depth of 326 feet from the surface and has reached a length of 1,600 feet. The southeast entry was turned 100 feet farther down the main slope and is now about 550 feet long.

About 450 feet down the slope from the first northwest entry, the second northwest entry was turned. The point of this entry is 413 feet below the surface, and reached, on January 27, 1922, a total length of over 3,000 feet. The second southeast entry extended over 2,900 feet about the same date, making the total length of this level, which lies directly under the Northwest Diagonal pavement, over 5,900 feet.

At a distance of about 550 feet down the Main Slope from the second entry, the third northwest and southeast entries were turned, the distance below the surface being 500 feet. On February 4, 1922, the third Northwest level was nearly 2,000 feet long, while the southeast level was 1,300 feet.

The fourth entries are situated about 570 feet down the Main Slope from the third entries, and at point 587 feet below the surface. On March 31, 1922, the fourth northwest level had a total length of over 1,100 feet. The corresponding southeast level reached over 500 feet in an opposite direction on February 14, 1922.

There is a return airway slope which parallels the main slope, lying a hundred feet southeast from it. Crosscuts every 55 feet connect this with the main entry. This return air course is connected with the surface by an air shaft 179.9 feet deep sunk at the place where bore hole No. 8 originally was drilled, so that it meets the air slope at the contact of the coal seam with the overlying surficial deposits. A fan at the entrance of the shaft keeps the mine ventilated.

The portion of the seam from which coal has been removed from rooms has been along and between the first and second levels. The rooms are about 20 feet in width, and the pillars left between the rooms are about 30x50 feet. The rooms are connected by six-foot crosscuts. No pillars have so far been removed.

HANDLING OF THE COAL

The coal is drawn out of the mine, five cars at a time, each car holding two tons of coal. The cars are emptied by means of a rotary dump into a hopper with an eccentric feed which pushes the coal onto two shaker screens, the first having holes of 7/8-inch in diameter and the second, 3 inches in diameter. The coal that passes over both of these screens is carried on to the picking table, and from there it passes on as lump coal to bins or directly into a railroad car.

The coal that passes through the 3-inch holes is called "nut coal." The nut coal drops down a chute and is picked up by a bucket elevator and emptied into a bin lying directly above the washer, into which it is fed. The pulsations of the water in the washer against the bottom of the bin cause the coal to pass out of the bin into the washer, regulating the feed.

In the washer dirt and rock are separated from the coal, and are passed into a chute, whence a mine car serves to convey them to a waste dump. The clean coal passes into a sluice box and from there is washed into a watering elevator, which in turn lifts it and discharges it onto shaker screens having a 2-inch mesh. The nut coal that passes over the 2-inch mesh screen is passed down a chute and is conveyed to the bins.

As the coal passes out of the hopper below the rotary dump the pea coal and slack coal drop through the screen having the ⅞-inch holes, into a bin. From here it is carried up an elevator which empties into a revolving screen having ¼-inch holes, through which the slack coal passes. The pea coal goes out through the end of this revolving screen and is conveyed down to the pea coal washer by the side of the nut coal washer.

A new bin and washer for the pea coal was in the process of construction in the summer of 1922 and when this is completed it is intended that both of the old washers will be used for the nut coal only.

From the washer the pea coal drops into a screw conveyor and is carried over into a bin by the side of the slack coal bin.

The slack coal, which has been separated from the pea coal in the above operation, is conveyed into a bin over the concentrating tables.

Two Overstrom Universal concentrating tables were recently installed. The coal is conveyed to these by a drag feed and sluiced onto the tables. The tables are riffled and have a rotary motion. The coal, being lighter than the rock, is washed down over the riffles into the sluice trough along the lower side of the table, and is carried by a sluice box to the sludge tank. The refuse on the concentrating tables is washed along the table between the riffles and passes off the end of the table into a sluice box which carries it down into the creek.

The sludge tank is approximately 40 feet long, 10 feet wide, and 8 feet deep. In addition to the water and coal from the concentrating tables, all of the water from the washers and the overflow from the watering elevators is fed into this tank. The particles of coal settle to the bottom and by the use of a slow drag along the bottom, the coal is carried to one end of the tank. From here an elevator lifts it into a drag conveyor. This conveyor carries it across to the opposite side of the plant, where it is dumped into the slack coal bin.

The water for the washing plant is taken from Squalicum Creek. The water from the sludge tank is used repeatedly.

The plant is equipped with two 90 H. P. boilers and one of 80 H. P. Electricity is supplied by the Stone and Webster Company. The hoist is of 500 H. P. capacity. Compressed air for the jack hammers used in drilling is furnished by an Ingersoll-Rand Compressor, which produces 1,250 cubic feet per minute. The compressor is operated by a 250 H. P. Westinghouse electric motor. Three of the pumps in the mine are also run by this compressor. The rest of the pumps are electrically driven.

PRODUCTION OF THE COAL.

The production of the coal on a commercial scale began in November, 1918. The output steadily increased until the strike which occurred in April, 1922. The daily production up to that time had reached over 1,000 tons. The mine was closed for a period of nearly two months and was then reopened with non-union labor. The production was about half the normal rate in the summer of 1922.

PRODUCTION[1] OF COAL FROM BELLINGHAM COAL MINES IN SHORT TONS

	Mixed Steam	Lump	Nut	Lump Nut	Pea	Steam and Slack	Mine Run	Total	Cost, Dollars Per Ton
November, 1918, to July 31, 1919		6,327.65				433.78	6,936.00	13,697.43	
August 1, 1919, to December 31, 1919		6,201.76	121.15			4,038.29	16,706.37	27,067.57	4.9806
January 1, 1920, to December 31, 1920		31,667.10	23,380.98			59,043.38	282.87	114,374.33	4.3052
January 1, 1921, to December 31, 1921		48,247.54	40,353.06	7,801.77	6,465.85	91,753.78		194,622.00	4.1558
Total from Nov., 1918, to Dec. 31, 1921		92,444.05	63,855.19	7,801.77	6,465.85	155,269.23	23,925.24	349,761.33	
1922									
January	8,419.55	4,625.42	4,852.82	1,117.55	870.66			19,886.00	
February	6,694.08	3,438.86	3,893.00	750.03	812.03			15,588.00	
March	12,661.39	5,090.92	5,987.57	2,146.01	1,508.11			27,394.00	
April		47.33						47.33	
May	504.01	449.91	286.43		48.65			1,289.00	
June	2,465.81	2,915.67	1,995.08	350.33	1,425.11			9,152.00	
July	1,554.25	2,996.12	2,275.31	612.26	2,596.06			10,034.00	
Total, January to July, 1922	32,299.09	19,564.23	19,290.21	4,976.18	7,260 62			83,390.33	

[1]Statistics obtained by the writer directly from the Bellingham Coal Mines.

DISPOSITION OF THE COAL

The coal is either loaded directly into railroad cars or from bins located on the north side of the tipple. Trucks used for transportation to Bellingham and other nearby points are loaded from bins situated on the south side.

The following list, obtained through the courtesy of the Bellingham Coal Mines, shows the disposition of their sales from January 1 to July 31, 1922.

	Short Tons
Railways	5,008.97
Cement plants	39,141.02
Foreign (Canada)	2,214.45
State	2,771.91
Other sales	33,138.11
Local sales	4,813.76
Total disposition of sales	87,088.22
Power coal	2,692.00
Total disposition	89,780.22

QUALITY OF THE COAL

The coal is black, shiny black in streaks, and rather soft, its cleavage being largely cubical. Some streaks of brownish black or dull black material run through it, however, and the shaly portions of it are also brownish black. The coal is said to be a good steam coal but appears to have no coking properties. It is often referred to as lignite, but more properly it should be classified as a low grade bituminous coal.

The following analyses were made by A. C. Hansen and Charles A. Stewart, working under the supervision of the Department of Mining and Metallurgy, State College of Washington. The samples were collected by the writer during the field examination in July, 1922. Samples I, II, and III should represent fairly well the quality of the coal of the Bellingham Coal Mines.

PROXIMATE ANALYSES OF COAL FROM MINE NO. 1
BELLINGHAM COAL MINES

A, as received.

B, moisture free.

I. Sample from Bellingham Coal Mines, taken across face of room No. 8, 3d level north, 30 feet up from entry, about 1,530 feet northeast of main slope. Sample taken according to U. S. Geological Survey specifications[1], which does not include partings more than three-eighths of an inch in thickness. (The section measured across this face is given on pp. 90, 91.)

II. Sample from Bellingham Coal Mines, taken across face of 4th north entry, 1,150 feet northwest of main slope. Sample taken in similar manner as I. Section exposed from roof to floor was 7 feet, 9 inches, in which the 4-inch brown shale parting occurred one foot above the floor.

III. Sample from face of 4th south entry, 660 feet southeast of air course. Section was measured from roof to 4-inch brown shale parting, a thickness of 7 feet, 2 inches. Sample taken in similar manner as I and II.

IV. Sample from concentrating tables, taken from five batches which were caught from the tables every two hours during operation. This sample represents experimental work only.

V. Sample of washed coal, taken from four batches every few minutes during operation. The coal in this case is that which had been recovered by the washing and separating from pieces broken loose from attached blocks of rock.

Sample	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B.T.U.
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	0.68	11,467
B	....	36.12	46.61	17.27	....	11,965
III. A	4.70	35.11	47.73	12.46	0.94	11,657
B	....	36.84	50.01	13.15	....	12,232
IV. A	6.00	31.41	45.07	17.52	0.77	10,896
B	....	33.41	47.95	18.64	....	11,591
V. A	4.98	35.32	39.32	20.38	1.18	10,372
B	....	37.15	41.37	21.48	....	10,915

[1]Hayes Handbook for Field Geologists, revised by Sydney Paige. 1921, p. 73.

SIGNIFICANCE OF THE MINE

Mine No. 1 of the Bellingham Coal Mines is listed by the State Mine Inspector as one of six coal mines in the State which had a production in 1921 of over one hundred thousand tons. The production of these six mines, recorded as follows, was taken from a list which shows the same information for all the other mines in the State:

COMPANY	Average Number Employees	Days Worked	Coal Shipped	Total Output
Northwestern Imp. Co. No. 7 and 7 Ext. (Kittitas County)	512	210	404,745	419,312
Northwestern Imp. Co. No. 6 and No. 8 (Kittitas County)	405	214	332,012	358,896
Northwestern Imp. Co. No. 2 and No. 3 (Kittitas County)	346	210	273,792	263,099
Washington Union Coal Co. No. 1 (Thurston County)	221	211	245,182	253,506
Bellingham Coal Mines Co. (Whatcom County)	201	241	171,434	186,237
Northwestern Imp. Co. No. 5 (Kittitas County)	179	238	118,429	126,808

The total output of all the coal mines of the State of Washington in 1921 is given by the State Mine Inspector as 2,422,106 tons. The Bellingham Coal Mines during that year thus took out one-thirteenth of the coal mined in the State.

Of the six biggest producers of the State, the Bellingham Coal Mines is the largest mine operating on a strictly commercial basis. The other large mines use the coal they extract largely to supply the railroads, which own them.

It is evident, therefore, that this mine is of considerable consequence from several standpoints. The coal seam is very thick, it lies at a fairly low angle (10°) favorable to mining, the quality of the coal is fairly good, the location is excellent as regards market and transportation, and an industry of this sort is much needed in Bellingham at this time. The natural conclusion is that with favorable circumstances regarding labor conditions, this mine should expand rapidly; also that other mines located on this same seam may very likely prove to be of great commercial value in the future.

BLUE CANYON COAL MINE

Blue Canyon station of the Northern Pacific Railway is situated on the northeast shore of Lake Whatcom just one mile from Park, a small settlement at the head of the lake. The greater part of the coal mine workings has been in section 15, township 37 north, range 4 east.

The topographic features of the region are pronounced. The mine is situated in a mountain, whose sides are precipitous, rising abruptly from the deep Lake Whatcom below. The rocks, chiefly bedded sandstones, dip steeply into the mountain side, with their upturned edges broken off by the agencies of weathering into large rude blocks. These blocks, and other accompanying debris, have fallen and shifted down the steep slope in great slides. The slides are not, in the common sense of the term, landslides, for the whole outside shell of the mountain seems to be shifting downward into the lake. It has been found that the railroad, following the lake shore, must, year by year, be raised, for otherwise it also would be shifted below the level of the water. The mountain side is covered with dense growths of vegetation—trees and underbrush—and they too are shifted gradually down hill, likewise the entrances to the mine workings are shifted downward and caved in. All this destructive action makes the problem of engineering extremely difficult.

These huge land slips may be the result of several causes. In the first place, the original earth movements which tilted the beds have placed the rocks in an unstable position. It is not at all impossible, and in fact, quite probable, that recent faulting and deep seated earth disturbances have had something to do with these surficial movements. Together with these actions, later glacial erosion caused the Lake Whatcom depression to be gouged out and its bordering mountain sides to be scraped to precipitous and unstable slopes.

In the particular region of the mine, however, there is one very important structural feature which is partly the cause of the slides as well as most of the troubles in the mining operations. The coal seam is the underlying bed of the dipping sedimentary strata of the coal measures. Below this, the basement rocks are a kind of talc-schist which, when wet, become extremely slippery, so that anything resting upon it would tend to work its way down a slope.

The mine maps secured through the courtesy of J. J. Donovan, one of the trustees of the property, and Andrew Ecklund, superintendent of the mine, show the principal workings of the property. It is through the study of these maps, together with a personal study of the surface features with Ecklund, that the following description has been compiled.

The "First Opening" was made on the coal in Blue Canyon Creek in the southeast quarter of section 15 at an elevation of 1,122.7 feet above sea level, or 806 feet above the level of Lake Whatcom. From this opening a slope extended 540 feet in the direction of the dip of the coal seam, N. 10° W. The first level extended 400 feet to the northeast with its entry not far from the entrance of the mine. The entry of the second level was 280 feet from the surface and extended to the northeast for 500 feet and to the southwest for about 800 feet, connecting with Mine No. 3 and Mine No. 4. The elevation of the entry of the second level was 1,009.1 feet. The elevation of the third level was 919.5 feet, which was the end of the slope. Mine workings to the northeast extended for 270 feet; to the southwest they connected with the other workings, a distance of about 1,500 feet, to mines No. 5 and

No. 6, near the center of the section line between sections 15 and 22. Rooms in the coal seam were made between these workings, but the pillars were left standing. The maps show these early workings to the northeast of the main slope to have been fairly regular, with dips ranging from 12° to 38°. To the southwest of the main slope the workings show a decided curve in the strike, indicating a small syncline. Dips recorded there seem to be around 29° or 30°. In one place a "rock fault" is noted. The most striking feature of all, however, is the presence of the so-called "Big Roll" encountered at the end of the slope which apparently cut off the coal from all of these first workings. The Big Roll extended in a northeast-southwest direction and was the cause of the abandonment of this first mining operation. The date, December 12, 1892, is indicated on the map at the northeast end of the levels.

The "Second Opening," which bears the date 1907, was located on the line between sections 15 and 22, about 1,750 feet west of the First Opening. At this point of entrance the elevation is noted as being 658 feet and the name, "Mine No. 2," is given for this tunnel and its connections. The tunnel was driven for 778 feet, bearing N. 7° E., through a faulted area (the southwest continuation of the Big Roll) into the steeply dipping coal seam beyond. The dip of the coal at the end of the tunnel is recorded as being 42°, N. 10° W. At this point a slope was sunk for 300 feet, following down the dipping coal bed, 44° 30′. There were apparently two levels which extended, one from the upper end of the slope, and the other from a point near the bottom of the slope. Both continued for over 1,600 feet towards the northeast, curving quite irregularly with the strike of the formation. Coal was removed from stopes between these levels or gangways up to the Big Roll. The dip of the coal seam was apparently from 20° to 60°, but generally near 40°. The footwall is recorded on the map in different places as "white schist" or "blue schist," while the hanging wall was apparently good in some places but not in others. Rolls are also shown to occur in various places where the coal pinched out. The thickness of the coal varied considerably. At the foot of the slope it was 4 feet, farther along the vein is recorded as being barren, again it thickened to 4 feet, and in another place to 12 feet. Beyond this it was 3½ feet, then 4 feet again, while at the end of the gangway it was only 2½ feet. Close to the center of these workings the overlying rocks were prospected and three upper seams were encountered. The thicknesses of the upper coal beds are not recorded on the maps.

From another point farther to the west another tunnel, called "Mine No. 1," was driven to cut the coal and to connect with the western end of the workings. This tunnel is said to follow a fault or contact between white schist and coal for part of the way at least, and apparently had many twists and turns in its course until it connected with the western extension of the coal on the up-throw side of the fault, at the lower end of the slope just described. The elevation of 393 feet is given for the entrance of Mine No. 1, which was only about 300 feet distant from the bunkers on the railroad.

The fine grained character of the coal made it impossible to handle the product as in most coal mines. A flume was constructed through which the coal was washed down from the upper workings. It is said that the largest pieces were seldom over the size of a man's head.

The coal seam, as is reported by Ecklund, averaged about 7 feet thick where there was no disturbance in the formation, but varied elsewhere from 0 to 40 feet in thickness. The dip averaged about 30°, but became steeper in depth. The three seams above the main coal averaged 2 feet in thickness.

On examination of the formation on the hill above the mine workings, rock in place was found to be dipping 47°, N. 60° W. These beds, especially the interbedded shaly layers, were filled with carbonaceous fossil stems and numerous fossil leaves.

The reason for the coal being in such a finely divided state is probably not just its own constitution, but its having been shifted and crushed owing to the sliding of the coal measure formations over the slippery surface of the underlying schist.

It is reported that in places the coal rested directly upon the schist, and in other places that there was a layer of rock, a sort of conglomerate, between the coal and schist. Where this underlying conglomeratic layer was present, the foot wall was not nearly so apt to cave as when the schist formed that wall. Naturally, caving and sloughing was a bad feature in the mine, and gas was a special danger.

The irregularity of the thickness of the coal seam, the soft character of it, and of its walls, the presence of bad gas, the caving and sliding nature of the formation, the presence of rolls and faults, and the difficulties encountered in surface sliding, all were factors in making the mining practically impossible to continue on a commercial basis. The composition of the coal and its coking property, however, always made it attractive in spite of the difficulties.

Two causes may be attributed for the irregularity of the thickness of the coal seam. One is that the coal has been squeezed and bunched here and there by the overlying formation shifting on the underlying slippery talc schist. The other is that the vegetable matter which formed the original coal seam was laid down on the irregularly eroded surface of the schist, filling topographic depressions in one place, but lensing out in another, the whole being afterwards covered by sandy and clayey strata.

Since the Blue Canyon coal seam, the lower coal at Cokedale, and the anthracite in the glacier field all lie at the base of the coal measures and against the underlying schist formation, it would appear that these seams are all of the same geologic horizon. Fossil leaves from these beds, so far as collected, appear to be similar[1]. There is, however, much to be done in proving the stratigraphic correlation of these layers. It may be concluded, however, that the base of the coal measures in Whatcom and Skagit counties should be a favorable horizon for coal prospecting.

The Blue Canyon coal is considered to be a good quality, although occurring in badly broken form. The small particles which make it up are black and shiny. The larger pieces crumble easily along cleavage planes produced though shearing. It is said that it possesses coking properties. It may be classified as bituminous coal.

TABLE OF ANALYSES OF THE BLUE CANYON COAL

I. Henry Landes; Wash. Geol. Survey, Ann. Rept. for 1901, Vol. 1, Pl. XXV.

II. Analysis made at the U. S. Navy Yard, Washington, D. C., G. O. Smith, U. S. Geol. Survey, 22d Ann. Rept., Pt. 3, 1902, p. 490.

III. Analysis made by Paul Hopkins, Univ. of Wash. Henry Landes and C. A. Ruddy, Wash. Geol. Survey, Ann. Rept. for 1902, Vol. 2, p. 270.

IV. R. P. Tarr; Mines and Minerals, Vol. 30, 1907, pp. 108-110, 135-138.

V. Sample collected by the writer. Analyzed by Hansen and Stewart. Sample taken from exposed seam of caved tunnel, No. 7, of the Blue Canyon coal mine. It represents a specimen rather than a sample. The material was fragile and even flaky and pulverulent. Superintendent Ecklund stated, however, that the quality of this coal was found to be fairly uniform. A, as received. B, moisture free.

Coal	Fixed Carbon	Volatile Matter	Ash	Moisture	Sulphur	Phos-phorus	B.T.U.
I.	60.96	28.74	9.95	0.35	....	....	....
II.	62.744	31.479	3.679	1.790	0.308	0.006	....
III.	57.71	36.59	2.21	2.73	0.76	....	....
IV.	54.21	30.97	13.14	1.68	....	....	....
V. A	55.01	41.25	2.18	1.56	1.05	....	11,919
B	55.88	41.90	2.22	....	....	....	12,088

[1]Smith and Calkins: A geological reconnaissance across the Cascade Range. U. S. Geol. Survey, Bull. 235, 1904, p. 97.

GLEN ECHO COAL MINES

It is reported that altogether about 1,000 tons of a very good grade of coal have been taken out of the recently developed Glen Echo coal mine and trucked to Bellingham. The mine was opened in 1920 and closed in 1921 because glacial drift was encountered. It is located near the head of Anderson Creek. The corner (not accurately shown on the U. S. topographic sheet) between sections 5 and 9 (T. 38 N., R. 4 E.) lies in the bottom of the creek within 100 feet southeast of the entry to the tunnel.

One peculiar feature of this mine is that it is located very near the crest of a pronounced anticlinal fold. The creek cuts right down through the axis of the anticline. The main workings consist of No. 1 tunnel, which is 600 feet long and which follows the coal seam on the strike, from the surface of the hillside until the tunnel enters glacial drift which also lies very close to the surface. The coal known as No. 1 coal seam dips almost vertically, 75° to 80°, N. 30° W. The following is a general section of the strata which are encountered in this tunnel, according to Andrew Ecklund, superintendent of the mine:

Hanging wall	....
Hard bony coal	6 inches
Clean coal	18 inches
Carbonaceous rock	4 inches
Clean coal	14 inches
Bony rock	2 inches
Coal	6 inches
Footwall	....
(Total thickness, about 5 feet)	

PROXIMATE ANALYSES OF GLEN ECHO COAL

A, as received.

B, moisture free.

Sample secured from roof of tunnel from between timbers. Not accurately taken of the full face, but is probably a fair representative of the seam. Hansen and Stewart, analysts.

Sample	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B.T.U.
A	6.82	33.98	34.48	24.72	0.52	9,254
B	....	36.46	37.00	26.46	....	9,930

Besides this coal bed, Ecklund says that there are three overlying seams which are stratigraphically arranged approximately as follows:

	Feet
No. 4 coal seam (coal and bony coal)	3½
Sandstone	75
No. 3 coal seam (coal and shale)	3
Sandstone	50
No. 2 coal seam (coal and shale)	4
Sandstone	60
No. 1 coal seam	5

No. 1 tunnel is connected with the surface above by airways, where coal was also removed. A mine track served to take cars from the tunnel to the bunkers, 950 feet to the southwest. The bunkers are 34x110x90 feet high. The coal was dumped from the mine cars into a hopper, then passed over a 1½-inch mesh screen. The lump coal was passed over a picking table, cleaned there, and sent into a loading bin. The finer coal was carried in a chute to gig washers. After being washed it was carried by a 16-foot elevator and dropped into a classifier where it was sorted into fine coal, pea coal, nut coal, and egg coal sizes. All these were passed into bins to a platform where trucks were loaded. The trucks had to drive over a 3,900-foot plank road to a gravel road, one mile long, and then on the Northeast Diagonal pavement to Bellingham—a total distance of ten miles.

Besides No. 1 tunnel there are several other prospect holes. One opening in particular, on the opposite side of the creek from the bunkers and the mine, is in the form of an inclined shaft, which is said to follow the coal seam

It was from these workings that the bulk of the Rocky Ridge coal was taken. The coal was drawn from the mine in cars and dumped into a chute which carried it down into the bunkers near the lake shore. From here it was transported by boat to the west end of Lake Whatcom, where it was accessible for local use or for shipment.

Vein No. 4 lies above vein No. 3 at a stratigraphic distance of 149 feet. The dip of this seam is 41°, S. 38° W. This dip is identical with that of vein No. 3, taken at slope No. 2. The location of this opening is 127 feet in elevation above the lake level. The distance between the walls of the slope is 7 feet. Coal is reported to be present throughout this 7 feet, but not in solid form, alternating in layers with shale, bone, etc. The slope is said to be 55 feet long, but at the time of the investigation it was filled with water.

Vein No. 5 lies stratigraphically 99 feet above vein No. 4. A prospect, known as slope No. 1, on vein No. 5, is located at a point 400 feet southwest of Rocky Ridge landing and at an elevation of about 100 feet above the lake level. It follows vein No. 5, which dips 40° in the direction of S. 38° W. The slope was filled with water at the time of the investigation, but it is reported that the seam contained 4 feet of coal and two feet of shale.

GENEVA COAL MINE

The Geneva Coal Mine was recently opened by the Pacific Atomized Fuel Company and a small amount of coal was taken out and used locally. The mine is situated just outside of the city limits of Bellingham, a mile south of the west end of Lake Whatcom (NE¼, SW¼, Sec. 34, T. 38 N., R. 3 E.). The coal was drawn out on a skid road, 2,800 feet long, to bunkers situated beside the Geneva pavement, near a big bend in the road in the center of the northern part of section 34, about three miles from the center of the city.

The principal workings consist of a tunnel 360 feet long, driven on the strike of a coal seam which averages 28 to 29 inches thick, from which some overhead stoping has been carried on, and a cross cut drift, 174 feet long with its entry 150 feet from the surface opening. The drift runs against the dip and cuts several smaller coal seams. The dip of the coal is 21° to 25°, bearing about N. 10° E.

The stratigraphic section as exposed in the drift was measured and found to be as follows:

	Approximate Stratigraphic Thickness
Black coaly shale (hanging wall)	....
Coal (main seam)	28 inches
Bone	few inches
Sandstone, clay, and greenish shale, interbedded	7 feet, 8 inches
Coal	6 inches
Clay shale	1 foot, 4 inches
Bony coal	1 foot, 10 inches
Clay shale	5 inches
Bony clay	10 inches
Bony coal	8 inches
Clay shale	1 foot, 4 inches
Coaly shale	8 inches
Clay shale	1 foot, 4 inches
Coal (lower 6 inches clayey)	2 feet, 3 inches
Greenish clay shale, Sandstone, Clay	50 feet
Coal	6 inches
Clay	9 inches
Sandy clay	....

A sample of coal was taken from the face of the main tunnel where the principal seam was 28 inches thick. The hanging wall was of black coaly shale or slaty shale and the footwall was of somewhat the same kind of material.

Farther down the slope of the hill, about 250 feet from the first opening and about 68 feet lower in elevation, is another tunnel, driven on the strike of a coal exposure. This seam lies, however, at a higher stratigraphic horizon, probably 40 feet above the thicker seam, according to the approximate measurements used. The dip was taken at the face of the tunnel, 34 feet from the entry, and found to be 24°, bearing N. 30° E. The stratified section exposed was measured as follows:

	Stratigraphic Thickness
Hanging wall of impure fire clay	....
Coal	1 foot, 7 inches
Coaly clay	3 or 4 inches
Coal	10 inches
Clay shale with coal	1 foot, 6 inches
Footwall of massive clay shale	....

PROXIMATE ANALYSIS OF COAL FROM GENEVA MINE

A, as received.

B, moisture free.

Sample taken across 28-inch seam in face of tunnel, 380 feet from surface.

Sample	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B.T.U.
A	5.52	32.70	24.80	36.98	1.12	7,161
B	....	34.67	26.35	39.04	....	7,579

SILVER BEACH COAL MINE

The Silver Beach coal mine has so far never developed into a commercial mine, having only reached the prospect stage. It is located close to the Northern Pacific Railroad station at Silver Beach, on the shore of Lake Whatcom, near a building previously used as a hotel (NE¼, SW¼, Sec. 22, T. 38 N., R. 4 E.). Early prospecting uncovered five thin coal seams near the edge of the lake shore, just north of the railroad, and recently the Pacific Atomized Fuel Company has sunk a 226-foot inclined shaft to one of the coal seams, continuing on the level with a tunnel for 134 feet in the direction of the dip, cutting across the formation.

It is reported that after driving 32 feet through clay and sandstone, 22 inches of coal were encountered. Beyond this, sandstone and clay beds were cut, together with four small stringers of coal, until a seam, 4½ feet thick, of "burnt" coal was reached. The tunnel was carried only 2 feet farther through sandstone. As reported so far, none of these seams are of any great importance as regards quality.

A stratigraphic section was measured by the writer along the shore in 1921. Since then the outcrop has been covered by material from the dump of the mine. The dip of the formation averages about 41°, bearing S. 4° W. to S. 15° W. The following section shows the thickness of strata as measured on the outcrop:

(South end near railroad)	Approximate Stratigraphic Thickness in 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 ¼-inch pebbles	40
(Northern end near the present dump chute)	

The writer is of the opinion that the first coal encountered in the inclined shaft is No. 1 seam, of this section. The 22 inches of coal in the tunnel is then No. 2 seam, and the last 4½ feet of coal would thus be No. 3 seam.

This group of seams may possibly be correlated with those of Rocky Ridge. The two groups lie on opposite sides of a syncline or geological trough which runs through this end of Lake Whatcom. These seams may also be of the same series as that which has been opened up in the Geneva mine.

WHATCOM CREEK COAL PROSPECT

One-third of a mile below Whatcom Falls (SW¼, NE¼, NW¼, Sec. 28, T. 38 N., R. 3 E.) and crossing the creek which forms the outlet to Lake Whatcom, is a coal bed which dips 75°, S. 80° E. The coal seam is irregular in thickness, on account of having been squeezed evidently through lateral pressure in the rocks. In places it measures 6 inches thick and in others as high as 16 inches, while it is said that in the old prospect hole, which was driven on an incline for some 20 or 30 feet, the seam widens to 3 feet. The hanging wall is of clay shale, and the foot wall is of black shale and fire clay lying above clay shale, all lying intercalated in a general series of sandstones, which at this point stand in a nearly vertical position. The coal appears to be of good grade, and, it is said, was removed for local consumption. It is possible that this seam may be correlated with one of those at Silver Beach.

LONG POINT PROSPECT

Between two points of land which extend as promontories into Lake Whatcom on its north shore, lies an exposure of coal associated with fire clay (SE¼, SW¼, Sec. 25, T. 38 N., R. 3 E.), which was prospected years ago and is now nearly covered with debris. The bed is said to be several feet wide and, judging from fragments thrown out on the surface, appears to contain a very good grade of coal. The associated shaly sandstones dip about 20°, bearing S. 70° W. Each of the two points of land that extend into the lake lie in the direction of the strike of resistant beds of sandstone and conglomerate which make up the promontories. One of these series of beds lies stratigraphically below the coal, while the other, at Long Point, lies above the seam. On the east side of

Long Point the dip of the coarse conglomeratic sandstone was measured and found to be about 68°, S. 45° W. On the other point, the conglomerates and sandstones dip about 20°, S. 60° W. Very prominent joint planes running north and south divide the rock mass into strips. All these rocks are cross-bedded.

The coal may probably be correlated in general with one of the coal seams of Rocky Ridge. The whole section between the two promontories was not exposed, so it is quite possible that all the series of coal seams found at Rocky Ridge may also be found here. It is quite likely, judging from the geologic structure of the region, that the coal bed may also be correlated with one of those of Silver Beach.

There are said to be a number of coal prospects in the region of Woodlawn, which lies just east of this point, but they have evidently been abandoned and are now obliterated by a thick growth of vegetation.

PROSPECTS NEAR MANLEY'S CAMP

It is reported that coal was once prospected and even mined at a number of places in the region about Manley's Camp.[1] There are still remains of old bunkers on an old skid road, near the range line, in the southeast corner of section 1, T. 37 N., R. 3 E. The coal is said to have been brought down on a skid road from somewhere in the southeast quarter of section 12 of the same township. The coal outcrop was evidently covered at the time of this investigation, for only fragments of coal could be found in a small creek which flows northeast in this section. The rocks of the neighborhood dip toward the northwest at rather steep angles.

A mile west of Manley's Camp are a few other old workings which are now practically obliterated by a thick

[1]The name "Manley's Camp" is given on the U. S. topographic sheet, but most of the people seem to call it "Manning's Camp."

growth of vegetation as well as by caving and general surface disintegration. An old tunnel occurs in one place (NE¼, NW¼, Sec. 2, T. 37 N., R. 3 E.) running in the direction of the dip of the rocks which is 35°, N. 35° W., which is said to cut a coal seam 30 feet from its entry. The rocks at the entry contain fossil leaves.

The coal outcrops of this region may be of the same general horizon as those of Rocky Ridge, for the geological structure of the region shows that the strata of this region fold there and dip under the hill east of Manley's Camp, coming out again along the shore of Lake Whatcom. It is also quite possible that these coal outcrops may be correlated with the coal seams of the Geneva mine which lies a short distance to the northwest.

PROSPECTS NEAR DEMING

Two miles due west of Deming (SW¼, SW¼, Sec. 35, T. 39 N., R. 4 E.), on the side of a hill just above and one-fourth mile south of the Wildcat Shingle Mill, is a coal and fire clay exposure which has recently been prospected by several Bellingham men (Herman Hoff, James Pinkey, A. C. Benicke, and V. I. Bradway). It is reported that the company formed will probably be called the Cedarville Coal Company. There are three openings on the coal seam—an open cut prospect and two tunnels above. It has not, however, been definitely determined whether or not it is the same seam which is encountered at each opening. The strata lie in practically a vertical position and have a strike nearly north and south. The workings all follow the strike.

The following section was obtained from the surface exposure which was partly prospected:

(Reading from east to west on vertical beds)

White fire clay	2 feet
Greenish shale	5 feet
Coaly shale	3 feet
Greenish shale	......

(All were badly weathered.)

PROXIMATE ANALYSIS OF COAL FROM PROSPECT NEAR DEMING

A, as received.

B, moisture free.

Sample taken from dump, recently brought out of the tunnel. Material was a black, flaky coal which had undergone considerable underground pressure. Hansen and Stewart, analysts.

Sample	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B.T.U.
A	6.47	24.24	30.89	38.40	1.94	7,541
B	....	25.91	33.03	41.06	....	8,062

A tunnel, two hundred yards south and up the hill from this prospect, was driven 65 feet into the hill on the strike of a surface exposure of coaly material. The section was taken at the face of the tunnel, on vertical strata:

(Reading from east to west.)

Shaly sandstone	16 inches
Coaly shale, squeezed into flakes	3 inches
Clay	18 inches
Coaly flaky shale	3 inches
Clay	10 inches
Coaly clay	12 inches
Coal, squeezed into black flaky pieces	18 inches
Bony coal, forming wall	....

The upper tunnel occurs about 100 yards south of the lower tunnel and 100 feet higher, but since these workings had caved, they could not be examined. It was reported, however, that a shaft 20 feet deep in the tunnel encountered a three foot seam of coal.

It is quite probable that the coal found here may be correlated in general with the Glen Echo seams, but since very little detailed geologic work was done in this region it is not possible to state definitely how it should be correlated. Considering the way in which the beds have been distorted and compressed at this point, while to the east within a half mile, the beds have an entirely different strike, and dip at a much lower angle, it seems to the writer that trouble may be encountered in mining in such a country. It is quite possible that faulting may be found with further work. To the east the rocks dip about 30° to the southeast, while to the west they are found to dip northwest. It is quite possible, therefore, that the property lies on the crest, or near the axis of the continuation of the anticline found in the Glen Echo coal mine, but in a much more disturbed portion of it.

Other coal seams are reported to occur in this region and one in particular is said to be two feet thick, occurring in a little stream bed, one-half mile east of these prospects (SE¼, SW¼, Sec. 35). The strata dip at this point 32°, S. 40° E.

PROSPECTS ON SAMISH LAKE ROAD

There are at least two prospects along the Samish Lake Drive, on the south side of Chuckanut Creek. The strata in both of these dip to the north northwest. The coal beds exposed in them are undoubtedly in the same general horizon.

The prospect on John Bullock's place (NE¼, Sec. 21, T. 37 N., R. 3 E.) is in the form of a tunnel, about 100 feet long, driven into the hillside on the strike of the coal seam, which is reported to be 3 feet thick. The surface beds are dipping about 68°, N. 10° W. The following section was measured at the surface, for the tunnel could not be entered, and all the material there was found to be much weathered:

Clayey shale (overlying)	10 feet	
Shale with very thin coal seams	3½ feet	
Coal		6 inches
Clay and shale with coaly streaks	2½ feet	
Coal		3 inches
Shale with coal streaks		15 inches
Coal		1 inch
Shale and coal streaks	2 feet	
Shale (underlying)		

One-half mile east of Bullock's prospect is another opening owned by Richard Diezman. A tunnel was driven against the dip of the rocks for a distance, reported to be about 160 feet. Two coal seams are reported to occur on the surface of the hillside above the tunnel and one or two in the tunnel itself. The sandstones at the entry dip 50°, N. 20° W.

These coal seams may possibly be correlated in general with the seam east of Lake Padden, and that, in turn, may possibly be the same as one of those at the Geneva mine. At least these beds are probably in the same general geologic horizon.

PROSPECT NEAR LAKE PADDEN

A mile east of Lake Padden, near the north-south section line (SW¼, Sec. 10, T. 37 N., R. 3 E.), is an old prospect which is now caved and grown over by underbrush. According to C. T. Slentz of Bellingham, it was formerly prospected by W. D. Nulle and it is reported to carry a three foot bed of coal. The dip of the sandstone at the surface is 80°, S. 65° W. The prospect was evidently in the form of a slope, following the dip of the strata. This coal seam may possibly be correlated with one of those along the Samish Lake Drive and with one of those of the Geneva mine.

PROSPECTS NEAR ALGER

The contact between the sandstones of the coal measures and the older underlying schist formation passes through Lake Samish and along the side of the mountain range which is a continuation of Lookout Mountain. At Alger this contact swings north again to South Bay and Blue Canyon. The mountain spur which extends south to Alger is thus a syncline, with the beds dipping from each side towards the center. On the west side, near the boundary line between Skagit and Whatcom counties, is an old prospect tunnel. This is located on Lux Gerard's place in a little creek beside a cut-off road near the range line (SE¼, Sec. 36, T. 37 N., R. 3 E.). It is reported that the tunnel is 200 or 300 feet long and cuts an irregular shaped coal seam. The old dump showed some coal which had the same appearance as that of the Blue Canyon seam. An exposure of coal farther up on the hillside, in a very disturbed area, showed the strata to be dipping about 70°, N. 8° W. Beginning with the upper beds, the following section was measured:

Gray sandstone and sandy shale	....
Black coaly shale	8 inches
Black coal and some shale	8 inches
Shale	15 inches
Weathered coal	26 inches
Coaly shale	8 inches
Coal with a little clay, decomposed	10 inches
Gray shaly sandstone	....

Above the side of the old and abandoned Fairhaven railroad of the Great Northern, and one-half a mile north of Alger, is an old incline shaft which was filled with water when this examination was made. Evidently coal was encountered down the incline, for material somewhat similar to that on the property of Lux Gerard was present on the dump. The shaly beds exposed at the surface dip 52°, N. 50° E.

These coal seams appear to be very near the contact between schist and sandstone and they may possibly be correlated with the Blue Canyon seam or with coal beds lying just above it. The geologic structure of this region —that is, the synclinal structure just referred to—shows that there is a little basin here of at least two square miles which it might be well to investigate further by continued prospecting near this schist-sandstone contact. The coal, unless cut off by lensing, would probably be found to pass under the mountain and come out the other side by Silver Creek and Cain Lake.

COAL SEAMS NEAR CHUCKANUT DRIVE

Unfortunately, the writer did not have time to examine the old workings which are said to occur along the waterfront of Chuckanut and Samish bays. There are a number of thin seams of coal and lignite which are exposed along the bluffs and which are cut by the waterfront road, a concrete pavement, known as Chuckanut Drive. This drive is one of the most beautiful ways in the State. From Inspiration Point to Chuckanut, the road follows very closely along the strike of the beds, then turns toward the southwest and cuts through a syncline and some badly disturbed and faulted beds, and then follows at an angle along the strike of the strata. In the northern portion of the road the beds dip toward the west and southwest. In the southern portion, they dip toward the north and northeast. At a prominent point northwest of Samish, where the road makes a big loop, and the Great Northern Railroad passes through a tunnel below it, the base of the coal measures is encountered and the old underlying schist formation is found as the principal rock exposed. The part of the road which passes through these lower beds of the coal measures, cuts a number of coaly layers. This portion of the road lies in Skagit County—from the county line to Sunset Point and a little beyond.

As many as six thin beds of coal occur here, a few inches each in thickness, associated with a little shale and great massive beds of sandstone, with many shaly layers carrying fossil imprints of various sorts of leaves, all of which attract the attention of many people who are constantly passing by in cars. These coal seams may be estimated to occur from nearly 1,000 to at least 3,000 feet stratigraphically above the base of the sandstone series. The region of the contact between the sandstones and the underlying schist is covered with landslide material, gravel, etc., and nothing has been reported of underground workings cutting the contact.

The thin seams which occur along the drive may be correlated with those exposed along the Northern Pacific Railroad, northwest of Blue Canyon, and also with the little seams which are present in the cuts recently made for a new road along the west side of South Bay, Lake Whatcom. It is quite possible that the Blue Canyon seam might be found present at the contact of the coal measures with the schist if the contact were prospected.

PROSPECTS NEAR GOSHEN

Although glacial drift and alluvium cover the greater part of the region about Goshen, there are still a few points of bedrock for the most part in the form of sandstone, exposed here and there, and along with them a few coal seams which are all badly weathered. One ridge of sandstone in particular crosses the road between sections 11 and 12, T. 39 N., R. 3 E., dipping 10° and bearing N. 50° W. It is reported that a coal seam was once exposed in this sandstone. A water well in the southwest corner of section 12 of the same township is reported to have cut a coal bed three feet thick at a depth of 70 feet. Other wells of this vicinity are also reported to have cut coal, and coal is said to have been found on the surface as float in places.

In the southeast quarter of section 22, T. 22 N., R. 3 E., there are some exposures of sandstone which dip a little south of west at low angles of only four or five degrees, while in the southeast quarter of section 24, a conglomeratic sandstone dips at a low angle, toward the southeast. In a dug well in the same section near the range line between sections 24 and 19, and near the center of the section line, a decomposed coal seam was exposed just below the surface of the ground. The dip of the coal seam was measured and found to be 2°, S. 45° E. The following section was measured in the well:

Surface of ground—	
Soil	36 inches
Coal, decomposed	10 inches
Shale	2 inches
Coal and some shale	8 inches
Shale	36 inches
Coaly seam	3 inches
Shale and water	....

Near the center of the north line in section 24, it is reported that A. C. Benicke dug a prospect hole and encountered a seam of coal. Near this point the writer found a piece of coal as float on the surface. Sandstone occurs in the road near by, but it was not determined whether or not the exposure is in place.

CONCLUSIONS

Since this report is largely confined to the extreme western portion of Whatcom County, or the immediate vicinity of Bellingham and Lake Whatcom, the Glacier coal field is excluded from any conclusions derived from this particular investigation.

QUALITY OF THE COAL

It appears that the Blue Canyon coal is the best grade represented within the area investigated, even possessing coking qualities. The Bellingham coal is of a low grade bituminous or sub-bituminous character, high in ash, but is a good heating coal. In appearance the Glen Echo coal resembles more nearly the Blue Canyon coal, while that of the Geneva seam is more like the Bellingham coal.

RELATIVE SIZE OF THE SEAMS

The main Bellingham seam is far the largest of the known coal seams in the area. At present the upper seven or eight feet of a fourteen foot seam are being mined. This means that little else in this mine besides coal is being dug into and taken to the surface. The Blue Canyon seam was found to vary greatly in size, being only about four feet thick at the point where the work was discontinued. The Glen Echo seam was mined where it was about five feet thick, but its nearly vertical position was not favorable for continued exploitation. The other coal seams known at present are not of large enough size to warrant mining at this time, although eventually they will probably be worked. Some of them may reach nearly three or four feet in thickness.

PROBLEMS OF MINING

Although the Bellingham seam cannot be handled by gravity, since the coal must be taken from a dipping vein which lies under the surface of a fairly level country, and under a mantle of glacial drift, over 250 feet thick, it is otherwise quite accessible and the seam does not dip more than 10 degrees where it is being worked at present. The mining conditions at Blue Canyon present extremely difficult problems, likewise those of Glen Echo. The Geneva mine, though located on a thin seam, 28 inches thick, is not in a difficult location for carrying on mining operations.

LOCATION FACTORS

As for transportation, nearly all of the coal exposures are favorably located. Most of them are near or on a railroad. The Bellingham seam could hardly be more favorably located in this respect, since it is not only beside the railroad but within a city with a good harbor. The only objection to the location of this coal bed is that trouble may arise when pillars are removed. There is a possibility that the resultant caving would break the overlying formation in such a manner that ground water from the overlying glacial gravels or even bay water might leak into the mine. Caving effects within the City of Bellingham would be detrimental to surface buildings.

PROSPECTING

There are a number of coal prospects over the region. Some of these are at the base of the coal measures along the extension of the Blue Canyon seam. This prospecting may be continued and there is a possibility that something profitable may result from it. The coal seams which lie stratigraphically between the Blue Canyon and Bellingham seams have been prospected in many places, but so far these seams have not been found much over three or four feet in thickness. Prospecting for the Bellingham seam has not been carried on to any great extent because of the lack of surface exposures. Core drilling is the only economical method suitable to employ with this seam and this sort of work has been limited to the small area about the present mine.

STRATIGRAPHIC FEATURES

The Blue Canyon coal occurs at the base of the coal measures lying against schist, while the Bellingham seam lies at a stratigraphic position over 10,000 feet higher. The total thickness of the entire series is at least 12,000 feet, and thin coal seams are present throughout nearly every phase of it. At a horizon 8,500 feet above the base of the whole series occurs the most prominent of the thinner coal seams.

The presence of fossil leaves throughout the entire formation and the lack of marine shells, show that the strata were originally formed largely in fresh water lakes and swamps. The age of the beds is Eocene, the formation being locally known in Washington as the Puget formation.

SYNCLINES, THE PROSPECTIVE COAL BASINS

Six synclines were determined through this geological investigation and coal beds were found to dip into each one. Of these synclines, the one farthest north, called herein the Van Wyck syncline, is probably the only one which may possibly contain the main Bellingham seam. The exact position of this structural trough could not be determined because of lack of enough surface exposures. Its existence is a certainty, however, and the approximate position given is probably not far from the actual.

SPECIAL RECOMMENDATIONS

It is herein recommended that prospecting for the extension of the main Bellingham coal seam be carried on. The most feasible method would be core drilling, since the surface of the ground under which the coal lies is covered with glacial drift and other surficial deposits.

Before drilling, geological structure of the formation should be taken into consideration.

The structure was determined approximately from the few but pronounced surface exposures studied during the field investigation. The results of this work are presented on the accompanying map (Plate I). The exact positions of the various coal seams cannot be given, but the positions of the Squalicum anticline and Van Wyck syncline (indicated on the map) show that there is a possibility that the main Bellingham coal seam as well as the other coal beds may be found to underlie the area north and northeast of the present mine, beyond King Mountain.

Several possibilities might arise in prospecting this area, which cannot be determined from present evidence:

1. The coal may be deeper in the syncline than shown and may cover a larger area.
2. The coal may be less deep in the syncline and may cover a smaller area, or, but less probably, may not dip under the surface at all.
3. Faulting may be present, which might alter conditions under the glacial drift covered area.
4. Pre-glacial channels may be present.
5. The quality of the coal may differ from that in the present mine.
6. The coal seams may be thicker or thinner than where they have hitherto been encountered.

Nothing, however, at present indicates these possibilities except that the coal may prove to be deeper and may cover a greater area.

Since the Van Wyck syncline is not symmetrical in form, the northeastern flank would be the side to approach from the standpoint of mining, since it possesses the low dips, whereas the rocks near King Mountain dip very steeply to the northeast, and would probably complicate mining operations.

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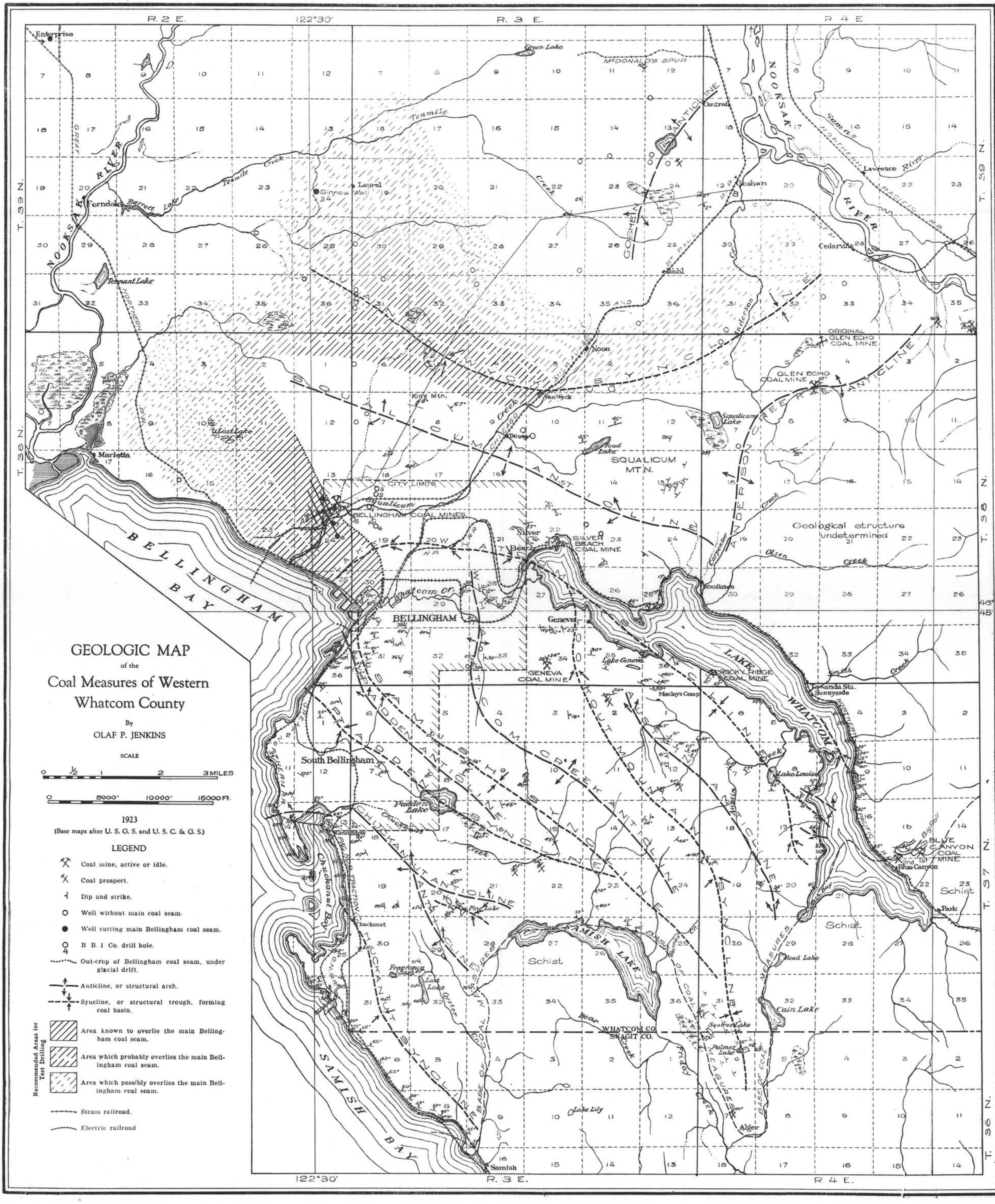
GEOLOGIC MAP
of the
Coal Measures of Western
Whatcom County
By
OLAF P. JENKINS
SCALE
0 ½ 1 2 3 MILES
0 5000' 10000' 15000 FT.
1923
(Base maps after U. S. G. S. and U. S. C. & G. S.)
LEGEND
Coal mine, active or idle.
Coal prospect.
Dip and strike.
Well without main coal seam.
Well cutting main Bellingham coal seam.
B. B. I. Co. drill hole.
Out-crop of Bellingham coal seam, under glacial drift.
Anticline, or structural arch.
Syncline, or structural trough, forming coal basin.
Recommended Areas for Test Drilling
Area known to overlie the main Bellingham coal seam.
Area which probably overlies the main Bellingham coal seam.
Area which possibly overlies the main Bellingham coal seam.
Steam railroad.
Electric railroad
R. 2 E.
122°30'
R. 3 E.
R. 4 E.
T. 39 N.
T. 38 N.
T. 37 N.
T. 36 N.
48°
45'
BELLINGHAM BAY
SAMISH BAY
LAKE WHATCOM
SAMISH LAKE
NOOKSAK RIVER
BELLINGHAM
South Bellingham
BELLINGHAM COAL MINES
CITY LIMITS
SILVER BEACH COAL MINE
GENEVA COAL MINE
ROCKY RIDGE COAL MINE
GLEN ECHO COAL MINE
ORIGINAL GLEN ECHO COAL MINE
BLUE CANYON COAL MINE
SQUALICUM MTN.
Geological structure undetermined
SQUALICUM ANTICLINE
GOSHEN ANTICLINE
ANDERSON CREEK ANTICLINE
PADDEN ANTICLINE
CHUCKANUT ANTICLINE
CHUCKANUT SYNCLINE
WHATCOM CREEK SYNCLINE
BASE OF COAL MEASURES
WHATCOM CO.
SKAGIT CO.
Schist
Enterprise
Ferndale
Marietta
Laurel
Sinnes Well
Goshen
Cedarville
Lawrence
Noon
Van Wyck
Dewey
Silver Beach
Geneva
Woodlawn
Lake Geneva
Manley's Camp
Lawanda Sta.
Sunnyside
Blue Canyon
Park
Chuckanut
Samish
Alger
Green Lake
Tennant Lake
Lost Lake
Squalicum Lake
Padden Lake
Lake Louise
Pine Lake
Reed Lake
Cain Lake
Squires Lake
Palmer Lake
Lake Lily
Barrett Lake
Tenmile Creek
Squalicum Creek
Whatcom Cr.
Olsen Creek
Smith Creek
Chuckanut Creek
Oyster Creek
Friday Creek
Bear Creek
Chuckanut Bay
McDONALD'S SPUR
King Mtn.

Cross section along line A-B of map, Plate I, showing the underground geologic structure and the possible, as well as the known, position of the main Bellingham coal seam.