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HENRY LANDES, State Geologist

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The Mineral Resources of Washington

With Statistics for 1919

By ERNEST N. PATTY and SHELDON L. GLOVER

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LETTER OF TRANSMITTAL

Governor Louis F. Hart, Chairman, and Members of the Board of Geological Survey:

Gentlemen: I have the honor to submit herewith a report entitled "The Mineral Resources of Washington, with Statistics for 1919," by Ernest N. Patty and Sheldon L. Glover, with the recommendation that it be printed as Bulletin No. 21 of the Survey reports.

Very respectfully,

HENRY LANDES,
State Geologist.

University Station, Seattle, January 3, 1921.

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ILLUSTRATIONS.

INTRODUCTION

The basic importance of the mineral industries to the commercial welfare of a nation has been strikingly emphasized by the recent war. With foreign sources of supply suddenly closed we were forced to meet pressing war demands with the domestic production of a large variety of mineral resources. To many of these we had paid little or no attention previous to the war and the forced search for new sources of supply resulted in the discovery of many valuable deposits. Washington's most noteworthy contribution was the discovery and development of extensive deposits of magnesite in Stevens County. These have proven to be the largest and most important deposits on the continent and at the present time are supplying the major demands of the refractory industry of the United States.

The necessity of economic independence in mineral wealth is now appreciated and it is one of the aims of the Geological Survey to investigate and call attention to the mineral resources existing in the State. It is also the endeavor of the Survey to compile statistics of production and to present them in such a manner as to be of tangible use to producers and those interested in the utilization of our mineral wealth, while at the same time keeping confidential the data of individual producers.

It is the purpose of this report to present not only bare statistical figures for each individual product, but to make new interpretations and to give comparative production figures together with a discussion of the factors influencing the changes. Descriptions are included of a number of mineral deposits, which are now semi-dormant, but may be found to possess a potential value.

The subject matter of the report has been brought as closely as possible up to the close of 1920. Statistical figures are complete up to the close of 1919.

SUMMARY OF VALUE OF MINERAL PRODUCTION OF WASHINGTON FROM 1910 TO 1919, INCLUSIVE.

Non-metallic Products	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
Coal	$9,764,465	$8,174,170	$8,122,572	$9,965,362	$7,142,084	$5,393,524	$7,155,317	$11,356,357	$14,564,445	$10,997,733
Clay products	3,023,854	2,861,758	2,388,870	2,390,226	1,809,491	1,454,436	1,589,574	1,532,043	1,324,400	1,800,000
Portland cement	1,031,704	1,496,807	2,012,785	2,853,260	2,303,433	1,790,499	2,245,027	2,367,045	2,114,730	2,868,599
Granite	642,992	1,345,551	140,581	140,581	72,079	260,688	90,525	52,053	65,293	(a)
Sandstone	438,581	301,843	344,476	560,468	450,436	(a)	(a)	(a)	45,368	(a)
Limestone	36,186	32,478	20,370	62,913	10,008	11,550	30,339	59,229	99,992	(c) 100,000
Basalt	(b)	(b)	667,828	632,915	1,068,042	1,452,869	754,831	328,331	154,205	(c) 175,000
Lime	267,735	228,933	234,832	178,945	189,260	171,023	166,653	156,553	226,104	(c) 217,227
Magnesite	.....	.....	.....	.....	.....	.....	5,362	783,188	1,050,790	1,438,184
Mineral waters	12,571	14,654	17,542	18,834	28,777	11,703	9,476	7,265	(a)	(a)
Sand and gravel	481,569	319,760	345,289	385,886	324,628	211,480	387,337	199,565	332,141	536,132
Miscellaneous	.....	.....	.....	6,520	2,140	36,560	39,034	86,001	129,335	(c) 156,043
Totals	$15,699,657	$14,775,954	$14,295,145	$17,195,910	$13,400,378	$10,794,332	$12,473,475	$16,927,630	$20,106,803	$18,288,918
Metallic Products										
Gold	$788,145	$847,677	$680,964	$696,275	$557,173	$391,419	$577,655	$492,324	$304,593	$252,862
Silver	110,886	129,204	254,326	200,068	146,468	129,709	220,510	232,632	310,093	290,051
Copper	11,038	39,776	179,192	147,883	103,571	178,662	650,675	600,464	474,834	469,593
Lead	58,180	38,186	5,732	8,909	2,555	13,875	372,550	841,913	374,299	113,746
Zinc	.....	.....	.....	.....	.....	30,368	226,960	121,948	3,537	.....
Totals	$968,249	$1,054,843	$1,120,214	$1,053,135	$809,767	$744,033	$2,048,350	$2,289,281	$1,467,356	$1,126,252
Grand Totals	$16,667,906	$15,830,797	$15,415,359	$18,249,045	$14,210,145	$11,538,365	$14,521,825	$19,216,911	$21,574,159	$19,415,170

(a) Included under miscellaneous to conceal figures of individual producers. (b) Included with granite. (c) Estimated, in part.
N.B.The value of coke produced in bee-hive ovens or as by-product coke is not included in these totals.

TOTAL VALUE OF MINERAL PRODUCTION BY COUNTIES FOR 1918.

COUNTY	Non-metals, etc.	Metals
Adams	$19,000	.....
Benton	365	.....
Chelan	14,400	$151
Clallam	.....	241
Clarke	68,912	.....
Cowlitz	27,658	.....
Douglas	3,428	.....
Ferry	200	409,012
Grays Harbor	30,316	.....
Island	2,592	.....
King	6,144,997	6,988
Kitsap	74,890	.....
Kittitas	5,275,804	2,673
Klickitat	7,420	.....
Lewis	479,546	497
Lincoln	2,000	.....
Okanogan	16,000	84,717
Pend Oreille	386,755	17,736
Pierce	2,966,505	.....
San Juan	70,845	3,000
Skagit	1,090,704	.....
Snohomish	21,602	117,924
Spokane	563,991	.....
Stevens	1,288,944	826,456
Thurston	439,600	.....
Wahkiakum	14,528	.....
Walla Walla	3,832	.....
Whatcom	585,877	10,026
Whitman	3,450	.....
Yakima	29,703	.....
Total	$19,633,775	$1,479,412
Non-metals		*19,633,774
Grand Total		*$21,113,197

* There exists a difference in the U. S. Geological Survey and State Mine Inspector's totals for coal production during 1918. The State Mine Inspector's totals were used in the table on page 10. In this summary the U. S. Geological Survey totals are used. For this reason the two grand totals do not balance.

FUELS (HYDROCARBONS)

THE COAL MINING INDUSTRY

By JOSEPH DANIELS.

The coal deposits of Washington rank high among its important mineral resources and the coal industry is the largest single producer of mineral wealth within the State. The general extent of the resources of coal is fairly well known; detailed information regarding particular localities may be found in many of the publications of the National and State surveys. In the following pages a summary is presented of the principal coal resources and the mining industry.

The coal fields of districts of western Washington extend from the international boundary on the north to Columbia River on the south in a discontinuous belt in Whatcom, Skagit, King, Pierce, Thurston, Lewis, and Cowlitz counties. A smaller field lies in Kittitas County on the east side of the Cascade Range. Small outliers of coal are known to exist in Clallam and Stevens counties. Practically all of the commercial coal occurs in the Eocene formations of Tertiary age, although some Lower Miocene or Oligocene coal-bearing sedimentaries of relative unimportance are known to occur in Clallam, Lewis, and Cowlitz counties. As already indicated, the principal fields are disconnected, however there is some continuity in the King-Pierce county area, and in the Thurston-Lewis county area.

Coals of all rank from subbituminous to anthracite are found in the State. No true lignite is known to occur although some of the subbituminous coal of the southwestern areas approach lignite in character. However, these coals do not contain as much moisture, their fixed carbon content is slightly higher, and they do not disin-

tegrate as rapidly as the lignite of the Great Plains province. The subbituminous coals are generally found along the flank of the Eocene areas near the foothills of the Cascade Range; the anthracite coal, wherever found, is close to or within the Cascades, and the true bituminous coals occupy an intermediate geographic position.

Subbituminous coal is found in the Bellingham Bay district in Whatcom County; in the northern portion of King County in the vicinity of Grand Ridge, Issaquah, Newcastle, and Renton; and in the Thurston, Lewis, and Cowlitz county fields with the exception of a limited area in the eastern portion of Lewis County. The bituminous coals occur in Whatcom County near Blue Canyon, on Lake Whatcom; in Skagit County near Sedro-Woolley and Hamilton; in King, Pierce, the eastern portion of Lewis, and in Kittitas counties. Some semi-bituminous coal occurs locally in Pierce and in Lewis counties. Anthracite coal has been found in Whatcom County near the town of Glacier and in Lewis County at the head of Cowlitz River near the summit of the Cascades. The Clallam County coal is classed as bituminous; the Stevens County deposit is probably subbituminous. The bituminous coals may be divided into two classes, free-burning and coking; the coking coals are found in Skagit, King, Pierce, Kittitas, and Lewis counties, but the distribution and coking properties are not uniform. The changes in rank from subbituminous to anthracite coal are regarded as the results of metamorphism in varying degree. The dynamic forces which resulted in the uplift of the Cascade range appear to have been the most important factors in the alteration of the coal.

Structually the coal fields of the State show many marked types from the simple monoclinal basin of low dip and uniform seams to the complicated, folded and faulted areas in which the beds are tilted at high angles and the coal badly sheared and squeezed. As examples

of extremes, the Washington Union Mine at Tono in Thurston County, and the mines of the Wilkeson-Carbonado-Fairfax district of Pierce County, may be cited. The mantle of glacial drift which covers a large portion of western Washington effectively hides the underlying rocks and conceals the structure to such an extent that, in many of the fields, information can only be obtained from mine operation. Intrusions of igneous rock occur at many places. All of these factors have had an important influence in the method of prospecting, entry, and operation of the mines of the State.

The most common method of entry is by a drift, or an incline; but one operating mine uses a vertical shaft. The topography and the surface cover of debris have in most cases determined the point and manner of opening rather than considerations of future operation. The result is a large number of shallow mines whose operations are confined at present to easily accessible coal above the general drainage level of the district. Some of the older mines have extended their operations to deep levels, but these are the exception rather than the general rule. The immediate future will probably see an extension in depth of workings for many of the established operations.

The methods of mining coal have been largely governed by the structure of the deposits such as the angle of dip, thickness of bed, character of the seam, presence of faults, and the like. The room-and-pillar method or a modification, such as chute-and-pillar or breast-and-pillar, is generally used; the longwall method is employed at but one property. In general, methods developed from anthracite mining practice are common in the complicated fields; the usual bituminous mining methods are represented in the others. Mine pillars are generally drawn on a retreating system of operation. The mining is usually done by hand although a small proportion of

coal, less than ten per cent, is mined by machine. Approximately twenty-five per cent of the coal is "shot from the solid." It is evident that the varying and high dips in most of the active fields are not favorable for machine mining. The post-puncher type of machine appears to be most suitable for this work. The chain cutter type is rarely seen in Washington mines. Permissible and black powders share equally in the work of blasting down the coal with a lesser proportion of dynamite making up the balance.

Movement of mined coal from the working face to haulage levels is generally effected by gravity. Sheet iron is used in places of moderate dip; gravity planes in low dips. Horse or mule haulage is most frequent; mechanical underground haulage has not been extensively applied. Coal reaches the surface plant without transfer from the cars loaded underground.

Practically all of the coal mined in the State is given some preparation before shipping. In the Pierce, Thurston, and Lewis County fields simple screening without hand-picking or sorting is the practice at many of the mines. In the other districts of the State the coal is prepared by screening, hand picking, and washing. The steep dips, the character of the partings in the coal seams, the cost of underground labor, all affect the problem of preparation. Very few mines attempt to sort and pick waste underground; practically everything mined together with the accompanying roof rock is sent to the surface plant.

Sixty per cent of the mined coal is washed; of this approximately 25 per cent is refuse. The proportion of lump and egg coal produced is very low, the finer sizes such as nut, pea, slack or buckwheat making up the bulk of the shipped sizes. These facts are of vital importance not only in the preparation but in the marketing and utilization of the product.

Washington coals, on the whole, are high ash coals, a general characteristic of Tertiary coals of the Pacific Coast. This ash is usually found in the coals of high specific gravity, which are generally designated as bony coals, and is so intimately mixed with the pure coal substance of the beds as to make effective separation commercially impossible. A contributing factor is a large percentage of extraneous refuse which is not effectively removed in the washing processes. The entire problem is under investigation by the U. S. Bureau of Mines and the College of Mines at the University of Washington, and it is hoped that the results of the studies and tests now being made will lead to a bettering of the grade of commercial coal entering the future market.

The price of coal varies principally with the size. To a certain extent the rank of the coal, sub-bituminous on the one hand and coking coal on the other, affects the price, but in the final analysis the cost of mining and preparation, which may be the same for a low grade as for a high grade coal, governs the price at the mine. This is particularly true for King and Pierce counties which produce the bulk of commercial coal.

The production of coal is given in the accompanying tables, which were compiled by the State Inspector of Coal Mines. Table 1 gives the entire production of the State since 1860; Table 2, a summary of production and value of coal and coke since 1900; Table 3, the production by counties since 1912. It will be noted that the total reported production of the State is 83,431,736 short tons; that the average value of coal at the mine has progressively risen from $1.83 in 1900 to $3.59 in 1919; that coke has correspondingly advanced from $4.90 to $8.65 with a peak price in 1918 of $8.97. Kittitas, King, and Pierce counties in the order named are the principal producers.

The bulk of the production of Kittitas County comes from the mines of the Northwestern Improvement Com-

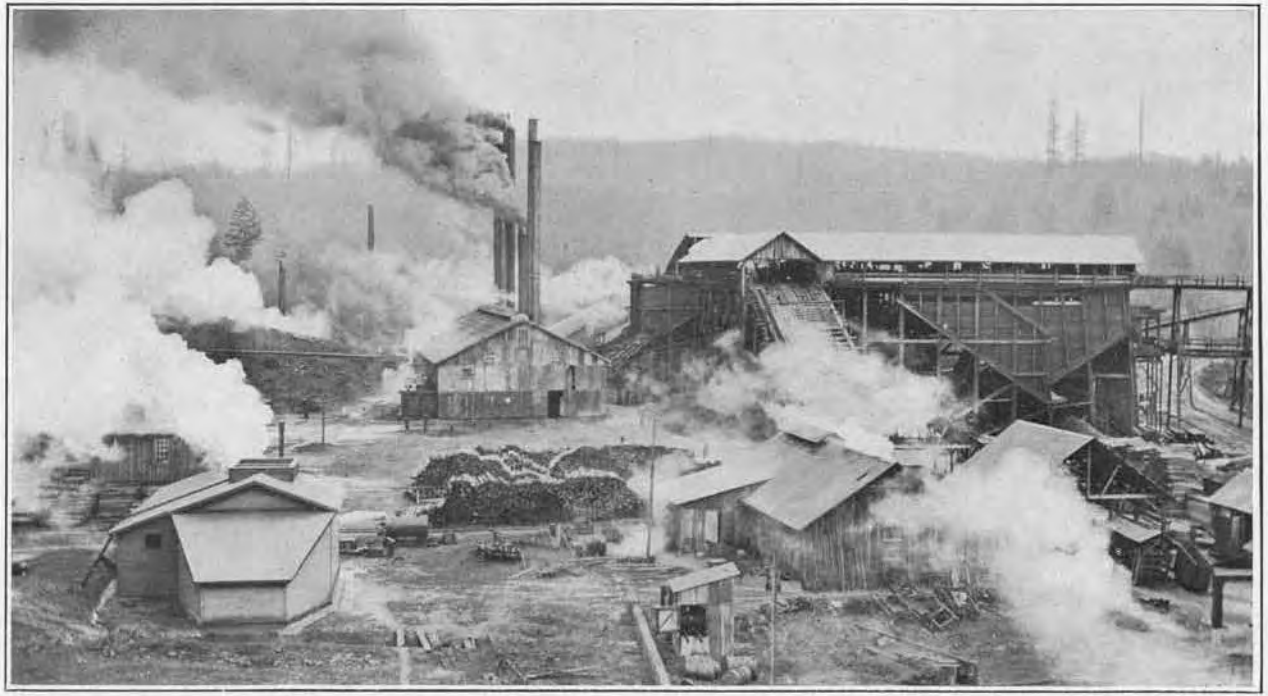
pany, a subsidiary of the Northern Pacific Railway, whose output is used entirely by that road. The Washington Union Mine in Thurston County is owned and operated by the Oregon-Washington Railroad and Navigation Company as a supply for its needs. The other mines in the State are commercial ones. During 1919, sixty-nine mines reported production; of these thirty-two produced more than 10,000 tons each. Table 4 gives the list of producers and data regarding their operations. Table 5 is a directory of the operators.

Most of the coal mined is consumed in the State. Railroad, domestic, industrial, coke and gas manufacturing, and bunker trade for steamships represent the distribution of the output. Alaska receives a small proportion of the output of the State; very little coal is exported except as bunker coal for steamships. On the other hand, a considerable quantity of coal, estimated to amount to 275,000 tons in 1919, is imported from British Columbia, most of which enters the Puget Sound district from the Vancouver Island collieries. Coal from Utah and Wyoming also is shipped into Washington and is competing with the local coals particularly in the central and eastern parts of the State. Exact figures showing the consumption of coal by different users in Washington are not available. Figures compiled by the United States Geological Survey for the entire country indicate that the railroads are the largest consumers of coal, using 28%; the iron and steel industries use 15% in the production of coke; the domestic trade about 12%; electrical utilities, 6%; fuel at the mines, 2%; artificial gas manufacture, the cement and the clay product industries each use less than 1%; exports amount to approximately 7%; and the remainder is used in general industrial consumption. The forgoing figures probably do not hold for Washington but they are indicative of the trend of the coal industry. The great use of fuel oil, the electrifica-

tion of railroads, smaller production of coke, and limited use of coal in electric utilities in this State are factors which would affect the application of general figures to the local situation. The important fact is that the Washington product is suitable for all the uses outlined.

The question of more effective preparation and utilization of Washington coal is of utmost importance in dealing with the future. Economy and greater efficiency in the use of the coal must be looked to as the means of offsetting the high price of this necessary basic substance. The depletion of the resources and supplies of fuel oil is turning the attention of users back to the formerly discarded coal, but the consumer has learned the lessons of efficient use of oil and he approaches the use of coal in a critical attitude. Some attention has been given this matter in the Northwest; the subject can be touched on but briefly here.

The production of larger sizes of coal for the domestic trade can be increased by more careful methods of mining and handling coal, but in the screening and washing processes low-ash coal can only be obtained at a sacrifice in the quantity of lump and egg sizes. This means a greater amount of fine sizes which must be absorbed by the market at a fair price or the coal industry will cease to attempt to produce better grades of product. The fine sizes can be utilized by briquetting; by pulverization and use in the form of a spray similar to oil; by distillation to produce valuable by-products such as gas, tars, and oils as well as a residue which can be used as a high-grade fuel and for the direct production of gaseous fuel as in gas producers. From the efficiency standpoint, improvement in firing, combustion, and in the design of furnaces and heat utilizing appliances will materially help in solving the problems of utilization, not alone of fine sizes but of low rank coals.



Morgan Slope Mine at Black Diamond.

From a local standpoint much work has been done in pulverizing coal utilization by the Pacific Coast Coal Company and other organizations. Briquetting on a commercial scale has been carried on for many years by the same company, and it has conducted experiments and investigations of small mechanical stokers suitable for domestic use. By-product coking is represented by the Lake Union plant of the Seattle Lighting Company where illuminating gas, coke, ammonia, tars, and oils are produced. A plant for the low temperature distillation of non-coking coals is now in operation near Seattle by the Beacon Coal Mines Company.

Industrial development of the State is largely dependent on an ample supply of fuel. The coal resources of Washington are the largest of the Pacific Coast States and will serve the needs of the community for many years. The important deposits are in most instances close to tidewater shipping points and to the principal cities and centers of western Washington. All developed areas are served by the principal transportation systems of the State. Growth in population, in industry and in trade has usually been related to coal resources, and it is safe to conclude that the great deposits of coal in this State will be one of its greatest future assets.

TABLE 1—PRODUCTION OF COAL IN WASHINGTON, 1860-1919, IN SHORT TONS.*

Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity
1860.....	5,374	1870.....	17,844	1880.....	145,015	1890.....	1,263,689	1900.....	2,418,034	1910.....	3,979,569
1861.....	6,000	1871.....	20,000	1881.....	196,000	1891.....	1,656,249	1901.....	2,466,190	1911.....	3,548,322
1862.....	7,000	1872.....	23,000	1882.....	177,340	1892.....	1,140,575	1902.....	2,690,789	1912.....	3,346,946
1863.....	8,000	1873.....	26,000	1883.....	244,990	1893.....	1,208,850	1903.....	3,290,468	1913.....	3,831,647
1864.....	10,000	1874.....	30,352	1884.....	166,936	1894.....	1,131,660	1904.....	2,998,633	1914.....	3,040,361
1865.....	12,000	1875.....	99,568	1885.....	380,250	1895.....	1,163,737	1905.....	2,846,901	1915.....	2,409,331
1866.....	13,000	1876.....	110,342	1886.....	423,525	1896.....	1,202,534	1906.....	3,290,523	1916.....	3,019,600
1867.....	14,500	1877.....	120,896	1887.....	772,601	1897.....	1,330,192	1907.....	3,722,433	1917.....	4,002,759
1868.....	15,000	1878.....	131,660	1888.....	1,215,750	1898.....	1,775,257	1908.....	2,977,490	1918.....	4,128,424
1869.....	16,200	1879.....	142,666	1889.....	1,030,578	1899.....	1,917,607	1909.....	3,590,639	1919.....	3,059,580
										Total....	83,431,376

* From Mine Inspectors' Reports, totals for 1860-1891, inclusive, are taken from U. S. G. S. Reports.

TABLE 2—SUMMARY OF PRODUCTION FOR THE YEARS 1900-1919.

YEAR	Total Coal Production in Short Tons	Total Value at Mine	Average Value Per Ton at Mine	Tot'l Coke Producti'n in Short Tons*	Total Value of Coke*	Average Value of Coke Per Ton
1900	2,418,034	$4,425,002	$1 83	35,921	$176,012	$4 90
1901	2,466,190	4,858,394	1 97	49,197	245,985	5 00
1902	2,690,789	5,300,854	1 97	40,569	202,845	5 00
1903	3,290,468	6,580,936	2 00	47,916	239,580	5 00
1904	2,998,633	5,697,402	1 90	46,175	230,875	5 00
1905	2,846,901	5,779,209	2 03	50,972	242,117	4 75
1906	3,290,523	6,021,157	1 83	44,944	215,731	4 80
1907	3,722,433	7,706,890	2 07	49,798	308,250	6 19
1908	2,977,490	6,054,002	2 03	37,381	205,595	5 50
1909	3,590,639	9,245,895	2 57	42,335	232,837	5 50
1910	3,979,569	10,266,400	2 58	58,715	322,932	5 50
1911	3,548,322	8,507,384	2 44	40,301	233,948	5 81
1912	3,346,946	8,122,572	2 43	48,889	270,759	5 54
1913	3,831,647	9,965,362	2 60	75,732	425,632	5 62
1914	3,046,361	7,142,084	2 35	78,573	404,126	5 15
1915	2,409,331	5,393,524	2 24	88,695	471,752	5 32
1916	3,019,600	7,155,317	2 37	93,722	487,210	5 20
1917	4,002,759	11,356,357	2 84	122,772	915,348	7 46
1918	4,128,424	14,564,445	3 53	144,349	1,295,258	8 97
1919	3,059,580	10,997,733	3 59	65,332	565,356	8 65

* Prior to 1917 the total production and value of coke is given for the coke at the mines only.

TABLE 3—PRODUCTION OF COAL IN WASHINGTON, 1912-1919, BY COUNTIES, IN SHORT TONS.

COUNTIES	1912	1913	1914	1915	1916	1917	1918	1919
King	$1,050,953	$1,359,274	$1,042,607	$844,956	$889,275	$1,314,366	$1,331,601	$952,632
Kittitas	1,235,690	1,330,596	1,237,564	879,062	1,316,993	1,741,237	1,739,379	1,322,534
Lewis	127,982	148,592	87,558	78,259	109,121	130,578	174,621	126,493
Pierce	789,320	832,272	553,841	488,603	533,162	606,049	600,917	397,641
Skagit	.....	.....	.....	.....	.....	1,000	5,897	3,820
Stevens	.....	.....	.....	.....	.....	.....	.....	844
Thurston	136,478	153,588	112,189	112,096	165,066	204,688	271,406	212,730
Whatcom	6,523	7,325	6,602	6,255	5,983	4,841	4,603	42,886
Totals	$3,346,946	$3,831,647	$3,040,361	$2,409,331	$3,019,600	$4,002,759	$4,128,424	$3,059,580
Total value	$8,122,572	$9,965,362	$7,142,084	$5,393,524	$7,155,317	$11,356,357	$14,564,445	$10,997,733

TABLE 4—COAL MINING STATISTICS FOR THE YEAR 1919.

NAME OF COMPANY	No. of Mines	Name of Mine	Town	Tons of Coal Shipped	Sold to Employes and Local Trade	Used for Power	Ch'ged Into Coke Ovens	Total Coal Production	Total Coke Production
KING COUNTY—									
Black River Coal Company	1	Black River	Earlington	3,469	665	.....	.....	4,134	.....
Carbon Coal & Clay Company	2	Carbon and Daly	Bayne	55,770	3,200	5,657	.....	64,627	.....
Central Coal Company	1	Grand Ridge	Issaquah	44,422	1,427	.....	.....	45,849	.....
Crane Valley Coal Company	1	Jones	Krain	742	.....	.....	.....	742	.....
Cumberland Coal Mining Company	1	Eureka	Cumberland	10,396	48	.....	.....	10,444	.....
Denny-Renton Clay & Coal Company	2	No. 1 and Shaft	Taylor	17,992	14,699	6,254	.....	38,945	.....
Denny-Renton Clay & Coal Company	1	Kummer	Kummer	660	49	216	.....	925	.....
Durham Colliery Company	2	Nos. 1 and 2	Durham	50,590	181	.....	.....	50,771	.....
Hyde Coal Company	1	Hyde	Cumberland	63,753	294	2,710	.....	66,757	.....
Indian Mining Company	1	Indian	Near Renton	.....	1,017	.....	.....	1,017	.....
John McQuade	1	McQuade	Cedar Mountain	.....	2,321	.....	.....	2,321	.....
Kingley Coal Company	1	Kangley	Kangley	1,922	42	452	.....	2,416	.....
National Coal Company	1	No. 6	Cumberland	2,999	63	319	.....	3,381	.....
Northwestern Improvement Company	1	Hiawatha	Hiawatha	7,395	.....	.....	.....	7,395	.....
Ozark Coal Mining Company	1	Navy	Cumberland	27,741	161	.....	.....	27,902	.....
Pacific Coast Coal Company	1	No. 11	Black Diamond	237,565	2,600	12,837	.....	253,002	.....
Pacific Coast Coal Company	1	Ford	New Castle	150,603	1,959	28,510	.....	181,072	.....
Pacific Coast Coal Company	1	Cannon	Pacosco	3,307	1,608	9,473	.....	14,388	.....
Pacific Coast Coal Company	1	Issaquah	Issaquah	41,065	982	.....	.....	42,047	.....
Pocahontas Coal & Coke Company	1	Pocahontas	Palmer	9,586	15	64	.....	9,665	.....
Raven Coal Company	1	Raven	Ravensdale	4,913	57	184	.....	5,154	.....
Renton Coal Company	1	Renton	Renton	99,857	4,936	7,890	.....	112,683	.....
Renton Coal Company	1	Sludge Dump	Renton	6,513	.....	482	.....	6,995	.....
Totals for county	26	.....	.....	841,260	36,324	75,048	.....	952,632	.....
KITTITAS COUNTY—									
Cle Elum Coal Company	1	Cle Elum	Cle Elum	952	661	.....	.....	1,613	.....
Independent Coal & Coke Company	1	Queen	Cle Elum	69,289	2,112	8,916	.....	80,317	.....
Northwestern Improvement Company	2	Nos. 6 and 8	Roslyn	236,538	8,391	14,415	.....	259,344	.....
Northwestern Improvement Company	2	Nos. 2 and 3	Ronald	222,977	783	6,842	.....	230,602	.....

TABLE 4—COAL MINING STATISTICS FOR THE YEAR 1919—Continued.

NAME OF COMPANY	No. of Mines	Name of Mine	Town	Tons of Coal Shipped	Sold to Employes and Local Trade	Used for Power	Ch'ged Into Coke Ovens	Total Coal Production	Total Coke Production
KITTITAS COUNTY (Continued)—									
Northwestern Improvement Company	1	No. 5	Roslyn	141,461	234	7,445	.....	149,140	.....
Northwestern Improvement Company	2	No. 7 and No. 7 Ext.	Cle Elum	262,412	4,129	8,072	.....	274,613	.....
Northwestern Improvement Company	1	Cle Elum	Cle Elum	352	103	.....	.....	465	.....
Roslyn Cascade Coal Company	1	No. 1	Ronald	46,418	1,127	548	.....	48,093	.....
Roslyn Cascade Coal Company	1	No. 2	Ronald	60,193	.....	1,636	.....	61,829	.....
Roslyn Coal & Coke Company	1	Plant	Lakedale	7,699	.....	92	.....	7,791	.....
Roslyn Fuel Company	1	No. 1	Beckman	45,240	1,412	9,902	.....	56,554	.....
Roslyn Fuel Company	1	No. 2	Beckman	80,030	11	2,761	.....	82,802	.....
Roslyn Fuel Company	1	No. 3	Lakedale	66,248	3	1,704	.....	67,955	.....
Roslyn Fuel Company	1	Summit	Cle Elum	1,209	170	47	.....	1,426	.....
Totals for county	17	.....	.....	1,241,018	19,136	62,380	.....	1,322,534	.....
LEWIS COUNTY—									
Centralia Coal Mining Company	1	Empress	Centralia	1,458	.....	270	.....	1,728	.....
Ford's Prairie Coal Company	1	Ford's Prairie	Centralia	7,052	1,436	1,156	.....	9,644	.....
Mendota Coal & Coke Company	1	No. 1	Mendota	28,455	351	4,440	.....	33,246	.....
Monarch Coal Mining Company	1	Monarch	Kopiah	18,701	115	460	.....	19,276	.....
Mountain Coal Company (Formerly Phoenix)	1	Ladd	Ladd	3,155	.....	218	.....	3,373	.....
Olympia Coal Mining Company	1	Packwood	Packwood	13,568	191	600	.....	14,359	.....
Pacific Red Ash Coal Company (Formerly Sheldon)	1	Sheldon	Chehalis	1,149	967	1,204	.....	3,320	.....
Salzer Valley Coal Company	1	Salzer Valley	Centralia	34	3,366	.....	.....	3,400	.....
Superior Coal Company	1	No. 2	Chehalis	25,495	3,872	.....	.....	29,367	.....
Victory Coal Company	1	Victory	Centralia	8,164	616	.....	.....	8,780	.....
Totals for county	10	.....	.....	107,231	10,914	8,348	.....	126,493	.....
PIERCE COUNTY—									
Carbon Hill Coal Company	6	Carbonado	Carbonado	151,685	1,518	10,287	333	163,823	172
Fairfax Mine, Incorporated	1	Fairfax	Fairfax	.....	227	1,909	17,725	19,861	13,565

TABLE 4—COAL MINING STATISTICS FOR THE YEAR 1919—Continued.

NAME OF COMPANY	No. of Mines	Name of Mine	Town	Tons of Coal Shipped	Sold to Employes and Local Trade	Used for Power	Ch'ged Into Coke Ovens	Total Coal Production	Total Coke Production
PIERCE COUNTY (Continued)—									
Pacific Coast Coal Company	1	Burnett	Burnett	90,712	1,481	6,916	.....	99,109	.....
Pierce County Coal Company	3	Nos. 7, 8 and 10	Morristown	44,756	3,950	5,270	.....	53,976	.....
Wilkeson Coal & Coke Company	1	Wilkeson	Wilkeson	23,357	591	.....	36,924	60,872	22,151
Totals for county	12	.....	.....	310,510	7,767	24,382	54,982	397,641	35,888
SKAGIT COUNTY—									
Cokedale Coal Company	1	Cokedale	Cokedale	3,791	29	.....	.....	3,820	.....
Totals for county	1	.....	.....	3,791	29	.....	.....	3,820	.....
STEVENS COUNTY—									
Colville Valley Coal Company	1	.....	Valley	134	10	700	.....	844	.....
Totals for county	1	.....	.....	134	10	700	.....	844	.....
THURSTON COUNTY—									
Washington Union Coal Company	1	Tono No. 1	Tono	205,705	1,659	5,366	.....	212,730	.....
Totals for county	1	.....	.....	205,705	1,659	5,366	.....	212,730	.....
WHATCOM COUNTY—									
Bellingham Coal Mines	1	Bellingham	Bellingham	34,112	4,332	3,659	.....	42,103	.....
Glen Echo Coal Company	1	Glen Echo	Near Bellingham	.....	240	.....	.....	240	.....
Whatcom County Coal Company	1	Blue Canyon	Blue Canyon	543	.....	.....	.....	543	.....
Totals for county	3	.....	.....	34,655	4,572	3,659	.....	42,886	.....
TOTALS FOR STATE	71	.....	.....	2,744,304	80,411	179,883	54,982	3,059,580	35,888

TABLE 5—DIRECTORY OF COAL MINES, 1919.

NAME OF COMPANY	Name of Mine	Company Postoffice Address	Mine Postoffice Address	Railroad to Mine
KING COUNTY—				
Black River Coal Company	Black River	5th and Weller Sts., Seattle, Wash.	Renton	Pacific Coast R. R.
Carbon Coal & Clay Company	Carbon	Bayne, Wash.	Bayne	N. P. and Milwaukee
Carbon Coal & Clay Company	Daly	Bayne, Wash.	Bayne	
Central Coal Company	Grand Ridge	Securities Bldg., Seattle, Wash.	Issaquah	Northern Pacific
Crane Valley Coal Company	Jones	Enumclaw, Wash.	Enumclaw	None
Cumberland Coal Mining Company	Eureka	Cumberland, Wash.	Cumberland	Northern Pacific
Denny-Renton Clay & Coal Company	Shaft	Hoge Bldg., Seattle, Wash.	Taylor	Pacific Coast R. R.
Denny-Renton Clay & Coal Company	Kummer	Hoge Bldg., Seattle, Wash.	Black Diamond	Pacific Coast R. R.
Durham Colliery Company	No. 1	Tacoma Bldg., Tacoma, Wash.	Durham	N. P. and Milwaukee
Durham Colliery Company	No. 2	Tacoma Bldg., Tacoma, Wash.	Durham	
Hyde Coal Company	Hyde	L. C. Smith Bldg., Seattle, Wash.	Cumberland	Northern Pacific
Indian Mining Company	Jones Bros.	2737 34th Ave. So., Seattle, Wash.		
John McQuade	McQuade	Renton, Wash.		
Northwestern Improvement Company	Hiawatha	Northern Pacific Bldg., Tacoma	Durham	Northern Pacific
Ozark Coal Mining Company	Navy	Cumberland, Wash.	Cumberland	N. P. and Milwaukee
Pacific Coast Coal Company	No. 11	L. C. Smith Bldg., Seattle, Wash.	Black Diamond	Pacific Coast R. R.
Pacific Coast Coal Company	Ford	L. C. Smith Bldg., Seattle, Wash.	New Castle	Pacific Coast R. R.
Pacific Coast Coal Company	Cannon	L. C. Smith Bldg., Seattle, Wash.	Pacosco	Pacific Coast R. R.
Pacific Coast Coal Company	Issaquah	L. C. Smith Bldg., Seattle, Wash.	Issaquah	Northern Pacific
Pocahontas Coal & Coke Company	Pocahontas	Palmer, Wash.	Palmer	Northern Pacific
Renton Coal Company	Renton	Electric Bldg., Seattle, Wash.	Renton	N. P. and P. S. E.
Western Coke & Collieries Company	Snoqualmie	Arctic Bldg., Seattle, Wash.	Preston	Northern Pacific
KITTITAS COUNTY—				
Cle Elum Coal Company	Cle Elum	Cle Elum, Wash.	Cle Elum	Northern Pacific
Independent Coal & Coke Company	Queen	White Bldg., Seattle, Wash.	Cle Elum	Northern Pacific
Northwestern Improvement Company	No. 6	Northern Pacific Bldg., Tacoma	Roslyn	Northern Pacific
Northwestern Improvement Company	No. 8	Northern Pacific Bldg., Tacoma	Roslyn	Northern Pacific
Northwestern Improvement Company	No. 7	Northern Pacific Bldg., Tacoma	Cle Elum	Northern Pacific
Northwestern Improvement Company	No. 5	Northern Pacific Bldg., Tacoma	Cle Elum	Northern Pacific

TABLE 5—DIRECTORY OF COAL MINES, 1919—Continued.

NAME OF COMPANY	Name of Mine	Company Postoffice Address	Mine Postoffice Address	Railroad to Mine
KITTITAS COUNTY (Continued)—				
Northwestern Improvement Company...	No. 2 Ronald.....	Northern Pacific Bldg., Tacoma....	Cle Elum.....	Northern Pacific
Northwestern Improvement Company...	No. 3 Ronald.....	Northern Pacific Bldg., Tacoma....	Cle Elum.....	Northern Pacific
Northwestern Improvement Company...	No. 7 Extension.....	Northern Pacific Bldg., Tacoma....	Cle Elum.....	Northern Pacific
Roslyn Cascade Coal Company.....	No. 1.....	Roslyn, Wash.	Cle Elum.....	Northern Pacific
Roslyn Cascade Coal Company.....	No. 2.....	Roslyn, Wash.	Cle Elum.....	Northern Pacific
Roslyn Fuel Company.....	No. 1.....	White Bldg., Seattle, Wash.....	Cle Elum.....	Northern Pacific
Roslyn Fuel Company.....	No. 2.....	White Bldg., Seattle, Wash.....	Cle Elum.....	Northern Pacific
Roslyn Fuel Company.....	No. 3.....	White Bldg., Seattle, Wash.....	Cle Elum.....	Northern Pacific
LEWIS COUNTY—				
Fords Prairie Coal Company.....	Ford's Prairie.....	Centralia, Wash.	Centralia.....	P. S. & W. R. R.
Mendota Coal & Coke Company.....	No. 1.....	Centralia, Wash.	Mendota.....	Northern Pacific
Monarch Coal Mining Company.....	Monarch.....	Centralia, Wash.	Kopiah.....	Eastern Railway & Lumber Co.
Mountain Coal Company.....	Ladd.....	Mineral, Wash.	Mineral.....	Milwaukee
Olympia Coal Mining Company.....	Packwood.....	Centralia, Wash.	Centralia.....	Northern Pacific
Pacific Red Ash Coal Company.....	Sheldon.....	Tacoma, Wash.	Chehalis.....	N. P. and G. N.
Salzer Valley Coal Company.....	Salzer Valley.....	Centralia, Wash.	Centralia.....	None
Superior Coal Company.....	No. 2.....	Chehalis, Wash.	Chehalis.....	Northern Pacific
Victory Coal Company.....	Victory.....	Centralia, Wash.	Centralia.....	Northern Pacific
PIERCE COUNTY—				
Carbon Hill Coal Company.....	New No. 9.....	Carbonado, Wash.	Carbonado.....	Northern Pacific
Carbon Hill Coal Company.....	Wingate.....	Carbonado, Wash.	Carbonado.....	Northern Pacific
Carbon Hill Coal Company.....	Douty.....	Carbonado, Wash.	Carbonado.....	Northern Pacific
Carbon Hill Coal Company.....	No. 6.....	Carbonado, Wash.	Carbonado.....	Northern Pacific
Carbon Hill Coal Company.....	No. 10.....	Carbonado, Wash.	Carbonado.....	Northern Pacific
Carbon Hill Coal Company.....	Miller.....	Carbonado, Wash.	Carbonado.....	Northern Pacific
Fairfax Mine Company.....	Fairfax.....	Tacoma, Wash.	Fairfax.....	Northern Pacific
Pacific Coast Coal Company.....	Burnett.....	L. C. Smith Bldg., Seattle, Wash...	Burnett.....	Northern Pacific
Pierce County Coal Company.....	No. 7 Winsor.....	Spiketon, Wash.	Spiketon.....	Northern Pacific
Wilkeson Coal & Coke Company.....	Wilkeson.....	Wilkeson, Wash.	Wilkeson.....	Northern Pacific

TABLE 5—DIRECTORY OF COAL MINES, 1919—Continued.

NAME OF COMPANY	Name of Mine	Company Postoffice Address	Mine Postoffice Address	Railroad to Mine
SKAGIT COUNTY—				
Cokedale Coal Company	Cokedale	Sedro Woolley, Wash.	Sedro Woolley	Great Northern
STEVENS COUNTY—				
Colville Valley Coal Company	Colville Valley	Valley, Wash.	Valley	Great Northern
THURSTON COUNTY—				
Washington Union Coal Company	Tono	Tono, Wash.	Tono	Great Northern
WHATCOM COUNTY—				
Bellingham Coal Mining Company	Bellingham	Seaboard Bldg., Seattle, Wash.	Bellingham	Milwaukee

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THE COKING INDUSTRY

By Joseph Daniels.

DISTRIBUTION OF COKING COALS.

The coking coals of the State are found in a belt extending from Skagit County on the north to Lewis County on the south, along the western foothills of the Cascade Range, and in a limited belt on the east side of the Cascades in Kittitas County. The distribution is not continuous in the western belt; scattered areas are found in Skagit, King, Pierce, and Lewis counties.

The character of the coking coals is not uniform. All of the areas are believed to be the result of metamorphism of Eocene coals which are normally sub-bituminous and bituminous in rank. The folding and tilting to which the beds have been subjected has changed the relative proportions of volatile matter and fixed carbon and has given some of them coking properties in varying degree. The reason some coals coke and others do not is not thoroughly understood; in the case of Washington coals analyses alone do not tell whether coke can be made. One bed of a series will coke, the others may not; some areas, as for example, portions of Pierce County, contain better coking coals than other areas. Even in the Pierce County field, the same seams show marked variation in different portions of the area. The fact remains that the difference exists and no conclusions can be reached until experimental and operating tests are made to determine the coking properties.

Analyses of the coals of the State are to be found in various bulletins of the United States Geological Survey, the United States Bureau of Mines, and the Washington Geological Survey. In the main, the coals which possess coking properties have a relatively high volatile and a low fixed carbon content in comparison with the standard types of coking coals. Ash is generally high in the seams,

with consequent higher ash in the resulting coke. Experiments are now being conducted to determine whether this ash can be reduced by more effective methods of preparation.

HISTORY OF COKING.

The Wilkeson district of the Pierce County field was opened in 1876, and shortly afterward pit coke was made at the plant of the Tacoma Coal and Coke Company near the site of the present operations of the Wilkeson Coal and Coke Company. The earliest reported production was in 1884 when 400 tons were made. In 1885, 311 tons were reported. This coke was sold locally and in Portland for foundry use. The success of the primitive operation in pits led to the building of two beehive ovens in 1885. From that date to 1914 the entire production of the State was represented by beehive coke.

The coking industry in Pierce County grew out of the two ovens built in 1885. In 1886 nine more were completed, and 21 started; in 1887, 30 ovens were in operation. The original plant of the Tacoma Coal and Coke Company was abandoned in 1898, but in the meantime, 1891, the Wilkeson Coal and Coke Company had completed a battery of fifty ovens. In 1892, the Sedro Coal Company, at Cokedale, in Skagit County, built four ovens and produced coke from unwashed slack coal. The number of ovens at this plant was increased to 30 in 1895, and to 40 in 1896. At the close of 1898, there were two establishments in the State with 90 ovens.

About 1901, the coke industry received a great impetus through the establishment of smelting industries on Vancouver Island. The plant at Fairfax, consisting of 58 ovens out of a total of 60, was completed; Montezuma began the construction of 25 ovens; and an additional 50 ovens were added to the Wilkeson plant. Carbonado also erected six ovens as an experimental plant, but the

attempt was not successful. The total number of ovens at the close of 1902 was 231, in five establishments.

Twenty-five ovens were built at South Willis in 1903, but they did not produce much coke. In 1905 the Cokedale plant was abandoned. This plant had produced coke for use at the iron blast furnace at Irondale, but apparently the fuel was not as desirable as the charcoal which was substituted for it. In 1908 a battery of 50 ovens was projected at Snoqualmie in King County, but only 12 ovens appear to have been completed and no coke was made. The status of the industry remained stationary until 1912 when Carbonado built 50 ovens, six of which represented the experimental ovens built in 1902. To these, 21 more were added in 1913, making a total of 71 ovens. In 1917 the Wilkeson Coal and Coke Company added 60 ovens to its establishment, making it the largest plant in the State with 160 ovens. About the same time, the Carbon Hill Coal Company began the construction of 66 additional ovens at Crocker on the mine railway branch near Orting. Thus without increasing the number of establishments, the total number of beehive ovens in the State had risen to 419 at the close of 1918.

During the war period there was marked activity in coke production. The ovens at South Willis, which had been idle for many years, were put in operation by the Wilkeson Coal and Coke Company in 1915. The ovens at Montezuma have been inactive since 1916. In 1918 there was some talk of rebuilding the ovens at Cokedale, but the matter did not crystallize until 1920 when it is definitely stated that 35 out of the old battery of 40 ovens will be placed in service. The plant at Snoqualmie was completed during 1919 and 1920 by the Western Coke and Collieries Company and coke shipments begun in April, 1920. During 1919 the ovens at Crocker were leased by

the Carbon Hill Coal Company to the M. S. Allison Company, Inc.

The following table summarizes the beehive coke oven plants in the state in June, 1920.

Company	*Location*	*No. of Ovens*
Wilkeson Coal & Coke Co.	Wilkeson	160
Wilkeson Coal & Coke Co.	South Willis	25*
Carbon Hill Coal Co.	Carbonado	71
Carbon Hill Coal Co.	Crocker	66‡
Fairfax Mine, Inc.	Fairfax	60
Washington Manganese Coal & Copper Company	Montezuma	25
Western Coke & Collieries Co.	Snoqualmie	50
Cokedale Coal Co.	Cokedale	35§
Total		492

* Leased by Wilkeson Coal & Coke Co. ‡ Leased to M. S. Allison Co., Inc. § Projected plant.

In 1914 the Seattle Lighting Company constructed a battery of five by-product ovens consisting of 20 chambers of the Kloone type at its Lake Union plant for the manufacture of illuminating gas. These ovens, however, have been producing coke which has been used for metallurgical as well as domestic use. Up to the time of the building of the by-products plant at Anyox, B. C., for the Granby Consolidated Mining, Smelting, and Power Co., this was the only installation of by-product ovens on the coast.

COKING PRACTICE.

The coal used in the beehive ovens usually comes directly from the local mines adjacent to the ovens. The by-product plant at Seattle has usually been supplied by Pierce County coal. At the present time all the coal used is washed fine sizes. The general practice of preparation is to screen the coal and then treat it on jigs and concentrating tables to remove the ash and associated impurities. Detailed flow sheets of the Pierce County washeries may be found in Bulletin 10 of the Washington Geological Survey.

The beehive ovens employed in the State are of the usual type and show no special features in design or construction. Some mechanical chargers and unloaders are in use, but hand methods are the rule. The product made is 48 and 72-hour coke, although some 96-hour coke is made for special use. The 48-hour coke is generally sold to smelters and the 72 and 96-hour coke goes to the foundry trade. The charges may vary from 10,000 to 14,000 pounds, and the yields vary between 60 and 65 per cent. The by-product plant at Seattle uses 13,000-pound charges and a coking period of 24 hours.

ANALYSES.

The analyses of coke will vary with different plants at different times. However, a few analyses are given below:

	Moisture	Volatile Matter	Fixed Carbon	Ash
Wilkeson	0.76%	1.99%	79.58%	18.67%
	0.72	2.81	78.20	18.27
	0.70	1.26	77.70	20.34
	0.78	1.53	77.71	20.98
Carbonado	1.12	2.81	79.21	16.86
	0.55	1.25	78.44	19.76
Fairfax	0.52	1.25	79.49	18.74
	0.07	1.04	80.49	18.40
	0.18	1.35	79.47	19.00
	0.09	1.01	80.49	18.41
Seattle Lighting Co	0.39	0.63	80.50	18.48
	0.40	1.00	80.00	18.60
	0.25	1.45	78.40	19.90
	0.10	3.58	77.61	18.71

The ash content of the coke made during the past few years has been steadily increasing and the foregoing analyses represent minimum ash. Usually the Pierce County coke has a moisture content up to four per cent, volatile matter up to four per cent, minimum ash from 18 to 20 per cent, with fixed carbon making up the balance. Sulphur is usually low, less than one per cent, and phosphorous is believed to be within the limits of ferrous

metallurgy. All the coke is suitable for non-ferrous metallurgy, and the 72 and 96-hour coke is believed to be structurally satisfactory for iron smelting purposes in the blast furnace.

MARKETS AND PRODUCTION

The market for Washington coke has, in the past, extended from Alaska to California, the bulk of the production being consumed at the Tacoma and Anyox smelters. A small quantity has gone to northern California smelting; foundries, shipyards, and industrial plants supplying the market for the better grades. The establishment of the by-product plant of the Granby Company at Anyox has cut off a large market. Actual development of new industries, particularly electro-metallurgical and electro-chemical, will call for increased quantities of coke, but it is believed that the existing plants can meet all of the demands for many years.

Washington coke meets the competition of British Columbia coke, not only from Vancouver Island but from Crow's Nest Pass. Utah coke competes in the southern markets; and there is always a certain amount of high grade eastern coke entering the local and southern markets. Very little foreign coke enters the local ports; on the other hand, it is not believed that Washington coke will be able to create a foreign market.

Statistics of production, yield, and prices are given in the accompanying Table I. From them it will be seen that Washington has produced 1,509,672 short tons of coke valued at $8,821,060 at the ovens. Since 1914 the figures include by-product coke. The production of by-product coke has been 147,373 tons, all of which has come from the Lake Union plant of the Seattle Lighting Company. (Table II.) The remaining production, 1,362,373 tons, is beehive coke, practically all of which has come from Pierce County.

The average yield of all coke per ton of coal treated has been fairly constant, remaining in the vicinity of 60 per cent. Prices have been steadily rising since 1915 and the average price per ton is higher than in most of the producing states of the country.

The past production has been ample to meet the demands of the various metallurgical industries, foundries, and industrial plants of the northwest. It is estimated that the ovens now built can produce a minimum of 150,000 tons of coke annually. The largest production, 136,552 tons in 1915, was obtained from 382 beehive ovens and 20 by-product chambers. The proximity of most of the ovens to tidewater shipping points enables the coke to enter any Pacific Coast market. The ash content and the high price will ordinarily not permit Washington Coke to develop a market far from the domestic demand, but it should fill an important place in local development.

TABLE 1—STATISTICS OF MANUFACTURE OF COKE IN WASHINGTON
1884 to 1919.

YEAR	Coke Produced	Total Value of Coke at Ovens	Value of Coke at Ovens (per ton)	Per Cent of Coke Yield Per Ton of Coal
1884	400	$1,900	$4 75	57.5
1885	311	1,477	4 75	57.0
1886	825	4,125	5 00	58.9
1887	14,625	102,375	7 00	65.0
1888	.....	.....	.....	.....
1889	3,841	30,726	8 00	55.0
1890	5,837	46,696	8 00	64.0
1891	6,000	42,000	7 00	60.0
1892	7,177	50,446	7 03	58.0
1893	6,731	34,207	5 08	59.0
1894	5,245	18,249	3 48	61.2
1895	15,129	64,632	4 27	65.9
1896	25,949	104,894	4 04	67.0
1897	26,189	115,754	4 42	67.0
1898	30,197	128,933	4 27	62.2
1899	30,372	151,216	4 98	59.8
1900	33,387	160,165	4 80	61.5
1901	49,197	239,028	4 86	62.7
1902	40,305	199,195	4 94	58.8
1903	45,623	214,776	4 71	62.4
1904	45,432	207,357	4 56	59.0
1905	53,137	251,717	4 74	62.0
1906	45,642	226,977	4 99	59.4
1907	52,028	293,019	5 63	60.6
1908	38,889	213,138	5 48	57.1
1909	42,981	240,604	5 60	61.7
1910	59,337	437,540	5 86	63.0
1911	40,180	216,262	5 38	66.6
1912	49,260	279,105	5 67	62.6
1913	76,221	432,770	5 68	64.2
1914	84,923	472,531	5 56	63.7
1915	136,552*	700,832	5 13	66.7
1916	125,872*	662,987	5 27	61.5
1917	122,758*	906,318	7 38	59.7
1918	123,788*	1,092,741	8 18	60.6
1919	65,332*	565,356	8 65	63.4
Totals	$1,509,672	$8,821,060	.....	.....

* Includes by-product coke.

TABLE 2—PRODUCTION OF BY-PRODUCT COKE IN WASHINGTON, 1914-1919.*

YEAR	Coke Produced (Short Tons)	Breeze Produced (Short Tons)	Total Coke Produced	Yield of Coal in Coke	Yield of Coal in Breeze	Total Yield	Value Coke	Value Breeze	Total Value
1914	6,751	441	7,192	66.8	4.37	71.17	$36,858 66	$441 38	$37,300 04
1915	30,182	4,142	34,324	65.07	8.9	73.97	158,472 17	4,120 81	162,592 98
1916	29,516	3,959	33,475	64.51	8.65	73.16	159,321 69	3,984 46	163,306 15
1917	27,635	3,889	31,524	61.38	8.64	70.02	210,857 81	4,160 90	215,018 71
1918	26,260	3,959	30,219	61.83	9.32	71.15	233,815 01	3,958 42	237,773 43
1919	26,955	3,959	30,914	61.14	8.98	70.12	207,116 23	3,967 01	211,083 24
Totals	147,299	20,349	167,648	.....	.....	.....	$1,006,441 57	$20,632 98	$1,027,074 55

* Figures furnished by Seattle Lighting Company.

OIL SHALES.

During the past year the Survey has undertaken a preliminary investigation of the possibilities of developing oil shale deposits in this State. One hundred samples were collected from the shale measures of western Washington. These samples were collected from scattered points in King, Pierce, Grays Harbor, Lewis, Thurston, Cowlitz, Clallam, and Whatcom counties, and of course cover only a minor portion of the possible outcrops of oil-bearing shales.

The samples were brought to the laboratories at the University of Washington and subjected to distillation tests. The basic principle of the shale testing operations is to heat the oil shale until the volatile hydrocarbons vaporize, and at the same time, destructively distill any other organic matter present in the shales.

The yield of oil obtained from the samples varied from seven gallons to the ton down to nothing. In no case was sufficient oil secured to place the recovery of shale oil on a commercial basis. The yield of ammonium sulphate varied from 90 pounds to the short ton, to zero. There is but little doubt that ammonium sulphate would provide a very valuable by-product if the shales held a fair amount of oil. However, the recovery of ammonium sulphate for its own sake would not be a profitable scheme even with a yield of 90 pounds to the ton.

While the results of the preliminary investigation have been decidedly negative, the chances of yet finding deposits of oil shales that will be of ultimate commercial value, are by no means exhausted. It is the plan of the Survey to carry this investigation further.

The deposits of oil shales occurring in Colorado, Utah, and Wyoming occur as flat-lying formations, or only slightly inclined, with 14° as the maximum dip. It

has been noted in this area, as well as in similar oil shale regions that where the formations are compressed into steeply-dipping folds, they do not usually yield returns comparable with corresponding flat-lying beds. Apparently the metamorphic reactions in buckling and contorting the strata would generate sufficient heat to dissipate the oil.

TABULATION OF OIL DISTILLATION TESTS ON CERTAIN REPRESENTATIVE SHALES OF WASHINGTON.

SAMPLE NO.	LOCATION				Yield Oil Gallons Per Ton	Amonium Sulphate, Lbs. Per Ton	Notes
	Sec.	Twp.	Range	County			
7	5	18 N.	6 E.	Pierce	5.5	15.21	Sampled on outcrop in canyon.
27	33	14 N.	2 W.	Lewis	None	30.57	Sampled in railroad cut.
42	21	15 N.	1 W.	Thurston	2.0	None	Sampled in Tono coal mine.
52	12	14 N.	4 E.	Lewis	2.0	7.01	Sampled in Ladd coal mine.
57	10	13 N.	4 E.	Lewis	None	90.21	Sampled on outcrop in river canyon.
63	12	26 N.	42 E.	Spokane	7.0	14.70	Near Spokane country club (this was the only sample tested from Eastern Washington).
69	11	8 N.	3 W.	Cowlitz	Trace	33.97	Outcrop in cut of logging railroad.
76	25	31 N.	10 W.	Clallam	None	32.57	Outcrop in railroad cut.
90	8	21 N.	7 E.	King	3.0	8.27	Exposed in Green River canyon.
1	4	18 N.	6 E.	Pierce	3.0	1.67	Sampled on outcrop in canyon.
8	5	18 N.	6 E.	Pierce	1.0	22.14	Sampled on outcrop in canyon.
12	16	23 N.	5 E.	King	None	9.71	Sampled on road cut.
15	5	20 N.	12 W.	Grays Harbor	None	10.40	Outcrop on beach.
24	5	18 N.	6 E.	Pierce	1.0	24.60	Sample taken under ground.
28	33	14 N.	2 W.	Lewis	None	20.06	Sample taken in railroad cut.
34	3	14 N.	1 W.	Lewis	Trace	21.80	Sample taken in Mendota coal mine.
39	21	15 N.	1 W.	Thurston	Trace	19.40	Sample taken in Tono coal mine.
44	21	15 N.	1 W.	Thurston	2.0	None	Sample taken from outcrop back of Tono mine.
60	11	13 N.	4 E.	Lewis	2.0	12.92	Outcrop in river canyon.
65	30	8 N.	1 W.	Cowlitz	None	26.92	Outcrop on Coweman river.
71	24	9 N.	2 W.	Cowlitz	Trace	31.84	Exposed in creek bed.
92	8	21 N.	7 E.	King	2.0	12.92	Exposed in Green River canyon.

METALS

METAL MINING CONDITIONS IN WASHINGTON

By Ernest N. Patty

Washington, during recent years, ranks twelfth among the various states in point of the production of gold, silver, copper and lead. The value of the output of these four metals has averaged slightly better than one and one-half million dollars annually. During 1918, copper made up 32.4 per cent of the total, lead 25.6, silver 21.2 and gold 20.8 per cent. About 75 per cent of the production for the past three years has come from twelve mines; the balance from small properties which make occasional shipments of sorted ore.

When visiting the large number of properties, in various stages of development, scattered over the northern half of the state, there are found certain facts that aid in formulating a prediction as to future developments. One of the first of these is the absence of bonanzas or of mammoth low-grade ore bodies. Deposits such as the Electric Point, form exceptions and it is probable that equally profitable properties may later be brought in. Mammoth low-grade ore bodies may some day be found in Washington, but there is no probable potential deposit that can be pointed to with even a slight degree of certainty. The workable ores are quite generally of milling grade and it is from the production of mill concentrates that the future output of the State will largely be maintained. At present the area is quite backward in efficient milling practice, but this condition is improving and should not long be an interfering factor. There are a number of deposits of medium-grade ore that, with a little further development, should reasonably be expected to yield a sufficient tonnage to warrant the erection of well-designed concentrators.

The physical conditions for mining operations are generally favorable; for the deposits occur in the mountainous area which extends from British Columbia to cover the northern half of the State. Excellent timber can be locally secured, while electric power is obtainable from local power companies or it can be generated from the swift-moving mountain streams. The topography generally favors opening the deposits through crosscuts although mining through shafts is not uncommon. Transportation was formerly a serious problem but the principal districts are now connected with transcontinental railway lines by means of well-constructed branch lines and the outlying properties can be reached from the railroad by automobile.

The mines are served by the Tacoma and Northport smelters of this State, the Bunker Hill plant at Kellogg, Idaho, and the Trail Smelter at Trail, B. C. Occasional shipments are made to the U. S. Smelting Company at Midvale, Utah, and the East Helena, Montana, plant.

The greatest handicap for many of the properties is the lack of sufficient capital to work the deposits on an efficient business basis. Like all other mining states, Washington has experienced its era of "wild-catting" and the legitimate properties are now being made to suffer from the reactions brought about through the losses incurred by mining investors. Too often mining investors and mining operators refuse to look upon present-day mining as a highly organized form of scientific business activity. The result is, that when capital is available a portion of the money spent in mining development work is sometimes hopelessly wasted. It is often the case that the men charged with the responsibility of directing the development of a prospect or small mine have no special training or experience to guide their descisions and thus they are naturally highly susceptible to serious, but normally avoidable, errors.

The worthy properties, and there are a number of such in the State, can be best put on a paying basis by strong, well-organized and financed development companies under the direction of a skilled and experienced engineering staff. It seems logical that in the future more organizations of this type will be formed to guide the partially developed and encouraging prospect into a producing mine.

In the following pages the status of each metal is discussed separately:

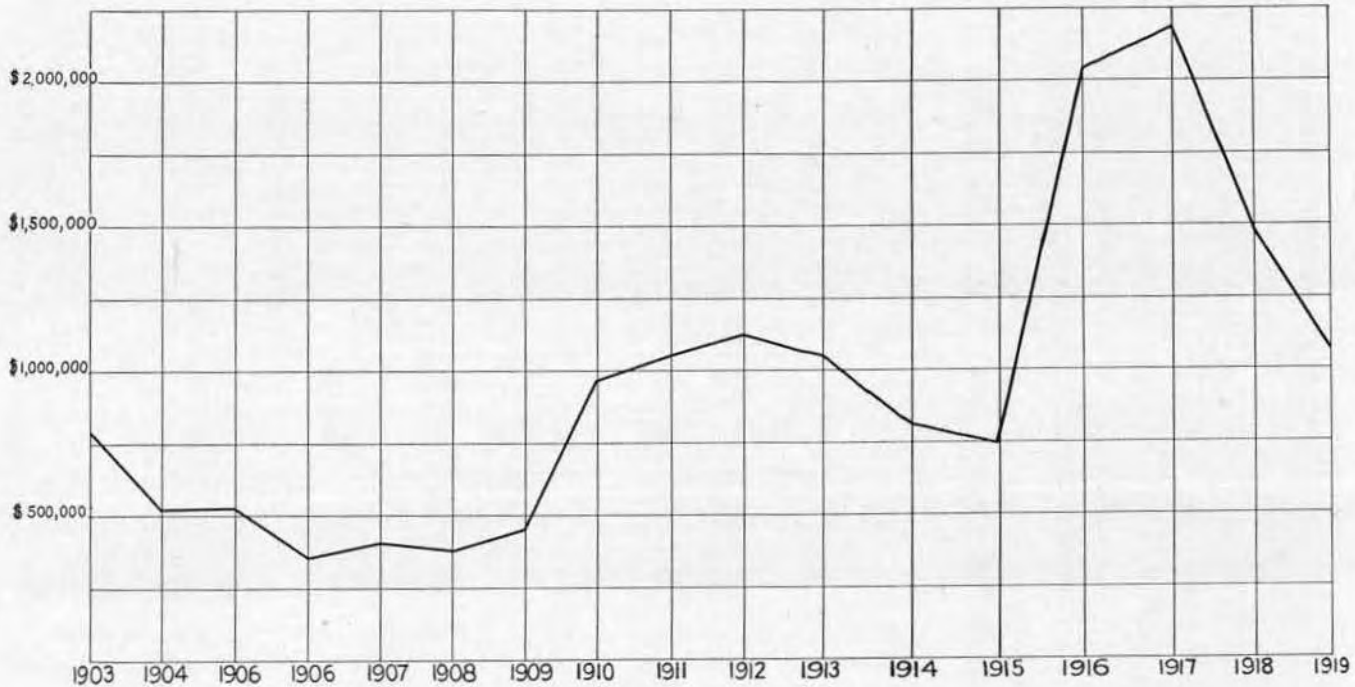


FIG. 1.—Combined value of production of gold, silver, copper, lead, and zinc, for Washington, 1903 to 1919, inclusive.

METAL MINES NOW OR RECENTLY IN OPERATION.

Mine	Location	County	Principal Metals Produced
Blewett (Amalgamated Gold Mines Co.)	Blewett	Chelan	Gold
Chatterboy (Lucille Dreyfus)	Danville	Ferry	Copper-gold
La Fleur Mt. Copper	Danville	Ferry	Copper
Addison Copper	Keller	Ferry	Copper
Laurier	Laurier	Ferry	Copper
Castle Creek	Republic	Ferry	Silver-lead
Knob Hill	Republic	Ferry	Gold-silver
Last Chance	Republic	Ferry	Gold-silver
Lone Pine	Republic	Ferry	Gold-silver
Quilp	Republic	Ferry	Gold-silver
San Poil	Republic	Ferry	Gold-silver
Surprise	Republic	Ferry	Gold-silver
American Flag	Sheridan	Ferry	Silver
Phil Sheridan	Sheridan	Ferry	Silver
Apex	Miller River	King	Gold
Mineral Creek Copper	Lake Kachess	Kittitas	Copper
Swauk Dredging & Mining Co.	Liberty	Kittitas	Gold
Eagle Peak Copper	Longmire Springs	Lewis	Copper
Neutral	Chesaw	Okanogan	Iron
Arlington	Conconully	Okanogan	Silver-lead-copper
Carl Frederick	Conconully	Okanogan	Silver
Hargrove	Conconully	Okanogan	Silver-lead-copper
Last Chance	Conconully	Okanogan	Silver-lead-copper
Silver Ledge	Methow	Okanogan	Gold-silver
Andy O'Neal	Nespelem	Okanogan	Silver-copper
Apache	Nespelem	Okanogan	Silver
Double Header	Nespelem	Okanogan	Silver
Great Metals	Nespelem	Okanogan	Silver
Panama	Nespelem	Okanogan	Silver
Rebecca	Nespelem	Okanogan	Silver
Tip Top	Nespelem	Okanogan	Silver-copper
Four Metals	Nighthawk	Okanogan	Silver-lead-copper
Kaaba	Nighthawk	Okanogan	Silver-lead-copper
Ruby	Nighthawk	Okanogan	Silver

METAL MINES NOW OR RECENTLY IN OPERATION—Continued.

Mine	Location	County	Principal Metals Produced
Copper World Extension	Oroville	Okanogan	Copper
O. K.	Oroville	Okanogan	Copper
Submarine	Oroville	Okanogan	Silver-lead
Trinidad	Tonasket	Okanogan	Silver-lead
Azurite	Winthrop	Okanogan	Copper
Bella May	Metaline	Pend Oreille	Lead-silver
Diamond R.	Metaline	Pend Oreille	Lead-silver
Oriole	Metaline	Pend Oreille	Silver-lead-zinc
Bead Lake	Newport	Pend Oreille	Silver-lead-copper
Ries	Newport	Pend Oreille	Silver-lead-copper
American Arsenic	Reiter	Snohomish	Arsenic
Sunset	Index	Snohomish	Copper
Florence Rae	Sultan	Snohomish	Copper
Kromona	Sultan	Snohomish	Copper
Sultan Group	Sultan	Snohomish	Lead
Bonanza	Bossburg	Stevens	Silver
Young America	Bossburg	Stevens	Silver-lead
Copper King	Chewelah	Stevens	Copper
United Silver-Copper	Chewelah	Stevens	Silver-copper
Daisy	Daisy	Stevens	Silver
Tempest	Daisy	Stevens	Silver
O-lo-lim	Detillion Bridge	Stevens	Copper
Silver Queen	Kettle Falls	Stevens	Silver
Loon Lake	Loon Lake	Stevens	Copper
Loon Lake-Blue Bird	Loon Lake	Stevens	Copper
Electric Point	Northport	Stevens	Lead
Frisco-Standard	Northport	Stevens	Silver
Gladstone	Northport	Stevens	Lead
Gorien Zinc	Northport	Stevens	Lead
Great Western	Northport	Stevens	Zinc-lead
Last Chance	Northport	Stevens	Zinc-lead
Lead Trust	Northport	Stevens	Lead
Melrose	Northport	Stevens	Silver
New England	Northport	Stevens	Zinc

METAL MINES NOW OR RECENTLY IN OPERATION—Concluded.

Mine	Location	County	Principal Metals Produced
Northport Mine	Northport	Stevens	Zinc
United Treasurer	Northport	Stevens	Silver
Galena Hill	Orient	Stevens	Silver-lead
Aichan Bee	Turk	Stevens	Silver-lead
Deer Trail	Turk	Stevens	Silver
Queen and Seal	Turk	Stevens	Silver-lead
Reardon Copper	Turk	Stevens	Copper
Red Cloud	Turk	Stevens	Copper
Boundary Red Mountain	Sumas	Whatcom	Gold-silver

TOTAL VALUES OF THE PRODUCTION OF GOLD, SILVER, COPPER, LEAD AND ZINC BY COUNTIES FOR THE PERIOD OF 1909-1919, INCLUSIVE.

COUNTY	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	Total
Asotin	.....	$68	.....	.....	.....	.....	.....	$55	.....	.....	.....	$123
Benton	.....	.....	.....	.....	.....	.....	$167	.....	.....	.....	.....	167
Chelan	$4,293	6,941	$22,100	$35,636	$8,704	$1,604	4,342	8,798	$691	$151	$137	93,397
Clarke	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2,338
Clallam	39	.....	.....	257	.....	111	688	374	628	241	.....	.....
Ferry	238,439	814,913	896,848	712,250	751,826	625,173	459,985	694,378	487,708	409,012	319,703	6,410,235
King	10,887	21,118	13,099	9,419	6,403	.....	.....	1,716	9,301	6,988	3,134	82,065
Kittitas	5,876	3,619	2,830	2,163	3,714	4,426	4,024	4,882	6,020	2,673	990	41,217
Lewis	.....	.....	447	.....	.....	.....	.....	.....	.....	497	520	1,464
Okanogan	14,415	14,894	11,191	18,220	12,993	10,182	40,131	39,138	41,460	75,717	37,917	316,258
Pend Oreille	.....	.....	3,248	.....	.....	.....	30,368	118,074	132,816	17,736	497	302,739
Pierce	.....	241	.....	.....	.....	.....	261	2,709	881	.....	609	4,701
Skagit	.....	5	13	.....	.....	.....	.....	.....	431	.....	.....	449
Skamania	.....	.....	.....	.....	.....	22	.....	394	.....	.....	.....	416
Snohomish	708	105	435	721	3,028	8,061	10,946	75,703	50,865	117,924	111,730	380,226
Stevens	173,747	106,319	105,412	339,347	260,918	144,092	180,576	968,666	1,418,494	826,456	651,015	5,017,751
Wahkiakum	.....	.....	.....	.....	.....	.....	.....	.....	80	.....	.....	80
Whatcom	562	26	190	2,201	5,549	15,739	12,545	133,463	139,442	10,026	.....	319,743
Whitman	.....	.....	204	.....	.....	357	.....	.....	.....	.....	.....	561
Yakima	.....	.....	.....	.....	.....	.....	.....	.....	468	.....	.....	468
Totals	$448,966	$968,249	$1,056,017	$1,120,214	$1,053,135	$809,767	$744,033	$2,048,350	$2,289,285	$1,467,421	$1,126,252	$12,974,398

PRODUCTION OF COPPER BY COUNTIES, IN POUNDS AND VALUES, 1909-1918

COUNTY		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	Period Total
Chelan	Weight	.....	.....	.....	.....	.....	104	117	111	.....	.....	332
	Value	.....	.....	.....	.....	.....	$14	$20	$27	.....	.....	$61
Ferry	Weight	696	611	161,158	77,968	55,544	159,142	317,396	828,264	273,624	127,813	2,001,576
	Value	$79	$8	$20,145	$12,865	$8,610	21,166	55,544	203,752	$74,700	$31,570	428,439
King	Weight	.....	.....	.....	.....	.....	.....	.....	.....	4,870	.....	4,870
	Value	.....	.....	.....	.....	.....	.....	.....	.....	1,330	.....	1,330
Kittitas	Weight	.....	.....	.....	.....	.....	.....	.....	.....	4,002	.....	4,002
	Value	.....	.....	.....	.....	.....	.....	.....	.....	1,093	.....	1,093
Lewis	Weight	.....	.....	3,425	.....	.....	.....	.....	.....	.....	2,014	5,439
	Value	.....	.....	428	.....	.....	.....	.....	.....	.....	497	925
Okanogan	Weight	29,405	24	.....	966	1,070	16,081	43,106	31,144	83,524	169,890	375,219
	Value	3,822	3	.....	159	166	2,139	7,544	7,662	22,803	41,965	86,263
Pend Oreille	Weight	.....	.....	411	.....	.....	.....	.....	.....	490	149	1,050
	Value	.....	.....	51	.....	.....	.....	.....	.....	134	37	222
Pierce	Weight	.....	1,770	.....	.....	.....	.....	1,422	10,381	3,084	.....	16,657
	Value	.....	224	.....	.....	.....	.....	240	2,554	832	.....	3,859
Skagit	Weight	.....	.....	101	.....	.....	.....	.....	.....	.....	.....	101
	Value	.....	.....	13	.....	.....	.....	.....	.....	.....	.....	13
Snohomish	Weight	4,977	.....	.....	.....	.....	263	41,226	295,485	180,948	452,043	974,942
	Value	647	.....	.....	.....	.....	35	7,215	72,689	49,400	111,654	241,640
Skamania	Weight	.....	.....	.....	.....	.....	142	.....	1,280	.....	.....	1,422
	Value	.....	.....	.....	.....	.....	19	.....	315	.....	.....	334
Stevens	Weight	220,145	85,063	153,112	1,007,076	897,467	602,996	617,659	1,478,357	1,647,490	1,170,488	7,879,854
	Value	28,619	10,803	19,139	166,168	139,107	80,118	108,090	363,676	449,770	289,111	1,654,681
Yakima	Weight	.....	.....	.....	.....	.....	.....	.....	.....	1,486	.....	1,486
	Value	.....	.....	.....	.....	.....	.....	.....	.....	402	.....	402
Totals	Weight	255,134	86,918	318,207	1,086,010	954,081	778,728	1,020,926	2,645,022	2,199,518	1,922,406	11,266,950
	Value	$33,167	$11,038	$39,776	$179,192	$147,883	$103,571	$178,662	$650,675	$600,464	$474,834	$2,419,262

PRODUCTION OF LEAD BY COUNTIES, IN POUNDS AND VALUE, 1909-1918.

COUNTY		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	Period Total
Ferry	Weight	.....	128	.....	.....	.....	5,063	162	3,646	1,395	.....	10,934
	Value	.....	$5	.....	.....	.....	$219	$8	$251	$120	.....	$603
Okanogan	Weight	231	248	.....	.....	1,639	22,391	23,138	1,704	2,455	785	52,383
	Value	$1	11	.....	.....	72	873	1,087	118	211	56	2,429
Pend Oreille	Weight	.....	.....	11,982	.....	.....	.....	.....	37,695	130,324	193,878	373,879
	Value	.....	.....	539	.....	.....	.....	.....	2,601	11,208	13,765	28,113
Skagit	Weight	.....	401	.....	.....	.....	.....	.....	.....	.....	.....	40
	Value	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	2
Snohomish	Weight	.....	.....	.....	.....	.....	1,317	.....	.....	.....	.....	1,317
	Value	.....	.....	.....	.....	.....	51	.....	.....	.....	.....	51
Stevens	Weight	288,677	1,321,871	836,602	127,387	200,848	36,196	271,915	5,356,229	9,655,513	5,077,152	22,172,390
	Value	$12,413	58,162	37,647	5,732	8,838	1,412	12,780	369,580	830,374	360,478	$1,697,416
Totals	Weight	288,700	1,322,287	848,584	127,387	202,487	65,507	295,215	5,399,274	9,789,687	5,271,815	23,610,943
	Value	$12,414	$58,180	$38,186	$5,732	$8,909	$2,555	$13,875	$372,550	$841,913	$374,299	$1,728,614

PRODUCTION OF GOLD BY COUNTIES, IN VALUE, 1909-1918.

COUNTIES	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	Period Total
Adams	.....	$68	.....	.....	.....	.....	.....	.....	.....	.....	$68
Benton	.....	.....	.....	.....	.....	.....	$166	.....	.....	.....	166
Chelan	$4,232	6,867	$21,846	$35,130	$8,590	$1,575	4,279	$8,682	$683	.....	91,884
Clallam	39	.....	.....	256	.....	110	685	372	624	$239	2,325
Ferry	210,437	714,808	778,526	605,698	645,009	513,276	351,973	399,376	332,071	276,062	4,827,236
King	10,501	19,420	11,245	7,711	4,568	.....	.....	1,344	5,742	4,672	65,203
Kittitas	5,929	3,589	2,801	2,141	3,677	4,387	3,990	4,832	4,848	2,636	38,730
Okanogan	8,907	13,088	4,723	3,302	2,837	2,724	10,281	18,902	6,403	1,585	72,842
Pend Oreille	.....	.....	633	.....	.....	.....	.....	.....	170	.....	803
Pierce	.....	.....	.....	.....	.....	.....	.....	41	.....	.....	41
Skagit	.....	.....	.....	.....	.....	.....	.....	.....	12	.....	12
Snohomish	49	88	433	717	2,622	7,217	3,402	1,844	518	1,272	18,222
Stevens	121,498	30,182	27,074	23,823	23,480	11,894	4,063	8,972	3,757	8,198	262,941
Wahkiakum	.....	.....	.....	.....	.....	.....	.....	.....	80	.....	80
Whatcom	559	26	189	2,186	5,492	15,635	12,520	133,200	137,382	9,929	317,118
Whitman	.....	.....	203	.....	.....	355	.....	.....	.....	.....	558
Yakima	.....	.....	.....	.....	.....	.....	.....	.....	34	.....	34
Other counties	.....	9	4	.....	.....	.....	.....	.....	.....	.....	13
Totals	$362,051	$788,145	$847,677	$680,964	$696,275	$557,173	$391,419	$577,655	$492,324	$304,593	$5,698,276

PRODUCTION OF SILVER BY COUNTIES, IN VALUE, 1909-1918.

COUNTIES	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	Period Total
Asotin	.....	.....	.....	.....	.....	.....	.....	$28	.....	.....	$28
Chelan	$61	$74	$254	$506	$114	$15	$44	118	$8	$151	1,345
Ferry	27,921	100,092	98,177	93,687	98,208	90,513	52,463	90,997	80,822	101,378	834,258
King	385	1,698	1,854	1,708	1,835	.....	.....	372	2,230	2,314	12,396
Kittitas	46	30	29	22	37	39	34	50	80	38	405
Okanogan	1,689	1,792	6,468	14,759	9,918	4,446	21,219	12,368	12,044	32,110	116,813
Pend Oreille	.....	.....	851	.....	.....	.....	.....	56	1,279	394	2,580
Pierce	.....	.....	.....	.....	.....	.....	12	114	39	.....	165
Skagit	.....	2	.....	.....	.....	.....	.....	.....	419	.....	421
Skamania	.....	.....	.....	.....	.....	.....	.....	79	.....	.....	79
Snohomish	12	17	2	4	406	761	269	1,170	048	5,000	8,589
Stevens	11,217	7,172	21,552	143,624	89,493	50,588	55,643	114,895	132,675	168,669	795,528
Whatcom	3	.....	1	15	57	106	25	263	2,060	39	2,569
Yakima	.....	.....	.....	.....	.....	.....	.....	.....	28	.....	28
Other counties	.....	9	16	1	.....	.....	.....	.....	.....	.....	26
Totals	$41,334	$110,886	$129,204	$254,326	$200,068	$146,468	$129,709	$220,510	$232,632	$310,093	$1,775,230

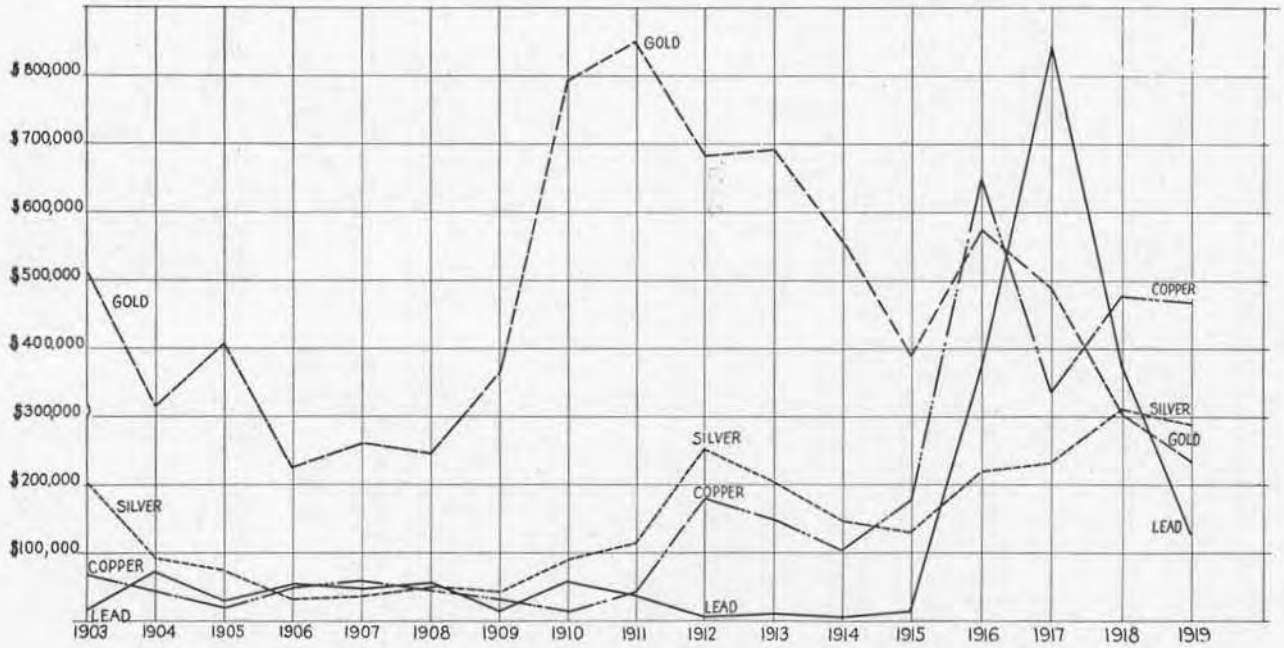


FIG. 2.—Value of individual production of gold, silver, copper, lead, and zinc, for Washington, 1903 to 1919, inclusive.

TOTAL METAL MINE PRODUCTION OF WASHINGTON.

1860 to 1919	Value	Fine Ounces	Pounds	Total Value
Gold	$27,989,750			
Silver		7,621,803		
Copper			15,397,340	
Lead			34,675,076	
Recoverable Zinc			3,193,670	
Grand total value				$39,080,339

Since 1903 the State and County totals are accurate, but previous to that time, the totals are largely those of the mint and lack detailed information regarding districts or counties. The still earlier figures are based largely on estimates that are considered reasonably accurate.

The various statistics have been compiled jointly by the U. S. Geological Survey and the Washington Geological Survey.

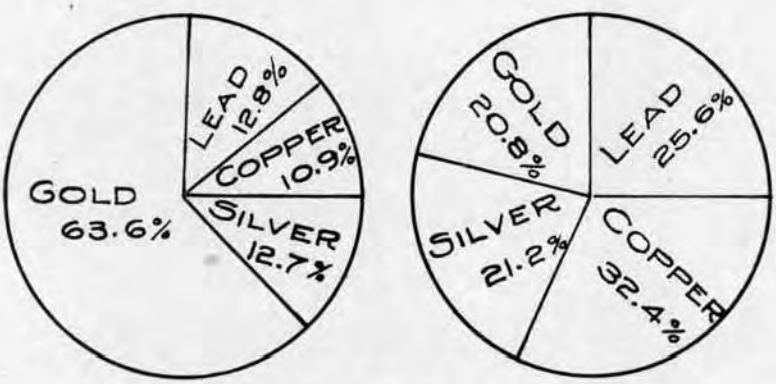


FIG. 3.—Graph showing comparative production of major metals in Washington, 1908 and 1918.

QUANTITY OF ORE SOLD OR TREATED IN WASHINGTON 1860-1908.

	Gold (Value)	Silver (Fine Ozs.)	Copper (Pounds)	Lead (Pounds)	Total Value
*Prior to 1866	$9,000,000	125,500	.....	.....	$9,161,108
*1866	1,000,000	12,500	.....	.....	1,016,737
†1867	400,000	5,000	.....	.....	406,650
†1868	400,000	5,000	.....	.....	406,650
‡1869	300,000	3,750	.....	.....	304,969
‡1870	300,000	3,750	.....	.....	304,969
‡1871	320,107	4,000	.....	.....	325,407
‡1872	260,000	3,250	.....	.....	264,297
‡1873	206,341	2,355	.....	.....	209,395
‡1874	154,535	1,925	.....	.....	156,995
‡1875	81,932	1,000	.....	.....	83,172
§1876	26,988	320	.....	.....	27,359
§1877	300,000	41,667	.....	.....	350,000
§1878	300,000	21,739	.....	.....	325,000
§1879	75,000	17,857	.....	.....	95,000
¶1880	135,800	886	.....	.....	136,819
**1881	120,000	1,450	.....	.....	121,639
**1882	120,000	1,450	.....	.....	121,653
**1883	80,000	387	.....	.....	80,430
**1884	73,952	912	.....	.....	74,964
**1885	126,172	52,208	.....	.....	182,035
**1886	147,548	123,752	.....	.....	270,062
**1887	160,503	94,516	.....	.....	253,129
**1888	145,000	123,750	.....	.....	261,325
**1889	193,709	81,984	.....	.....	270,744
**1890	204,000	69,628	.....	.....	277,109
**1891	371,897	165,883	.....	.....	536,121
**1892	373,553	151,554	.....	.....	505,405
**1893	228,394	134,961	.....	.....	333,664
**1894	232,761	9,683	.....	.....	238,861
**1895	373,148	109,060	.....	.....	444,037
**1896	395,490	233,407	.....	.....	554,207
**1897	449,664	242,780	.....	.....	595,332
**1898	612,118	329,549	.....	857,555	838,968
**1899	729,388	289,661	76,410	1,032,069	962,774
**1900	732,437	302,570	36,831	1,091,945	973,711
**1901	661,240	377,381	29,520	216,841	901,823
**1902	374,471	721,450	40,426	242,516	771,408
1903	507,885	294,500	500,570	405,412	791,991
1904	314,463	157,598	350,047	1,760,309	518,028
1905	405,078	125,376	108,709	605,043	526,200
1906	221,648	45,878	235,030	926,100	350,533
1907	259,074	55,359	297,812	820,035	398,635
1908	242,234	88,823	312,030	1,150,429	378,816
Totals	$22,116,530	4,636,069	1,987,394	9,108,254	$26,108,122

*Browne, J. R., Mineral Resources of the States and Territories West of the Rocky Mountains, 1868 (with estimate of silver).

†Estimated by C. N. Gerry, U. S. Geological Survey.

‡Raymond, R. W., Statistics of Mines and Mining in the States and Territories West of the Rocky Mountains, 1870-1876.

§Director of the Mint, Annual Receipts 1876-1879.

¶Emmons, S. F., U. S. Geological Survey, Mineral Resources, page 85, 1892.

**Director of the Mint, Annual Receipts 1881-1903.

For figures later than 1908 see tables in first of report.

ANTIMONY

The deposits of antimony in Washington are relatively small and unimportant and during normal times cannot compete with the cheaper ores from China. Certain deposits that carry appreciable associated silver values are likely to reopen if the present demands for silver continue. In such an event the antimony would be secured as a by-product. There has, however, been no production of antimony recorded in Washington since 1917. The known properties are as follows:

The Reedy deposit is located five miles up Gold Creek, a tributary of Methow River, 20 miles above Pateros. This property is reported to have shipped 1,000 tons of ore since 1907. It is equipped with water power which operates an oxide treatment plant and an air compressor for mining. The following analysis of the ore is reported:

Sb	36-54 per cent.	Cu	none
Fe	4.03 per cent.	As	none
S	16-67 per cent.	$CaCO_3$	2.28
SiO_2	32.84 per cent.	$MgCO_3$	4.45
Zn	3.34 per cent.		

In the Covada district the R. E. Lee prospect contains a series of small veins carrying nearly pure stibnite. The veins average from one-half to three inches in width and are exposed for only a few feet along the strike. The Longstreet Mine, situated in sec. 25, T. 32 N., R. 36 E., has an aplite dike extending the full length of the claim; this dike exhibits appreciable amounts of stibnite.

Several carload shipments of good-grade antimony ore have been made from the Lucky Knock Mine near Tonasket, in northern Okanogan County. The sulphide mineral, stibnite, is said to occur as irregular replacement deposits in limestone. An oxidizing plant was built on the property, but there has been no activity since 1916.

The Wells-Fargo Mine is situated in sec. 36, T. 31 N., R. 38 E., 12 miles west of Gray Station in Stevens County.

The ore is stibnite (carrying silver) in a quartz vein which averages three to five feet in thickness. The property is still in the prospect stage, but the prospects are said to be encouraging.

A narrow vein of stibnite occurs on Money Creek, three miles above the Great Northern Railway station of Miller River, in King County. Several years ago a mill was built to treat this ore, but the venture was not a financial success. Several other small deposits of stibnite are known to occur in this area, particularly along Miller River.

An antimony property, owned by Mr. Boyle of Sultan, is located in Sultan Basin, one and one-half miles from the Forty-five Mine. Mr. Van Epps of Leavenworth has located a property on Icicle Creek, Chelan County, but there are no data available as to the extent of the deposit.

ARSENIC

Arsenopyrite (iron 34.3 per cent, arsenic 46 per cent) associated with gold values is a common mineral in a number of ore deposits in the Cascade Mountains. These properties are not worked continuously, and the ore is usually shipped to the Tacoma smelter where the arsenic is recovered as a by-product in a special treatment unit of the plant. The Apex Gold Mines Company, near the station of Miller River, King County, has been one of the largest shippers of ore containing arsenic. Arsenopyrite is a common ore mineral at the Cleopatra and Mono mines, also located in the Miller River Mining District; it is also prominent in the gold veins of the Monte Cristo and Blewett districts.

The high price paid for arsenic during 1920 encouraged the American Arsenic Company to develop a deposit of realgar (arsenic monosulphide) near Reiter, Snohomish County. The head offices of the company are located at Burlington, Washington. The mine is 2,000

feet above and four miles by trail north of Reiter, a station near Index on the Great Northern Railway.

The arsenic occurs principally as realgar with subordinate amounts of orpiment and arsenolite. The ores fill a small fracture in the granodiorite country rock. The ore has been developed by a drift 150 feet in length, this development shows the vein to vary in width from two to twelve inches, with five inches as an average. Practically the entire filling is realgar of excellent grade. There are several minor veinlets trending off at various angles from the drift, and nearby there are exposed several small but continuous veinlets of ore. The ore from the largest vein is of sufficient width and quality that it can be sorted and shipped direct. A 15-ton flotation mill was completed on the property during July, 1920, to provide concentration facilities for the lower-grade material.

Several other occurrences of realgar and orpiment are known in the State, but so far no deposits of commercial importance have been developed. At Mineral, in Lewis County, a deposit of realgar was treated several years ago to make white arsenic, but the plant was unable to compete with the white arsenic produced at certain smelters. Realgar and orpiment occur associated with an igneous dike in sec. 8, T. 21 N., R. 7 E., near the town of Ravensdale, King County.

CHROMITE

During the war period Washington produced several hundred tons of chromic iron ore, but following the reentrance of foreign competition, all of the local properties closed down. The war-time search for chromite, however, served to bring to light new deposits which may later develop a commercial value. Washington is known to contain the largest potential water power resources of any state in the Union, and as this is developed it is believed that the electric furnace will come into more com-

mon use. The manufacture of ferrochrome in the electric furnaces would open a local market favorable to the nearby chrome properties.

The recent war taught the necessity of national economic independence in mineral resources, and since the western chrome deposits form the domestic chrome reserves of the country, they are valuable from the standpoint of national protection.

Chromite occurs associated with basic intrusive rocks, chiefly peridotite, pyroxenite, and their alteration product, serpentine. The chromite occurs usually as irregular lenses and stringers which are the results of magmatic segregation from the basic rocks.

Chromic iron ore finds its chief use as a refractory lining for metallurgical furnaces where high temperatures and the corrosive action of molten metals must be withstood. As ferrochrome it serves an important use in the manufacture of chrome steel. The demand for chromic oxide in the chemical industry is not unimportant.

The best known chrome deposits in the State are those on Cypress Island of the San Juan group, which can be best reached from Anacortes. There is developed here a limited tonnage of shipping ore that will average 40 per cent chromic oxide, and several thousand tons of ore averaging 25 per cent chromic oxide, that reliable mill tests prove can be concentrated to a 40-45 per cent product carrying only two per cent silica. These ore bodies occur as irregular seams and lenses enclosed in serpentine.

Several large deposits are known to exist in the Sister Peaks district in T. 37 N., R. 6 E., southwestern Whatcom County. Two properties in this district are near the headwaters of Skookum Creek, and were located by O. D. Post and R. L. Lambert of Sumas. The Sister Peak Mountains are made up of peridotite, carrying chromite

as an accessory mineral, distributed through the rock. The deposits are in the form of lenses and are the result of magmatic segregation. The ore is of good grade, but serious transportation difficulties make the deposits at present valueless. The properties can be best reached from Camp No. 2 of the McCoy-Loggie Lumber Company near the town of Acme. The country is rugged, and no trails exist for the last five miles of the trip.

Several deposits of chromite are known to occur in a serpentine and peridotite area which extends from T. 23 N., R. 15 E., north of Cle Elum Lake, eastward to Blewett. This formation is well shown on the Snoqualmie and Mt. Stuart folios, prepared by the U. S. Geological Survey. The known deposits of chromite have been found to occur as small lenses, usually of excellent grade. During the war Richard Denny of Tacoma mined and shipped 15 tons of chromite that averaged 50 per cent chromic oxide. This ore came from a small deposit on the east side of Hawkins Mountain. On Boulder Creek, one-half mile east of the wagon road, John and William Burke have opened a small lens of chromite which yields assays around 50 per cent.

During 1917 chromite deposits were located on Mount Chopaka near the town of Nighthawk in northern Okanogan County. The country rock is peridotite and the deposits are reported to be of considerable size.

COPPER

Copper ranks first among the metallic minerals now being produced in Washington. The peak output was reached during 1916 and 1917 when the industry was stimulated by the heavy war demands for this metal. During 1918 copper totalled 33.4 per cent of the total value of the metallic ore production of the State. This position it has only gained during recent years, for previous to 1914 the low price discouraged operations and

the copper mined was but 10 per cent of the value of metallic production.

The bulk of this metal comes from the United Silver-Copper Mine near Chewelah, and the Sunset Copper Mine near Index in the Cascades. During 1918 six mines produced nearly 90 per cent of the total. In order of their importance they were the United Silver-Copper, Sunset, Copper World Extension, Lone Star, Turk, and Loon Lake mines.

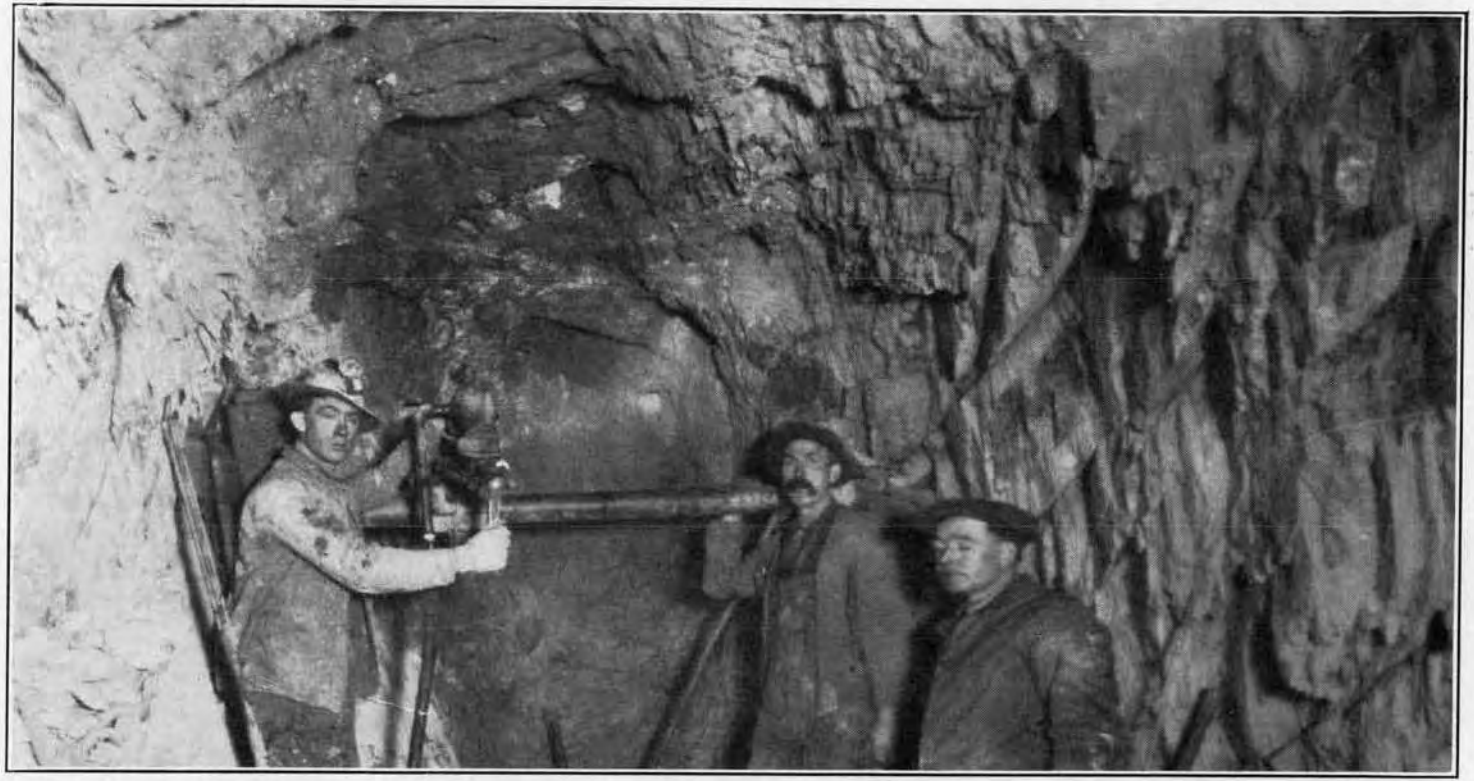
Fifty-eight per cent of the total value was shipped to the smelters in the form of mill concentrates. The ratio of concentrated to crude ore is gradually increasing owing to the improved and extended milling practice of the state.

COPPER PRODUCED IN WASHINGTON, BY KINDS OF ORE, IN DRY POUNDS.

YEAR	Dry or Siliceous Ore	Copper Ore	Lead Ore	Per Cent Produced From Crude Ore	Per Cent Produced From Concentrates	Total Pounds	Value
1913.....	153,633	800,374	74	78	22	954,081	$147,883
1914.....	32,431	746,297	.....	72	28	778,728	103,571
1915.....	13,451	1,007,475	.....	57	43	1,020,926	178,662
1916.....	60,418	2,584,230	374	75	25	2,645,022	650,675
1917.....	51,391	2,147,102	1,025	56	44	2,199,518	600,468
1918.....	14,448	1,907,565	393	42	58	1,922,406	474,854
1919.....	.....	.....	.....	.....	.....	2,552,134	469,593

During 1919 and 1920, the copper market the world over was in a demoralized condition. In spite of these adverse conditions, output has been surprisingly well maintained when we remember that even the large producers were operating on a very slender margin of profit.

The variability of the copper market during the past two years has been caused by the natural functioning of the law of supply and demand; abnormal metal prices during the war period resulted in an immense production of copper. Consumers built up large reserves of the metal to guard against emergency conditions. The sudden termination of the war found the allied nations with



Drifting on United Copper-Silver vein, 1200-foot level.

sufficient copper stores on hand to normally supply them for a year or more in advance. It was soon evident that the war-time market price fixed by the government could not be maintained. The United States produces about two-thirds of the world's copper supply and the large producers of this country formed a combination to prevent a collapse of the market. Hoping that the rehabilitation of war-devastated Europe would reopen new demands, they curtailed production much below normal. The slowness in completing the peace terms and the difficulties of rejuvenating the peace time industries in Europe have so far frustrated the hopes of an improved demand for copper. The closing months of 1920 finds copper selling slightly below 15 cents per pound, this being lower than the pre-war price. Under present costs it is believed that there is not a copper mine in the State that can profitably operate with copper at the present price.

GOLD

Washington, until recent years, has been thought of principally as a gold-producing State. This output up to 1919 totals in round numbers $28,000,000 and previous to 1915, gold easily outranked all other metals. Since that date, however, gold production has been rapidly declining until 1918 finds it outranked by copper, lead, and silver. The gold crisis that at present confronts mining of gold the world over, has been one of the major factors to curtail the yield; this slump has been aided by the fact that the richer free-milling surface ores have been mined out and mining operations must now be carried deeper where the ores are not always as rich and are often of a refractory nature which discourages ordinary concentration practice.

The Republic District is easily the premier gold camp of the State, and gold production reached its apex during 1911 when this district was producing on an intensive

scale. Any future extensive advancement of gold production from this area appears to be contingent upon the solving of certain metallurgical problems that will make the large tonnage of low-grade Republic ores of commercial value. When production costs reach a normal level, there is every reason to believe that such a project may be successfully worked out.

Other gold producing districts are the Orient, Oroville-Nighthawk, Blewett, Monte Cristo, and Mount Baker areas; a number of properties in these districts will renew operations as soon as relief is offered for the present gold situation. This condition of high mining costs and low market price for gold, which has paralyzed the gold mining industry, is too well known to warrant elaboration.

The present output comes largely from the shipments of siliceous gold ores from the Republic district to smelters where low treatment costs are granted on account of the utility of the ores as a siliceous flux. The copper and silver ores from other camps invariably carry small quantities of gold, which factor assists in raising the production of the State.

A gold dredge was recently put in operation on the gold-bearing gravels of the Swauk and tributary streams in the vicinity of Liberty, Kittitas County. If this operation proves successful it will add materially to the gold yield of the State.

GOLD PRODUCED IN WASHINGTON, BY KINDS OF ORE, IN FINE OUNCES.

YEAR	Placers	Dry or Siliceous Ore	Copper Ore	Lead Ore	Per Cent Shipped Crude	Per Cent Shipped as Conc.	Total Ounces
1913	200.47	33,323.21	158.48	.14	90	10	33,682.30
1914	278.45	26,453.86	220.93	.....	68	32	26,953.24
1915	346.36	18,277.72	308.59	2.23	90	10	18,934.90
1916	400.40	26,979.03	563.76	.87	73	27	27,944.06
1917	283.86	23,240.61	281.93	9.77	70	30	23,816.17
1918	165.93	14,107.36	463.82	.72	93	7	14,737.83
1919	.....	.....	.....	.....	.....	.....	12,232.20

The First Thought Mine in the Orient district, which was formerly a substantial producer of gold, is expected to reopen when mining costs again permit of normal operations.

An important yield of gold has been made from a number of properties in the Oroville-Nighthawk area. At the present time all the gold properties are closed down. Future development work in this area may prove the existence of low-grade ore bodies which will afford a profit under large scale operations.

The first quartz mining in the State occurred in the Blewett district, and since that time a considerable output of gold has been made. The surface-oxidized ores were free-milling but below these sulphides appeared, and gravity concentration and cyanidation were resorted to with varying degrees of success. The vein material occurs as lenticular, vein-like masses in serpentine, and these pockets, while often very rich, are separated by enough barren ground to make necessary much deadwork.

The Monte Cristo district in the western Cascades is credited with a production of $7,000,000, and at one time was the scene of mining operations on a large scale. The complexity of the gold, copper, lead, zinc, iron, arsenic, and antimony ores offers metallurgical difficulties which retard successful operation. The following is quoted from the Mining Summary Report of Fisher:[1] "Two factors have been adverse to successful operation in this district. The greater of these factors has been perhaps the formation of numerous subsidiary companies to perform the various operations involved in handling the output of the camp from the mines to the smelters. Mining companies, tramway companies, concentrating companies, and the railroad com-

[1]Fischer, A. H., "A Summary of Mining in the State of Washington." Eng. Exp. Station, University of Washington, Bulletin No. 4, p. 20. 1918.

Town of Blewett, center of Blewett Mining District.

pany all had to make a profit, with the result that instead of one fair mining profit from the operations it was necessary to make several corporations pay dividends. The ore value was not high enough to stand heavy overhead charges, and the result was the ultimate closing down of the principal mines of the camp. The railroad was later taken over by the Northern Pacific Railway Company and operated by it for a time, until the caving of some of the tunnels stopped traffic and suspended practically all activity at Monte Cristo and at other camps along the line. Within the last few years the road has been reopened under lease to a lumber company, and Monte Cristo and other districts have been given an opportunity for new development. The more important mines of the camp have been consolidated into two large groups, and several smaller properties also are undergoing development. At the present writing it seems probable that the near future will see Monte Cristo again shipping ore and concentrates."

The Boundary Red Mountain and the Lone Jack Mines are the important producing properties of the Mount Baker District. The Boundary Red Mountain Company operates a 50-ton mill employing amalgamation. The mine closed down temporarily during 1917 to await more favorable mining conditions. The Lone Jack Mine has been idle since the mill was destroyed by fire some years ago. At both mines the values are in free gold in well-defined quartz veins. Since a high recovery can be effected by amalgamation, the milling problems are comparatively simple.

IRON

For a complete description of the iron ore resources of Washington, reference should be made to Bulletin No. 2, University of Washington Bureau of Industrial Research, "An Investigation of the Iron Ore Resources of

the Northwest," by William H. Whittier, (published by the University in 1917). In this report the iron deposits of the State are divided into four principal districts.

The ore bodies of the Cle Elum district occur on the eastern slopes of the Cascade Mountains, along Cle Elum River, about 23 miles from the Northern Pacific and C. M. & St. P. Railway lines. The ores are of sedimentary origin and consist of mixtures of hematite and magnetite. Various analyses show them to average from 41 to 56 per cent iron with little or no phosphorous, sulphur or manganese. They are low in silica but high in alumina, which would make them refractory in smelting. Since no estimates have been attempted by any of the men who have examined these deposits, it is impossible to state even approximately the quantity of ore available. Its extent, however, from the description indicates that the deposits are quite extensive in superficial area.

Two bodies of magnetite ore, known as the Denny and Guye prospects, outcrop near the summit of Snoqualmie Pass, in King County. This ore is of excellent quality, but the quantity available has never been determined. The ore occurs as broad bands near the contact of grandiorite intrusive into metamorphosed sediment.

Near the town of Hamilton, in Skagit County, are located deposits of magnetite which have been mined in a limited way. In 1902 and 1903 the Pacific Steel Company used a small proportion of the Hamilton ore along with Texada ore in their blast furnaces at Irondale. This use demonstrated that an excellent pig iron of bessemer grade can be manufactured from a mixture of these two ores. The deposits are favorably situated for low mining and transportation costs; their quality is poor but the deposits are known to be quite extensive.

Deposits of limonite and hematite of good grade occur near Valley in Stevens County. The limited development work discourages any attempt to estimate the quantity available. A total of about 3,000 tons was mined 20 years ago and shipped to the Tacoma Smelter for flux. During recent years several hundred tons of the ore have been shipped to the calcining plant of the Northwest Magnesite Company at Chewelah where it is mixed with magnesite in the manufacture of ferro-magnesite.

Diamond drilling has been in progress during recent years on the Copper Key claim in the Belcher district, Ferry County. The results of the drilling have not been given out. The deposits are large, irregular-shaped lenses of high-grade magnetite largely enclosed in limestone and dolomite. The ore was evidently derived from closely associated stocks of monzonite porphyry.

The only producing iron mine in the State is the Neutral property near Chesaw, Okanogan County. This ore is a very high-grade magnetite and supplies several thousand tons annually to the Northwest Magnesite Company for use in the manufacture of ferro-magnesite. The ore body is reported to be extensive for a lenticular deposit of this type.

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LEAD

It was not until 1916 that Washington began to mine important tonnages of lead ore. The meteoric rise in production was due to the discovery of the Electric Point Mine with its large chimneys of lead ore. This ore averages six parts of cerussite to one part of galena; it carries but a small amount of silver. During 1917 the favorable lead market resulted in a year of maximum production, this was followed by a reduced output in 1918 and 1919. The mine has good ore reserves developed. It has been operating the greater part of 1920 and its yield for that year will be more than double the 1919 total.

Stevens County has supplied over 90 per cent of the lead produced in the State. During the next few years some reenforcement may be expected from the Oroville-Nighthawk, Ruby, and Conconully districts in northern Okanogan County and the Newport district in Pend Oreille County.

Lead smelter of Northport Smelting & Refining Company, at Northport.

PRODUCTION OF LEAD IN WASHINGTON.

YEAR	Average Price Per Pound (cents)	Total Pounds	Value
1913	4.4	202,487	8,909
1914	3.9	65,507	2,555
1915	4.7	295,215	13,875
1916	6.9	5,399,274	372,550
1917	8.6	9,789,687	841,913
1918	7.1	5,271,815	374,299
1919	5.3	2,146,157	113,746

MANGANESE[1]

GENERAL STATEMENT

Washington contains extensive resources of manganese ore. This fact was not appreciated until about 1917, when the high prices being paid for manganese ore brought to light deposits located in the Olympic Mountains.

The manganese-bearing lodes have been found in a belt two or three miles wide, that lies on the south and east flanks of the Olympic Mountains, and extends from a point south of Lake Quinault to the head of Dungeness River, a distance of 50 miles. Some of the better known outcrops in the Olympics are found along the north and south forks of the Skokomish River, and on Copper Creek, a tributary to the Dungeness River.

Although the belt on the Olympic slope is for the most part but 20 or 30 miles from tidewater on Hoods Canal, and about the same distance from the railroads between Puget Sound and Grays Harbor, it has not been completely explored because of the ruggedness, the thick forest, and the general lack of roads and trails in the region. The lack of transportation facilities is the strongest retarding feature in the opening up of the deposits. The lodes on the North Fork of the Skokomish River

[1]The information on the magnanese deposits of Washington has been, in part, abstracted from the notes of J. T. Pardee of the U. S. Geological Survey, and Henry Landes, Director of the Washington Geological Survey.

are more easily accessible than any others. The Triple Trip Mine can be reached by a good auto road from Hoodsport to Lake Cushman, and thence by a road recently completed, from Lake Cushman, six miles away. The railway of the Phoenix Logging Company has been carried two miles above the head of Lake Cushman, and it is planned to extend this railroad further up the river to a point beyond the mine.

Although the deposits on the South Fork of the Skokomish are but six miles in a straight line from the Triple Trip Mine, the country is so rough that they can be reached only by a circuitous route covering 20 miles or more.

Other deposits such as the Tubal Cain are located at distances varying from 10 to 20 miles from transportation, and at altitudes of 5000 to 6500 feet. To put the properties on a producing basis it will be necessary to build aerial tramways from the ridges down to the bottom of the major stream valleys, where a water-grade can be secured for highway or railway construction. Airplane transportation seems destined to eventually help solve the transportation problems over areas of such rugged topography. The greatest handicap would be the absence of a suitable landing field close to the deposits. Where mountain lakes of sufficient size are available near the deposits, hydroplanes could be used to bridge the distance between the property and Hood Canal.

GEOLOGIC RELATIONS, CHARACTER, AND EXTENT OF THE ORE BODIES

The geologic relations of all the deposits examined are similar. The lodes occur in greenstones, argillite and limestone, all of which are regionally metamorphosed rocks and are of probable Jurassic age. The greenstones, which form the bulk of the metamorphic series, are altered basic lavas. The limestone is strongly

discolored to a maroon-red with iron and manganese oxides, and is closely associated with most of the lodes. The lodes usually occur as large, lens-like masses composed mainly of an uncommon brown hydrous silicate of manganese with which is associated a red jaspery quartz, hematite, and traces of rhodonite, the common silicate of manganese.

The chief ore mineral has been identified[1] as bementite, a manganese silicate, which previously has been known only from rare occurrences. The bementite has a pale brown color, a sugary texture and breaks with an uneven fracture. In physical appearance it closely resembles quartzite and except for its weight, the freshly broken material might be mistaken for that material. Detailed chemical and microscopic analyses by Geo. Steiger and E. S. Larsen, Jr., in the laboratories of the U. S. Geological Survey have served to definitely identify the mineral. Chemical analysis of a practically pure sample gave manganese oxide (MnO) 41.58 per cent, SiO_2 39.92, FeO 4.15, MgO 4.46, CaO 0.40, $A1_2O_3$ 1.32, and water 8.39 per cent, thus giving a chemical formula (8MnO. 7SiO2. $5H_2O$.) Under the microscope the mineral appears as felted aggregates of fibres or plates associated with quartz, rhodonite, calcite and manganiferous calcite, these minerals being intergrown with the bementite and also deposited in veinlets that cut it. Near the surface the silicate minerals have been partly altered to the amorphous black oxide, which fills the fractures and joint planes and paints the rock faces a showy black color.

The Tubal Cain deposit is on Copper Creek, a tributary to the Dungeness River, and is best reached by 25 miles of road and trail from the town of Quilcene. The

[1] J. T. Pardee, E. S. Larsen, Jr., and Geo. Steiger, "Bementite and Neotocite from Western Washington;" Journal of the Washington Academy of Sciences, Vol. II, No. 2, January 19, 1921.

ore body is above timber line, the outcrops attaining a maximum elevation of 6,300 feet, so that the exposures are exceptionally good. The lenses of bementite are developed in a red limestone, and they form practically a continuous lode at least 1,500 feet long and six feet in average width. The natural cross-sections show that the lode persists to a depth of at least 500 feet. It is conservatively estimated that this body contains 450,000 tons of ore. Near the manganese lode is a bed of shale carrying impregnations of copper minerals. This copper was the object of considerable mining development work on the Tubal Cain property and it was not until recent years that the true nature of the manganese was appreciated. The property is well equipped with mining and power machinery and has camp buildings suitable for the accommodations of 35 men.

At the Triple Trip Mine the manganese occurs as a vein-like deposit averaging 24 to 30 inches in width and is exposed for a length of 500 feet. The strike of the deposit is S 60° W and the dip nearly vertical. The ore is closely associated with altered lava and a reddish iron-stained belt of limestone. The ore is chiefly the brown silicate, which near the surface is partly converted to the black oxide of the metal. The claim of Mr. MacKean which adjoins the Triple Trip Mine, contains a body at least six feet wide and 40 feet long.

The Apex Mine, now under lease to the Mt. Elinor Manganese Mining Company of Seattle, is a mile farther up the creek which flows by the Triple Trip deposit, and at an increased elevation of 1,500 feet. At the Apex the creek cuts into the deposit and exposes manganese on both walls of the gulch. The commercial ore has an average width of 15 feet, is exposed by open cuts for a length of 200 feet, and undoubtedly extends farther. The ore body is flanked on one side by an andesitic flow now altered to a greenstone and heavily stained with

manganese oxide. On the opposite side the ore merges into a 15-foot belt of low-grade manganese which averages 7 to 15 per cent metallic manganese; this gives way to a narrow band of hematite which in turn merges into a narrow band of red limestone. Near the surface the brown silicate of manganese is well masked with coatings of black oxide. The average tenor of the ore varies from 30 to 35 per cent metallic manganese, but by careful handsorting it should be possible to raise the grade considerably.

The ore bodies of the North Fork are not yet sufficiently exposed by workings to warrant estimates of tonnage, except that it can be said that the natural exposures are large and may perhaps be measured in hundreds of thousands of tons.

OTHER OCCURRENCES OF MANGANESE ORE

During the war several carloads of manganese ore were shipped from a deposit situated a short distance north of the town of Omak, Okanogan County. The following analysis of the ore was furnished by C. M. Anderson, 426 Epler Block, Seattle: Iron, 4.8 per cent; silica, 4.8; MnO_2, 78.21; phosphorous, 0.063; lime, 0.82; trace of arsenic and sulphur.

Deposits of manganese are known to occur near the town of Humptulips in west-central Grays Harbor County. No important shipments have yet been made from this section and little is known concerning the extent or grade of the ore.

During the war several carload shipments of manganese ore were made from a deposit situated on Pogue Flats, four miles by wagon road northeast of Omak, Okanogan County. Jenkins [1] states that the ore is associated with a quartz vein in granite. The upper horizon

[1]Jenkins, Olaf P., "Two Manganese Deposits in Northern Washington." Eng. & Min. Journal, vol. 105, p. 1082, June 1918.

of the deposit is weathered and the manganese is in the oxide state. The deposit is explored by a 60-foot shaft from which the shipments have been made. A sample of the ore yielded the following analysis: Iron 4.8 per cent, silica 4.8, MnO_2 78.21 per cent, phosphorous 0.063, lime 0.82, trace of arsenic and sulphur.

Manganese occurs in a quartz vein enclosed in granite at the St. Paul claim in the Nespelem District, 40 miles southeast of Omak. The manganese occurs principally as the mineral rhodochrosite (carbonate of manganese) but near the surface this has been altered to the oxide. No shipments are reported from this property; it is 30 to 40 miles from the railroad but only three miles from water transportation on Columbia River.

TREATMENT OF ORES

The metal manganese resembles iron in many particulars but is more difficult to reduce from its ores. When the reduction is effected in the blast furnace with iron ore to furnish enough iron to collect and alloy with the manganese, some 2.5 or 3 tons of coke are required to produce one ton of 80 per cent ferro-manganese, and about 20 per cent of the manganese is lost in the slag owing to the imperfect reduction of the ore.[1] Such an operation is very wasteful both in fuel and in the valuable manganese ore, and the electric furnace is so much more economical in both these particulars, that, under most favorable conditions, it can be used in competition with the blast-furnace method. With the large potential water-power resources of the Northwest, it seems logical that the use of electric furnace for the manufacture of ferro-manganese and other ferro-alloys will assume a position of considerable importance. The siliceous character of the Olympic manganese ores and

[1]Stansfield, Alfred, The Electric Furnace, pages 267-270; McGraw-Hill Co., 1914.

the fact that they are only of medium-grade, offers certain metallurgical problems. For their solution the utility of the electric furnace for the manufacture of silico-manganese or standard grades of ferro-manganese, naturally first asserts itself.

It appears to be only a question of time until steel plants will be erected on the Pacific Coast to supply western markets. Such plants will create a more substantial market for western manganese. The present market for ferro-manganese is largely east of the Mississippi River. The transcontinental freight costs seriously hamper competition with ferro-manganese produced in the East from the high-grade Brazilian ores, even with the low power costs in our favor.

MOLYBDENUM

GENERAL STATEMENT.

Molybdenite, the sulphide of the metal molybdenum, is generally found to be confined to granitoid rocks of the acidic type. Such rocks occur prominently over a large part of northern Washington, and it is not unusual to find in them deposits of molybdenite. The State has made no important production of molybdenite, and it is not probable that any substantial production will be made until the market offers better inducements for the development of new deposits.

Molybdenite is quite often found with the copper mineral chalcopyrite. If the copper content averages over a small per cent it renders the molybdenite valueless. Recent tests using selective flotation encourages the belief that it may be found commercially feasible to separate the chalcopyrite and molybdenite. The buyers ordinarily demand that the concentrates assay from 50 to 90 per cent MoS_2, and when treating a very low-grade ore, it is often difficult to secure a concentrate that will satisfy these specifications. Electrostatic treatment, surface and oil flotation are being used with varying de-

grees of success. For ordinary low grade ores oil flotation is the most common practice.

The chief use of molybdenite is as an alloy for the manufacture of high-speed tool steel and other special alloys. The electrical and the chemical industries have developed important but limited uses for the metal.

OCCURENCE OF MOLYBDENITE.

Andrew Starr of Tonasket owns a large deposit of low-grade molybdenite ore located on one of the spurs of Aeneas Mountain, ten miles from Tonasket, northern Okanogan County. The ore, which averages not over one per cent molybdenum, occurs along a mineralized zone through the granite country rock. This zone is 80 feet wide and of a known length of 400 feet. The molybdenite and associated small amounts of pyrite are scattered irregularly through the mineralized area. Several investigators have reported that this deposit is capable of developing a large tonnage of low-grade ore. There are 500 tons of milling ore on the dump. Apparently systematic sampling has not been done to determine the grade. Since the ore is in the sulphide form and free from harmful impurities, the concentration problems should not be difficult.

J. M. Risley of Twisp reports [1] the occurence of molybdenite about one mile south of monument No. 11 of the international boundary line and about 20 miles from Ashnola siding, a station in British Columbia on the Princeton Branch of the Great Northern Railway. The deposit is said to consist of three parallel veins from four to seven feet wide and traceable for a considerable length. Specimens submitted to the U. S. Bureau of Mines were estimated to contain one per cent MoS_2.

[1] Horton, F. W., "Molybdenite, Its Ores and Their Concentration." U. S. Bureau of Mines, III, p. 84.

The Crown Point Mine, at the head of Railroad Creek, a tributary to Lake Chelan, is well described by Horton.[1] Large and beautiful crystals of molybdenite occur in a nearly horizontal vein of quartz. The maximum thickness of the vein is three feet, as it runs back into the cliff, and at a distance of 75 to 100 feet it practically pinches out. On the whole, the quartz is remarkably free from any mineral other than molybdenite. A small mill was built on the property several years ago but was not well adapted to the ore. The property is credited with a production of 10 and 12 tons of high grade molybdenite during 1901 and 1902.

The Juno-Echo Mine near Chewelah, Stevens County, exhibits a fissure-contact quartz vein two and one-half feet in thickness and is well mineralized with molybdenite and chalcopyrite. The large percentage of chalcopyrite present renders the molybdenite of no immediate value.

On the claim of E. Schminski, north of Hellgate Rapids, San Poil District, Ferry County, there is known [2] to be a vein carrying molybdenite in possible commercial quantities.

Molybdenite associated with chalcopyrite occurs near the headwaters of Safety Harbor Creek, about 25 miles by air line from the foot of Lake Chelan.

A promising deposit of molybdenite occurs on Thunder Creek, one of the headwaters of Skagit River, Whatcom County. The railroad now being built by the city of Seattle to the dam sites on Skagit River will provide transportation for the district.

The miscellaneous occurrences in western Washington are as follows: Near Skykomish, King County, in the Devils Canyon Mine, eight miles from the station of Miller River, with chalcopyrite and bornite; in the Monte

[1] See note, p. 81.

[2] Pardee, J. T., "Geology and Mining Resources Colville Indian Reservation." U. S. Geological Survey, Bulletin No. 677, p. 108. 1918.

In the high Cascades.

Cristo district as fine flakes; near White River Glacier, on the north side of Mount Rainier; Deep Creek in the Bumping Lake District of Yakima County; Jack's Creek on the north side of Mt. Stuart. In eastern Washington molybdenite is also known to occur a few miles southwest of the New Germania Mine in Stevens County; two miles south of Nighthawk in Okanogan County; and 10 miles east of Riverside in Okanogan County.

NICKEL

No nickel is produced in Washington. The most promising prospect is the Congress Mine in the San Poil District, which is fully described by Bancroft.[1] Oxidized portions of the vein carry from 0.12 to 0.246 per cent nickel and .013 to .034 per cent cobalt and a picked specimen of sulphide ore showed 5.71 per cent nickel and 0.35 per cent cobalt.

Nickel has been reported from a locality on the Cowlitz River in Lewis County, and from a point near Sedro-Woolley, Skagit County. Some scattered, low-grade deposits of nickel occur in the serpentine area near Mount Stuart[2]. but no commercial ore has been developed.

PLATINUM

Platinum occurs sparsely distributed through basic igneous rocks such as peridotite, pyroxenite, and their metamorphic equivalent, serpentine. The gradual disintegration of these rocks yields the placer material favorable for mining operations. In the Cascade Mountains several large exposures of peridotite and serpentine occur, and it is natural that the streams draining these areas should furnish the small quantities of platinum

[1]Bancroft, Howland, "Ore Deposits of N. E. Washington." U. S. Geological Survey, Bulletin No. 550, p. 182.

[2]Smith, G. O., "Mount Stuart Folio." Geologic Atlas of the U. S. Geological Survey.

produced in the State. Negro Creek near Mt. Stuart; Mad River in Chelan County, north of Leavenworth; Similkameen River, northern Okanogan County; and the south fork of Lewis River in Clarke County are credited with a small production of platinum. Streams like Skookum Creek and Orisino Creek which drain a peridotite area in Whatcom County should be considered favorable for prospecting. Platinum occurs in the black sands along the Pacific Coast and numerous devices have been unsuccessfully tried in an effort to recover the "white metal" from the associated heavy sands.

A large portion of the platinum is secured from the refining of gold bullion, nickel, and copper. These sources represent the gleanings from immense tonnages of ore, the platinum being solely a refinery by-product.

The detection and accurate determination of platinum calls for more than ordinary skill in assaying. A number of flagrant cases have come to the attention of the Survey, where high platinum assays have been returned from samples carrying not more than a slight trace or even no platinum. The assays represent in some cases ignorance and in others malicious machinations with the intent to create a demand for further work or the opportunity to sell some freak machine for the recovery of platinum. Samples for platinum assays should be sent only to the most responsible assayers, and it is well to check one assayer against another on the same pulp sample.

In the Castle Creek District, northern Ferry County, there is standing today a treatment plant for platinum that cost $50,000 to build, yet it never recovered a dollar's worth of platinum. The black shales which supposedly carried several ounces of platinum were found, after the mill was completed, not to carry any of the metal.

QUICKSILVER

Deposits of cinnabar (mercuric sulphide) near the town of Morton, Lewis County, have been the subject of considerable mining activity at various times. The ore is low-grade, occurring in veinlets, or is sparingly distributed through a formation that is prevailingly an arkose sandstone underlain by shale. Two small exposures of an igneous rock (presumably andesite) occur in the workings.

A Johnson-McKay retort furnace was built on the property to treat the ores. The retort holds about 700 pounds of ore and the furnace has a capacity of two tons per day. The statement is made that 200 tons of ore were treated during one period of operations that yielded 75 flasks of mercury, each flask weighing 75 pounds. A body of the better-grade ore averaged 1.4 per cent mercury, but the general tenor of the ores is below this. The property has been idle for several years.

In Kittitas County cinnabar occurs at the Washington Quicksilver Mine, also the Ben Nevis Quicksilver Mining Company near Hawkins Mountain and the Big Thing Quicksilver property situated in sec. 8, T. 22 N., R. 16 E. These deposits are developed only in a limited way, and the ore exposed is of low grade. In Chelan County cinnabar is known to occur on Squaw Mountain, three miles from Wenatchee, and at a point near Orondo.

SILVER

GENERAL STATEMENT

The silver market has been subject to unusual fluctuations during the past two years, and these changes have been partly reflected in the output of the metal. Silver began to advance in price during the early days of the war and by January, 1918, it was quoted at 89 cents per ounce. Later that year the market began a meteoric climb, the apex of which was not reached until January,

1920, when silver was selling at $1.37 an ounce. India and China, because of war-time trade, gained an enormous increase of purchasing power, and this allowed them to convert their surplus into silver. The unprecedented demands from India and China helped largely to create a rising silver market. During 1920 these foreign demands suddenly subsided, and the price began dropping until late in the year silver was quoted as low as 65 cents an ounce. The domestic producers now, however, receive a minimum price of one dollar an ounce by selling the silver to the Government Mint, under a clause contained in the Pittman Act.

Ninety-seven per cent of Washington's silver is ordinarily produced in Stevens, Ferry, and Okanogan counties. The Stevens County silver comes mainly from the United Silver-Copper mine near Chewelah, and from intermittent shipments made by the smaller mines.

The gold ores of the Republic district, Ferry County, average around seven ounces of silver for each ounce of gold, but this ratio is of course variable. The ores from this district account for the major share of the silver total from that county.

Okanogan County is coming to the front as a producer of silver and further increases can be expected since a new 75-ton concentrator has been completed at the Ruby Mine near Nighthawk, and shipments of hand-sorted ore are going out from the Ruby-Conconully district. The Nespelem area is served by a small custom mill and the several small mines in this district, aided by the Arlington Mine in the Ruby-Conconully area, have during the past two years largely maintained the county's output of the metal.

THE PITTMAN ACT

The Pittman Act, passed during 1918, was originally framed to assist in stabilizing a rising silver market by selling to England at one dollar an ounce the silver lying

inert in the Treasury vaults. England used this silver to settle foreign balances, particularly with India and China. The measure has since acted to save the silver miners of the United States from heavy losses. The Act provided that 207,000,000 ounces of silver be melted up into bullion for necessary shipment abroad. This silver was principally in the form of coins and as the silver was retired, Federal Reserve Bank notes were issued in their place. As a foundation for these bank notes the Government was given the power to purchase silver from the miners of the United States at one dollar per ounce. This served to provide a fixed minimum price for domestic silver.

During 1919, with prices rising, the Pittman Act was inoperative as far as sales of silver to the Government was concerned. Early in 1920 the silver decline began and it gained such momentum that by June, 1920, the price of the metal was quoted at 87 cents per ounce. The purchasing feature of the Pittman Act became effective May 17, 1920, and the close of 1920 finds the silver miners of the United States selling their metal to the Government for one dollar an ounce, while foreign producers are securing around 65 cents per ounce. The Director of the Mint has been given standing orders to buy silver at one dollar an ounce, 1,000 fine, up to an aggregate amount of 207,000,000 ounces. The act requires, however, that the silver must be the product of mines situated in the United States and of reduction works so located. A clear and unequivocal proof to that effect is required. The silver purchased will be minted into coins or placed in the Treasury as a reserve against outstanding silver certificates.

The normal production of silver in the United States averages from 50 to 70 million ounces annually. Basing an estimate on the silver production for 1919 and 1920 it

becomes evident that it will take four years at least to complete the purchases of silver provided for in the Act.

SILVER PRODUCED IN WASHINGTON, BY KINDS OF ORE, IN FINE OUNCES.

YEAR	Placers	Dry or Siliceous Ore	Copper Ore	Lead Ore	Total Ounces	Total Value
1913	69	186,696	140,214	4,200	331,239	$200,068
1914	83	168,499 a	90,574	5,705	264,861	146,468
1915	94	150,633 b	95,766	9,344	255,837	129,709
1916	104	154,546 c	172,404	8,067	335,121	220,510
1917	86	120,510 d	154,747	6,977	282,320	232,632
1918	45	156,772 e	149,858	3,418	310,093	310,093
1919	.....	.....	.....	.....	259,384	290,051

(a) Includes 143,919 oz. from gold ore and 24,580 oz. from silver ore.
(b) Includes 98,811 oz. from gold ore and 50,822 oz. from silver ore.
(c) Includes 133,482 oz. from gold ore and 21,064 oz. from silver ore.
(d) Includes 100,158 oz. from gold ore and 20,352 oz. from silver ore.
(e) Includes 103,322 oz. from gold ore and 53,450 oz. from silver ore.

TUNGSTEN

Like molybdenum, ores of tungsten are invaliably derived from granitoid rocks. The tungsten deposits of Washington occur chiefly in northeastern Washington, and in all instances are closely allied to granite rocks.

The New Germania Mine in the Deer Trail District of Stevens County has been the premier tungsten producer of the State. The tungsten ores of wolframite, scheelite, and secondary ferritugstite occur in a two-foot quartz vein cutting granite.[2] Fluorite, tourmaline, galenobismutite, and pyrite form the chief associated vein minerals.

Tungsten minerals average about five per cent of the vein filling. The vein is exposed for 400 feet along its strike and 200 feet along its downward continuation. A small mill was built on the property during 1909, and at intervals over a period of several years concentrates, averaging 65 per cent WO_3 and totalling several hundred tons, were shipped. The property was owned by German capitalists, and the concentrates were shipped to that country. The mine is now held by the Alien Property Custodian. Under a reasonably encouraging domestic

[2]U. S. Geological Survey Bulletin No. 550, p. 121.

tungsten market, it can be expected to resume as a producer.

On one of the branches of Sand Creek, in sec. 3, T. 28 N., R. 37 E., Stevens County, a small tungsten deposit was worked in a limited way during the war; and during 1917 several small shipments of sorted ore were made.

On Blue Grouse Mountain, 10 miles north of Deer Park, Stevens County, is located the Tungsten King Group. The mineral hubnerite, associated with the bismuth mineral, cosalite, and with pyrite, are found in several well-defined quartz veins of fine-grained pegmatite dikes. A small mill was built to treat the ores, but the mine has been idle for several years. Not enough development work has been done to determine the future of the property.

During 1915 some wolframite deposits on Tungsten Peak, near Cathedral Peak, 45 miles northwest of Oroville, became the property of the Tungsten Mines Company, and the owners produced a small quantity of ferrotungsten in an electric furnace at Tacoma.

A quartz vein carrying coarse crystals of hubnerite is reported by Handy[1] to occur six miles south of Tonasket and a half mile west of the Okanogan River. This property is only in the prospecting stage and no definite statement can be made as to its extent or quality. In one open cut hubnerite makes up approximately five per cent of the vein filling.

The Silver Leaf scheelite deposit near the town of Covada, Ferry County, is promising but wholly undeveloped.

The Stockwell tungsten property, a prospect of some promise, occurs near the post office of Bissel, southeastern Ferry County. On this claim there is a six-inch vein of wolframite extending for a legnth of 650 feet and with

[1]Handy, F. M., "An Investigation of the Mineral Deposits of Northern Okanogan County." Bulletin No. 100, State College of Washington.

a difference of elevation from end to end of 190 feet. In Yakima County tungsten deposits have been prospected near Bumping Lake in the Cascade Mountains with promising results.

Wolframite occurs in the shaft of the Addison Copper Company near Keller, Ferry County. No effort has been made to develop the tungsten in this particular locality.

Tungsten finds its chief use as an alloy in the manufacture of special, high-grade alloy steels. The electric industry is the next largest consumer.

ZINC

The development of the Metaline District in northern Pend Oreille County and the Last Chance and Great Western mines in the Northport District of Stevens County were responsible for the favorable zinc production from 1915 to 1917 inclusive. The Metaline deposits occur as irregular replacements in limestone. The known rich ores of the district have been mined out and future production is contingent upon the finding of new ore bodies or the milling of low-grade ores. In Stevens County the Northport Mining Company has developed a considerable tonnage of milling ore, and is making tentative plans for the erection of a concentrator. The nearby Last Chance and Great Western mines have small tonnages of milling ore developed. No production can be expected from these properties until concentration facilities are installed. The discovery, early in 1920, of a deposit of zinc carbonate near Northport, Stevens County, gave the State an appreciable zinc production for the year 1920. Until August, 1920, there were shipped from this property six carloads of ore averaging 40 per cent zinc.

ZINC PRODUCTION OF WASHINGTON.

Year	*Total Pounds*	*Value*
1915	244,906	$30,368
1916	1,693,734	226,960
1917	1,195,567	121,948
1918	38,873	3,537

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NON-METALLIC MINERALS

By ERNEST N. PATTY.

INTRODUCTION

Deposits of non-metallic minerals form an important component of the mineral wealth of the State. Prospectors and other mining men should familiarize themselves with the occurrence and properties of the various occurrences, for the State has by no means been thoroughly prospected for this class of products. Many of these minerals, if found in deposits of commercial size, would yield profitable returns to the locator.

For the sake of simplicity, coal, structural, and several miscellaneous industrial materials are described under separate headings. In general the non-metals are not discussed in the order of their importance but by alphabetical arrangement.

BARITE

The mineral barite has not been mined as a commercial product in this State. The outcrop of a vein of barite is reported by Weaver[1] as occurring on the Chamokane group of claims, near the headwaters of Chamokane Creek, 15 miles west of Springdale, Stevens County. The width or exposed length of the vein is not given.

An intergrowth of barite and calcite forms the gangue for the ore minerals of the High Grade Mine[2], Deer Trail District, Stevens County.

The amount of gangue is variable from a few inches to six feet in thickness. Leading out from the ore lenses are stringers of barite varying in thickness from three to ten inches. The occurrence of barite is mentioned as a minor gangue mineral in the description of several ore

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[1]Weaver, C. E., "The Mineral Resources of Stevens County." Washington Geological Survey, Bulletin No. 20, p. 212. 1920.

[2]Patty, Ernest N., "The Metal Mines of Washington." Washington Geological Survey, Bulletin No. 23. 1921.

deposits in northeastern Washington. These occurrences are of no possible economic importance.

DIATOMACEOUS EARTH

The production of diatomaceous earth is as yet an infant industry in this State. Several large deposits of excellent grade are known to exist and since the utility of the material is becoming better known and appreciated, the belief is encouraged that the industry has a future. The principal commercial deposits are in the Squaw Creek district of southeastern Kittitas County and the Quincy district of northwestern Grant County.

Diatomaceous earth, called also infusorial earth and kieselguhr, is a highly porus and very light earthy material that resembles chalk in its physical appearance. Unlike chalk it does not effervesce when treated with hydrochloric acid; further, the purer grades of earth will float for several minutes on water. The earth has a clean, white color, but impurities of clay, organic matter, oxide stains, etc. may add discolorations.

Diatomaceous earth is made of remains of minute aquatic plants and is composed chemically of hydrous silica. The Quincy and Squaw Creek deposits of this State mark the sites of small, ancient lakes in which the diatoms flourished. Their myriad millions of silica tests accumulated on the floors of the lakes over a time sufficient for the microscopic skeletons to build up deposits 10 to 12 feet or more in thickness. These lake bed deposits are found interbedded between flows of Miocene basalt. The deposits found near Puget Sound were formed in comparatively recent lakes.

The Squaw Creek deposits are 11 miles southeast of the station of Wymer on the Northern Pacific Railway, or 18 miles from the town of Kittitas on the Chicago Milwaukee & St. Paul Railway. The best developed property is that of the Majestic Diatomaceous Earth Com-

pany, where mining is in progress on a bed of earth having an average thickness of 10 feet. The overburden, which varies in thickness from 8 to 14 feet, is stripped off with a team and scraper. The earth is hauled by auto truck to the company's pulverizing plant at Wymer. The same company also has a lease on a similar deposit one and one-half miles northeast of the principal Majestic pit, but at the present time this property is idle. The Great Western Silica Company is developing a large pit one mile west of the Majestic deposit; this material will supply a new 20-ton mill recently completed at Roza Station on the Northern Pacific Railroad.

An area of several square miles in the Squaw Creek District is underlaid with diatomaceous earth. To open new deposits in the area, test pits or auger borings will have to be resorted to in order to locate the points where the beds are of commercial thickness and the overburden is light enough to permit of economic removal. The ground squirrels in burrowing out their holes, bring up chunks of the earth when the beds are not too deeply buried, and in prospecting the work of these squirrels should be observed.

One mile west of the station of Roza, a deposit of diatomaceous earth outcrops over an area of about three acres. As exposed in the pit, the bed has an average thickness of six feet and is covered by nine feet of overburden. The Great Western Silica Company and the American-Japanese Silica Company operate on this deposit. The American-Japanese Company has a mill at Roza and the Great Western formerly operated a small mill at the deposit but have since built a larger mill at Roza and will confine future mining to their holdings on Squaw Creek.

An area of several square miles, situated 15 miles south of the town of Quincy, Grant County, is known to be underlaid by a deposit of diatomaceous earth of vary-

ing thickness and occurring at various depths below the surface. At one point a large pit has been opened and at different intervals during the past few years, several thousand tons of the material have been marketed. The thickness of the bed in this large pit averages 12 feet and it is capped by a clay and basalt overburden five feet in average thickness. The property has been idle for the past year. The earth was hauled by auto trucks to Quincy; there it is pulverized in a small mill, sacked, and shipped.

Several deposits of diatomaceous earth are known to occur in the near vicinity of Puget Sound, but their porosity and location in an area of heavy rainfall causes them to absorb and carry a very high moisture content which mitigates against their utility.

An extensive deposit of diatomaceous earth is known to occur along Nookachamps Creek just north of the town of Big Lake in west central Skagit County. The thickness of the deposit is not known; it is exposed over a large area but carries a high moisture content. It is near railroad transportation and is of excellent composition. Deposits of a similar nature occur along the Sammamish River between Woodinville and Redmond. Samples have been received at various times from numerous other deposits in the near vicinity of Puget Sound. This material was formed in lakes of comparatively recent origin.

PRODUCTION OF DIATOMACEOUS EARTH IN WASHINGTON.

Year	Short Tons	Value
1916	1,320	$10,700
1917	1,995	18,910
1918	....	Concealed[1]
1919	....	Concealed

The major tonnage of the earth shipped from Washington goes to sugar refineries where it is used as a filtering and clarifying medium. This clarifying property is given by the extreme porosity and absorptive powers of

the earth. It also finds many uses as an insulating agent against heat or cold. The microscopic size and hardness of the siliceous skeletons of the diatoms make an excellent metal-polishing agent.

The earth is generally shipped in the pulverized form. It is prepared in varying types of grinding machines; from the pulverizer a suction fan lifts the powdered earth and the air current carries it over a series of bins. The current is so adjusted that the heavier material, which obviously is the first to fall, is dropped in a large rectangular bin; the remaining material is carried over other bins and three grades are thus secured. The impalpable powder remaining in suspension in the current is led into a bag house where the air passes through cloth walls thus precipitating the fine powder. The graded material is sacked into 50-pound bags for shipment.

Mention should also be made of the occurrence of several large deposits of finely divided volcanic ash. This material has somewhat the same physical properties of diatomaceous earth and is often mistaken for it. On account of the harshness of the angular volcanic glass, it should be found superior to diatomaceous earth for use in rough scouring powders. Deposits of the ash occur at several points in the south-central section of the State. Some of the better known deposits are near Pasco; on Snipes Mountain near the town of Outlook; and several thick beds near Beverly.

DOLOMITE

The entire production of dolomite comes from the quarries of the Tulare Mining Company, five miles east of Colville, Stevens County. This company began operations in October, 1917, and has operated steadily since that time. All of the output goes to the paper mills in

[1]Production concealed because there were only two producers.

Oregon, where it is used in making bisulphide acid for cooking the wood pulp in paper manufacture.

The crude dolomite is calcined in two large rectangular kilns before shipment. The finished product averages in composition 53 per cent calcium oxide and 47 per cent magnesium oxide.

The deposit has immense reserve tonnages and the plant and camp buildings are of permanent construction and equipment. Production figures are included under limestone.

In Stevens and Pend Oreille counties there are a number of large limestone deposits carrying variable amounts of magnesium. Since calcium and magnesium carbonates are capable of replacing one another in practically all proportions, it is not surprising that there can be found in this area all gradations from practically pure limestone to true dolomite. Bulletin No. 4 of the Washington Geological Survey[1] gives the results of analyses from a number of the deposits together with other information valuable to those interested in such materials.

REFERENCES ON DOLMITE

Shedd, Solon, "Cement Materials of Washington." Washington Geological Curvey, Bulletin No. 4.

Weaver, C. E., "Mineral Resources of Stevens County." Washington Geological Survey, Bulletin No. 20.

Whitwell, G. E., and Patty, Ernest N., "Magnesite Deposits of Washington." Washington Geological Survey, Bulletin No. 25. In preparation.

FLOURSPAR

Pardee[1] briefly described a 16-inch vein of flourite that occurs near the town of Keller, southern Ferry County. "Near the northeast corner of sec. 24, T. 30 N., R. 32 E., pits expose a vein of pure flourite 16 inches in width that strikes N. 65°W., and stands vertically between walls of

[1]Shedd, Solon, "Cement Materials and Industry in the State of Washington." Geological Survey, Bulletin No. 4. 1912.

Dolomite calcining plant of the Tulare Mining Company; No. 2 Quarry is visible in extreme left of picture.

the Colville granite. Margins of the deposit show the outlines of cubical crystals, and the mass may be readily cleaved to large transparent octahedrons that show pale shades of green with zonal bands of violet." The deposit is operated by C. Fogarty, who made several small shipments during 1918.

MAGNESITE

The magnesite deposits of Washington were discovered during 1916 and they now form the determining factor in assuring our economic independence with regard to this important mineral. Previous to the opening of the war in 1914, 97 per cent of the magnesite used in this country came from Europe, principally Austria-Hungary. The Washington deposits were generally classed with dolomite, limestone, and marble, and it was not until 1916, when the demand for domestic magnesite was extremely acute that the true utility of the deposits was appreciated.

These deposits are located in Stevens county at distances varying from 5 to 15 miles from the towns of Valley and Chewelah, on a branch of the Great Northern Railway. They are of the crystalline type and occur as large replacement lenses along a narrow belt of dolomite. This dolomite trends diagonally across the county for a distance of 20 miles, the width of the belt averaging 1,000 feet. There are seven known large deposits which have a total reserve tonnage of at least seven million tons of commercial magnesite. The magnesite industry in Washington will be fully described in a report[2] soon to be published by the Survey.

[1]Pardee, T. T., "Geology and Mineral Deposits of the Colville Indian Reservation, Washington." U. S. Geological Survey, Bulletin No. 677, p. 127, 1918.

[2]Whitwell, G. E., and Patty, Ernest N., "The Magnesite Deposits of Washington." Washington Geological Survey, Bulletin No. 25.

LIST OF THE COMMERCIAL PROPERTIES

Deposit	*Controlled by*	*Remarks*
Finch	Northwest Magnesite Co.	Operating
Keystone	Northwest Magnesite Co.	Held for reserve use
Allen	American Mineral Production Co.	Operating
Moss	American Mineral Production Co.	Operating
Woodbury	American Mineral Production Co.	Held for reserve use
Red Marble	American Mineral Production Co.	Held for reserve use
Double Eagle	American Refractories Co.	Operating

Crude magnesite ($MgCO_3$) possesses but scant utility, but when the material is heated to a rather high temperature the mineral is broken down and carbon dioxide

WASHINGTON GEOLOGICAL SURVEY BULLETIN NO. 21. PLATE VIII

Calcining plant of the Northwest Magnesite Company, at Chewelah.

driven off as a gas. The residue of magnesium oxide is an inert material which possesses high refractory and numerous other properties which give it commercial value. The loss of weight occasioned by the escape of the carbon dioxide reduces the weight of the material a little more than one-half. It requires 2.2 to 2.4 tons of crude magnesite to mave one ton of either caustic-calcined magnesite or dead-burned magnesite. Dead-burned magnesite is an inert product that carries but a minor trace of carbon dioxide and it has wide and important uses as a lining for high-temperature metallurgical furnaces. Caustic-calcined magnesite retains a minor percentage of the original

carbon dioxide; this gives it the property of later taking up additional carbon dioxide from the air and also combining with water to make a plastic material widely used in the manufacture of monolithic flooring, stucco, slabs for insulating and pipe coverings. The Washington mag-

WASHINGTON GEOLOGICAL SURVEY BULLETIN NO. 21. PLATE IX

Finch Magnesite Quarry of the Northwest Magnesite Company.

nesite at present goes entirely into the manufacture of refractories. The American Mineral Production Company is building a furnace of special design for the manufacture of caustic-calcined magnesite, but at present this material is supplied principally from California.

The Northwest Magnesite Company is the largest producer of magnesite on the continent. The entire production which now comes from the Finch quarries is handled by a five-mile aerial tramway to the company's calcining plant on the railway near the town of Chewelah. This

plant has a capicity of 7,500 tons of dead-burned magnesite monthly. Plans are now being formulated to extend the tramway an additional five miles from the Finch to the Keystone deposit. This means that mining operations will also be extended to the Keystone deposit.

The American Mineral Production Company has a five-mile standard gauge railroad connecting the Allen and Moss quarries with the railroad at Valley. In the absence of a calcining plant, the company now ships daily, under special agreement, about 200 tons of crude magnesite to the calcining plant of the Northwest Magnesite Company.

The American Refractories Company calcines magnesite in four shaft kilns located near the Double Eagle quarry. The finished product is then hauled by auto trucks a distance of 13 miles to the railway at Valley.

At the present time the Stevens County area supplies the bulk of the magnesite used in the refractory trade. The magnesite market is east of the Mississippi River and the freight charge from Chewelah, Washington, to Pittsburg, Pa., is $18.40.

Practically all magnesite is calcined before shipment. The average price for dead-burned magnesite during 1919 was approximately $29.00 to $32.50 per net ton, f.o.b. cars Chewelah.

A bill framed to place a tariff on all imported magnesite passed the House of Representatives August 7, 1919. It was favorably reported without alteration to the Senate during March, 1920, but Congress adjourned without taking any action on the measure. This bill provided a duty on crushed or ground commercial ore of one-half cent per pound, calcined, dead-burned, or grain magnesite three-quarters of a cent per pound, and on magnesite bricks three-quarters of a cent per pound and 10 per cent ad valorem. The pre-war cost of Austrian magnesite de-

livered at the Atlantic seaboard was approximately $16.00 per ton. The hearings before the Congressional Committee brought out the average cost of the dead-burned magnesite at Chewelah to be $25.00 per ton; add to this a freight charge of $18.40 and it gives a differential of $27.40. In other words, it would require a duty of slightly over one cent per pound on dead-burned magnesite to balance a differential based on Austrian pre-war costs. Testimony before the Congressional Committee revealed that the labor costs in the Austrian quarries, previous to the war, varied from forty cents to $1.10 for a 12-hour day for common labor.

Practically all magnesite is calcined before shipment.

PRODUCTION OF MAGNESITE IN WASHINGTON
(Calculated to basis of Crude Magnesite)

Year	*Short Tons*	*Value*
1916	715	$5,362
1917	105,175	783,188
1918	147,528	1,050,790
1919	121,000[1]	1,650,000[2]

[1]Approximate total.
[2]Estimated.

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MAGNESIUM SULPHATE (Epsom Salts)

Previous to the war the magnesium sulphate used in this country was largely imported from Germany, where it is manufactured as a by-product of the potash industry. Since April, 1916, large quantities of natural epsom salts have been mined and shipped from two lakes on Kruger Mountain, three miles northwest of and 1,000 feet above the town of Oroville, northern Okanogan County. One

lake is in Washington and the other lies just across the international boundary in British Columbia.

The Washington deposit has been known by the names of Bitter Lake, Salts Lake, Poison Lake, and Spotted Lake. It occurs in a small oval-shaped depression near the summit of Kruger Mountain. The lake has an area of only four acres and the depth of the salt deposit (as determined by drilling) varies from 4 to 20 feet. The lake has no outlet and during the summer months evaporation removes the larger portion of the water and leaves shallow pools of brine, immediately beneath which are solid rock-like masses of epsomite. On the lake bottom there is also found a slimy mud which possesses a very pungent odor.

The deposits are excellently described by Jenkins[1] and Handy[2].

Both men trace the origin of the deposits to nearby zones of pyrite and pyrrohotite associated with belts of dolomite. The natural oxidation of the sulphides evident produced sulphuric acid solutions which, in passing over the beds of dolomite, formed magnesium sulphate which is soluble and calcium sulphate which is much less soluble. The result was that the calcium sulphate that came with it was precipitated first as a thin layer of gypsum and over this the epsomite was laid down. This is not unlike the artificial process used in the manufacture of epsom salts by treating dolomite with sulphuric acid.

In mining the material it is impracticable to get all the salts out by digging, so water is allowed to dissolve parts of the deposit and the nearly saturated solution is pumped to tanks from which it is piped to the refining plant, located on the railway one mile above Oroville.

[1]Jenkins, O. P., "Spotted Lakes of Epsomite in Washington and British Columbia." American Journal of Science, Vol. XLVI, Nov., 1918.

[2]Handy, F. M., "An Investigation of the Mineral Deposits of Northern Okanogan County." State College of Washington, Bulletin No. 100.

During the summer season the bed of epsomite, 4 to 12 feet in thickness, is mined by underground methods, the overlaying shell of epsomite and mud being supported by timbers and lagging.

At the plant the material is purified by dissolving and reprecipitating the salts from a saturated solution. The saturation point is reached by heating and evaporating and then cooling the cleared solutions. Much of the material is of such excellent grade as to require no refining and is directly prepared for shipment. The deposits are operated by Stewart and Calvert with head offices at Oroville.

MINERAL PAINTS

ASBESTOS

There is an increasing demand for the lower grade forms of asbestos. It has been found that asbestos plaster has many desirable features, chief among which are the properties of deadening sound waves and its imperviousness to heat. Asbestos pulp is now mixed with cement and magnesite and made into highly satisfactory roofing, flooring, and other building materials.

A new and rather unique use for the material is that developed recently by the Asbestomine Company, with factories at Wenatchee and Seattle. This company grinds together short-fibred amphibole and diatomaceous earth and the resultant product is the base for both a fireproof and a cold water paint which they manufacture. Some of the material has also been made up into a plaster.

The diatomaceous earth is secured from both the Quincy and Squaw Creek deposits. The amphibole comes from the company's quarry six miles southwest of Pateros and one mile from Alta Lake, Okanogan County. The amphibole occurs as massive lenses near the margins of granitic rocks and is evidently the result of magmatic segregation from the granite. In places it has been partly

altered to talc. The deposit is of large size and its position on the hillside 500 feet above the road permits cheap open-quarry mining.

At Wenatchee the material is broken to two inches in a large jaw crusher. It then is fed to a gyratary crusher making a product that will pass a one and one-half-inch ring; a bucket elevator lifts the material to a storage bin. The amphibole and diatomaceous earth are then mixed by hand in the right proportions depending upon the product desired, and fed to a Raymond pulverizer. Air lifts the finer material from the Raymond mill and it is then fed by gravity into a 15 by 2½-foot tube mill where the final grinding is performed. The mill has an approximate capacity of 50 tons per 24 hours.

GRAPHITE

A deposit of graphite is reported to occur five miles from Morton, Lewis County. This is probably a bed of carbonaceous material that has been highly graphitized by metamorphic reactions. Samples submitted were of good grade and should be of use as a good preservative paint or as foundry facings.

Throughout the State there are a number of beds of graphitic shales and schists, which are smooth (free from sand) and should make a good body for ordinary mineral paints. For example, in northern Stevens County near the town of Boundary, as well as along the western foothills of the Cascades, deposits of graphitic schists are found with free graphite so well developed that it readily blackens the hands.

IRON OXIDES

Deposits of iron oxide in the forms of hematite and limonite are found at various localities in the State. The Kulzer Iron Mine, located three miles southeast of Valley, Stevens County, is a deposit of limonite, the limits of which have not been defined. Small tonnages of the ore

have been mined for various uses and at one time a small paint factory was built at Valley to utilize this ore, but the venture was not successful from a commercial standpoint.

Near the town of Yelm, Thurston County, in secs. 4 and 6, T. 17 N., R. 1 E., a considerable deposit of limonite occurs. The horizontal extent is undetermined, but the thickness varies from two to six feet. This material has the following composition:

SiO_2	14.90
Fe_2O_3	54.05
Al_2O_3	7.25
Organic	2.80
Moisture	18.20

A small plant consisting of rolls, screens, and roasting furnace was built on the property, but was found not suitable for fine-grinding the ore for paint.

The Marshall Paint Company of Eatonville and Tacoma reported a production during 1913, 1914 and 1915, but no data are available as to its present output.

CLAY AND SHALE

Many deposits of clay and shale suitable for making mineral paint or for forming paint filler and adulterant are located in the State. Of the first class are great beds of clay near Tekoa in Whitman County, near Clayton in Stevens County, and at Clay City in Pierce County. These are on the order of ochres and are fine-grained clays generally very low in sand and high in iron oxide. Many of the white or light-colored clays of eastern Washington, with suitable treatment, could be used as paint fillers and so, also, could some of the shales of the State.

MINERAL WATERS

Under this heading are included a considerable variety of waters, some containing a very small amount of dissolved mineral matter and others with a large per-

centage. Not all waters containing dissolved mineral impurities are called mineral waters, however, as it is not uncommon for city water supplies to show a higher content of such material than many of the bottled waters. That supplied in medicinal baths and for general distribution and drinking is not included in figures on the subject but only such waters as are bottled in practically their natural state and then sold.

Washington is well supplied with mineral springs and lakes but only a very few of these have ever been put to commercial uses. They are of many different types, some being warm or moderately hot, but the majority are not noticeably heated. As to the mineral content there is great diversity, as the various springs have come into contact with a great variety of more or less soluble substances before issuing from the surface of the ground. Probably the springs that are most familiar to the general public are those in the Mount Rainier National Park at Longmire Springs, where different types of highly mineralized water, both warm and cold, issue freely from the ground.

In 1918 only one company reported a production of mineral water and so the output is necessarily concealed; in 1917 there were four producing concerns, and six companies reported during 1913 and 1914. The counties from which water has been marketed are: Clallam, Grant, King, Klickitat, Skamania, Thurston, and Yakima.

The producers operating during recent years were:

Diamond Mineral Spring, Auburn, King County.

Klickitat Spring, Klickitat, Klickitat County.

Olympia Hygiene Spring, Tumwater, Thurston County.

Solduc Hot Springs, Solduc, Clallam County.

Yakima Artesian Mineral Spring, North Yakima, Yakima County.

Ahtanum Soda Springs, near Tampico, Yakima County.

In addition to these, two companies have exploited the medicinal properties of water for bathing purposes. They are: Soap Lake Mineral Water Company, Soap Lake, Grant County; Scenic Hot Springs, Scenic, King County.

The relatively small output of mineral water in Washington is due largely to the excellence of the regular water supplies of the cities and towns.

PRODUCTION OF MINERAL WATERS, 1912-1918.

YEAR	No. of Commercial Springs	Quantity Sold (gallons)	Average Price per Gallon (cents)	Value of Medicinal Waters	Value of Table Waters	Total Value
1912	5	156,171	11	$8,008	$9,534	$17,542
1913	6	150,498	13	9,175	9,659	18,834
1914	6	180,787	16	19,062	9,715	28,777
1915	5	158,865	7	6,150	5,553	11,703
1916	4	151,528	6	1,821	7,655	9,476
1917	4	155,265	5	540	6,725	7,265
1918	1	(a)	(a)	(a)	(a)	(a)

(a) Output concealed.

REFERENCES ON MINERAL WATERS

The Mineral Resources of Washington: Landes, Washington Geological Survey, Bulletin 11, 1914.

Mineral Resources of the United States: U. S. Geological Survey, (published annually).

SILICA (Quartz)

A deposit totalling several million tons of practically pure quartz occurs in sec. 14, T. 27 N., R. 42 E., 12 miles north of Spokane and six miles by road from a branch of the Great Northern Railway. The resistance of the quartz to weathering and erosion has caused the deposit to appear as a mound-shaped mass, 650 feet in diameter and standing 200 feet or more above the level of the valley floor. The deposit is clearly of pegmatitic origin and represents a siliceous segregation from the surrounding Loon Lake granite. This segregation was so complete

that the quartz is remarkably free from iron or other impurities.

The deposit is owned by James Howell of Coulee City and is held under lease by J. M. McCartney and C. Harvey Smith, P.O. Box 615, Spokane. It is worked in a small way intermittently, but as yet no important market has been created for the product. Most of the material so far mined has gone into the manufacture of silica brick. The more extensive utilization of the water power resources of the state may create a demand for pure silica for use in the manufacture of ferro-silicon in the electric furnace.

No high-grade glass sands have so far been discovered in the northwest; this quartz could be utilized in glass making, but the costs of grinding and screening would make a high-grade sand more desirable, providing, of course, that such a deposit will be discovered. Quartz is often used as an abrasive and as a foundry flux.

There are a number of large pegmatite dikes in northern Spokane County, which offer a supply of siliceous material for uses where a high degree of purity is not a prerequisite.

The beds of quartzite occurring on both flanks of the Cascade Range and in northeastern Washington form potential sources of supply for siliceous material of varying grades of purity. On McClellan Pass Highway, east of Enumclaw, King County, the Denny-Renton Company of Seattle is mining a quartzite material for use in the manufacture of silica brick.

On the Siegmund ranch, one mile north of the Far West Clay plant at Clay City, Pierce County, there is a vein of practically pure quartz. This is 25 feet wide and traceable for a length of several hundred yards. The deposit has been prospected for gold, and high assays have been reported, but the vein as a whole apparently

only averages a trace of gold. It may, however, find utility for use in the manufacture of silica brick or some other allied use. The deposit is essentially white vein quartz, minor fractions of which are colored to rose quartz.

SODIUM SULPHATE

A deposit of sodium sulphate occurs in Grant County, in secs. 15 and 16, T. 17 N., R. 28 E., 12 miles west of Warden, a station on the Chicago, Milwaukee & St. Paul Railway. Paul Donaldson of Ephrata, who is interested in the property, advised[1] that the deposit occurs over an area of approximately nine acres and varies in thickness from a few inches up to 12 feet. Several thousand tons of this material have been marketed at various times.

STRONTIUM

A deposit of strontianite (strontium carbonate) and celestite (strontium sulphate) occurs near the town of LaConner, Skagit County. An annual production of 100 to 200 tons was maintained from the property for several years. The material was sent to both eastern and western markets for use in the manufacture of fireworks. The property has been idle since 1918 and further development work will be necessary before any new production can be made.

TALC AND SOAPSTONE

Talc, often called soapstone or steatite, is a hydrous magnesium silicate ($H_2O.3Mg.4SiO_2$). Commercially, the higher grades are called talc and the lower soapstone.

The Western Talc Company, with head offices at Everett, is operating a small talc mine nine miles north of Mondovi, Lincoln County. Work started during 1917; later, a small mill was built and shipments have been made intermittently. The deposits are found along shear

[1]Personal communication.

zones through dolomite. A chemical analysis gives the following composition:

Moisture and ignition	6.17
Silica	46.02
Alumina	11.13
Lime	.66
Iron oxide	.43
Magnesia	35.68

The talcose material is handled to the mill by a surface tram. A Sturtevant rotary crusher first breaks the material to pass a ¾-inch ring. It is then ground to minus 200 mesh by two Raymond pulverizers. A Raymond separator, operating on the principle of air flotation, separates the talc from the grit and other impurities. The talc powder is put into 100-pound sacks and hauled to the railroad by auto trucks. The entire output goes to paper mills, where it is used as a filler.

Talc deposits are located near Marblemount, in Skagit County, but their development has been retarded by poor and costly transportation. New development will be encouraged by the railroad now being constructed by the city of Seattle to its power sites on the Skagit River.

STRUCTURAL AND MISCELLANEOUS INDUSTRIAL MATERIALS.

By Shelden L. Glover and Ernest N. Patty.

THE CEMENT INDUSTRY

CONDITION OF THE INDUSTRY DURING THE PAST FIVE YEARS

There are five large Portland cement plants operating in Washington, and their output totals in value between two and three million dollars annually. The local material supplies a large portion of the markets of Washington, Oregon, Idaho, Montana, British Columbia, and Alaska.

The years of 1913 and 1914 were the banner periods to date for the local cement industry. The year of 1915 showed a decrease of practically 30 per cent under the figures for the previous year. This was due to the readjustments from a period of over-production and the lessening demands occasioned by the partial curtailment of construction work. The tenor of the market during 1916 was more satisfactory because the revival of construction work for the manufacturing and shipping industries created a healthy market.

The cement industry, in common with most manufacturing enterprises, faced unusual conditions during 1917. During the first half of the year, the demands for cement were good but with the entrance of the United States into the war, there came the adverse factors of war-time industrial conditions. Ordinary construction operations were closely curtailed. The necessary railroad embargoes were far reaching; they affected supplies of fuel, mill machinery, and raw materials. These conditions existed also through 1918 with the shortage of labor growing more acute. The extensive shipbuilding industry that was so quickly built up along the Pacific Coast, opened a market for cement that prevented sales from dropping well below subnormal level. The average price per barrel at the

General view of plant of the Lehigh Portland Cement Company, at Metaline Falls.

plants averaged $1.89 during 1918, this being the highest figure reached since the beginning of the industry in this section.

Conditions slightly improved during 1919 and the price of cement attained an average price of $2.04 per barrel. The demands were limited by the extremely high costs for all building material which held construction work to a minimum. Late in 1920 conditions appeared more optimistic. There is now in progress a partial renewal of general construction work and the reinauguration of postponed hard-surface road building.

DEVELOPMENT OF THE INDUSTRY

The first step in Washington toward the making of cement was taken in 1904, when in Pend Oreille County (then a part of Stevens County) a small plant for the manufacture of natural hydraulic cement was established and run a short time. It was the intention of the owners to later construct a Portland cement plant, but this plan failed.

The first Portland cement made in the State was by the Washington Portland Cement Company at Concrete, Skagit County, May, 1907. This plant is located at the confluence of the Skagit and Baker rivers. Clay is secured one-quarter of a mile from the plant and a tramway connects the plant with large limestone quarries situated a mile up Baker River. The plant uses the dry process and has a maximum capacity of 2,500 barrels per 24 hours.

The Superior Portland Cement Company, located just across Baker River to the west of the Washington Company's plant, was the second plant constructed in the state. Like its neighbor it secures the necessary limestone and clay near the plant and this is handled over a narrow gauge railroad. The plant first used the dry system of cement manufacture, but during 1917 it was remodeled and the more modern wet process was adopted.

It was during April, 1911, that the plant of the Inland Portland Cement Company was completed at Metaline Falls in the northeastern corner of the State. Since the construction also involved the development of a power project of 2,500 horsepower, the actual operations were not inaugurated until August, 1911. Limestone is secured from a large deposit located about 1,500 feet above and three-quarters of a mile west of the plant, while the shale comes from a deposit on Sullivan Creek, one-half mile distant. The material from both quarries is won by steam-shovel mining and is then transported to the plant over aerial tramways. A portion of the shales, needed to secure the desired composition of the "mix," is mined from a deposit near the mouth of Sand Creek, four miles south of Metaline Falls. The total cost of the limestone delivered to the plant averages 65 cents per ton; the shales, 75 cens per ton. The plant operates under the dry process. The two rotary kilns have a combined capacity of 1,800 barrels per 24 hours. During 1914 the name of the concern was changed to the Lehigh Portland Cement Company.

The plant of the International Portland Cement Company, which is located at Irvin, nine miles east of Spokane, manufactured its first cement during July, 1913. The limestone and shales are obtained from near Lake Pend Oreille, Idaho, about 50 miles from the plant. The normal capacity of the two rotary kilns is 1,600 barrels per 24 hours. For a period during 1918 the plant was used to calcine magnesite from the deposits of the American Mineral Production Company near Valley.

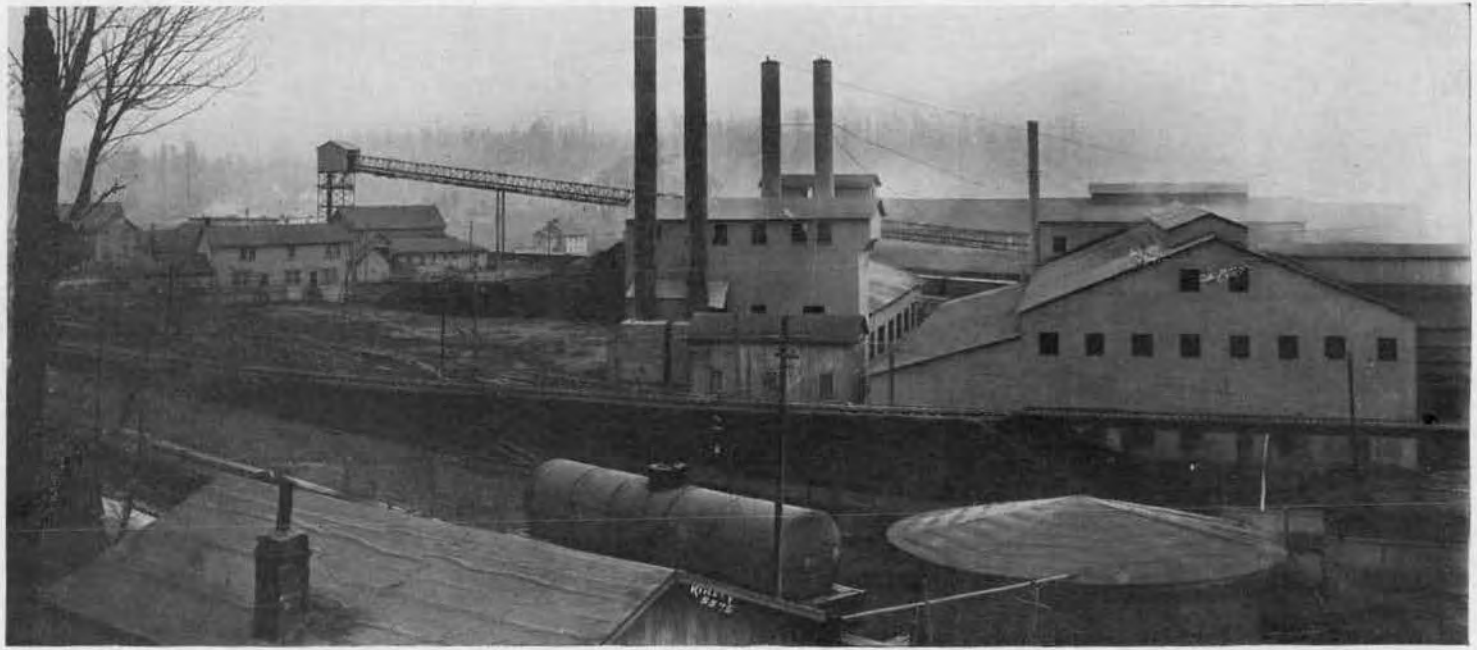
The first company in Washington to use the wet process in the manufacture of Portland cement was the Olympic Portland Cement Company, Ltd., at Bellingham, which began operations during 1912. Limestone is secured 35 miles from Bellingham and clay five miles distant. The

plant normally operates two rotary kilns, giving a capacity of 2,000 barrels each 24 hours.

The cement manufacturers have made excellent progress in the utilization of powdered coal for firing their rotary kilns. Previously, crude oil was the staple fuel, but at the present time the Bellingham plant is the only one using fuel oil. The two plants at Concrete used oil up until 1917 when the shortage of this fuel caused them to install equipment for preparing and firing pulverized coal.

Clays and shales suitable for the manufacture of Portland cement occur widely distributed over the State. It is only occasionally that deposits of suitable limestone occur in close proximity to these shales. Such favorable conditions, however, do exist at a number of localities, and where the added feature of cheap transportation is also present, the deposits have a potential value for the future. The growth of the cement industry is necessarily contingent upon the growth of the markets. The Northwest furnishes the market for the local cement industry, and since under normal conditions a steady growth can be expected over this area, a healthy, gradual increase seems to be the logical prediction for the cement industry of Washington. One of the promising markets for cement is for hard surfacing streets and highways.

For a very complete description of the deposits of cement material throughout the State, with analyses showing their chemical composition, the reader is referred to Bulletin No. 4 of the Washington Geological Survey, by Solon Shedd.



General view of plant of the Washington Portland Cement Company, at Concrete.

PORTLAND CEMENT PRODUCED AND SHIPPED, STATE OF WASHINGTON, 1912-1918.

YEAR	SHIPMENTS		Average Factory Price (Bbl.)	Total Production	Stock on Hand Dec. 31
	Quantity (barrels)	Value			
1912.....	1,362,416	.....	.....	1,438,137	.....
1913.....	2,023,172	$2,853,260	1.41	2,339,202	.....
1914.....	2,045,465	2,303,433	1.13	2,017,344	.....
1915.....	1,378,107	1,790,499	1.31	1,496,216	480,534
1916.....	1,575,919	2,245,027	1.44	1,369,485	272,913
1917.....	1,468,191	2,367,045	1.69	1,513,792	385,707
1918.....	1,116,754	2,114,730	1.89	931,489	214,220
(a) 1919.....	1,402,616	2,868,599	2.04	1,393,907	.....

(a) Figures subject to revision.

LIST OF CEMENT PLANTS IN WASHINGTON

Operator	*Locality*	*County*
Lehigh Portland Cement Co.....	Metaline Falls	Pend Orielle
Superior Portland Cement Co.....	Concrete	Skagit
Washington Portland Cement Co.....	Concrete	Skagit
International Portland Cement Co....	Spokane	Spokane
Olympic Portland Cement Co.....	Bellingham	Whatcom

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CLAYS AND CLAY PRODUCTS

CLAYS MINED AND SOLD

The value of clays mined and sold as raw clay in this State has neer been very great, but it is steadily increasing. In 1916, 1,840 tons were sold for $6,251.00; in 1918

the amount had increased to 3,435 tons valued at $17,637.00.

The clays represented by these figures are practically all of the plastic variety, but include a small amount of hard shale. They are of the following classes in approximately the order of value as given: Buff-burning terra cotta clay, red-burning brick clay, and fire clay. The terra cotta clay is almost entirely from Stevens and Spokane counties, and, for the most part, is used by plants located in the near vicinity of the pits. The brick clay listed is from King and Stevens counties. It includes a clay that has been used as a slip clay, but now finds its chief use in smelting operations, and other clay that is used in various commercial lines not allied with the ceramic industry. The fire clay is from Spokane, Pierce and Whatcom counties.

Many excellent deposits of clay are only awaiting a market in order to be developed. Medium-grade whiteware clay, fire clay, stoneware and pottery clay, and all types of red-burning clays are widely distributed over the State. The greatest markets center are on Puget Sound and at Spokane, and, frequently, these points are most abundantly supplied with raw clays, so conditions should soon become favorable for the production of a much greater tonnage.

In the case of common structural and sanitary ware, such as brick, tile, and sewer pipe, the manufacturer, in almost all instances, owns and operates his clay pit, but the maker of terra cotta, pottery and whiteware more advantageously contracts for his clay from other parties. So, with an increasing demand for the higher grade products in the West, will come a like increase in the quantity of raw clay sold.

CLAY PRODUCTS

Clay products valued at well over a million dollars were manufactured in 1918. The following list gives the general types in order of relative value:

1. Common brick
2. Sewer pipe
3. Fire brick
4. Paving brick
5. Fire proofing
6. Terra cotta
7. Front brick
8. Drain tile
9. Miscellaneous
10. Pottery

The price per thousand of common brick was high in 1907; it dropped in later years, but advanced again until in 1918 it reached the maximum figure of which we have record, at least higher than at any time since 1905. On the other hand the decline in quantity of common brick manufactured has been practically steady since 1910. The value of total output reached its low ebb in 1915, having been at its maximum in 1909; it recovered somewhat in 1916 and 1917 but was again dropping in 1918.

Owing to the fact that less than three plants are making vitrified brick, figures relative to that branch of the industry are not given in detail. The price per thousand, however, was at its peak in 1918, but the total value of the marketed product was well below the high mark of 1913.

Front brick had been dropping in price since 1908 but turned, and in 1918 reached its maximum since 1905. The total output in quantity and value has been lower in 1917 and 1918 than at any time since 1905.

Fire brick reached its highest price in 1918 having been steadily climbing. The value of total output was also at its peak in 1918, but the maximum quantity credited to any one year was made in 1917.

Drain tile was higher in the value of total output during 1909 than at any time since, but was recovering in 1918. Sewer pipe has been falling irregularly since 1910,

and reached its lowest point in 1918; however, for three years it led the list in value of total output. Fireproofing, including hollow structural block, reached its peak production in 1915. In 1918 the production was lower than at any time since 1909, although the price per ton was at its maximum.

Architectural terra cotta had its greatest production in 1912, being in 1918 lower than at any time since 1907. Pottery in 1906 was of considerable value in point of total production, but later declined to a very small proportion of the clay-products valuation. The indications now, however, are that it will soon be an important factor once more.

The total production of the various products rose steadily until the year 1909 when the sum of $3,060,486 was reached, since then the decline has been steady, except for a slight recovery during 1916 and 1917, until the low mark of $1,306,763 was recorded in 1918. This is the lowest since 1905. Likewise the number of operating plants has been falling steadily. In 1909 there were listed 72 while in 1918 but 32 reported production. This has had its influence on the ranking of the State with the rest of the United States as a clay-products producer. In 1910 and 1911, it ranked eleventh, which, considering the population, was an excellent figure; it has fallen steadily until it now ranks about twenty-sixth, the lowest since 1905.

Much of this seeming adverse state of affairs is only an indication of much better times for the industry as a whole. No doubt, for the population, there were too many operating plants at one time; this condition has automatically adjusted itself, even swinging to the other extreme. Building, during the last few unsettled years, has been confined to that of absolute necessity, leaving normal expansion, investment and improvement construc-

tion untouched. The State is well and abundantly supplied with a great variety of clays suitable for most ceramic purposes. So with the return to more settled conditions of market and labor, and with the present high prices, there is no reason why all the clay-working branches should not experience a period of great prosperity. This will mean the reopening of many plants that are now ready to operate, and a normal and proper adjustment between production and market with benefit to all concerned.

VALUE OF CLAY PRODUCTS MANUFACTURED IN WASHINGTON, 1913–1918.

PRODUCT	1913	1914	1915	1916	1917	1918
Brick—						
Common—						
Quantity	47,435,000	31,657,000	43,279,000	45,163,000	43,487,000	31,164,000
Value	$475,874	$351,565	$285,423	$309,130	$367,906	$353,857
Average price per M.	$7.00	$6.81	$6.59	$6.84	$8.46	$11.35
Vitrified—						
Quantity	42,717,000	(b)	14,861,000	20,278,000	(b)	(b)
Value	$701,550	(b)	$265,691	$322,182	(b)	(b)
Average price per M.	$16.42	$18.99	$17.88	$15.94	$20.40	$25.34
Front—						
Quantity	6,122,000	5,319,000	4,246,000	4,425,000	3,565,000	2,476,000
Value	$128,989	$109,197	$67,740	$70,509	$60,404	$60,884
Average price per M.	$21.07	$20.53	$15.95	$15.93	$16.94	$24.59
Fancy—						
Value	.....	.....	.....	(b)	.....	.....
Fire—						
Quantity	.....	.....	1,569,000	4,009,000	5,146,000	4,042,000
Value	$66,178	$29,869	$45,414	$94,992	$143,696	$151,914
Average price per M.	.....	.....	$28.94	$23.69	$27.92	$37.58
Drain tile—						
Value	$28,172	$48,750	$33,558	$37,138	$30,755	$60,132
Sewerpipe—						
Value	$501,102	$462,898	$318,397	$347,288	$340,621	$309,243
Arch. terra cotta—						
Value	$316,628	$220,788	$234,377	$275,693	$190,468	$94,361
Fireproofing and hollow bldg. tile—						
Quantity (short tons)	.....	.....	.....	.....	27,352	15,678
Value	$157,039	$127,371	$192,263	$125,033	$183,812	$112,143
Average price per ton	.....	.....	.....	.....	$6.72	$7.14
Pottery—						
Value	(b)	(b)	(b)	(b)	$966	(b)
Miscellaneous—						
Value	$14,664	$459,053	$11,573	$5,357	$11,858	$14,465
Total value	$2,390,226	$1,809,491	$1,454,436	$1,589,574	$1,532,043	$1,303,763
Number of operator	45	51	43	40	33	32
Rank of State	15	18	21	22	26	.....

(a) Included in "Miscellaneous."
(b) Value of products could not be included without disclosing the operations of individual establishments.

PRODUCERS OF CLAY PRODUCTS 1919

Operator	Name of Product	Location of Works
Chelan County		
Bird & Hobson Brick Co.	Common brick	Wenatchee
Clarke County		
Carson Brothers	Common brick	Vancouver
Hidden Brick Co.	Not operating	Vancouver
King County		
Abrahamson Brick Co.	Common brick, drain tile	Seattle
Builders Brick Co.	Common brick, drain tile, hollow block	Seattle
Denny-Renton Clay & Coal Co.	Paving brick, front brick	Renton
Denny-Renton Clay & Coal Co.	Front brick, drain tile, sewer pipe, hollow block, fire brick	Taylor
Denny-Renton Clay & Coal Co.	Terra cotta, fire brick, silica brick, paving brick, front brick, sewer pipe	Van Asselt
Lake Union Brick & Fireproofing Co.	Common brick, drain tile, fireproofing	Seattle
Lohse Brick Co.	Common brick	Youngstown
Northern Clay Co.	Terra cotta	Auburn
Puget Sound Brick & Tile Co.	Common brick	Seattle
Seattle Brick & Tile Co.	Common brick	Seattle
Seattle Pottery Co.	Flower pots	Riverside
Superior Brick & Tile Co.	Common brick, drain tile	Woodinville
Kitsap County		
Harper-Hill Brick & Tile	Common brick, fireproofing	Seattle
Klickitat County		
N. B. Brooks	Common brick	Goldendale
Lewis County		
Chehalis Brick & Tile Co.	Common brick, drain tile	Chehalis
Okanogan County		
Williams & Finnie Brick Co.	Fireproofing, common brick	Oroville
Pierce County		
Far West Clay Co.	Front brick, fireproofing	Clay City
Skagit County		
Knapp Brick & Tile Co.	Common brick, drain tile, fireproofing	Tiloh
Star Brick & Tile Co.	Common brick, drain tile	Bayview
Snohomish County		
Everett Brick Co.	Common brick, drain tile	Everett
Meadowdale Pottery	Flower pots	Meadowdale
Snohomish Brick & Tile Co.	Common brick, drain tile	Snohomish

PRODUCERS OF CLAY PRODUCTS 1919—Continued.

Name of Product	Operator	Location of Works
Spokane County		
American Fire Brick Co.	Front and fire brick, sewer pipe, fireproofing	Mica
Inland Empire Pottery Co.	Stoneware, earthenware, flowerpots	Hillyard
J. T. Davie Brick Co.	Common brick	Meed
Pioneer Brick Co.	Common brick	Spokane
Washington Brick, Lime & Sewer Pipe Co.	Sewerpipe, segment block	Dishman
Wash. Brick, Lime & Sewer Pipe Co.	Common brick	Freeman
Stevens County		
Chewelah Brick & Lime Co.	Common brick, drain tile	Chewelah
Wash. Brick, Lime & Sewer Pipe Co.	Front, fire & silica brick, terra cotta	Clayton
Walla Walla County		
Walla Walla Construction Co.	Common brick, fireproofing	Walla Walla
Whatcom County		
Coast Clay Co.	Not operating	Grandview
Whitman County		
Geo. Herboth	Common brick, drain tile	Uniontown
Yakima County		
Granger Brick & Tile Co.	Common brick, fireproofing	Granger

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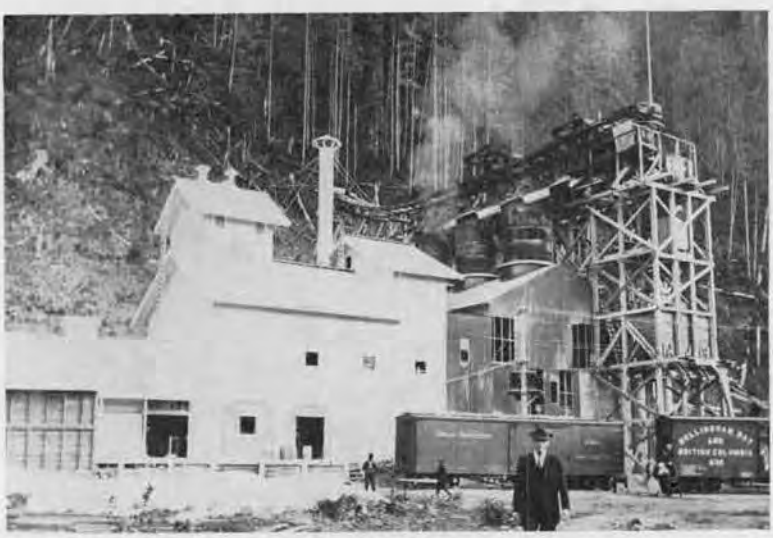
LIME

In this report lime and limestone are treated separately. Confusion can be avoided if it is remembered that figures included under lime represent limestone that is first calcined to lime (CaO) before being utilized. The figures do not include crude limestone mined and shipped for building stone, road construction, smelter flux, etc.

The major portion of the limestone mined in this State goes into the manufacture of Portland cement and since its value is recorded in the final product, the crude value is not included.

The production of lime in Washington is an industry of considerable importance. The normal market demands about 25,000 tons yearly. These are supplied

WASHINGTON GEOLOGICAL SURVEY BULLETIN NO. 21. PLATE XII



Plant of International Lime Company, at Kendall

chiefly from plants located in San Juan, Whatcom, and Stevens counties. The lime kilns in San Juan County are located on tidewater and enjoy a cheap water haul to the markets on Puget Sound. The International Lime Company is the only important producer in Whatcom County. In Stevens County the Idaho Lime Company at Evans and the Tulare Mining Company[1] at Colville are the chief producers, although there are several smaller plants that operate sporadically.

[1]See Dolomite.

BURNT LIME IN SHORT TONS.

YEAR	TOTALS		Average Price Per Ton	No. Plants Operating
	Amount	Value		
1913	28,070	178,945	$6.38	.....
1914	29,430	189,260	6.43	8
1915	27,240	171,023	6.28	8
1916	26,895	166,653	6.19	8
1917	23,328	156,553	6.71	7
1918	22,118	226,104	10.22	6

* Does not include hydrated lime.

Lime produced in this State finds its principal use in building operations, chemical works, paper mills, sugar factories, as a fertilizer, and for the spraying of orchards.

All of the plants are located in forested regions and wood is generally used as a fuel in the kilns.

The production of hydrated lime is important, but the limited number of producers causes the figures to be necessarily concealed.

LIST OF LIME KILNS NOW OR RECENTLY IN OPERATION

Operator	*Location*	*County*
Henry Cowell Lime & Cement Co.	Friday Harbor	San Juan
Henry Cowell Lime & Cement Co.	Deer Harbor	San Juan
Orcas Lime Co.	Deer Harbor	San Juan
Tacoma & Roche Harbor Lime Co.	Roche Harbor	San Juan
Idaho Lime Co.	Evans	Stevens
Tulare Mining Co.	Colville	Stevens
International Lime Co.	Kendall	Whatcom
Tulan Mining Co.	Sumas	

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SAND AND GRAVEL

GENERAL OCCURRENCE

Deposits of sand and gravel suitable for ordinary uses are found in great abundance in the northern part of Washington, where they have been left as glacial deposits. It is fortunate, also, that many of these deposits have been worked over by streams and portions of the gravel and sand transported long distances, thereby giving a wider distribution than would have otherwise been the case. With the exception of the Willapa Hills of southeastern Washington, the Palouse country of eastern Washington, and the uplands south of the Snake River, which were neither affected by glaciation or by glacial drainage, deposits of sand and gravel may be found anywhere in the State.

For more detailed information on the subject reference should be made to a report[1] recently published by the Survey. The primary object of the investigation was to judge the quality of the various deposits of sand and gravel with respect to their use as road materials. This was accomplished by observing their efficiency in actual service and by subjecting the materials to laboratory tests.

LOCATION OF PITS

The governing factors which usually prevail in opening sand and gravel pits are the quality of the material, nearness to market, and low cost of transportation. These conditions are well fulfilled along Puget Sound and, obviously, it is in that part of the State that the largest number of productive pits are found. The sands and gravels are glacial in origin, and are chiefly composed of unweathered material, which is not only hard and resistant, but very clean as well. The major portion of the

[1]Leighton, Morris M., "The Road Building Sands and Gravels of Washington." Washington Geological Survey, Bulletin No. 22. 1919.

A gravel road in Western Washington.

material used along Puget Sound is won from the many gravel terraces flanking the waterways. These terraces attain heights varying from 50 to 300 feet. The material is cheaply mined by hydraulicking. The sand and gravel is run into chutes and then passed over screens, where it is sized before dropping into bunkers or on barges. Where possible, barges are used to transport the material to markets.

When gravity cannot be employed, the sands and gravels are elevated to a convenient height and then screened and dropped into bunkers ready for shipment.

A canvass of the information on file in the offices of the various county engineers reveals the fact that there are between 150 and 200 sand and gravel pits in the State, which have been in operation during the past two years. In many instances these are local pits used for some particular piece of road construction because of their nearness to the job. It is also customary for each County to open several small pits at strategic points from which they can draw the material as desired for road and other construction work. In contrast are the pits of large gravel companies from which extensive tonnages are mined yearly. Pits of this type are always opened close to favorable transportation and large market centers.

Owing to the fact that many small pits were operated all over the State and no record kept of their output, it is impossible to secure an accurate figure for all the sand and gravel in the State.

GLASS AND MOULDING SANDS

So far as known there are no deposits of glass sands in the State. However, no thorough search has yet been made for the material. Some of the silica sands and sandstone might be ground and then used as glass sands. (See also Silica.) A glass factory is at present operating

at Anacortes but the raw materials are shipped in from outside the State.

The suitability of a sand form making glass may be determined roughly by inspecting it for the following properties: The sand should consist almost entirely of quartz, or silica (most glass sands contain from 98 to more than 99 per cent silica); it should be nearly white or easily washed white; the grains should be uniform in size, either angular or rounded, and preferably should not be larger than 20 mesh nor smaller than 80 mesh. Whiteness is not essential, however, in sand for ordinary window glass and cheap bottles and jars.

Practically all of the moulding sand used in the State is now shipped in from Illinois and adjoining States. During the war several thousand tons of moulding sand were produced in King, Spokane and Pierce counties. The present practice is believed to be largely a matter of custom. As far as is known no special effort has been made to locate or utilize deposits in this State that would be suitable for this use. It is highly probable that local sources of supply can be found.

STATISTICS OF THE PRODUCTION OF SAND AND GRAVEL, IN SHORT TONS.

YEAR	Building Sand		Paving Sand		Gravel		Engine Sand		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1913	259,270	$74,394	90,211	$39,240	665,757	$226,180	1,943	$ 825	1,020,841	$345,289
1914	141,385	57,808	318,977	82,456	836,623	238,117	*	*	1,301,771	385,886
1915	197,625	51,471	83,827	27,628	478,707	129,016	4,370	2,365	772,629	211,480
1916	449,643	102,944	*	*	816,811	234,618	*	*	1,401,237	338,337
1917	163,564	39,350	174,143	37,879	446,145	113,874	*	*	895,120	199,565
1918	49,165	42,122	251,292	96,716	434,428	177,932	*	*	908,102	332,141
1919									1,231,814	536,132

* Concealed.

Owing to the fact that many small pits were operated all over the State and no record kept of their output, it is impossible to secure an accurate figure for all the sand and gravel used in the State.

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SAND-LIME BRICK

Sand-lime brick has been produced steadily for a number of years by the Spokane Pressed Brick Company, whose plant is located at Mead, a few miles north of Spokane. The average price per thousand for common brick in 1918 has been $8.94, compared with $7.54 in 1917 and $6.43 in 1916. The average price for front brick was $11.35. As only one plant was operating in the State production figures can not be published.

In manufacturing this brick a medium fine-grained sharp sand is preferred, and one containing not over eight per cent clay if possible. Slaked lime, in quantity from five to ten per cent, is intimately mixed with the sand, and the bricks are made by the dry-press process. These are subjected for a certain time to live steam under pressure which causes the sand grains of the brick to become bonded together with a calcium hydrate and hydrous calcium silicate. The product is then ready for use and generally has the appearance of common cut sandstone.

The use of sand-lime brick is becoming more general, especially for garages and similar structures, where a light interior with lowest cost is desirable. These features, together with the strength and durability of the product, which compares favorably with common clay brick, makes it a very satisfactory building material.

STONE.

INTRODUCTION

Stone of several kinds is quarried in Washington, and the output has been quite extensive in some years. This industry, even more than many others, is very sensitive to changing conditions; when markets become low the quarries are closed instead of accumulating stocks on hand, and so production is very erratic. The resources of the State are excellent in this regard, however, so, given the demand for the various commercial stones, the market can be well supplied.

Figures in this report represent stone produced and sold or used by the quarrymen. This includes rough stone, rubble, and rip rap, but only such manufactured products as are put on the market by the quarrymen themselves. In the latter class are building and monumental stone, crushed stone, flagstone, curbstone, and paving blocks. The limestone mentioned does not include that burned into lime nor made into Portland cement, separate reports covering these topics.

The principal kinds of stone quarried, in their order of value, are: basalt, limestone, granite, sandstone, and marble. In all, these reached a value of $365,098 in 1918, this production being far below that of 1915, when a value of $1,758,817 was reported.

RANK OF WASHINGTON FROM 1912-1918, ACCORDING TO VALUE OF TOTAL STONE PRODUCTION.

YEAR	Rank Among Other States	Total Value	Percentage of U. S. Total Output	No. of Plants
1912	21	$1,174,047	1.50	32
1913	19	1,399,475	1.67	36
1914	15	1,600,615	2.07	27
1915	14	1,758,817	2.36	29
1916	26	903,635	1.14	26
1917	34	454,594	.55	26
1918	.....	365,098	.....	.....

PRODUCTION OF CRUSHED STONE IN WASHINGTON, 1912-1918, BY USES, IN SHORT TONS.

YEAR	Road Metal		Railroad Ballast		Concrete		Total	
	Quantity*	Value	Quantity*	Value	Quantity*	Value	Quantity*	Value
1912	166,926	$96,775	5,645	$2,847	40,659	$29,591	213,230	$129,213
1913	170,952	122,579	11,706	9,998	9,134	4,508	191,792	137,085
1914	162,777	87,259	20,459	12,269	24,029	20,668	207,265	120,196
1915	213,039	111,461	3,120	2,388	470	500	216,629	114,349
1916	149,452	81,380	.....	.....	5,257	3,156	154,709	84,536
1917	58,975	36,054	.....	.....	41,545	33,233	100,520	69,287
1918	29,427	29,653	†	†	26,969	23,779	56,396	53,432

* Short tons. † Figures concealed so as not to disclose the operations of individual companies.

BASALT

Basalt occurs very generally throughout Washington. The Columbia lava plains in the eastern part of the State contain over 20,000 square miles, and this great area is almost wholly basalt. Surface deposits of soil and sand conceal much of the rock, but in exposed positions along drainage channels and valley sides, it appears as black cliffs, sometimes of great height. In western Washington basalt and related rock occur commonly as surface flows over broad areas, as sills interbedded with the sedimentary rocks, and as dikes cutting through these formations. Out of the 39 counties in the State, it is doubtful if even two are not well supplied with this rock.

Basalt shows the result of the various conditions under which the different bodies cooled from the molten condition. Some are porous, even approaching pumice in appearance; these are friable and not well suited for most purposes. Others are only slightly porous and grade into types which are extremely compact and resistant to wear. They all may be quarried without much difficulty and are readily susceptible to trimming and crushing. This makes the rock available for many uses and, in fact, the dense varieties are unexcelled for road making material.

The general distribution of basalt has led to the opening of quarries in all parts of the State wherever construction work was under way. These are usually closed when the building operations have finished, but many other larger quarries with good transportation and operating facilities show a steady production from year to year. Some are operated by private concerns or individuals, but it is quite customary for the State, as well as for many counties and municipalities, to own and operate quarries.

QUARRIES RECENTLY IN OPERATION

Operator	*Location*	*County*
City of Ritzville	Ritzville	Adams
T. E. Goodenough	Ritzville	Adams
W. J. Smith	Ritzville	Adams
Columbia Contract Co.	Camas	Clarke
Clarke County	Vancouver	Clarke
Star Sand Co.	McCoffin	Cowlitz
Mohr Construction Co.	Waterville	Douglas
Riverside Quarry	Riverton	King
Independent Asphalt Paving Co.	Charleston	Kitsap
Pacific Bridge Co.	Klickitat	Klickitat
John Piril	White Salmon	Klickitat
Washington State	Meskill	Lewis
Northern Pacific Railway Co.	Veazie	Pierce
Spokane County	Spokane	Spokane
Brookfield Quarry & Towage Co.	Brookfield	Wahkiakum
Washington State	Dixie	Walla Walla
Walla Walla County	Walla Walla	Walla Walla
Yakima County	Yakima	Yakima

VALUE OF BASALT IN WASHINGTON 1912-1918

YEAR	Riprap and Rubble	Paving	Crushed Stone			Building	Total
			Road Metal	Railroad Ballast	Concrete		
1912.....	575,029	.....	71,544	2,847	18,250	158	667,828
1913.....	504,392	.....	110,969	3,998	4,428	9,128	632,915
1914.....	957,278	.....	79,727	12,269	18,468	300	1,068,042
1915.....	1,353,367	3,397	93,167	2,388	500	50	1,452,869
1916.....	680,996	*	71,210	.....	.....	.....	754,831
1917.....	258,777	*	36,054	.....	28,583	.....	328,331
1918.....	90,347	*	29,655	*	23,779	*	154,205

* Value concealed so as not to disclose individual operations.

LIMESTONE

Limestone occurs in 11 counties in Washington and in considerable abundance. It differs markedly from the great beds in other parts of the United States in that here the deposits are usually lens-shaped, being thick in their central part but thinning rapidly in lateral directions. So the tonnage of the various deposits is irregular and apt to be uncertain unless careful investigation be made.

The beds have been folded and tilted from their original position and metamorphic action has, in practically all cases, obliterated stratification and so altered the rock that it is virtually marble. There is great diversity in

the appearance and composition of different deposits. They range from pure white to nearly black and from practically pure calcium carbonate to dolomite and true magnesium carbonate or magnesite, with great variation in the content of silica and alumina. The impurities have greatly impaired the usefulness of the material for some purposes but have opened entirely new fields for a few of the deposits.

The limestones which are of economic importance are found, with one exception, in the northern counties of the State. These are Pend Oreille, Stevens, Ferry, Okanogan, Chelan, Whatcom, Skagit, Snohomish, King, and San Juan Counties, the exception being Asotin County in the extreme southeastern corner of the State. West of the Cascade Mountains the deposits are very high in calcium carbonate and well suited for burning and special purposes but are usually of small extent. In eastern Washington the limestone bodies are larger but are more often impure.

Travertine (calcareous tuffa) is a form of limestone that owes its origin to the deposition of calcium carbonate by springs whose waters have become saturated with this substance while flowing underground. It is very abundant in some parts of the United States and, when occurring in sufficient quantity, is especially valuable, due to the usual purity of such material. A few small deposits occur in Washington, and two of these have been worked at different times. In Klickitat and Pierce counties small amounts of lime have been burned, and the deposit in the latter county, near McMillan, is now being quarried for agricultural purposes and as a flux.

The chief uses of limestone in Washington is in the manufacture of lime and cement; these are mentioned under separate headings and the value of the output for these purposes is not included with that of stone. The

uses considered here are in road making, as a flux in smelter operations, as a soil sweetener and a component of fertilizers for agricultural purposes, and, what are minor uses in this State, in sugar and paper manufacture.

PRODUCERS OF LIMESTONE OPERATING AT PRESENT OR RECENTLY.

Operator	Locality	County
Bunker Hill Smelter		Pend Oreille
Metaline Lime & Stone Co.	Metaline	Pend Oreille
Henry Cowell Lime & Cement Co.	Deer Harbor	San Juan
Orcas Lime Co.	Deer Harbor	San Juan
Tacoma & Roche Harbor Lime Co.	Roche Harbor	San Juan
Idaho Lime Co.	Evans	Stevens
Northport Smelting & Refining Co.	Northport	Stevens
International Lime Co.	Sumas	Whatcom

VALUE OF LIMESTONE SOLD IN WASHINGTON, 1912-1918.

Year	Roadmaking	Flux	Agriculture	Other Uses	Tota's
1912	$2,255	$10,718		$7,397	$20,370
1913	4,630	47,107	$696	10,480	62,913
1914			1,800	8,208	10,008
1915	212	19	606	10,713	11,550
1916		14,813	5,282	10,516	30,338
1917		43,126	5,587	10,516	59,229
1918		76,741	2,052	21,199	99,992

GRANITE

Granite and associated rock occur throughout broad areas in several parts of the State. Distinctions in composition and texture are seldom made, and granodiorite, syenite, and other light-colored crystalline rocks are quarried under the same name. It is found in Spokane, Pend Oreille, Stevens, Ferry, Okanogan, Chelan, Whatcom, Skagit, Snohomish, King, and Whitman counties.

Quarries have operated extensively at Index, Halford, and Baring. In these places the rock is well situated for working, forming as it does cliffs and hills above the railroad and from which a building stone of pleasing appearance can be obtained for the Sound markets. A large

amount of rubble and riprap material for harbor and sea-wall work has also been taken from this vicinity.

Granite has been quarried near Spokane for a long time. The city is situated in an area in which true granite is abundant, so convenient quarry locations are not hard to obtain. Three quarries have been operating near Medical Lake, 16 miles southwest of Spokane; two others are located 12 miles north of the city, and a third was operated about six miles southeast of the city.

At different times granite has been quarried at several other places as, for example, at Wawawai on the Snake River in Whitman County and near Electron in Pierce County. Production from these, although suspended at the present time, can be resumed when the market conditions warrant.

GRANITE[1] QUARRIES NOW OR RECENTLY IN OPERATION

Operator	*Location*	*County*
Baring Granite Works	Baring	King
King County	Franklin, North Bend, & Snoqualmie	King
Pierce County	Electron	Pierce
Great Northern Railroad	Halford & Index	Snohomish
Index Granite Co.	Index	Snohomish
Culver and Merwin	Spokane	Spokane
General Construction Co.	Spokane	Spokane
Wash. Monumental & Cut Stone Co.	Silver Lake & Medical Lake	Spokane
J. W. Morris	Medical Lake	Spokane
Alfred Giles	Medical Lake	Spokane

Granite is used for a variety of purposes and it depends on many conditions as to which use leads in value of total production. Dressed stone, for building and monumental purposes, has had a large output; curbing and paving blocks have found a good market, and, in certain years, rubble and riprap have been produced in large amount as certain improvements were progressing.

[1]Includes true granite, granodiorite, and syenite.

VALUE OF GRANITE SOLD IN WASHINGTON, 1912-1918.

YEAR	Sold in the Rough					Dressed for		Made Into Paving Blocks	Curbing	Flgg'ing	Crushed Stone			Other	Total
	Building	Monumental	Rubble	Riprap	Other	Building	Monumental				Road Making	Railr'd Ballast	Concr'te		
1912	$583	$1,628	$13,180	.....	.....	$30,822	$10,501	$7,877	$40,596	$450	$21,776	.....	$11,188	$780	$140,581
1913	2,211	1,674	.....	$9,568	.....	29,167	9,335	20,632	51,478	.....	6,980	$6,000	.....	3,234	140,279
1914	953	2,049	.....	25,921	$1,800	13,252	8,177	617	8,488	.....	7,532	.....	2,200	1,090	72,079
1915	4,214	4,934	125,208	230	.....	86,446	6,708	3,078	10,880	.....	18,082	.....	.....	908	260,688
1916	*	*	*	*	.....	24,736	10,858	.....	*	*	*	.....	*	*	90,525
1917	.....	5,514	*	*	.....	23,703	9,626	.....	*	*	.....	.....	.....	.....	52,053
1918	.....	12,477	.....	21,167	.....	22,212	*	.....	*	*	.....	.....	.....	.....	65,293

* Value concealed so as not to show individual operations.

MARBLE

Some marble has been quarried as such during the last few years in Washington but never in sufficient quantity to be economically important. At one time there was considerable output from quarries located west of Chewelah in Stevens County, but this material was found later to be a high-grade of magnesite instead of marble, and development was started along new lines and a far more valuable product is now turned out.

There is no very good reason why marble is not quarried in this State for practically all the limestone here is of the metamorphic crystalline variety, or really marble. It occurs in Chelan, Cowlitz, Lincoln, Okanogan, Skagit, Spokane, Stevens, and Whatcom counties and doubtless exists in still others not mentioned.

The Stevens County deposits are probably the largest and, in some ways, the most promising in the State. A little development work has been done on some of these, and tests of the stone have shown it to compare favorably with marble from the eastern States.

SANDSTONE

The principal sandstone areas of the State occur throughout western Washington. There, during Tertiary time, great beds of sand were laid down in former lakes and marine embayments together with gravel and clay. This material now exists as sandstone interbedded with conglomerate and shale and forms the productive coal measures of the State. Igneous rocks on the basaltic order have been intercalated with the sedimentary material in many places, and in other parts form the chief rock of the region.

East of the Cascade Mountains is a similar although smaller area of which Cle Elum and Roslyn form a center. These sandstones and shales extend through Yakima County and north into Chelan County. Other small

areas occur in Stevens, Ferry, and Okanogan counties, but they are of little economic importance.

A few localities have been the chief source of sandstone in the State. In these a good quality of easily quarried stone is conveniently situated with regard to transportation facilities and market, and in some years the total value of the output of the several quarries has reached a large figure. In the vicinity of Wilkeson, stone has been quarried steadily for several years; at Tenino are large quarries that have been intermittently operated; and near Bellingham are quarries located on Chuckanut Bay. In addition to these, a great amount of stone for riprap was taken out at Waterman, Kitsap County, during the years 1912, 1913, and 1914.

Sandstone has been much used in construction work in the larger cities of western Washington, but is being replaced by other cheaper materials during late years. It will always be in demand for paving on the steep grades encountered in many of the cities, and the ease and low expense with which it can be quarried makes it also desirable for rubble and riprap.

QUARRIES NOW OR RECENTLY OPERATED

Operator	*Locality*	*County*
Wilkeson Sandstone Quarry Co.	Wilkeson	Pierce
Tenino Stone Co., Inc.	Tenino	Thurston
Hercules Sandstone Co.	Tenino	Thurston

VALUE OF SANDSTONE PRODUCED IN WASHINGTON, 1912-1918.

YEAR	Rough Building	Dressed Building	Paving	Rubble	Riprap	Total
1912	.....	$67,532	$40,201	$1,828	$234,915	$344,476
1913	$1,410	58,626	20,672	5,240	474,520	560,468
1914	2,372	15,674	13,213	263	418,914	450,436
1915	.....	*	*	.....	*	*
1916	*	*	*	*	*	*
1917	.....	*	.....	*	*	*
1918	.....	.....	.....	.....	.....	45,368

* Value concealed so as not to show individual operations.

SLATE

A slate deposit occurs in sec. 19, T. 31 N., R. 39 E., near Red Marble magnesite deposit in Stevens County, 13 miles by road from the railroad at Valley. The owner's name is unknown, and the property has been idle for a number of years.

The color of the slate varies from blackish-gray to dark green. Carbonaceous matter included in the original shales gives the blackish cast, while the green coloration is caused by the development of chlorite.

Slates are usually divided into two general classes as to mineral properties—clay slates and phyllites or mica slates on account of the high degree of metamorphism to which they have been subjected and also on account of the considerable mica developed.

In accordance with their uses, they are classed as roofing slates or milling slates. The prerequisite of a roofing slate is that it must have a desirable and permanent color. It should have sufficient cleavage to separate into plates a quarter of an inch or less in thickness, with smooth surfaces. The strength should be sufficient to withstand shipping and service with a small breakage loss. Milling slates are those which may be manufactured into wainscoating, flooring, switchboards, etc. They need not have the perfect cleavage required of roofing slates, but they should have sufficient strength to withstand shipment and ordinary usage. When used for switchboards, a high degree of non-conductivity or resistivity is necessary; hence, contain appreciable amounts of metallic sulphides must not be present.

The slate from this deposit should answer both uses fairly well, judging solely from its physical appearance and a few preliminary tests. Its cleavage is parallel to the bedding planes and it cleaves fairly well, although

the cleavage shows a tendency to run a little "wild," and trouble might be experienced in obtaining a perfectly smooth shingle of even thickness. While there are some cross fractures, it would not be difficult to mine blocks of such dimensions as to produce sheets two feet or more square, and in some parts of the quarry much larger plates could be secured. There is some minor local crumpling and folding and, as is true of all slate quarries, there would be a high percentage of waste. The plates lying about the quarry which had evidently been mined several years ago stand up well to the weather. They are quite flexible and seem to be low in lime, showing no reactions when treated with acids. They also exhibit the property of being fairly sonorous.

It is difficult to determine the extent of possible deposits. The surface, as a general rule, is covered with a heavy mantle of soil and underbrush. It should be possible to open up similar deposits along the prominent belt of argillite in which they occur.

POSSIBLE UTILITY

There is a limited tonnage of slate shipped into Washington each year from the eastern States. This is used principally for roofing and some other minor needs. As far as known the slate from this deposit compares favorably with the eastern slates, and if the existence of the material becomes better known and its utility assured, there is no reason why it should not supply some of the western market.

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OF THE

WASHINGTON GEOLOGICAL SURVEY

ADDRESS

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Volume 1.—Annual Report for 1901. Part 1, Creation of the State Geological Survey, and An Outline of the Geology of Washington, by Henry Landes; part 2, The Metalliferous Resources of Washington, Except Iron, by Henry Landes, William S. Thyng, D. A. Lyon and Milnor Roberts; part 3, The Non-Metalliferous Resources of Washington, Except Coal, by Henry Landes; part 4, The Iron Ores of Washington, by S. Shedd, and the Coal Deposits of Washington, by Henry Landes; part 5, The Water Resources of Washington, by H. G. Byers, C. A. Ruddy and R. E. Heine; part 6, Bibliography of the Literature Referring to the Geology of Washington, by Ralph Arnold. Out of print.

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PUBLICATIONS OF THE U. S. GEOLOGICAL SURVEY, IN COOPERATION WITH THE WASHINGTON GEOLOGICAL SURVEY.

(For copies of these publications address the Director, U. S. Geological Survey, Washington, D. C. Water-Supply papers may also be obtained, upon request, from the U. S. Geological Survey district office, 406 Federal Building, Tacoma, Washington.)

Topographic Maps of the Following Quadrangles.

Arlington, Beverly, Cedar Lake, Chehalis, Connell, Coyote Rapids, Hoquiam, Lake Crescent, Malaga, Moses Lake, Mount Vernon, Ocosta, Pasco, Port Angeles, Port Crescent, Priest Rapids, Prosser, Pysht, Quincy, Red Rock, Samish Lake, Van Zandt, Walla Walla, Wallula, Wenatchee, Wickersham, Winchester.

Summary Report.

Water-Supply Paper No. 492: Water Resources of Washington, 1878-1919. Completed for publication.

Power Reports.

Water-Supply Paper No. 253: Water Powers of the Cascade Range, Part I, Southern Washington.

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River Profiles.

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Water-Supply Paper No. 366: Profile Surveys of Snoqualmie, Sultan and Skykomish rivers.

Water-Supply Paper No. 368: Profile Surveys of Wenatchee River and tributaries.

Water-Supply Paper No. 376: Profile Surveys, Chelan and Methow basins.

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Qualitative Report.

(Principally in cooperation with State Board of Health.)

Water-Supply Paper No. 339: Quality of Surface Waters of Washington.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE, BUREAU OF SOILS, IN COOPERATION WITH THE WASHINGTON GEOLOGICAL SURVEY.

(For copies of these publications address one of the members of congress from Washington.)

Reconnoissance Soil Survey of the Eastern Part of Puget Sound Basin.

Reconnoissance Soil Survey of the Western and Southern Parts of the Puget Sound Basin.

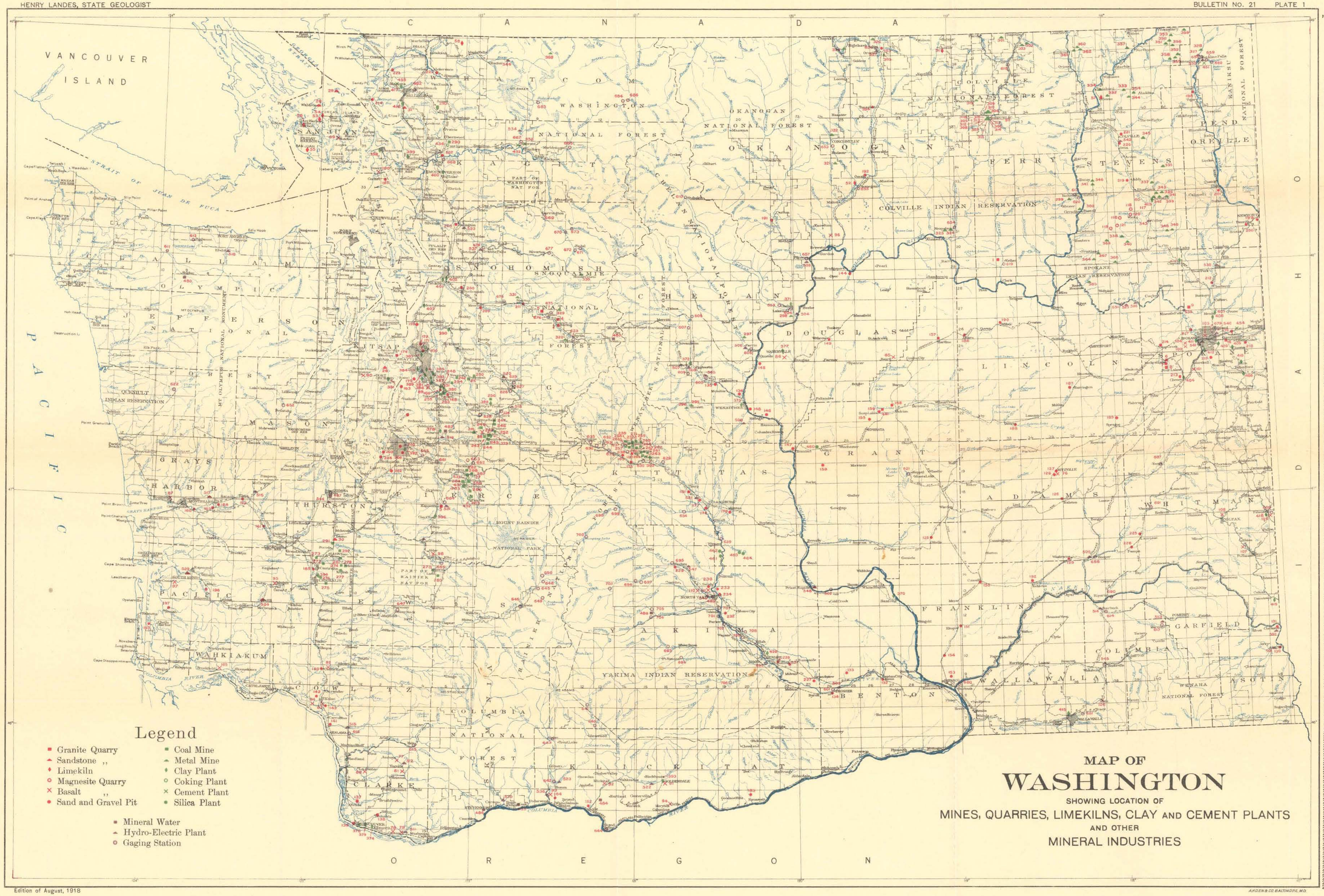
Reconnoissance Soil Survey of Southwestern Washington.

Reconnoissance Soil Survey of the Quincy Area.

Reconnoissance Soil Survey of Stevens County.

Reconnoissance Soil Survey of Franklin County.

Reconnoissance Soil Survey of Spokane County.



Edition of August, 1918

GRANITE QUARRIES

No.	OPERATOR	LOCALITY	COUNTY
1	San Poil Granite Company	Keller	Ferry
2	Baring Granite Works	Baring	King
3	Pierce County Quarry	Kapowsin	Pierce
4	Great Northern Railway Co	Index (Halford Quarry)	Snohomish
5	Index Granite Company	Index	"
6	Alfred Giles	Silver Lake	Spokane
7	Wash. Monumental & Cut Stone Co	Medical Lake	"
8	Wash. Monumental & Cut Stone Co	Silver Lake	"
9	Culver & Merwin	Spokane	"
10	Huetter Construction Co	"	"

SANDSTONE QUARRIES

No.	OPERATOR	LOCALITY	COUNTY
26	International Contract Co	Waterman	Kitsap
27	Wilkeson Sandstone Quarry Co	Wilkeson	Pierce
28	Alaska Barge Co	Waldron Island	San Juan
29	Sucia Island Quarry Co	East Sound	" "
30	Tenino Stone Co,, Inc	Tenino	Thurston
31	Chuckanut Stone Co	Bellingham	Whatcom

LIME KILNS

No.	OPERATOR	LOCALITY	COUNTY
51	John Nopp	Chesaw	Okanogan
52	Chas. Ostenberg & Son	Okanogan	"
53	Henry Cowell Lime & Cement Co	Deer Harbor	San Juan
54	Orcas Lime Co	" "	" "
55	Henry Cowell Lime & Cement Co	Friday Harbor	" "
56	Tacoma & Roche Harbor Lime Co	Roche Harbor	" "
57	Idaho Lime Co	Evans	Stevens
58	International Lime Co	Sumas	Whatcom

MAGNESITE QUARRIES

No.	OPERATOR	LOCALITY	COUNTY
60	Northwest Magnesite Co., Finch Quarry	Chewelah	Stevens
61	Northwest Magnesite Co., U.S. Marble (Keystone) Quarry	"	"
62	American Mineral Products Co., Allen Quarry	Valley	"
63	American Mineral Products Co., Moss Quarry	"	"
64	American Mineral Products Co., Red Marble Quarry	"	"
65	American Mineral Products Co., Woodbury Quarry	"	"
66	Valley Magnesite Co., Double Eagle Quarry	"	"

BASALT QUARRIES

No.	OPERATOR	LOCALITY	COUNTY
76	City of Ritzville	Ritzville	Adams
77	Clarke County Quarry	Amboy	Clarke
78	Columbia Contract Co	Camas	"
79	Karnaoth Bros. Quarry	"	"
80	Clarke County Quarry	La Center	"
81	" " "	Yacolt	"
82	Cowlitz County Quarry	Castle Rock (near)	Cowlitz
83	A. L. Secor Quarry	Kelso	"
84	Star Sand Co	Ladu	"
85	Douglas County Quarry	Baird (near)	Douglas
86	Mohr Construction Co	Waterville	"
87	City of Hoquiam	Hoquiam	Grays Harbor
88	Franklin Quarry & Construction Co	Franklin	King
89	Riverside Quarry	Riverton	"
90	Independent Asphalt Paving Co	Charleston	Kitsap
91	Klickitat County Quarry	Goldendale	Klickitat
92	Pacific Bridge Co	Klickitat	"
93	John Piril Quarry	White Salmon	"
94	Klickitat County Quarry	Maryhill	"
95	Washington State Quarry	Meskill	Lewis
96	Okanogan County Quarry	Brewster	Okanogan
97	Pacific County Quarry	South Bend	Pacific
98	J. M. Clapp Quarry	Alder	Pierce
99	" " "	Port Stanley	San Juan
100	Washington State Quarry	Fidalgo	Skagit
101	Spokane County Quarry	Marshall	Spokane
102	Garden Springs Quarry Co	Spokane	"
103	General Construction Co	"	"
104	West Road Stone Co	"	"
105	Brookfield Quarry & Towage Co	Brookfield	Wahkiakum
106	Washington State Quarry	Dixie	Walla Walla
107	Whitman County Quarry	Albion	Whitman
108	" " "	Colfax	"
109	City of Palouse	Palouse	"
110	Jensen & Peterson Quarry	Yakima	Yakima
111	Washington State Quarry	"	"

SAND AND GRAVEL PITS

No.	OPERATOR	LOCALITY	COUNTY
125	Othello Town Pit	Othello	Adams
126	Adams County Pit	Ralston	"
127	" " "	Ritzville	"
128	August Rutz	"	"
129	Washtucna Town Pit	Washtucna	"
130	Asotin Town Pit	Asotin	Asotin
131	" County Pit	Clarkston	"
132	Benton " "	Kiona	Benton
133	" " "	Prosser	"
134	John Knappland	"	"
135	Chelan County Pit	Cashmere	Chelan
136	" " "	Wenatchee	"
137	Clarke " "	Vancouver	Clarke
138	" " "	"	"
139	Minsinger Brothers & Co	"	"
140	Jarvis and Burkheimer	Castle Rock	Cowlitz
141	Nicholson and Carson	Kalama	"
142	Cowlitz County Pit	Kelso	"
143	" " "	"	"
144	Douglas " "	Bridgeport	Douglas
145	" " "	Orondo	"
146	" " "	Rock Island	"
147	" " "	Trinidad	"
148	Columbia Eng. & Constr. Co	Wenatchee	"
149	Douglas County Pit	Withrow	"
150	Connell Town Pit	Connell	Franklin
151	Franklin County Pit	Eltopia	"
152	" " "	Kahlotus	"
153	Samuel Loney	Pasco	"
154	Franklin County Pit	"	"
155	Grant County Pit	Adrian	Grant
156	Robert Ingram	Ephrata	"
157	Grant County Pit	Hartline	"
158	" " "	Quincy	"
159	G. Vandertuuk	Soap Lake	"
160	Independent Sand & Gravel Co	Aberdeen	Grays Harbor
161	Grays Harbor County Pit	Cedarville	" "
162	" " " "	Elma	" "
163	" " Constr. Co	Melbourne	" "
164	Montesano Town Pit	Montesano	" "
165	Keystone Sand & Gravel Co	Coupeville	Island
166	Valley Sand & Gravel Co	Renton	King
167	Pembroke Sand & Gravel Co	Maury Island	"
168	Lake Gravel Co	Renton	"
169	Richmond Beach Sand & Gravel Co	Richmond Beach	"
170	Central Sand & Gravel Co	Seattle	"
171	Edgewater Sand & Gravel Co	"	"
172	Greenlake Gravel Co	"	"
173	Vashon Sand & Gravel Co	Vashon Island	"
174	Parker Asphalt Paving Sand Co	Creosote	Kitsap
175	Kittitas County Pit	Cle Elum	Kittitas
176	Rovig Lumber Co	Ellensburg	"
177	Kittitas County Pit	"	"
178	M. M. Wheeler	Kittitas	"
179	Kittitas County Pit	Nelson	"
180	" " "	Roslyn	"
181	" " "	Thorp	"
182	Klickitat County Pit	Lyle	Klickitat
183	" " "	Roosevelt	"
184	White Salmon Town Pit	White Salmon	"
185	Twin City Sand & Gravel Co	Centralia	Lewis
186	Lincoln County Pit	Almira	Lincoln
187	" " "	Harrington	"
188	" " "	Odessa	"
189	" " "	Sprague	"
190	" " "	Wilbur	"
191	Okanogan County Pit	Carlton	Okanogan
192	Omak Cement Products Co	Omak	"
193	Okanogan County Pit	Oroville	"
194	" " "	Tonaskat	"
195	Nahcotta Sand & Gravel Co	Long Island	Pacific
196	Pacific County Pit	Menlo	"
197	" " "	Nemah	"
198	Pend Oreille County Pit	Ione	Pend Oreille
199	" " " "	Newport	" "
200	" " " "	Penrith	" "
201	" " " "	Usk	" "
202	Pierce County Pit	Lakeview	Pierce
203	Pioneer Sand & Gravel Co	Steilacoom	"
204	Tacoma " " " "	"	"
205	Atlas Sand & Gravel Co	Tacoma	"
206	Harrington Brothers Co	"	"
207	C. L. LaPlant Co	Sedro Woolley	Skagit
208	Snohomish County Pit	Arlington	Snohomish
209	P. J. McHugh	Monroe	"
210	Snohomish County Pit	Snohomish	"
211	" " "	Startup	"
212	Spokane County Pit	Chattaroy	Spokane
213	" " "	Cheney	"
214	" " "	Deep Creek	"
215	" " "	Moran	"
216	Hawkeye Fuel Co	Spokane	"
217	Union Sand & Gravel Co	"	"
218	Spokane County Pit	Trent	"
219	Stevens " "	Addy	Stevens
220	George Hughson	Colville	"
221	Colville Town Pit	"	"
222	Washington Contract Paving Co	Cedarville	Whatcom
223	Lind Gravel Co	Ferndale	"
224	Whidbey Island Sand & Gravel Co	Lummi Island	"
225	Whitman County Pit	LaCrosse	Whitman
226	" " "	Pampa	"
227	Yakima County Pit	Grandview	Yakima
228	" " "	Granger	"
229	Pacific Power & Light Co	Naches	"
230	Yakima County Pit	Selah	"
231	" " "	Sunnyside	"
232	" " "	Union Gap	"
233	Bowen Gravel Co	Yakima	"
234	W. J. Aumiller	"	"

COAL MINES

No.	OPERATOR	LOCALITY	COUNTY
240	Carbon Coal & Clay Co	Bayne	King
241	Pacific Coast Coal Co	Black Diamond	"
242	" " " "	Coal Creek	"
243	Hyde Coal Co	Cumberland	"
244	National Coal Co	"	"
245	Ozark Coal Co	"	"
246	Durham Colliery Co	Durham	"
247	Northwestern Improvement Co	"	"
248	Black River Coal Co	Earlington	"
249	Pacific Coast Coal Co	Franklin	"
250	Central Coal Co	Issaquah	"
251	Pacific Coast Coal Co	"	"
252	Pocahontas Coal & Coke Co	Palmer	"
253	Denny-Renton Clay & Coal Co	Renton	"
254	May Creek Coal Co	"	"
255	Pacific Coast Coal Co	"	"
256	Denny-Renton Clay & Coal Co	Taylor	"
257	Roslyn Fuel Co., No. 1	Beekman	Kittitas
258	" " " No. 2	"	"
259	" " " No. 3	"	"
260	" " " Wright Mine	"	"
261	" " " Summit Mine	Cle Elum	"
262	Independent Coal & Coke Co	"	"
263	Northwestern Improvement Co., Cle Elum Mine	"	"
264	Northwestern Improvement Co., No.7	"	"
265	Roslyn Coal & Coke Co	Ronald	"
266	Northwestern Improvement Co., No.3	Roslyn	"
267	Northwestern Improvement Co., No.5	"	"
268	Northwestern Improvement Co., No.6	"	"
269	Northwestern Improvement Co., No.8	"	"
270	Roslyn-Cascade Coal Co., No. 1	"	"
271	Roslyn-Cascade Coal Co., No. 2	"	"
272	Centralia Coal Mining Co	Centralia	Lewis
273	Fords Prairie Coal Co	"	"
274	Salzer Valley Coal Co	"	"
275	Sheldon Coal Co	Chehalis	"
276	Superior Coal Co	"	"
277	Agnew Fuel Co	Kopiah	"
278	Phoenix Coal Co	Ladd	"
279	Mendota Coal & Coke Co	Mendota	"
280	Pacific & Eastern Coal Co	Mineral	"
281	Olympia Coal & Mining Co	Packwood	"
282	Pacific Coast Coal Co	Burnett	Pierce
283	Carbon Hill Coal Co	Carbonado	"
284	" " " "	Douty	"
285	Fairfax Mine Inc	Fairfax	"
286	Carbon Hill Coal Co	Melmont	"
287	South Willis Coal Co	Morristown	"
288	Gale Creek Coal Mines Co	Wilkeson	"
289	Wilkeson Coal & Coke Co	"	"
290	Cokedale Coal Co	Cokedale	Skagit
291	Richmond Coal Co	Bucoda	Thurston
292	Washington Union Coal Co	Tono	"
293	Whatcom County Coal Co	Blue Canyon	Whatcom

METAL MINES

No.	MINE	LOCALITY	COUNTY
295	Golden Eagle	Blewett	Chelan
296	Washington Meteor	Chelan	"
297	Wenatchee Gold Mining Co	Entiat	"
298	Chelan Butte Gold Mining Co	Chelan	"
299	Hail Creek	Covada	Ferry
300	Silver Leaf	"	"
301	Lone Star and Washington	Danville	"
302	Lucile Dreyfuss	"	"
303	Minnehaha	"	"
304	Apollo	Republic	"
305	Ben Hur	"	"
306	Black Tail	"	"
307	Hope	"	"
308	Ida May	"	"
309	Knob Hill	"	"
310	Last Chance	"	"
311	Lone Pine	"	"
312	Morning Glory	"	"
313	Pearl	"	"
314	Quilp	"	"
315	Republic	"	"
316	San Poil	"	"
317	Surprise	"	"
318	Trade Dollar	"	"
319	Phil Sheridan	Sheridan	"
320	Apex	Berlin	King
321	Arlington	Conconully	Okanogan
322	Key	"	"
323	Apache	Nespelem	"
324	Double Header	"	"
325	Caaba	Nighthawk	"
326	O. K.	Oroville	"
327	Clark	Metaline	Pend Oreille
328	Lead-Zinc	"	" "
329	Sunset	Index	Snohomish
330	Ben Lomond	Monte Cristo	"
331	Iowa	Startup	"
332	Bonanza	Bossburg	Stevens
333	Dead Medicine	"	"
334	Young America	"	"
335	Chewelah Consolidated	Chewelah	"
336	Copper King	"	"
337	" Queen	"	"
338	Double Eagle	"	"
339	Eagle	"	"
340	Edna	"	"
341	Hecla	"	"
342	Juno-Echo	"	"
343	United Copper	"	"
344	Chloride Queen	Colville	"
345	Old Dominion	"	"
346	Daisy	Daisy	"
347	Tempest	"	"
348	Loon Lake	Loon Lake	"
349	Loon Lake Consolidated	" "	"
350	Anaconda	Northport	"
351	Copper King	"	"
352	Electric Point	"	"
353	Frisco-Standard	"	"
354	Galena Farm	"	"
355	Gladstone	"	"
356	Iroquois	"	"
357	Providence	"	"
358	Red Iron	"	"
359	United Treasurer	"	"
360	Montana and Washington	Orient	"
361	Galena Hill	Rockcut	"
362	International	"	"
363	Cleveland	Springdale	"
364	Deer Trail	Turk	"
365	Ololim	"	"
366	Germania Tungsten	"	"
367	Togo	"	"
368	Boundary Red Mountain	Glacier	Whatcom

CLAY PLANTS

No.	OPERATOR	LOCALITY	COUNTY
370	S. Garsi	Hanford	Benton
371	H. E. Dunham	Chelan	Chelan
372	Leavenworth Brick Co	Leavenworth	"
373	Wenatchee Brick & Tile Co	Wenatchee	"
374	Denny-Renton Clay & Coal Co	Image	Clarke
375	Carson Brothers	Vancouver	"
376	Hidden Brick Co	"	"
377	Frank Malfa	Waterville	Douglas
378	Northern Clay Co	Auburn	King
379	Standard " "	Bayne	"
380	Denny-Renton Clay & Coal Co	Renton	"
381	Abrahamson Brick Co	Seattle	"
382	Builders Brick Co	"	"
383	Lake Union Brick & Fireproofing Co	"	"
384	Lohse Brick Co	"	"
385	Seattle Brick & Tile Co	"	"
386	Seattle Pottery Co	"	"
387	Washington Brick & Tile Co	"	"
388	Denny-Renton Clay & Coal Co	"	"
389	" " " " " "	Taylor	"
390	Superior Brick & Tile Co	Woodinville	"
391	Harper-Hill Brick & Tile Co	Harper	Kitsap
392	Cle Elum Brick Co	Cle Elum	Kittitas
393	N. B. Brooks	Goldendale	Klickitat
394	Chehalis Brick & Tile Co	Chehalis	Lewis
395	Williams and Finnie	Oroville	Okanogan
396	Far West Clay Co	Clay City	Pierce
397	F. H. Goss Brick Co	Tacoma	"
398	Anacortes Brick Co	Anacortes	Skagit
399	Star Brick & Tile Co	Bayview	"
400	Knapp Brick & Tile Co	Tiloh	"
401	Everett Brick Co	Everett	Snohomish
402	Western Clay Products Co	"	"
403	Meadowdale Pottery Co	Meadowdale	"
404	Cheney Brick Co	Cheney	Spokane
405	Bergman Clay Mfg. Co	Chester	"
406	Wash. Brick, Lime & Sewer Pipe Co	Freeman	"
407	J. T. Davis Brick Co	Mead	"
408	National Brick Co	"	"
409	Wash. Lime, Brick & Sewer Pipe Co	Spear	"
410	American Fire Brick Co	Mica	"
411	A. T. Dishman	Spokane	"
412	Pioneer Brick Co	"	"
413	Chewelah Brick & Lime Co	Chewelah	Stevens
414	Wash. Brick, Lime & Sewer Pipe Co	Clayton	"
415	Wall Walla Construction Co	Walla Walla	Walla Walla
416	Coast Clay Co	Bellingham	Whatcom
417	J. F. Miller & Brothers	"	"
418	C. A. Brown	Palouse	Whitman
419	George Herboth	Uniontown	"
420	Granger Brick & Tile Co	Granger	Yakima

COKING PLANTS

No.	OPERATOR	LOCALITY	COUNTY
430	Seattle Lighting Co	Seattle	King
431	Carbon Hill Coal Co	Carbonado	Pierce
432	Fairfax Mine, Inc	Fairfax	"
433	Wilkeson Coal & Coke Co	Wilkeson	"
434	Cokedale Coal Co	Cokedale	Skagit

CEMENT PLANTS

No.	OPERATOR	LOCALITY	COUNTY
451	Inland Portland Cement Co	Metaline Falls	Pend Oreille
452	Superior Portland Cement Co	Concrete	Skagit
453	Washington Portland Cement Co	"	"
454	International Portland Cement Co	Spokane	Spokane
455	Olympic Portland Cement Co	Bellingham	Whatcom

SILICA PLANTS

No.	OPERATOR	LOCALITY	COUNTY
460	American Mineral Products Co	Quincy	Grant
461	American Japanese Silica Co	Roza	Kittitas
462	Great Western Silica Co	"	"
463	Majestic Diatomaceous Earth Co	Wymer	"
464	U. S. Kieselguhr Co	"	"

MINERAL WATERS

No.	OPERATOR	LOCALITY	COUNTY
480	Sol Duc Hot Springs	Sol Duc	Clallam
481	Soap Lake Mineral Water Co	Soap Lake	Grant
482	Diamond Mineral Spring	Auburn	King
483	Scenic Hot Springs	Scenic	"
484	Klickitat Mineral Springs	Klickitat	Klickitat
485	Collins Hot Springs	Collins	Skamania
486	Table Rock Mineral Water Co	Stevenson	"
487	Olympia Hygeian Springs	Olympia	Thurston
488	Ahtanum Soda Springs	Tampico	Yakima
489	Yakima Artesian Mineral Spring	Yakima	"

HYDRO-ELECTRIC PLANTS

No.	OPERATOR	LOCALITY	COUNTY
500	Washtucna Electric Co	Washtucna	Adams
501	Lewiston-Clarkston Improvement Co	Asotin	Asotin
502	Lewiston-Clarkston Improvement Co	Clarkston	"
503	Pacific Power & Light Co	Prosser	Benton
504	Chelan Electric Co	Chelan	Chelan
505	Wenatchee Valley Gas & Electric Co	Dryden	"
506	Wenatchee Valley Gas & Electric Co	Entiat	"
507	Great Northern Railway	Leavenworth	"
508	Tumwater Light & Power Co	"	"
509	Wenatchee Valley Gas & Electric Co	Wenatchee	"
510	Olympia Power Co	Port Angeles	Clallam
511	Western Light & Power Co	Camas	Clarke
512	Northern Clarke County Light & Power Co	Yacolt	"
513	Pacific Power & Light Co	Marengo	Columbia
514	Starbuck Electric Co	Starbuck	"
515	Washington-Oregon Corporation	Kalama	Cowlitz
516	Elma Light & Power Co	Elma	Grays Harbor
517	Northwest Electric & Water Works	Montesano	" "
518	City of Seattle	Cedar Falls	King
519	Puget Sd. Traction, Lt. & Power Co	Dieringer	"
520	Puget Sd. Traction, Lt. & Power Co	Snoqualmie Falls	"
521	City of Ellensburg	Ellensburg	Kittitas
522	Pacific Power & Light Co	Goldendale	Klickitat
523	" " " " "	White Salmon	"
524	Central Light & Mfg. Co	Pe Ell	Lewis
525	Washington Water Power Co	Little Falls	Lincoln
526	" " " "	Long Lake	"
527	North Washington Power Co	Oroville	Okanogan
528	Okanogan Valley Power Co	Pateros	"
529	Willapa Electric Co	South Bend	Pacific
530	Inland Portland Cement Co	Metaline Falls	Pend Oreille
531	Puget Sd. Traction, Lt. & Power Co	Electron	Pierce
532	City of Tacoma	Lagrande	"
533	Jim Creek Water, Light & Power Co	Arlington	Skagit
534	Superior Portland Cement Co	Concrete	"
535	Skamania Light & Power Co	Stevenson	Skamania
536	Pacific Power & Light Co	Underwood	"
537	Granite Falls Electric Co	Granite Falls	Snohomish
538	Little Spokane Light & Power Co	Milan	Spokane
539	Spokane & Inland Empire Ry	Nine Mile Falls	"
540	City of Spokane	Spokane	"
541	Washington Water Power Co	"	"
542	Stevens County Light & Power Co	Colville	Stevens
543	Kulzer Electric Light & Power System	Valley	"
544	Olympia Light & Power Co	Olympia	Thurston
545	Pacific Power & Light Co	Waitsburg	Walla Walla
546	Puget Sd. Traction, Lt. & Power Co	North Fork Nooksak	Whatcom
547	Pacific Power & Light Co	Naches	Yakima
548	Black Rock Power & Irrigation Co	Priest Rapids	"
549	Pacific Power & Light Co	Yakima	"

GAGING STATIONS

No.	STREAM	LOCALITY	COUNTY
601	Yakima River	Prosser	Benton
602	Columbia River	Vernita	"
603	Chelan Lake	Chelan	Chelan
604	" River	"	"
605	Wenatchee River	Dryden	"
606	Entiat River	Entiat	"
607	Wenatchee River	Leavenworth	"
608	Chiwawa Creek	"	"
609	Icicle Creek	"	"
610	Stehekin River	Stehekin	"
611	Soleduck River	Fairholme	Clallam
612	Lyre River	Piedmont	"
613	Tucannon River	Pomeroy	Columbia
614	" "	Starbuck	"
615	Lewis River	Amboy	Cowlitz
616	Kalama River	Kalama	"
617	Hall Creek	Inchelium	Ferry
618	Curlew Creek	Curlew	"
619	Sanpoil River	Keller	"
620	Stranger Creek	Meteor	"
621	Moses Lake	Neppel	Grant
622	Quinault Lake	Quinault	Grays Harbor
623	Miller River	Berlin	King
624	Cedar River	Cedar Falls	"
625	Snoqualmie R., (N. Fork)	North Bend	"
626	" " (S. Fork)	" "	"
627	" " (Middle Fork)	" "	"
628	Cedar River	Landsberg	"
629	Teanaway	Cle Elum	Kittitas
630	Yakima River	" "	"
631	Kachess River	Easton	"
632	" Lake	"	"
633	Yakima River	"	"
634	Manastash Creek	Ellensburg	"
635	Keechelus Lake	Martin	"
636	Yakima River	"	"
637	Cle Elum Lake	Roslyn	"
638	" " River	"	"
639	Yakima River	Umtanum	"
640	Klickitat River	Glenwood	Klickitat
641	Big Muddy Creek	Camp Klickitat	"
642	White Salmon River	Husum	"
643	" " "	Trout Lake	"
644	Columbia River	The Dalles	Oregon
645	Coal Creek	Lewis	Lewis
646	Cowlitz River	"	"
647	" "	Mossy Rock	"
648	" (Clear Fork)	Lewis	"
649	" (Upper Lake Creek)	"	"
650	Ohanapecosh River	"	"
651	Spokane River	Long Lake	Lincoln
652	Skokomish River (N. Fork)	Hoodsport	Mason
653	Salmon Creek	Conconully	Okanogan
654	Nespelem River	Nespelem	"
655	Okanogan River	Okanogan	"
656	Similkameen River	Oroville	"
657	Methow River	Pateros	"
658	Clark Fork	Metaline Falls	Pend Oreille
659	Sullivan Creek	" "	" "
660	" Lake	" "	" "
661	Puyallup River	Alderton	Pierce
662	White River	Buckley	"
663	" " flume	"	"
664	Puyallup River	Electron	"
665	" "	Puyallup	"
666	East Creek	Elbe	"
667	Baker River	Concrete	Skagit
668	Skagit "	Sedro-Woolley	"
669	Sauk River	Darrington	Snohomish
670	" " (above Whitechuck)	"	"
671	Sauk River (N. Fork)	Barlow Pass	"
672	" " (S. Fork)	" "	"
673	Whitechuck River	Darrington	"
674	Stilaguamish River (S. Fork)	Granite Falls	"
675	Skykomish River (N. Fork)	Index	"
676	" " (S. Fork)	"	"
677	Stilaguamish River (S. Fork)	Silverton	"
678	Sultan River	Sultan	"
679	Spokane River	Spokane	Spokane
680	Snake River	Burbank	Walla Walla
681	Mill Creek	Walla Walla	" "
682	Whatcom Creek	Bellingham	Whatcom
683	Baker Lake	Baker Lake	"
684	Stetattle Creek	Marblemount	"
685	Skagit River	"	"
686	" "	Reflector Bar	"
687	Rock Creek	Ewan	Whitman
688	Palouse River	Hooper	"
689	" "	Palouse	"
690	Snake River	Riparia	"
691	Palouse River	Winona	"
692	Reservation Drainage Canal	Alfalfa	Yakima
693	Simcoe Creek	Fort Simcoe	"
694	Toppenish Creek	" "	"
695	Naches River	Naches	"
696	Tieton River	" (Headworks)	"
697	" Canal	" "	"
698	American River	Nile	"
699	Bumping River	"	"
700	" Lake	"	"
701	New Reservation Canal	Parker	"
702	Old " "	"	"
703	Tieton River (N. Fork)	Rimrock	"
704	Ahtanum Creek (S. Fork)	Tampico	"
705	" " (N. Fork)	"	"
706	Satus Creek	Toppenish	"
707	Yakima River	Union Gap	"
708	Sunnyside Canal	Wapato	"
709	Yakima River	"	"