STATE OF WASHINGTON

Department of Conservation and Development

D. A. SCOTT, Director

DIVISION OF GEOLOGY

S. SHEDD, Supervisor

BULLETIN No. 30

(Geological Series)

The Mineral Resources of Washington

WITH STATISTICS FOR 1922

BY

SOLON SHEDD

With an Article on Coal and Coke

BY

GEORGE WATKIN EVANS

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LETTER OF TRANSMITTAL

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

SIR: I have the honor to submit herewith the manuscript of a report on the Mineral Resources of Washington and recommend that it be published as a Bulletin of the Department of Conservation and Development and designated as Geological Series No. 30.

Very respectfully,

S. SHEDD,

Supervisor, Division of Geology.

College Station, Pullman, Washington.
June 20, 1924.

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INTRODUCTION

The mineral deposits of Washington constitute one of its very important resources. Both metallic and non-metallic minerals are well represented in the State and the mining of each of these has come to be a very important industry, employing a large number of men and much capital.

The mineral industry in this State felt the effect of the World War and on the whole was stimulated by it and the value of the mineral output increased until 1920, when the output for Washington was $26,677,191. In 1921 there was a very marked decrease in the value of production, but in 1922 an improvement in the industry began which has continued through 1923.

Prior to 1916 but little attention had been given to the production of various minerals from domestic sources. This was due, partly at least, to the fact that it was cheaper to import them than it was to produce them at home. When imports were practically stopped as a result of the war, attention was given to the discovery and development of home supplies. As a result of this there was an increased production from many deposits already known, as well as the discovery of new ones. In Washington this resulted in the development of the magnesite deposits in Stevens County, the manganese deposits on the Olympic Peninsula, the chromite deposits in different parts of the State, as well as deposits of other minerals of lesser importance.

One of the aims of the Division of Geology is to help in the development of the mineral resources of the State. This may be done by investigating and calling attention to deposits of the various minerals found in the State. Statistics of production, with the principal uses of the various minerals are compiled and published for the use of producers and people in general who are interested in our mineral resources. Brief descriptions are given of a few of the mineral deposits even though they may not be producers at the present, in the hope that it may help in causing them to become producers.

In this report the statistics are given to the close of 1922. A discussion is also given of the condition of the mineral industry to the close of 1923.

The Division of Geology has a cooperative agreement with the United States Geological Survey by which the mineral statistics for Washington are collected jointly and considerable of the data given in this report has been obtained in this way. During the summer of 1923 the writer spent some time visiting the most important mining districts in the State in order to study the condition of the mining industry and the information obtained in this way is also included in this report.

MINERAL PRODUCTION OF WASHINGTON FROM 1915 TO 1922 INCLUSIVE

PRODUCTS	1915		1916	
	Quantity	Value	Quantity	Value
Antimony ore................short tons	(a)	(a)	(a)	(a)
Briquets, fuel................short tons	(a b)	(a b)	(a b)	(a b)
Cement ....barrels	1,378,107	$1,790,499	1,575,919	$2,447,779
Clay products..........................	....	(c)1,454,436	....	(c)1,589,574
Clay, raw....................short tons	829	(b)4,340	1,840	(b)6,251
Coal ....short tons	2,429,095	5,276,299	3,038,588	6,907,428
Coke ....short tons	136,552	700,832	(a b)	(a b)
Copper ....pounds	1,020,926	178,662	2,645,022	650,675
Diatomaceous earth....................	....	14,515	....	10,700
Gems and precious stones.......... ....fine ounces (troy)	....	....	....	850
Gold...................fine ounces (troy)	18,935	391,419	27,944	577,655
Lead ....short tons	148	13,875	2,700	372,550
Lime ....short tons	27,240	171,023	26,895	166,653
Magnesite ....short tons	....	....	715	5,362
Manganese ore................long tons	....	....	(a)	(a)
Manganiferous ore............long tons	....	....	(a)	(a)
Mineral paints, natural pigments ....short tons	(a)	(a)	(d)	(d)
Mineral waters.............gallons sold	158,865	11,703	151,528	9,476
Potash (K_2O)................short tons	....	....	(a)	(a)
Quicksilver ....flasks	....	....	(a)	(a)
Sand and gravel............short tons	772,629	211,480	1,401,237	387,337
Sand-lime brick	....	(a)	....	(a)
Silica (quartz)..............short tons	....	....	(a)	(a)
Silver ....fine ounces (troy)	255,837	129,709	335,121	220,510
Stone	....	1,758,817	....	903,635
Strontium ....short tons	....	....	(a)	(a)
Tungsten ore (60 per cent concentrates) ....short tons	(a)	(a)	11	15,230
Zinc ....short tons	122	30,368	847	226,960
Miscellaneous	....	229,070	....	1,046,792
Total value, eliminating duplications	....	$11,455,715	....	$14,521,014

(a) Value included under "Miscellaneous".

(b) Value not included in total value.

(c) Exclusive of pottery, value for which is included under "Miscellaneous".

(d) Canvass discontinued.

MINERAL PRODUCTION OF WASHINGTON FROM 1915 TO 1922 INCLUSIVE—Continued

PRODUCTS	1917		1918	
	Quantity	Value	Quantity	Value
Briquets, fuel................short tons	(a b)	(a b)	(a b)	(a b)
Cement ....barrels	1,403,191	$2,367,045	1,116,754	$2,114,730
Chromite ....long tons	(a)	(a)	(a)	(a)
Clay products..........................	....	1,533,039	....	(c)1,274,708
Clay, raw.....................short tons	1,613	(b)9,248	3,435	(b)17,637
Coal ....short tons	4,009,902	10,727,362	4,082,212	14,132,869
Coke ....short tons	(a b)	(a b)	123,788	(b)1,196,685
Copper ....pounds	2,199,518	600,468	1,922,406	474,834
Diatomaceous earth.........short tons	1,995	18,910	(a)	(a)
Ferroalloys ....long tons	(a b)	(a b)	(a b)	(a b)
Fluorspar ....short tons	....	....	(a)	(a)
Gems and precious stones..............	....	(a)	....	(a)
Gold..................fine ounces (troy)	23,816	492,324	14,738	304,658
Iron ore.......................long tons	....	....	(a)	(a)
Iron, pig......................long tons	2,361	(a b)	15,780	(a b)
Lead ....short tons	4,895	841,913	2,636	374,299
Lime ....short tons	23,328	156,553	22,118	226,104
Magnesite ....short tons	105,175	783,188	147,528	1,050,790
Mineral waters............gallons sold	155,265	7,265	(a)	(a)
Molybdenum ....pounds	(a)	(a)	....	....
Natural gas................M cubic feet	....	....	(a)	(a)
Platinum and allied metals........ ....fine ounces (troy)	(a)	(a)	10	1,075
Potash (K_2O)...............short tons	....	....	(a)	(a)
Sand and gravel............short tons	895,120	199,565	908,102	332,141
Sand-lime brick	....	(a)	....	(a)
Silver ....fine ounces (troy)	282,320	232,632	310,093	310,093
Stone	....	454,594	....	365,098
Strontium ore...............short tons	(a)	(a)	....	....
Tungsten ore (60 per cent concentrates) ....short tons	10	13,500	1	800
Zinc ....short tons	598	121,948	19	3,537
Miscellaneous (d)	....	1,809,700	....	1,360,720
Total value, eliminating duplications	....	$18,576,052	....	$20,999,691

(a) Value included under "Miscellaneous".

(b) Value not included in total value for State.

(c) Exclusive of pottery, value for which is included under "Miscellaneous".

(d) 1917: Fuel briquets, chromite, coke, ferroalloys, gems and precious stones, pig iron, molybdenum, platinum and allied metals, sand-lime brick, and strontium ore; 1918: Fuel briquets, chromite, pottery, diatomaceous earth, ferroalloys, fluorspar, gems and precious stones, iron ore, pig iron, mineral waters, natural gas, potash, and sand-lime brick.

MINERAL PRODUCTION OF WASHINGTON FROM 1915 TO 1922 INCLUSIVE—Continued

PRODUCTS	1919		1920	
	Quantity	Value	Quantity	Value
Asbestos ....short tons	(a)	(a)	....	....
Briquets, fuel................short tons	(a b)	(a b)	(a b)	(a b)
Cement ....barrels	1,402,616	$2,868,599	1,806,025	$4,096,227
Clay products........................	....	1,764,264	....	2,923,687
Clay, raw....................short tons	20,518	(b)21,964	1,319	(b)10,377
Coal ....short tons	2,990,447	10,691,222	3,757,093	14,560,000
Coke ....short tons	62,546	531,160	59,395	(b)627,451
Copper ....pounds	1,676,576	311,843	1,983,134	364,897
Diatomaceous earth.........short tons	974	14,821	953	12,083
Ferroalloys ....long tons	(a b)	(a b)	(a b)	(a b)
Gems and precious stones............	....	(a)	....	....
Gold ....troy ounces	12,232	252,862	5,847	120,860
Iron ore......................long tons	2,750	(a)	2,500	(a)
Iron, pig.....................long tons	(a b)	(a b)	....	....
Lead ....short tons	1,073	113,746	2,894	462,980
Lime ....short tons	19,534	232,723	31,033	324,042
Magnesite ....short tons	106,206	743,442	221,985	1,664,888
Mineral waters.............gallons sold	(a)	(a)	(a)	(a)
Platinum ....troy ounces	....	....	8	888
Potash (K_2O)...............short tons	(a)	(a)	....	....
Sand and gravel.............short tons	1,231,814	536,132	1,976,969	1,016,926
Sand-lime brick ....thousands	....	....	(a)	(a)
Silver ....troy ounces	259,384	290,510	199,678	217,649
Stone ....short tons	261,310	423,653	712,680	821,842
Talc ....short tons	(a)	(a)	....	....
Zinc ....short tons	....	....	213	34,546
Miscellaneous	....	493,007	....	528,765
Total value, eliminating duplications	....	$18,267,938	....	$26,677,191

(a) Value included under "Miscellaneous".

(b) Value not included in total value for State.

MINERAL PRODUCTION OF WASHINGTON FROM 1915 TO 1922 INCLUSIVE—Continued

PRODUCTS	1921		1922	
	Quantity	Value	Quantity	Value
Briquets, fuel................short tons	(a b)	(a b)	(a b)	(a b)
Cement ....barrels	1,612,891	$4,080,785	1,951,414	$4,684,624
Clay products..........................	....	(c)1,496,741	....	(c)1,982,759
Clay, raw...................short tons	439	(b)5,153	6,136	(b)14,745
Coal ....short tons	2,428,722	9,787,000	2,581,165	10,279,000
Coke ....short tons	27,260	(b)194,510	31,674	(b)285,881
Copper ....pounds	251,544	32,449	317,203	42,822
Diatomaceous earth.........short tons	(a)	(a)	(a)	(a)
Ferroalloys ....long tons	(a b)	(a b)	....	....
Gems and precious stones..............	....	(a)	....	....
Gold ....troy ounces	6,216	128,486	9,004	186,965
Iron ore.......................long tons	....	....	....	....
Lead ....short tons	72	6,460	691	75,966
Lime ....short tons	17,710	209,761	25,447	355,412
Magnesite ....short tons	....	....	(a)	(a)
Mineral waters.............gallons sold	(a)	(a)	(a)	(a)
Platinum ....troy ounces	....	....	3	306
Sand and gravel............short tons	1,481,574	881,842	1,802,121	844,252
Sand-lime brick ....thousands	....	....	(d)	(d)
Silica (quartz)...............short tons	(a)	(a)	....	....
Silver ....troy ounces	142,450	142,450	205,046	205,046
Stone ....short tons	542,490	789,364	(e)647,160	(e)887,175
Zinc ....short tons	225	22,468	614	70,009
Miscellaneous	....	159,088	....	519,165
Total value, eliminating duplications	....	$17,605,878	....	$19,725,300

(a) Value included under "Miscellaneous".

(b) Value not included in total value for State.

(c) Figures obtained through cooperation with Bureau of the Census.

(d) No canvass made.

(e) Exclusive of sandstone, value of which is included under "Miscellaneous".

PART I.

Metallic Minerals

METALLIC MINERALS

MINING CONDITIONS IN WASHINGTON DURING 1923

Washington, while not a large producer of metals, is credited with a total for gold, silver, copper, lead and zinc from 1860 to 1923, inclusive, of $42,102,767. Washington has been a producer of gold for many years and the largest part of the total given above has come from gold. Silver has never been produced in large amounts and only within the last few years, comparatively, has the output of lead and zinc been of much value.

Most of the metalliferous ores mined in Washington are of such a nature that they must be reduced by a chemical process which means that the majority of the mines are dependent very largely on transportation companies and custom smelters. Many of these mines are in a medium or low grade ore and hence to be worked at a profit they must be situated advantageously as regards transportation and be able to get a comparatively low rate for treatment. Unfortunately, some of the counties in which the largest amount of mineral occurs have only a small railway mileage.

The ore bodies as a general thing are not bonanzas nor are they mammoth bodies of low grade ore. The ores are usually of a milling grade and the question of concentration becomes a very important one. At present the milling practices are not as modern as they should be, but this condition is improving slowly. The treating of these ores in the district where they are mined would result in a great saving of money that is now paid out for freight and would undoubtedly be the cause of increased activity in the mining industry.

Gold. For the past five or six years the price of materials and labor has been so high that very little attention has been given to gold mining. Conditions have improved somewhat, however, and the production of gold in 1923 was about $125,000 more than in 1922. This increase in gold production was due almost entirely to increased activity in the Republic district. This greater output of gold was largely on account of the greater demand for the ores from the Republic district to be used as a flux by the smelters in British Columbia. While the Republic district showed an increase, the other large gold producer, the Boundary Red Mountain mine in Whatcom County, showed a decline, development work being the principal thing that was being done.

Silver. The amount of silver produced in 1923 showed a slight increase over that for 1922. This was a result very largely of the increased amount of siliceous ore shipped from the Republic district. The shipments of silver-copper ore were not large and as a result of this the amount of silver produced in Washington was not as great as usual.

One of the important developments in silver mining was the opening up of the Old Dominion mine near Colville in Stevens County. At one time this was a very important silver mine containing a high grade of silver ore. No production has been made from this property for many years until 1923, when development work opened bodies of silver-lead ore below the 600 foot level.

Production was also reported from the Last Chance and the Ruby mines in Okanogan County and from the Quilp mine in Ferry County.

Copper. The output of copper in Washington increased from 317,203 pounds in 1922 to 854,000 pounds in 1923, which is just about one-third of the amount produced in 1916, the year of the largest production. The larger part of the output came from the Sunset Copper Company from near Index in Snohomish County and from the United Silver Copper Company of Chewelah, Stevens County. The latter company has been for years the largest producer of copper, but in 1923 the Sunset Copper Company produced a large part of the output.

Lead. The lead industry in Washington in 1923 showed much greater activity than it had for several years past. The largest output of lead for any one year was in 1917 when it reached 9,789,687 pounds, with a value of $841,913. From that time on the production has fluctuated more or less until 1921 when the smallest production was made and the lowest price per pound received. Beginning with 1922, conditions began to improve and continued through 1923 so that the output for that year was twice what it had been in 1922, and the value almost three times as great. The Gladstone mine, near Northport, Stevens County, was responsible for most of the production. The ore is high-grade galena or lead sulphide and a medium grade cerussite or carbonate. The Electric Point mine which adjoins the Gladstone was idle in 1923. Other mines producing lead were the Santa Rita, Bonanza, and Young America, all in Stevens County, and the Bead Lake in Pend Oreille County. As a whole the lead industry in Washington was in a fairly prosperous condition in 1923.

Zinc. The output of zinc in Washington for 1923 was more than twice what it was for 1922 and almost twice what it had been for any previous year. This increase was a result of production of zinc carbonate from the Washington Black Rock mine, near Northport, Stevens County.

The mining industry as a whole showed a marked improvement for 1923 over the conditions that had prevailed for several years previous.

The following table gives the principal metal mines in this State, location of property, and kind of ore produced. This table was furnished by the U. S. Geological Survey and is the list to which blanks are sent in collecting statistics of the production of metals in Washington for Mineral Resources of the United States, published annually.

METAL MINES NOW OR RECENTLY IN OPERATION
Some Are Doing Important Development Work

MINE	Location	County	Principal Metals Produced
Royal Development Co....	Leavenworth.......	Chelan........	Copper-silver
Boston & New York......	Curlew.............	Ferry.........	
Iron Creek	Keller..............	Ferry.........	
Addison Copper	Keller..............	Ferry.........	Copper-lead-silver
Last Chance	Republic...........	Ferry.........	Gold-silver
Knob Hill	Republic...........	Ferry.........	Gold-silver
Quilp	Republic...........	Ferry.........	Gold-silver
Old Republic	Republic...........	Ferry.........	Gold-silver
Surprise (now idle)........	Republic...........	Ferry.........	Gold-silver
Apex	Miller River........	King..........	Copper
Snoqualmie M. Co.........	Miller River........	King..........	
Mineral Creek Copper.....	Lake Kachess......	Kittitas.......	Copper
Swauk Mining & Dredging Co. (now idle)..........	Liberty............	Kittitas.......	Gold
Golden Group	Liberty............	Kittitas.......	Gold
Black Jack Placer.........	Liberty............	Kittitas.......	Gold
Old Bigney Placer.........	Liberty............	Kittitas.......	Gold
Weninger & Little May...	Liberty............	Kittitas.......	Gold
Sunflower Placer	Liberty............	Kittitas.......	Gold
Peacock Silver	Ruby (Conconully)	Okanogan....	Silver-lead
Apache	Nespelem..........	Okanogan....	Silver
Double Header	Nespelem..........	Okanogan....	Silver
Panama	Nespelem..........	Okanogan....	Silver
Four Metals (now idle)...	Nighthawk.........	Okanogan....	Silver-lead-copper
Ruby	Nighthawk.........	Okanogan....	Silver
Trinidad	Tonasket..........	Okanogan....	Silver-lead
Bella May	Metaline...........	Pend Oreille..	Lead-silver
Bead Lake	Newport...........	Pend Oreille..	Lead-silver
Ries (now idle)............	Newport...........	Pend Oreille..	Lead-silver
American Arsenic	Reiter..............	Snohomish...	Arsenic
Sunset	Index..............	Snohomish...	Copper
Bonanza	Bossburg..........	Stevens.......	Silver
Young America	Bossburg..........	Stevens.......	Silver-lead
Silver Summitt	Chewelah..........	Stevens.......	Silver-lead
United Silver-Copper	Chewelah..........	Stevens.......	Silver-copper
Old Dominion	Colville............	Stevens.......	Silver-lead
Electric Point (now idle)..	Northport..........	Stevens.......	Lead
Gladstone	Northport..........	Stevens.......	Lead
Lead Trust	Northport..........	Stevens.......	Lead
Washington Black Rock..	Northport..........	Stevens.......	Zinc-lead
Melrose	Northport..........	Stevens.......	Silver
Reardon Copper	Turk...............	Stevens.......	Copper
Queen & Seal (now idle)..	Turk...............	Stevens.......	Silver-lead
Aichan Bee	Turk...............	Stevens.......	Silver-lead
Togo	Turk...............	Stevens.......	Silver-lead
Cleveland	Springdale.........	Stevens.......	Silver-lead
Silver Mountain	Daisy..............	Stevens.......	Silver-lead
Tempest	Daisy..............	Stevens.......	Silver-lead
Admiral	Valley.............	Stevens.......	
First Thought	Orient.............	Stevens.......	
Boundary Red Mountain.	Sumas.............	Whatcom....	Gold-silver
Mount Baker M. Co......	Glacier............	Whatcom....	

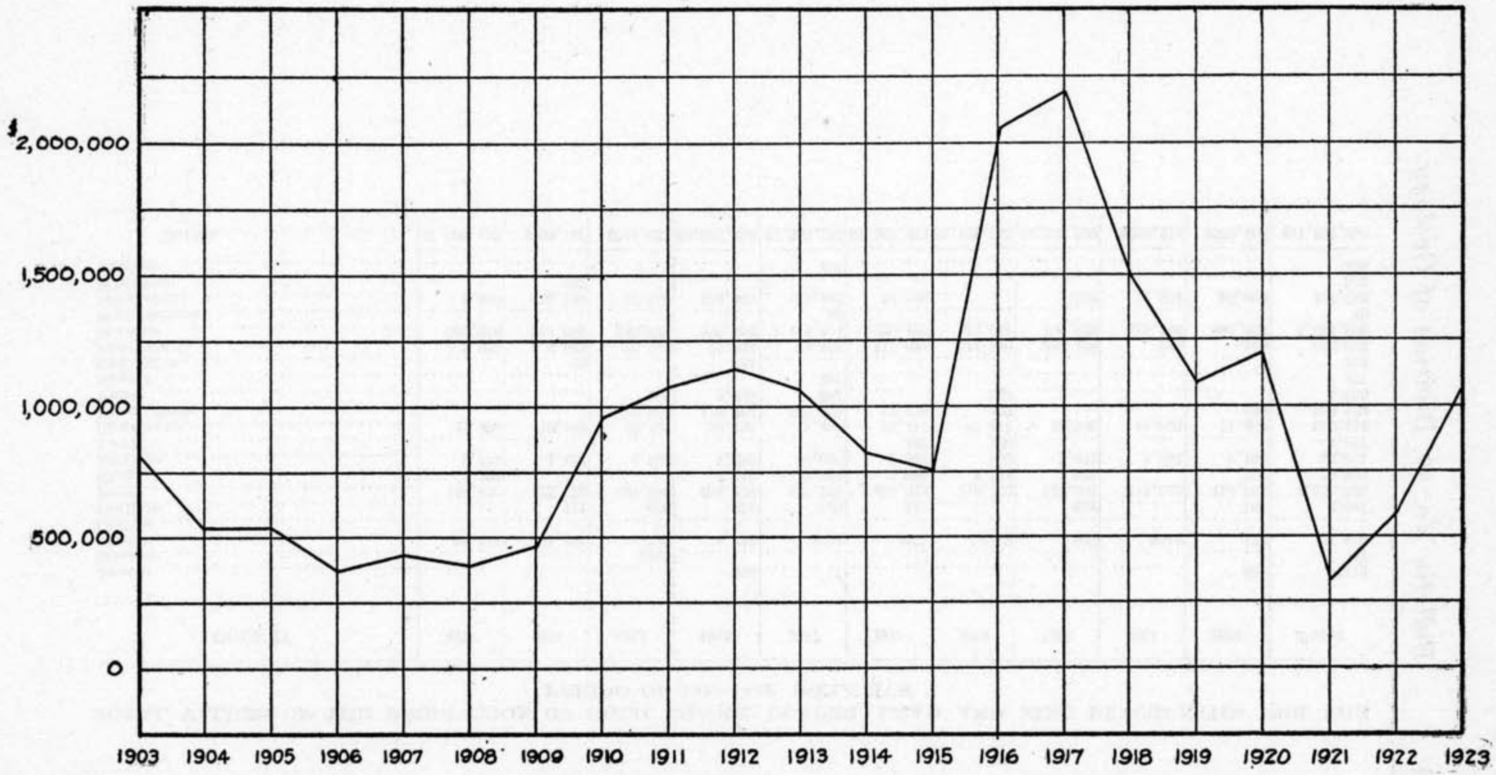

FIG. 1. Combined value of production of gold, silver, copper, lead, and zinc, for Washington, 1903 to 1923, inclusive.

TOTAL VALUES OF THE PRODUCTION OF GOLD, SILVER, COPPER, LEAD AND ZINC BY COUNTIES FOR THE PERIOD OF 1913-1922, INCLUSIVE

COUNTY	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
Asotin				$55						$57	$112
Benton			$167								167
Chelan	$8,704	$1,604	4,342	8,798	$691	$151	$137	$27	$213	173	24,840
Clarke											
Clallam		111	688	374	628	241		258		181	2,481
Ferry	751,826	625,173	459,985	694,378	487,708	409,012	319,703	147,304	117,545	118,765	4,131,399
King	6,403			1,716	9,301	6,988	3,134	1,893		367	29,802
Kittitas	3,714	4,426	4,024	4,882	6,020	2,673	990	1,091	2,891	3,180	33,891
Lewis						497	520				1,017
Okanogan	12,993	10,182	40,131	39,138	41,460	75,717	37,917	25,500	41,636	71,460	396,134
Pend Oreille			30,368	118,074	132,816	17,736	497			638	300,129
Pierce			261	2,709	881		609				4,460
Skagit					431						431
Skamania		22		394							416
Snohomish	3,028	8,061	10,946	75,703	50,865	117,924	111,730	225,408	200	108	603,973
Stevens	260,918	144,092	180,576	968,666	1,418,494	826,456	651,015	798,929	135,294	289,953	5,674,393
Wahkiakum					80						80
Whatcom	5,549	15,739	12,545	133,463	139,442	10,026		522	34,534	95,926	447,746
Whitman		357									357
Yakima					468						468
Totals	$1,053,135	$809,767	$744,033	$2,048,350	$2,289,285	$1,467,421	$1,126,252	$1,200,932	$332,313	$580,808	$11,652,296

PRODUCTION OF GOLD BY COUNTIES, IN VALUE, 1913-1922

COUNTY	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
Asotin										$57	$57
Benton			$166								166
Chelan	$8,590	$1,575	4,279	$8,682	$683		$135	$27	$207	169	24,347
Clallam		110	685	372	624	$239		257		180	2,467
Ferry	645,009	513,276	351,973	399,376	332,071	276,062	245,141	110,278	88,290	85,686	3,047,162
King	4,568			1,344	5,742	4,672	1,856	1,137		7	19,326
Kittitas	3,677	4,387	3,990	4,832	4,848	2,636	973	1,075	2,845	2,630	31,893
Lewis							39				39
Okanogan	2,837	2,724	10,281	18,992	6,403	1,585	1,389	2,553	1,923	1,428	50,115
Pend Oreille					170		100			5	275
Pierce				41							41
Skagit					12						12
Snohomish	2,622	7,217	3,462	1,844	518	1,272	1,795	3,010	198	107	22,045
Stevens	23,480	11,894	4,063	8,972	3,757	8,198	1,434	2,004	580	1,017	65,399
Wahkiakum					80						80
Whatcom	5,492	15,635	12,520	133,200	137,382	9,929		519	34,443	95,679	410,356
Whitman		355									355
Yakima					34						34
Other counties											
Totals	$696,275	$557,173	$391,419	$577,655	$492,324	$304,593	$252,862	$120,860	$128,468	$186,965	$3,674,169

PRODUCTION OF SILVER BY COUNTIES, IN VALUE, 1913-1922

COUNTY	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
Asotin	....	....	....	$28	....	....	....	....	....	....	$28
Chelan	$114	$15	$44	118	$8	$151	$2	....	....	$4	456
Clallam	....	....	....	....	....	....	....	$1	$6	1	8
Ferry	98,208	90,513	52,463	90,997	80,822	101,378	73,566	36,269	29,099	32,725	686,040
King	1,835	....	....	372	2,230	2,314	1,187	756	....	360	9,054
Kittitas	37	39	34	50	80	38	17	16	46	68	425
Lewis	....	....	....	....	....	....	31	....	....	....	31
Okanogan	9,918	4,446	21,219	12,368	12,044	32,110	32,360	18,538	38,017	68,312	249,332
Pend Oreille	....	....	....	56	1,279	394	323	....	....	220	2,272
Pierce	....	....	12	114	39	....	....	....	....	....	165
Skagit	....	....	....	....	419	....	....	....	....	....	419
Skamania	....	....	....	79	....	....	....	....	....	....	79
Snohomish	406	761	269	1,170	948	5,000	7,674	15,966	2	1	32,197
Stevens	89,493	50,588	55,643	114,895	132,675	168,669	175,350	146,100	75,189	103,108	1,111,710
Whatcom	57	106	25	263	2,060	39	....	3	91	247	2,891
Yakima	....	....	....	....	28	....	....	....	....	....	28
Other counties	....	....	....	....	....	....	....	....	....	....	....
Totals	$200,068	$146,468	$129,709	$220,510	$232,632	$310,093	$290,510	$217,649	$142,450	$205,046	$2,095,135

PRODUCTION OF COPPER BY COUNTIES, IN POUNDS AND VALUES, 1913-1922

COUNTY		1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
Chelan	Weight	....	104	117	111	....	....	....	4,113	....	....	4,445
	Value	....	$14	$20	$27	....	....	....	$757	....	....	$818
Ferry	Weight	55,544	159,142	317,396	828,264	273,624	127,813	5,313	....	1,213	27	1,768,336
	Value	$8,610	21,166	55,544	203,752	$74,700	$31,570	$988	....	$156	$4	396,490
King	Weight	....	....	....	....	4,870	....	489	....	....	....	5,359
	Value	....	....	....	....	1,330	....	91	....	....	....	1,421
Kittitas	Weight	....	....	....	....	4,002	....	....	....	....	3,582	7,584
	Value	....	....	....	....	1,093	....	....	....	....	484	1,577
Lewis	Weight	....	....	....	....	....	2,014	2,418	....	....	....	4,432
	Value	....	....	....	....	....	497	450	....	....	....	947
Okanogan	Weight	1,070	16,081	43,106	31,144	83,524	169,899	5,523	9,250	4,314	4,536	368,447
	Value	166	2,139	7,544	7,662	22,803	41,965	1,027	1,702	557	612	86,177
Pend Oreille	Weight	....	....	....	....	490	149	399	....	....	62	1,100
	Value	....	....	....	....	134	37	74	....	....	8	253
Pierce	Weight	....	....	1,422	10,381	3,084	....	3,275	....	....	....	18,162
	Value	....	....	249	2,554	832	....	609	....	....	....	4,244
Skagit	Weight	....	....	....	....	....	....	....	....	....	....	....
	Value	....	....	....	....	....	....	....	....	....	....	....
Snohomish	Weight	....	263	41,226	295,485	180,948	452,043	549,788	1,121,913	....	....	2,641,666
	Value	....	35	7,215	72,689	49,400	111,654	102,261	206,432	....	....	549,686
Skamania	Weight	....	142	....	1,280	....	....	....	....	....	....	1,422
	Value	....	19	....	315	....	....	....	....	....	....	334
Stevens	Weight	897,467	602,996	617,659	1,478,357	1,647,490	1,170,488	1,109,371	847,858	246,017	308,996	8,926,699
	Value	139,107	80,198	108,090	363,676	449,770	289,111	206,343	156,006	31,736	41,714	1,865,751
Yakima	Weight	....	....	....	....	1,486	....	....	....	....	....	1,486
	Value	....	....	....	....	402	....	....	....	....	....	402
Totals	Weight	954,081	778,728	1,020,926	2,645,022	2,199,518	1,922,406	1,676,576	1,983,134	251,544	317,203	13,749,138
	Value	$147,882	$103,571	$178,662	$650,675	$600,464	$474,834	$311,843	$364,897	$32,449	$42,822	$2,908,100

PRODUCTION OF LEAD BY COUNTIES, IN POUNDS AND VALUE, 1913-1922

COUNTY		1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
Ferry	Weight	....	5,063	162	3,646	1,395	....	143	....	....	6,358	16,767
	Value	....	$219	$8	$251	$120	....	$8	....	....	$350	$956
Okanogan	Weight	1,639	22,391	23,138	1,704	2,455	785	59,271	33,838	25,302	20,141	190,664
	Value	$72	873	1,087	118	211	$56	3,141	$2,707	$1,139	1,108	10,512
Pend Oreille	Weight	....	....	....	37,695	130,324	193,878	....	....	....	7,372	369,269
	Value	....	....	....	2,601	11,208	13,765	....	....	....	405	27,979
Skagit	Weight	....	....	....	....	....	....	....	....	....	....	....
	Value	....	....	....	....	....	....	....	....	....	....	....
Snohomish	Weight	....	1,317	....	....	....	....	....	....	....	....	1,317
	Value	....	51	....	....	....	....	....	....	....	....	51
Stevens	Weight	200,848	36,196	271,915	5,356,229	9,655,513	5,077,152	2,086,743	5,753,409	118,251	1,347,328	29,903,584
	Value	8,838	1,412	12,780	369,580	830,374	360,478	110,597	460,273	5,321	74,103	2,233,756
Totals	Weight	202,487	64,967	295,215	5,399,274	9,789,687	5,271,815	2,146,157	5,787,247	143,553	1,381,199	30,481,601
	Value	$8,909	$2,555	$13,875	$372,550	$841,913	$374,299	$113,746	$462,980	$6,460	$75,966	$2,273,253

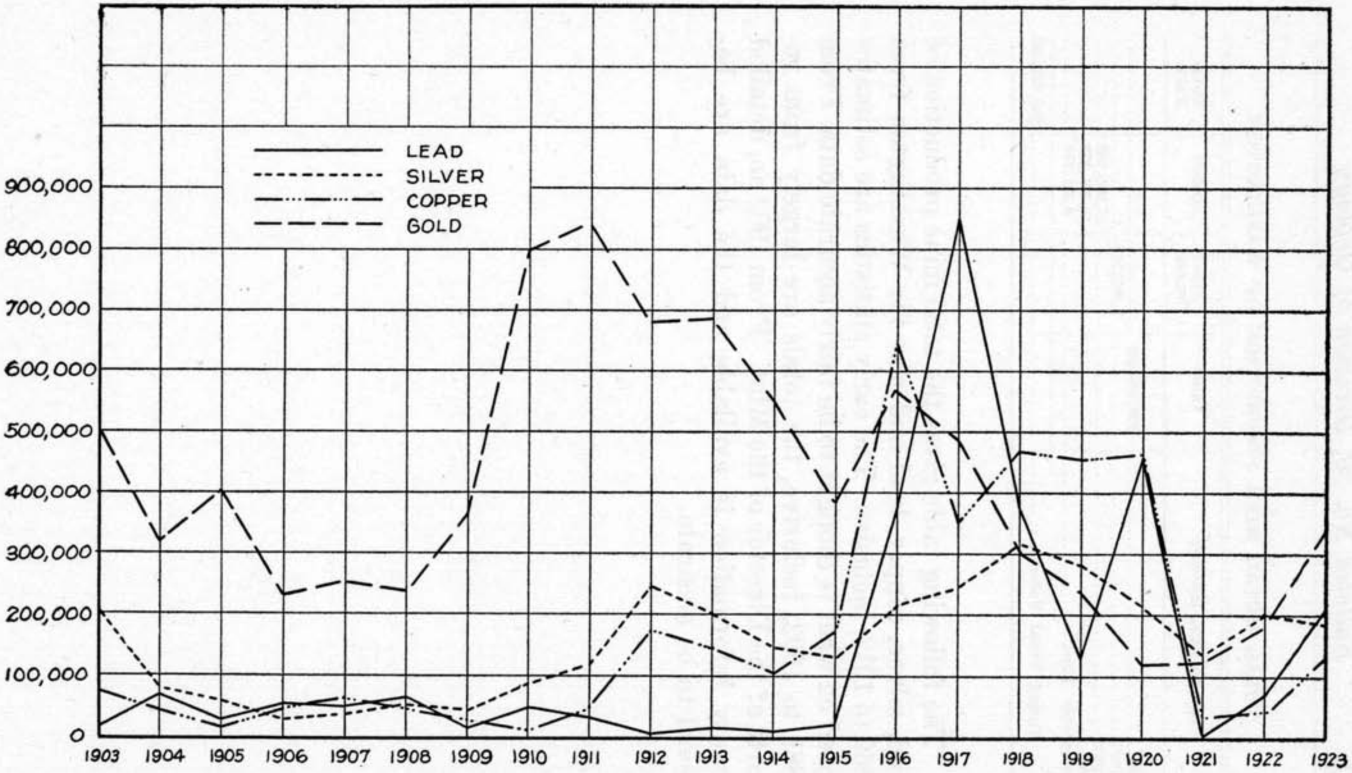

FIG. 2. Values of individual production of gold, silver, lead, and copper for Washington 1903 to 1923, inclusive.

TOTAL METAL MINE PRODUCTION OF WASHINGTON

1860 to 1923, inclusive	Value	Fine Ounces	Pounds	Total Value
Gold	$28,785,523	....	....	....
Silver	....	8,397,278	....	....
Copper	....	....	17,945,662	....
Lead	....	....	44,861,159	....
Recoverable Zinc	....	....	8,321,210	....
Grand Total Value	....	....	....	$42,102,767

The following table gives the total mine production of gold, silver, copper, lead and zinc for Washington from 1860 to 1912, inclusive. The early statistics are estimates based on what is thought to be fairly accurate data. From 1881 to 1902, inclusive, the totals are largely from reports of the Director of the Mint. From 1902 on, detailed county information is available and the data are believed to be accurate.

QUANTITY OF ORE SOLD OR TREATED IN WASHINGTON 1860-1912

	Gold (Value)	Silver (Fine Ozs.)	Copper (Pounds)	Lead (Pounds)	Zinc (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
1909	362,051	79,488	255,134	288,700	....	448,966
1910	788,145	205,345	86,918	1,322,287	....	968,249
1911	847,677	243,781	318,207	848,584	20,590	1,056,017
1912	680,964	413,538	1,086,010	127,387	....	1,120,214
Total	$24,733,846	5,584,062	3,324,525	11,504,934	20,590	$29,542,096

*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 1912 see tables in first of report.

GOLD

Gold is an element, occurring in nature either in the free state as native gold, or in combination with other elements in the form of minerals. It is often associated with copper, lead, and silver in greater or lesser amounts.

Ore minerals. Native, or metallic gold, where pure, has a characteristic yellow color, but when silver is added the color changes to a paler yellow. It has a metallic luster and when pure a specific gravity of 19.37. It is very malleable and ductile. Native gold occurs in the form of grains of various sizes and shapes in stream deposits and also disseminated through masses of quartz in quartz veins. Native gold is the most important source of gold.

Sylvanite is another ore of gold. This is a telluride of gold and silver ($(AuAg)Te_2$) containing 24.5 per cent of gold and 13.4 per cent of silver. It has a brilliant metallic luster and is silver-white, occasionally steel gray, in color. It has a specific gravity of about 8 and is a soft but brittle substance. In some localities, sylvanite is of considerable importance as a source of gold.

Calaverite is a telluride of gold ($AuTe_2$) in which some of the gold is usually replaced by silver. It usually contains about 40 to 44 per cent of gold. Calaverite is opaque, silver-white or bronze-yellow in color, and has a yellow-gray or greenish-gray streak. The surface is often covered with a yellow tarnish. It is a soft but brittle mineral and has a specific gravity of about 9. Calaverite is much like sylvanite, but contains less silver. In some localities it is of considerable importance as an ore of gold.

Uses of gold. The chief uses of gold are in coinage, gold plating, jewelry manufacture, gold leaf for gilding, and in the production of some pigments. The gold coins of the United States contain 900 parts gold in every 1000. The amount of gold used for coinage is about twice that consumed in the arts and industries. Due to the fact that gold is a very soft metal, it is not used in its native state, but is alloyed with other metals. The fineness of gold is estimated by jewelers in carats, 24 carat gold being pure. Sixteen carat gold would be gold containing 16 parts gold and 8 parts of some metal that is less valuable. Copper is usually added as the cheaper metal. This gives an alloy that is harder and has a darker color than gold.

Gold in Washington. Washington has been a fairly large producer of gold since 1860 and has usually been considered, when thought of as a mining state, as a producer of gold. The production of gold to January 1, 1923, amounted to $28,503,979. The production of gold in Washington has varied considerably from year to year, but from 1886 to the close of 1919 the value of the gold has not been for any one year below $150,000. The highest production for any one year was in 1911 when it reached a value of $847,677. The following year, or 1912, recorded a decline in gold production in Washington which continued, in the main, until the close of 1920, the value for that year being only $120,860. This was due largely to the increased cost of labor and supplies, which made it impossible in many cases to produce gold at a profit. Conditions have changed slightly, however, and since 1920 the gold production in Washington has increased somewhat, having a value in 1922 of $186,965.

The annual value of the gold produced in the State was greater than that of any other metal until 1916, when copper took first place in value of metals produced. Since that time the value of copper has gradually declined until 1921 when the value of the gold produced was again greater than that of copper.

The most important counties, as producers of gold, given in the order of value of output for 1922, are as follows: Whatcom, Ferry, Kittitas, Okanogan, and Stevens.

In 1922 Whatcom County produced $95,679, which is a little more than one half of the entire production of the State for that year, and almost three times the value of the production of the County for 1921. Most of this production came from the Boundary Red Mountain Mine, south of Sardis, British Columbia. The ore occurs in a quartz gangue through which is disseminated free gold, pyrite, chalcopyrite, and pyrrhotite. The free gold is usually finely divided and not visible to the naked eye.

Ferry County was the second largest producer of gold in 1922, the output being $85,686, or practically $10,000 less than that of Whatcom County. This is a slight increase over production for 1921. The Republic district is by far the largest producer in the county, and the Quilp, Knob Hill, and Surprise mines were the largest producers in the district. The ore is of such a nature that practically all of it is smelted, the larger part of it going to the British Columbia smelters.

Kittitas County ranks next with a production of only $2,628 for 1922. This is a slight increase in the value of the gold produced in the County for 1921. The gold from this county is from the Swauk district, where it occurs in the form of placer deposits.

Stevens and Okanogan Counties are each small producers of gold. In these counties, however, it is principally a by-product of copper, silver, or lead mining.

GOLD PRODUCED IN WASHINGTON, BY KINDS OF ORE, IN FINE OUNCES, 1913-1922

YEAR	Placers	Dry or Siliceous Ore	Copper Ore	Lead Ore	Per Cent Shipped Crude	Per Cent Shipped As Conc.	Total Ounces	Value
1913	200.47	33,323.21	158.48	.14	90	10	33,682.30	$696,275
1914	278.45	26,453.86	220.93	....	68	32	26,953.24	557,173
1915	346.36	18,277.72	308.59	2.23	90	10	18,934.90	391,419
1916	400.40	26,979.03	563.76	.87	73	27	27,944.06	577,655
1917	283.86	23,240.61	281.93	9.77	70	30	23,816.17	492,324
1918	165.93	14,107.36	463.82	.72	93	7	14,737.83	304,658
1919	60.32	12,016.93	153.01	1.94	98	2	12,232.20	252,862
1920	71.20	5,549.82	223.59	1.99	95	5	5,846.60	120,860
1921	148.66	6,015.38	24.91	26.56	69	31	6,215.51	128,486
1922	162.44	8,830.87	38.40	12.72	46	54	9,044.43	186,965

SILVER

Silver is a metal that occurs in nature either in the free state as metallic silver, or in combinations with other elements in the form of various minerals. It is usually associated with gold, copper, and lead.

Ore minerals. Silver occurs in a large number of combinations and forms a constituent in quite a large group of minerals. Some of the most important ores of silver are metallic silver, silver-bearing galena, pyrargyrite, proustite, stephanite, and argentite.

Native or metallic silver when pure is a white metallic mineral which easily tarnishes to a gray, black, or bluish black color. It is a soft malleable and ductile metal, a good conductor of heat and electricity. It has a specific gravity of about 5.5 and occurs either as crystals, massive, or compact. Native silver furnishes an important part of the silver of commerce. The silver-bearing lead ore, galena, is also a very important source of silver. This is the sulphide of lead and usually contains more or less silver, the fine grained granular variety known as steel galena usually containing more than the coarsely crystalline.

Pyrargyrite, a sulph-antimonide of silver (Ag_3SbS_3), containing 59.9 per cent of silver, is another important silver mineral. This mineral is reddish-black in color, but deep red by transmitted light. It has a specific gravity of about 5.8 and is a rather soft mineral with a metallic adamantine luster. It is commonly found associated with other minerals as proustite, cerargyrite, galena, and sphalerite. Pyrargyrite contains 22.3 per cent antimony and is known as dark ruby silver.

Proustite is a sulph-arsenide (Ag_3AsS_3) and is the light-red ruby silver ore. It contains 65.4 per cent silver and 15.2 per cent arsenic. It has a scarlet-vermillion color and an adamantine luster. It has a specific gravity of about 5.6 and is a comparatively soft mineral. It occurs associated with other silver ores and sulphides of the metals as lead and zinc. In some localities proustite is an important ore of silver.

Stephanite, or brittle silver, is a sulph-antimonide of silver (Ag_5SbS_4), having 68.5 per cent of silver and 15.2 per cent of antimony. It has a grayish-black or iron black color and metallic luster. It has a specific gravity of about 6.2 and about the same hardness as proustite. It occurs most commonly in massive and fine-grained compact forms and in disseminated grains. Stephanite occurs associated with other silver ores and sulphides of other metals as lead and zinc.

Argentite, also known as silver glance, is a sulphide of silver (Ag_2S), containing 87.1 per cent of silver. It has a blackish lead gray color, and dull metallic luster. The specific gravity is about 7.2 and the hardness about the same as that of the silver minerals described above. It usually occurs massive or in the form of arborescent growths.

Uses of silver. Silver alloyed with copper is used largely for coinage purposes. In some cases, as in China, Mexico, and several of the South American countries, it constitutes the main part of the coinage, while in others it forms only the small coins. The small coins of the United States are nine-tenths silver and one-tenth copper, the latter metal being added to give hardness. Silver is used very extensively in table-ware, jewelry, chemical apparatus, manufacture of certain compounds used in photography, silver-plating, and in the manufacture of various utensils used for domestic purposes. The metal is comparatively soft and on account of this it is seldom used in its pure state, but is usually alloyed with some other metal to harden it.

Silver in Washington. Silver has been produced in Washington in small amounts since a very early date. While early statistics are not very reliable, this state is credited with a production of 125,500 ounces of silver prior to 1866, and more or less for each year from that time on to the present. The output of silver since 1891 has averaged about 200,000 ounces a year. In 1902, Washington produced 721,450 ounces of silver and the value of the silver produced was greater than the value of the gold for that year. This is the only year, with the exception of 1922, when the value of the annual production of silver has been greater than that of gold. From 1896 to 1906, the production was fairly constant, ranging from 125,376 ounces as a minimum, to as high as 721,450 ounces as the highest. Beginning with 1902 a decline in the production of silver began, and in 1906 only 45,878 ounces were produced, with a value of only $30,738. An increase in production began then and continued until 1913, when it reached $200,068. Then there was a slight decrease until 1916, when the production began to increase again and continued until 1921, when it had a value of $142,450. In 1922 the production increased slightly, the value being $205,046.

The production of silver in Washington comes principally from Stevens, Okanogan, and Ferry Counties in the order named, Stevens County producing a little more than one-half of the entire output of the State for 1922. The silver is obtained either from the mining of silver ores or from the mining of lead, copper, or gold ore containing silver. In 1922 silver ore contained 37 per cent of the silver, copper ore 33 per cent, gold ore about 15 per cent, and lead ore about 15 per cent. The ore is shipped either in the crude state, as mined, or concentrated. The United Silver Copper Mine, northeast of Chewelah, was the largest producer of silver in 1922.

SILVER PRODUCED IN WASHINGTON, BY KINDS OF ORE, IN FINE OUNCES, 1913-1922

YEAR	Placers	Dry or Siliceous Ore	Copper Ore	Lead Ore	Total Ounces	Total Value
1913	69	186,696	140,214	4,260	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	18	104,980 f	146,891	5,251	259,384	290,510
1920	16	45,977 g	146,820	6,865	199,678	217,649
1921	48	68,991	65,716	7,695	142,450	142,450
1922	49	106,243	68,239	30,463	205,046	205,046

(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.
(f) Includes 64,578 oz. from gold ore and 40,402 oz. from silver ore.
(g) Includes 30,618 oz. from gold ore and 15,359 oz. from silver ore.

COPPER

Copper is an element with the properties of a metal and distinguished from other metals by its peculiar red color. Native copper has a specific gravity of about 8.8 to 8.9, is very ductile and malleable. Copper is one of the very widely diffused metals and occurs in the native state as well as in a great variety of combinations. Fresh surfaces have a metallic luster, but old surfaces become tarnished and dull, often being coated with alternation products.

Ore minerals. The most important ore minerals of copper are native copper, chalcopyrite, bornite, chalcocite, enargite, cuprite, malachite, and azurite.

Native copper occurs in strings, sheets, arborescent masses, and lumps in conglomerates, sandstones and rocks of this character. It occurs abundantly in the Lake Superior region of Wisconsin, and is a very important ore of copper.

Chalcopyrite and bornite are forms of copper, iron sulphide. Chalcopyrite, theoretically, has 55.5 per cent copper; is reddish-brown in color, but often has a purple tarnish. It has a metallic luster and grayish-black streak.

Chalcocite is a sulphide of copper, having 79.8 per cent metallic copper. In color, it is blackish to lead-gray and often shows a black tarnish. Enargite is a sulph-arsenate of copper with 48.3 per cent metallic copper. It is grayish-black to black in color, with a black streak and metallic luster.

Cuprite is the cuprous oxide and contains 88.8 per cent metallic copper. It has a submetallic or admantine luster, a red color, and brownish-red streak. Azurite and malachite are basic carbonates of copper. Azurite is azure-blue in color with a vitreous luster, and contains 55.3 per cent metallic copper. Malachite is bright green in color, with a vitreous luster, and contains 57.7 per cent metallic copper.

The carbonates are products of weathering and are found mainly in the upper weathered portions of copper deposits.

Uses of copper. The uses of copper are so large that only some of the most important ones will be given here. It is used extensively both as a metal and in the form of alloys.

The most important use of copper as a metal is as a conductor of electricity. Of the common metals only one, silver, is a better electrical conductor than copper. On account of this property it has been used extensively for making telegraph, telephone, and trolley wires. It is also used for electroplating by all large newspapers. Large amounts are used in the making of various alloys, such as brass, which is an alloy of copper and zinc in various proportions, the proportion of copper determining the properties of the alloy. The commonest proportion is about two of copper to one of zinc. Bronze, bell-metal, and gun-metal are alloys of copper, tin, and generally zinc. German silver is an alloy of copper, zinc and nickel. In addition to the above, there are many other alloys in which copper is a constituent. Copper is also extensively used in the arts and trades for such purposes as roofing, domestic utensils, plumbing, and copper-plate. Salts of copper are used for pigments, especially to produce blue and green. The sulphate of copper is used in calico printing, in copper plating, and galvanic batteries.

Copper in Washington. The bulk of the copper produced in Washington in 1922 came from the Chewelah district in Stevens County. Of a total production of 317,203 pounds, Stevens County is credited with 308,996 pounds, most of which came from the Chewelah district. For a number of years the Index district in Snohomish County produced considerable copper but no production is reported from this district for 1922. The other counties that produce copper in any amount are Kittitas and Okanogan, and these together produced only 7,118 pounds in 1922.

Previous to 1900, Washington had produced but very little copper, but from that time on the production has gradually increased until 1916 when it amounted to 2,645,022 pounds, with a value of $650,675. This is the largest production, and the value is considerably more than for any other year. This production was a result, partly at any rate, of the war demand. The output, however, kept up pretty well, being around 2,000,000 pounds until the close of 1920. The value nevertheless, decreased very materially, going as low as $364,897 in 1920. In 1921 the production was only 251,544 pounds, which is the smallest amount produced since 1910, when the amount was 86,918 pounds, with a value of only $11,038. Since 1921 the production of copper has increased somewhat in both amount and value; the production in 1922 being 317,203 pounds, or an increase over that of 1921 of 65,659 pounds, while the value was $42,822, or an increase of $10,393 over that of 1921.

COPPER PRODUCED IN WASHINGTON, BY KINDS OF ORE, IN DRY POUNDS, 1913-1922

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	(a)1,025	56	44	2,199,518	600,468
1918........	14,448	1,907,565	393	42	58	1,922,406	474,854
1919........	2,463	1,669,060	(b)5,053	18	82	1,676,576	311,843
1920........	2,073	1,975,604	(c)5,457	12	88	1,983,134	364,897
1921........	3,293	246,017	2,234	....	....	251,544	32,449
1922........	2,189	312,912	2,102	....	....	317,203	42,822

(a) Includes 490 pounds from lead zinc ore.
(b) Includes 4,025 pounds from copper lead ore.
(c) From copper lead ore.

LEAD

Lead as an element is classed as one of the useful metals and is remarkable for its softness and heaviness. It belongs to the class of white metals, but has a decided bluish-gray tint. A freshly cut surface is lustrous, but it soon tarnishes and becomes dull from a film of oxide that forms. Lead is not common in the native state, but is found in some few instances. The specific gravity of lead is about 11.4. It is very malleable, can be rolled into thin sheets, but cannot be drawn into fine wire.

Ore minerals of lead. The lead minerals are numerous but only a few of these are important commercially as sources of lead. The most important ore minerals of lead are galena and cerussite. Anglesite and pyromorphite are less important, but are of frequent occurrence.

Galena is the most important ore of lead. This is the sulphide of lead (PbS) and contains 86.6 per cent metallic lead. Color and streak are lead-gray, and the luster, metallic. It has a specific gravity of about 7.5 and is a comparatively soft mineral. It occurs associated with other lead minerals, and with pyrite, zinc blend, and siderite. It may be massive, crystalline, or coarse or fine grained. The very fine granular variety is known as steel galena and very often contains silver. Cerussite and anglesite are often found in the upper weathered portions of galena deposits.

Cerussite is lead carbonate ($PbCO_3$) and contains 77.5 per cent metallic lead. It is white, grayish, or yellowish in color, with an adamantine, sometimes submetallic luster. It has a specific gravity of about 6.5. It occurs granular, massive, and compact, often in bunches and open masses of slender prismatic crystals. This is an important ore mineral of lead and constitutes the main part of the ore in the upper working or weathered zone of many lead deposits.

Uses of lead. Lead is used extensively in the form of sheets and pipes in the construction of buildings. It is also used in the manufacture of weights, bullets, and shot. For the latter purpose it is usually alloyed with about 0.3 per cent of arsenic, which hardens it. Many very useful alloys of lead are produced, among these being type metal, an alloy of lead and antimony; solder, an alloy of lead and tin, and many others that might be mentioned. Fire plugs in automatic fire devices are low-fusion alloys containing lead, bismuth, and tin. Organ pipe metal is also an alloy of lead.

Some of the salts of lead are used extensively in the trades and industries. White lead is hydrated carbonate of lead and is extensively used as a pigment. Minium (Pb_3O_4) is used as a red pigment and in glass making. Litharge (PbO) is used in glass making, as a glaze for pottery, and as a collecting agent in assaying. Sublimated white lead is a mixture of lead sulphate, lead oxide, and zinc oxide. This is a high grade pigment and is used to a considerable extent. Mixtures of "white lead" and zinc oxide are used as white pigments and lead chromates are used for yellow and red pigments. Sugar of lead, lead acetate, is used in medicine and in the arts.

Lead in Washington. Washington has not been a large producer of lead in the past. The first production credited to this State is for the year 1898, when the amount is given as 857,555 pounds. Since this time there has been some production of lead each year, the amount varying much from year to year. For the first ten year period, from 1898 to 1907, inclusive, the largest production for any one year was 1,760,309 pounds in 1904, and the lowest 216,841 pounds in 1901. For the next ten year period, 1908 to 1917 inclusive, the production was small 65,507 pounds in 1914, until 1916 when the production was 5,399,274 pounds valued at $372,550. The banner year for lead in Washington was 1917, when the production reached 9,789,687 pounds with a value of $841,913.

This very large increase in production was a result largely of the discovery of the Electric Point Mine with its large chimneys of lead ore. During this year, the market for lead was especially good and this, along with the large production, gave an unusually high value for the output. From 1917 to the close of 1921 there was a very marked decline in both the production and value of the lead, so that the output for 1921 was only 143,553 pounds, with a value of only $6,460. In 1922 the mine production of lead increased to practically ten times what it was in 1921, and on account of better market conditions, the value was practically twelve times what it was in the previous year. Even with this increase in production, however, the amount was only about one-seventh and the value a little more than one-twelfth that for 1917.

The lead produced in Washington comes almost entirely from Stevens, Okanogan, and Pend Oreille Counties. The Gladstone Mine, near Northport, became a regular producer during 1922. It adjoins the Electric Point Mine and the occurrence of the ores is practically the same. The ore is cerussite or lead carbonate and galena or lead sulphide. The Santa Rita Mine, west of Springdale, was also a considerable producer of lead ore during 1922.

PRODUCTION OF LEAD IN WASHINGTON, 1913-1922

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
1920	8.0	5,787,247	462,980
1921	4.5	143,553	6,460
1922	5.5	1,381,199	75,966

ZINC

Zinc is one of the useful metals, harder and less malleable and ductile than lead. Native zinc is not positively known to occur in nature and if it does occur it is very rarely. It is found in combination with other elements and is widely disseminated. It has a brilliant metallic luster which possesses a bluish tint and crystalline structure. Zinc has a specific gravity of about 7.15 and is one of the group of metals which displays both metallic and non-metallic properties.

Ore minerals of Zinc. The principal ore minerals of zinc are sphalerite, Smithsonite, zincite, franklinite, calamine, and willemite.

Sphalerite, or zinc-blend, is a sulphide of zinc (ZnS), containing 65 per cent metallic zinc. It is often impure, containing iron, manganese, and cadmium. It varies much in color being yellow, brown, black, and sometimes green or red. It has a resinous to adamantine luster, a specific gravity of about 4, and is a little harder than lead sulphide with which it is often associated. Sphalerite occurs either massive, coarse to fine granular and compact, or in some cases in the amorphous form. This is one of the very important ore minerals of zinc.

Smithsonite is the carbonate of zinc ($ZnCO_3$) and has 52 per cent of metallic zinc. The color is variable, but is usually white or gray, and the luster, when crystalline, is vitreous to pearly. It has a specific gravity of about 4.35. It usually occurs in a massive earthy condition and is found associated with sphalerite, galena, calamine, and calcite.

Zincite is the oxide of zinc (ZnO) and contains 80.24 per cent metallic zinc. The color is deep red or orange-yellow and the luster adamantine. It has a specific gravity of about 5.6. It occurs foliated, granular, massive, or in coarse particles or grains. It is found as an ore of zinc associated with willemite and franklinite.

Franklinite consists of the oxides of zinc, iron, and manganese with usually about 20 per cent of zinc oxide. The color is black or brownish-black, and the streak dark brown, while the luster is metallic. The specific gravity is about 5.12. One of the principal localities where franklinite occurs is at Franklin Furnace in New Jersey where it is found associated with zincite and willemite.

Calamine is a hydrous silicate of zinc ($(ZnOH)_2SiO_3$), containing 15.54 per cent of metallic zinc. In color it is usually white, but is sometimes greenish and bluish. The luster is vitreous to almost pearly. It has a specific gravity of about 3.5 and occurs in various forms as massive, granular, fibrous, and stalactitic. Smithsonite is usually found associated with calamine.

Willemite is a silicate of zinc (Zn_2SiO_4) and contains 58.5 per cent of metallic zinc. The color, when pure, is white to greenish-yellow, but it may be apple-green or flesh-red. The luster is vitreous to resinous. It has a specific gravity of about 4 and occurs either massive or in disseminated grains.

Uses of zinc. Zinc is used very largely in the manufacture of galvanized iron, which consists of sheets of iron covered with a layer of metallic zinc. It is also used extensively in the manufacture of certain alloys as brass, bronze, and German silver. Zinc is also used in the manufacture of telegraph batteries as well as batteries for other purposes. Slabs of zinc are also used for de-silverizing lead. Zinc oxide is used in the manufacture of rubber and the sulphate is used extensively in dyeing and coloring yarns and fabrics. Zinc chloride is used somewhat as a preservative of wood that is to be placed in the ground. Zinc is also used extensively as a pigment, either alone or mixed with other substances.

Zinc in Washington. The first record of zinc having been produced on a commercial scale in this State is for 1911, when ores were marketed from which 20,590 pounds of zinc were recovered, with a value of $1,174.[1] This zinc came from the Oriole mine in Pend Oreille County. This appears to have been the only zinc produced in this State until 1915 when a production of 244,906 pounds was made with a value of $30,368. This also all came from Pend Oreille County. The following year (1916) the amount of zinc produced was 1,693,734 with a value of $226,960. From 1916 a decline in the production of zinc took place and continued until 1919, when no zinc was produced in Washington. Beginning with 1920, production was resumed again and gradually increased until in 1922 the production had reached 1,228,229 pounds, having a value of $70,009.

This increase in production has been due to a large extent to the discovery early in 1920 of a deposit of zinc carbonate about six miles east of Northport. This deposit occurs along the county road between Northport and Leadpoint. This property is known as Washington Black Rock Mine.

Zinc is reported to occur in a number of places in Washington, but so far the production has come from Pend Oreille and Stevens Counties.

[1]Mineral Resources of the United States, 1911. U. S. Geol. Survey (1912), Part 1, pp. 784, 787.

PRODUCTION OF ZINC IN WASHINGTON

YEAR	Av. Price Per Pound	Total Pounds	Value
1919	....	None	None
1920	$.081	426,496	$34,546
1921	.050	449,360	22,468
1922	.057	1,228,229	70,009

ANTIMONY

Antimony is an element resembling a metal in appearance and physical properties but in its chemical relations belonging to the class of non-metallic substances. Antimony is usually found in lamellar, radial, and botryoidal masses. It exhibits brilliant cleavage surfaces with tin white color. When exposed to atmospheric agencies the color changes to dark gray.

Ore minerals. Native antimony, on account of its rarity, is of little commercial importance. The chief ore mineral of antimony is stibnite (Sb_2S_3) which theoretically, contains 71.4 per cent of antimony and 28.6 per cent of sulphur. Stibnite is found in quartz veins cutting crystalline rocks and in metalliferous veins associated with lead and zinc ores. Stibnite fuses very easily, thin splinters melting even in the flame of a candle.

Uses. Antimony as a metal unalloyed is of very little commercial importance on account of its very restricted use. It, however, alloys readily with most heavy metals and forms an alloy that is harder than the pure metals. Most alloys of antimony have the property of slight expansion on solidifying, which is a very valuable property of metals to be used for certain purposes. Type metal is an alloy of antimony, lead, and tin; babbitt, anti-friction, or bearing metal usually consists of antimony, tin, and copper. Britannia metal, also known as "white metal," is an alloy of antimony, tin, and copper, with some zinc and rarely small amounts of other metals. The principal use of this metal is in making cheap domestic table-ware such as spoons and teapots. The metal was much more extensively used at one time than it is now. Antimony alloys are also used in making battery plates, toys, and cable coverings, while small amounts of antimony are used in certain brasses and aluminum alloys. A considerable amount of antimony alloyed with lead and known as "hard lead" is used for various purposes.

White antimony oxide is used in making opaque white enamel and other sanitary ware. For this purpose the tetra-oxide (Sb_2O_4) is mostly used. Antimony oxides are also used in the manufacture of glass and as paint pigments. Antimony sulphides are used in vulcanizing and coloring rubber, and in the manufacture of safety matches, percussion caps, certain kinds of fireworks, etc. Antimony and lead, in certain proportions, form what is known as "Naples yellow" which is used as a pigment in oil paints and in the glass and ceramic industry. Tartar emetic, and antimony fluoride are employed as mordants in dyeing.

Lead containing from 12 to 13 per cent antimony is used in the manufacture of bullets, while antimony sulphide is almost universally used as a constituent of primers in shells and catridges. Antimony sulphide is used as a powder in the charges of some shells. When these shells explode a dense white smoke is produced which helps in range finding.

New uses are being found for antimony and as a result of this the demand may gradually increase. The use of antimony compounds, especially the oxides in paints, is rapidly increasing and this seems to be a very promising field and one that may eventually call for a large amount of antimony.

Production. Antimony deposits occur in many places in the United States, and especially in the Western States. The comparatively high cost of mining in this country, however, does not permit of the mining of these ores, in competition with the Chinese and Mexican ores, during peace times. At the outbreak of the war, the price began to advance rapidly on account of the increased demand for antimony in the manufacture of war munitions and metallic antimony went from about 6 to 8 cents a pound to 44 cents a pound in March, 1916. These high prices caused a considerable development of some of the antimony deposits in the United States and in 1915 this country produced ore carrying about 2,100 short tons of antimony. These high prices of antimony also stimulated imports and this, along with the domestic production, caused the price of antimony to decline until the ordinary grades brought from 11 to 12 cents during the latter part of 1916. This made it impossible for many of the domestic mines to operate at a profit, and they were closed down.

The anticipation of the entrance of the United States into the war caused a recovery in prices of antimony, and by April, 1917, the price of ordinary grades had reached about 33 cents a pound. This increase in price again stimulated imports until they were far in excess of the demand and this had the effect of lowering prices and building up large reserve stocks, so that during the last half of 1917 the price was fairly constant at about 14 cents. This price made it impossible for the domestic antimony mines to be worked at a profit under the then existing conditions, and they were closed down and practically no antimony ore has been produced in the United States since 1918.

At the close of 1923 the price of white antimony oxide, Chinese, guaranteed 99 per cent (Sb_2O_3), in New York, was 7½ cents.

Deposits in Washington. Antimony is reported to occur in Ferry, King, Kittitas, Okanogan, Snohomish, and Stevens Counties. The deposits are all comparatively small and during normal times cannot compete with the ores from China. In some cases the ores carry considerable silver and the demand for silver has an important bearing on the working of these ores, the antimony in this case being obtained as a by-product.

In the Covada district of Ferry County stibnite fills small veins in the silicified zone of the Longstreet Mine closely associated with silver ore. It does not appear to be silver bearing of itself, however, and is rare in other parts of the district.[1] The R. E. Lee prospect is located 1¼ miles northeast of Covada about a quarter of a mile south of the Longstreet property. This property contains a series of small veins carrying almost pure antimony sulphide. One stringer, 3 inches wide, completely filled with stibnite or berthierite, is the widest; others range from one-half an inch to an inch in width, and are separated from one another by barren country rock, the whole mineralized zone being about two feet wide.[2]

In King County, antimony is reported as occurring in the form of gray copper, and antimonial silver in the Cleopatra Mine on Miller River. Antimony sulphide or stibnite occurs in the Great Republic Mine. In the past some attempts have been made to treat the antimony ores in this district, but they have all been financial failures.

Antimony ores occur in a number of places in Okanogan County, and from some of the deposits in this county antimony has been produced on a commercial basis. Several carloads of good grade antimony ore are said to have been shipped from the Lucky Knock Mine

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[1]Pardee, J. T. Geology and Mineral Deposits of the Colville Indian Reservation, U. S. Geol. Survey Bull. 677 (1918), p. 151.

[2]Bancroft, Howland. The Ore Deposits of Northeastern Washington, U. S. Geol. Survey, Bull. 550 (1914), p. 196.

situated near Tonasket. The ore is stibnite and is said to occur as irregular replacement deposits in limestone.[1] A plant was built on the property for treating this ore but there has been no activity for several years. Stibnite occurs in the Antimony Queen Mine and the Dixie Queen Mine near Methow and in the property of the Ruby Mining Company in the Mt. Chopaca district.

In Stevens County some antimony occurs, but the deposits have been but little developed and no antimony of importance has been produced from this county. The Wells-Fargo Mining Company owns property in the northwest quarter of Sec. 36, T. 31 N., R. 38 E., on which there is a white milky quartz vein that has a thickness of from three to five feet and in which bunches of stibnite occur along with subordinate amounts of pyrite. Some development work has been done on this property and the indications are said to be encouraging.

ARSENIC

Arsenic is an element which is usually classed among the non-metals, though it has some of the characteristics of a metal. Its appearance and luster are metallic, and it forms with certain metals compounds which though brittle correspond to true alloys. The addition of arsenic to most metals makes a very brittle alloy. An alloy of lead and arsenic, known as hard lead, is used for certain purposes. Arsenic is a good conductor of heat and electricity.

On freshly exposed surfaces arsenic is lead gray or tin white, but it soon tarnishes to dark gray and almost black when exposed to the atmosphere. In most of its mineral combinations, arsenic acts as an acid forming element. Exceptions to this are, of course, the sulphide and the simple oxides.

[1]Patty and Glover, The Mineral Resources of Washington, With Statistics for 1919, Wash. Geol. Survey Bull. 21 (1921), p. 58.

Ore minerals. Arsenic is occasionally found native, but in this form it is of no commercial importance in the production of arsenic. The principal minerals of arsenic are arsenopyrite (FeAsS), orpiment (As_2S_3), and realgar (As_2S_2). Arsenic is, however, a constituent of a large number of other minerals and in fact most of the arsenic of commerce is a by-product from the smelting of arsenical gold and copper ores.

Uses. Arsenic is used only in the form of its compounds. The native metal occurs too sparingly to be of commercial value. Arsenious oxide, the white arsenic of commerce, is used in the manufacture of certain pigments, and in making glass and enamels. The plate glass factories use large quantities of white arsenic, the consumption of a single company reaching as much as 50 or 60 tons a year. It is also used in making medicine. It is alloyed with lead in the manufacture of shot, about 0.3 being added to harden the lead. Large amounts of sodium arsenite are used in insecticides, as in sheep dips. Much arsenic and arsenates of soda are used in making Paris green, which has a very large use as an insecticide. Sodium arsenate solution has also been used very extensively the past few years by many of the railroad companies for killing weeds on rights of way.

One of the very important uses of arsenic at the present time is its use by the cotton growers as calcium arsenate in combatting the boll weevil pest. The use of calcium arsenate for this purpose began in 1919 and in 1922 about 8,000 tons was distributed, which was equivalent to 4,600 tons of white arsenic. This, however, did not supply the demand and by September the scarcity was acute and prices rose rapidly from August, when white arsenic sold for 8½ cents a pound, until December when it was selling for 15½ cents a pound.

Indications are that calcium arsenate may continue as the cheapest and most effective poison for the control of the boll weevil in the infested cotton fields. Its use may be expected to increase rapidly in the next few years, and there may still be some question as to the quantity readily available. There is very little doubt as to the adequacy of the supply of arsenical ores within the United States, but the important question is whether these ores can be mined and treated profitably for their arsenic content only, without increasing the price of arsenic to such a point that the price of cotton will not justify the use of the arsenic.

Freight charges are an important item in the distribution of arsenic, and cheap water transportation enables the imported material to compete with the domestic, especially in favorably located consuming centers. Thus Canadian arsenic from the Cobalt district may find its way into the central part of the United States, south of the Great Lakes, while supplies may come from Mexico by boat to ports on the Atlantic seaboard. Unfortunately many of the American smelters at which arsenic is recovered and many of the mines from which the arsenic produced in the United States comes, are in the western part of the country far from the consuming centers, which are in the eastern and southern part. This necessitates a heavy transportation charge.

Deposits in Washington. Many of the ores mined in Washington for the gold, silver, or copper that they contain, have also a considerable amount of arsenic, and in some cases the amount is sufficient to make it a source of profit.

Washington has the distinction of being the first state in the Union to produce white arsenic on a commercial scale. In 1901 the Puget Sound Reduction Company, at Everett, Snohomish County, installed a plant for collecting the fumes and refining arsenic. The ore treated by this company was largely from the Monte Cristo district in Snohomish County and carried a large amount of arsenic. The ore from this district carried relatively small amounts of gold and silver and was mined and treated for these. The principal ore in the Monte Cristo district is arsenopyrite, which theoretically contains 46.0 per cent of arsenic, 19.17 per cent sulphur, and 34.3 per cent of iron. Much of the arsenopyrite, however, has been changed by weathering to either realgar (AsS) containing 70.1 per cent of arsenic and 29.9 per cent of sulphur, or to orpiment (As_2S_3) containing 61.0 per cent of arsenic and 39.0 per cent of sulphur. The smelter at Everett has long since been dismantled and the mines in the Monte Cristo district have been producing but little ore for the past ten years.

Arsenical ores are found in many places in the Cascade Mountains in Washington. These ores occur on both the eastern and western sides of the range, especially in the northern part of the State. The counties from which arsenic has been reported are the following: Ferry, King, Lewis, Okanogan, Skagit, and Snohomish. In most cases the arsenic is an accessory mineral but in a few places it occurs as realgar and forms the principal part of the ore. This is especially true of a deposit at Mineral, in Lewis County, and at one time a plant was in operation there and white arsenic was being produced. During 1922 ore containing realgar was being concentrated at Gold Bar in south central Snohomish County and the output during the time of operation was more than a ton of realgar a day. The ore occurs along a faulted and brecciated zone in diorite.[1] The ores from the Miller River district in King County carry arsenic and they have been the source of a considerable part of the arsenic produced from ores mined in this State. Realgar occurs near Clear Lake in Skagit County, but so far as the writer is aware,

[1]Mineral Resources of the United States, 1922, Part I, U. S. Geological Survey, p. 64.

arsenic has not been produced commercially from this locality.

A deposit of realgar (AsS) occurs near Reiter, Snohomish County, which has been developed by the American Arsenic Company, which has its head office at Burlington, Washington. The following description of the property is from Bulletin No. 21, Washington Geological Survey:

"The mine is 2,000 feet above and four miles by trail from Reiter, a station near Index on the Great Northern Railway. The arsenic occurs principally as realgar with subordinate amounts of orpiment and arsenalite. 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 near-by 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 fifteen ton flotation mill was completed on the property during July, 1920, to provide concentration facilities for the lower grade material."

CHROMIUM

Chromium is a metal that in the compact form is whiter and more lustrous than iron, intensely hard, brittle, and less fusible than platinum. It oxidizes slowly in the air, but burns vividly in oxygen. It has a specific gravity of 6.9. Hot hydrochloric or sulphuric acid dissolves it, but strong nitric acid does not affect it. Chromium is not found native in nature but always in combinations with some other substance, the most common occurrence being as the mineral chromite.

Ore minerals. Chromite ($FeCr_2O_4$) is the principal ore of chromium. It has the theoretical composition of chromium oxide (Cr_2O_3) 68 per cent, and iron oxide (FeO) 32 per cent, but it usually contains small amounts of aluminum oxide (Al_2O_3), calcium oxide (CaO), and magnesium oxide (MgO). Its color is brownish-black and its streak brown. It has a conchoidal or uneven fracture and no distinct cleavage. It is usually nonmagnetic, but some specimens show slight magnetism because of the admixture of the isomorphous magnetite molecule. Its hardness is about 5.5. This is the principal source of chromium.

Chromite occurs principally in olivine rocks and in their alteration product, serpentine. The mineral is found not only as crystals embedded in the rock mass, but also as nodules in it and as veins traversing it. It is probably a segregation from the magma producing the rock. In a few places the mineral occurs in the form of sand on beaches.

Uses of chromium. The following summary of the uses of chromium is taken from the Mineral Resources of the United States, 1920.[1]

"Chromium has many uses, but is most largely used as a constituent of chrome steel, a steel made to resist great wear and violent stresses, such as those imposed upon armour plate, automobile springs, ball bearings, and jaws of rock crushers. The chromium is introduced into the steel as ferrochrome, containing usually between 60 and 70 per cent of chromium.

"A corrosion-resisting chrome steel known as 'stainless steel,' though first made long ago, has recently received considerable attention and may become of wide application. The properties of this steel are described by T. H. G. Monypenny.[2] 'As commonly made, it contains from 11 to 14 per cent of chromium and not more than 0.45 per cent of carbon. It strongly resists rusting and all forms of oxidation, even at high temperatures, and it is not corroded by many agents that attack ordinary steel, nor is it affected by nitric acid, though it is attacked by hydrochloric or sulphuric acid. Salt water, fruit juice and ammonia have no effect on it, whence the name "stainless." Although invented by an American, "stainless steel" was first used in England for making cutting steel, but it may be used for other purposes. During the World War it was used extensively for making the valves of internal-combustion engines, a use for which it is particularly suited, not only because it resists

[1]Sampson, Edward. "Chromite," Mineral Resources of the United States, 1920, U. S. Geol. Survey (1922), pp. 21-22.

[2]Monypenny, T. H. G., Stainless steel: Soc. Chem. Ind. Jour., Vol. 39, No. 22, pp. 390R-391R, 1920; abstract and editorial comment, Min. and Sci. Press, Vol. 122, No. 14, Apr. 2, 1921.

pitting but also because it retains its strength at high temperatures to a marked degree.'

"Monypenny states that stainless steel is subject to as great a variety of heat treatment as ordinary steel and that its physical properties are equal to those of ordinary steel and in some respects superior. The war delayed the development of stainless steel because of the lack of chromite, but its use should increase greatly, and it may even be used in structural work.

"Stellite is essentially an alloy of cobalt and chromium, to which is usually added a small quantity of tungsten to increase its strength. Its composition varies as follows:[1] Cobalt 50 to 60 per cent; chromium 30 to 40 per cent; tungsten, 8 to 20 per cent. It strongly resists corrosion and is of great hardness. Its hardness persists at high temperatures, so that during the war it was largely used in high speed lathe tools employed for turning shell and ordnance. It is extensively used in the manufacture of surgical and dental instruments.

"Chromite is used as a refractory material, principally in the steel industry. In fact, one of the chief objections to chromite is that it is so refractory that it will not sinter or form a bond, so that it is subject to considerable mechanical wear. About 60 per cent of the chromite used as a refractory is in the form of brick and the remaining 40 per cent is in the form of lump and crushed ore. It is used chiefly in the basic open-hearth process by which three-quarters of the steel produced in the United States is made. Chrome brick are used between the clay brick or silica brick foundation and the magnesite floor and also as a neutral bond between the basic lower and acid upper walls. The crushed ores are extensively used in making repairs and to some extent for protecting the acid roof. It has been estimated that about 1½ pounds of chromite are consumed for each ton of steel made. Small quantities of chromite refractories are used in certain parts of furnaces for smelting copper and nickel.

"The chemical industry consumes a large quantity of chromite in making chromates and bichromates of soda and potash and chromic acid. Before the war, the tanning industry consumed about two-thirds of the chromium chemicals, but during the war the proportion was reduced to about one-half. In dyeing textiles chromium salts are used as mordants. The cloth is saturated with the mordant and then introduced into a bath of the coloring matter, where a precipitate (lake) is formed on and in the fiber of the cloth. Chromium compounds are also used as pigments.

"Early in 1918 the War Industries Board, after a canvass of the consumers, made an estimate of the quantities of chromite that would be required in 1918 by the different domestic industries. The total estimated requirement was 130,000 tons of 50 per cent ore,

[1]Wright, S. B., Stellite: Canadian Min. Trans., Vol. 21, pp. 272-277, 1918.

which, reduced to percentages by uses, amounted to the following figures: For ferrochrome 52 per cent, for chemicals 31 per cent, for refractories 17 per cent. These figures, however, are approximate and would not apply to a normal year, but they show the order of magnitude of the requirements of the several industries."

Metallic chromium has no direct use, the metal being added to steel in the form of ferrochrome, an alloy of chromium and iron containing 60 to 70 per cent metallic chromium. Various steels are produced, such as chrome-vanadium-steel, chrome-tungsten-steel, and chrome-nickel-steel. These special steels containing chromium are used in articles where hardness and toughness are essential properties such as guns, armor plate, armor-piercing projectiles, automobile parts, machine tools, burglar-proof safes, cutlery, crusher-jaws, and stamp-mills.

Chromite deposits in Washington. The World War stimulated the search for and the development of already known deposits of chromium in Washington. As a result of this increased activity some new chromium deposits were discovered and some of those that were already known became producers so that for a few years Washington was a producer of chromium.

The best known body of chrome ore in this State is on Cypress Island, Skagit County. This island is one of the San Juan group and can be best reached from Anacortes. Another deposit from which some chromite has been produced is near Mount Hawkins in Kittitas County. During 1917 and 1918, these two localities are said to have produced about 200 tons, most of which contained between 45 and 50 per cent of chromic oxide. One lot from Cypress Island that contained about 25.5 per cent was concentrated in a plant in Seattle and yielded coarse and fine concentrates that contained in round numbers 44 and 50 per cent of chromic oxide. Samples from the deposits near Mount Hawkins are said to carry as much as 51 per cent chromic oxide. These high percentages indicate that the ore from these deposits carries but little ferric oxide or other substances capable of replacing chromic oxide and that these deposits may yield material suitable for use in industrial chemistry as well as ferro-chrome and chrome bricks.

Chromite deposits are reported from a number of places in the northern Cascade Mountains, and the fact that considerable amounts of chromite are found in the sands along some of the streams tributary to the Skagit, and Wenatchee Rivers would indicate that deposits of chromite occur along these streams.

Several large deposits are known to occur in the Sister Peaks district in T. 37 N., R. 6 E. in southwestern Whatcom County. The formation in this district is peridotite, carrying chromite as an accessory mineral, distributed through the rock.[1] The ore is of good grade, but is worthless at present on account of lack of transportation facilities. The properties in this district were located by O. D. Post and R. L. Lambert of Sumas.

Chromite deposits are reported also as occurring near the town of Nighthawk on Chopaka Mountain.

The following description of the chromite deposits on Cypress Island is taken from a report by J. T. Pardee.[2]

"HISTORY OF MINING"

"Chromite ore was mined on Cypress Island in 1917 by the Bilrowe Alloys Company for use in its smelter in Tacoma. Prior to this no production is reported. but a moderate amount of development work had been done on several claims that had been located 15 or 20 years earlier. In 1918 development work was extended, several new bodies were found, and a moderate amount of ore was produced by the Cypress Chrome Company.

GEOLOGY

"So far as known the island is underlain entirely by serpentine. Except a few patches of glacial drift, no other rock was seen in a traverse from the east to the west shore or reported by persons

[1]Patty, Ernest N. and Glover, Sheldon L., Min. Resources of Washington, Wash. Geol. Survey, Bull. 21 (1921), pp. 61-62.

[2]Pardee, J. T., Chromite Ores of Washington, U. S. Geol. Survey, Bull. 725 (1922), pp. 62-65.

familiar with the other parts of the island. The outcrops are numerous and extensive and are colored deep brown on the roughened weathered surface. The weathered layer is very thin, however, and the fresh rock shows the smooth curved fractures and predominating dark-green shades characteristic of serpentine generally. The microscopic texture of several specimens examined suggests that the serpentine was derived from olivine. The rock is traversed by many persistent shear or joint planes of a general northerly direction, and fault planes that extend eastward are exposed by some of the workings.

ORE BODIES

"*Distribution and occurrence.* Chromite is scattered through the serpentine in many places, in several of which it is sufficiently abundant to form workable ore bodies. The largest body of this description observed by the writer is on the Ready Cash claim, on the steep west slope of the island, about 1,100 feet above sea level and three-quarters of a mile from the shore. It was developed by an open cut 10 feet wide, 15 feet long, and 6 feet deep, from which about 25 tons of ore was mined. The serpentine is traversed by persistent narrow veins or seams that trend N. 25° W. and are filled with a rather soft light-green clay like material, apparently a decomposition product of the rock itself. Locally the seams are accompanied by chromite, which forms irregular veinlets an inch or more thick and bunches or pockets a foot or more in diameter. The surrounding masses of serpentine also contain more or less chromite in the form of scattered grains. On the south side of the cut, a face 6 feet high and 6 feet wide was estimated to be about half serpentine and half chromite. On the north a fault that strikes N. 75° E. and dips 60° S. cuts off the ore. In 1918 the Cypress Chrome Company developed this body further, extending its known limits considerably and mining about fifty tons of ore.

"On the southwest side of the island, on one of several claims belonging to the estate of George B. Smith and others, a short distance west of Mexican Bay, a small ore body is exposed by an open cut and short drifts. These workings are made along a fault plane that strikes N. 70° E., dips 80° N., and carries two or three feet of crushed and mixed serpentine and chromite. Small bunches and stringers of chromite are also scattered through the serpentine in the hanging wall. At a level 70 feet below the open cut, an adit is driven N. 65° W. for 60 feet, following prominent joint planes that dip 45° SW. In this working small bunches and streaks of chromite occur sparingly.

"At the lake near the center of the island, an adit level is driven northward 120 feet into the serpentine without disclosing more than a few grams of chromite, but several small streaks of chromite are said to crop out on the hill above.

"Bodies made up of chromite grains thickly disseminated in serpentine were discovered a short distance south of the lake by the Cypress Chrome Company while building a road from Strawberry Bay to the Ready Cash claim. A shipment from one of these bodies was milled at the Faust Concentrating Company's plant in Seattle. Other similar bodies are reported to occur short distances west and south of the Ready Cash claim.

"*Character and composition.* Ore from the Ready Cash body consists of rather coarse granular chromite intergrown with a small amount of micaceous amethystine or rose red mineral identified as the chrome chlorite kotschubeite. There is a little serpentine between the grains, and the aggregate is cut by veinlets of a rather coarse platy light-green chrome-bearing variety of horn-blende. Most of the other deposits consist of serpentine more or less thickly peppered with fine grains of chromite. Ore shipped from the Ready Cash claim by the Cypress Chrome Company averaged 47.5 per cent of chromic oxide. Ore from the Last Chance claim, south of the lake, that was milled in Seattle carried 25.5 per cent of chromic oxide. The coarse and fine concentrate made from it contained respectively 43.9 per cent and 49.6 per cent of chromic oxide."

COBALT

Cobalt is an element having the properties of a metal. It is steel-gray in color and has a specific gravity variously given at from 8.52 to 8.95. It closely resembles nickel, with which it is usually associated, the two metals having practically the same specific gravities and atomic weights. The two metals have also practically the same ductility and tenacity and both resemble iron in many respects.

Ores of Cobalt. The important ore minerals of cobalt are cobaltite and smaltite.

Cobaltite (CoAsS) is a silver-white or steel-gray mineral occurring either in the crystalline or massive form. Theoretically, it contains 19.3 per cent sulphur, 45.2 per cent arsenic, and 35.5 per cent cobalt. Usually cobaltite contains some iron and nickel. It occurs in large quantity at Cobalt, Ontario, where the ores are silver containing nickel and cobalt.

Smaltite ($CoAs_2$) is another important ore of cobalt. The theoretical composition of smaltite is 71.88 per cent arsenic, and 28.12 per cent of cobalt, but it usually contains some sulphur, nickel, and iron. The mineral is tin-white to steel-gray, and opaque, and has a grayish black streak. Smaltite is found associated with cobaltite and like it is especially abundant in the ores of Cobalt, Ontario.

Uses of Cobalt. The largest part of the cobalt used in the United States goes into the various grades of stellite and high speed steels. The Haynes Stellite Company of Kokimo, Indiana, is probably the world's largest user of cobalt. This company uses cobalt in making either malleable or nonmalleable alloys. The malleable alloys are composed almost entirely of chromium and cobalt, these being used in different proportions to give somewhat different results. These malleable alloys have been used in the manufacture of various things such as table-ware as spoons, knives, and forks; surgical instruments, pocket knives, and dental instruments; evaporating dishes, and lamp stands; and in certain forms of jewelry.

The nonmalleable stellite contains tungsten or molybdenum or both, alloyed with cobalt, and is used in competition with high speed steels. The production of stellite increased very materially in the last few years and the industry has become of considerable importance.

Cobalt is also used in coloring glass, pottery, and in insect poisons. As a coloring material in glass and pottery it produces blue colors. It is also used to a certain extent in the manufacture of various chemicals.

Cobalt in Washington. Cobalt in the form of smaltite nodules are reported from the Pin Money claim in the Belcher district in Ferry County. Analyses, however, by R. C. Wells of the U. S. Geological Survey, failed to show the presence of cobalt.[1]

[1]Bancroft, Howland. The Ore Deposits of Northeastern Washington, U. S. Geol. Survey, Bull. 550 (1914), p. 178.

Cobalt is also reported to occur in the Ontario and Black Republican mines near Leavenworth in Chelan County.

IRON

Iron is an element that until recently was thought to occur in nature as metallic iron, only in meteors. Recently, however, it has been found to occur in considerable quantities in some of the basaltic lava of Greenland. Iron has a specific gravity of about 8 and when practically pure is almost as white as silver and extremely tenaceous. Pure iron is rarely, if ever, produced.

Iron is put on the market in three different forms, each of which has different properties. Cast iron is the product of the blast furnace and contains much carbon. The carbon is not, however, evenly distributed throughout the mass. Cast iron is hard, comparatively brittle, readily fusible, but cannot be forged or welded. Cast iron as such finds but little direct use in the industries.

Wrought iron is a form of iron which contains a very small amount of carbon, is comparatively soft, malleable, ductile, and may be welded.

Steel is an alloy of iron and carbon in which the carbon ranges from a fractional part of one per cent to as high as three per cent. It may also contain small amounts of silicon. Special forms of steel are made by the addition of manganese, tungsten, nickel, chromium, vanadium, molybdenum, either separately or two or more together. Steel, like wrought iron, is malleable and may be welded.

Minerals important as ores of iron. The minerals important as ores of iron are hematite, magnetite, limonite, and siderite.

Hematite is the sesquioxide of iron (Fe_2O_3) containing 70 per cent of metallic iron. The hard crystalline forms are bright steel-gray to iron black, while the soft forms are red or reddish-brown. The luster varies much in the different varieties and may be metallic, sub-metallic, or dull. The specific gravity is about 5 for the solid crystalline variety, while the soft earthy varieties are about 4. Hematite occurs in a number of varieties that are given special names, as specular hematite, kidney ore, etc.

Magnetite is the magnetic oxide of iron (Fe_3O_4) and contains 72.4 per cent of metallic iron. The color is iron black and the luster metallic to sub-metallic and dull. It is a brittle mineral with a specific gravity of about 5.18. It is strongly magnetic, small fragments being readily attracted by a small magnet.

Limonite is a hydrous sesquioxide of iron ($2Fe_2O.3H_2O$) 59.8 per cent of metallic iron. When pure its color is various shades of brown and when impure it may be yellow or yellowish-brown. The luster is usually dull and earthy. It has a specific gravity of about 3.8 and occurs in bedded deposits with sedimentary rocks.

Siderite is a carbonate of iron ($FeCO_3$) containing about 48.3 per cent of metallic iron. It often contains as impurities more or less calcium and magnesium. It has a vitreous to pearly luster and a yellowish-gray to brown color. The specific gravity of siderite is about 3.8. It occurs in altered igneous rocks but is more common in the sedimentary rocks.

Uses of iron. Pure iron is but little used. Cast iron which is the product obtained from smelting ores in the blast furnace contains much carbon. From the cast iron, steel is produced and the amount of carbon is reduced but some still remains. Steel is used very largely by the railways for rails, bridges, rolling-stock, as structural material in buildings, bridges, in the manufacture of machinery, tools, bolts, nails, etc.

Certain low grade iron ores are used as fluxes in the smelting of various ores of other metals. Mineral paints such as ochres, umbers, and sienas, are made from soft impure iron ores.

Salts of iron are used in the industries. Copperas, hydrated iron sulphate is used as a mordant in dyeing, in certain pigments, as a polishing powder, and in inks. The iron alums are also used in the textile industry. The acetates and nitrates are also used in the textile industry as mordants and to modify color tones.

Iron in Washington. The iron resources of Washington have been the subject of studies and reports at various times by various people and the results of a number of these studies have been published and have become public property. The iron ores of this State occur mostly in King, Kittitas, Skagit, and Stevens Counties. Iron ore occurs in other parts of the State but probably only in small amounts. In each of these counties the iron ore is mainly in a single district as follows: The Snoqualmie Pass district in King County, the Cle Elum district in Kittitas County, the Hamilton district in Skagit County, and the Valley district in Stevens County.

Cle Elum district. This district is in the northwestern part of Kittitas County on the eastern slope of the Cascade Mountains. The Cle Elum River is the main stream draining the area. The ores in this district are mixtures of hematite and magnetite. Analyses show them to contain from about 42 to 68 per cent metallic iron. In appearance the ore in this district varies more or less and is either massive, laminated, or oolitic. The massive ore has a dull, greenish-black color and a brownish-black streak, the laminated ore varies somewhat in appearance but in the main is dark red with a deep red streak or powder, while the oolitic ore has a greenish-black color and a brownish-black streak. The analyses of the ore from this district show only a small amount of phosphorous, sulphur, and in most cases no titanium. This, along with a fairly high percentage of iron indicates a very good quality of iron ore.

Snoqualmie Pass. This region includes the Summit and Miller River mining districts. The summit mining district is situated in the heart of the Cascade Mountains in the east central part of King County and includes what are known as the Guye and Denny iron properties. The district is drained mainly by streams that empty into the Snoqualmie River. The relief of the region is very marked and is characterized by sharp divides, steep mountain peaks, and deep canyons.

The Denny property is located on the west side of Denny Mountain on the north fork of Denny Creek. The ore is a dark colored heavy magnetite and when powdered is almost black. The ore varies in texture from quite porous to very fine grained masses. Chemical analyses of this ore show a high percentage of iron, 55.48 to 71.17 per cent metallic iron, and only a small amount of phosphorous and sulphur, except in cases where pyrite occurs with the magnetite.

The Miller River district is in the northeastern part of King County, a short distance west of the summit of the Cascade Mountains. The district is drained principally by the South Fork of the Skykomish River. Baring is the station on the Great Northern Railway from which the properties in the district are reached. There are two main properties, the Anderson and the William Smith, in this district.

The ore mineral in this district is magnetite similar to that at Snoqualmie Pass. The analyses of the ore show from 55 to as high as 67 per cent of metallic iron and from 0.0264 to 0.37 per cent of phosphorous. Some of the analyses of the ore from the Anderson property show some sulphur and titanium.

Hamilton district. This district is situated in the central part of Skagit County on the south side of the Skagit River. The iron ores occur along the Skagit River from Hamilton to Marblemount, a distance of about twenty-five miles. The ore in this district is a mixture of hematite and magnetite. The ore is dark colored, massive in appearance, and has a reddish cast when powdered. Chemical analyses of the ore from this district show that it is not very high in metallic iron, ranging from about 30 to 46.6 per cent. The amount of silica, alumina, manganese, and phosphorous are also high in most of the samples analyzed. Some of the analyses also show the presence of some sulphur. On the whole, the iron ore in this district is not very high grade.

Valley district. This district is in the south central part of Stevens County about 35 miles north and 15 miles west of Spokane. The town of Valley is on the line of the Great Northern Railway which extends up the Colville Valley from Spokane to Marcus, then through Curlew to Oroville. The iron properties in this district are situated both to the east and west of the town of Valley.

The Kulzer property is about three miles east of Valley and consists of four claims. A large amount of time and money has been expended in development work on this property and at times some iron ore is produced. Some of it has been used as a flux in the smelter at Tacoma and some of it has gone to the Northwest Magnesite Company at Chewelah. The ores of this district are mainly hematite and limonite. They are deep red to almost black in color and when pulverized vary in color from dark red to brown. In composition the ore from this district varies more or less, carrying from about 50 to as high as 68 per cent of metallic iron. The phosphorous and silica are both fairly high, the latter in some cases being as much as 10.8 per cent.

The Hill property is about nine miles west of Valley and consists of a single claim known as the Iron Jack. Considerable development work has been done on this property by tunnels and shafts and prospecting by diamond drilling. The ore minerals are hematite, magnetite, and martite. The hematite is deep red and the magnetite black in color. The ore from this property is high grade, a single analysis showing 68 per cent of metallic iron with only a very small amount of phosphorous.

Other deposits in Stevens County. Iron deposits are found in other places in Stevens County, some of the more important of these being the following: Deer Trail district, Clugston Creek district, Deep Lake district, and Orient district.

The following information in regard to these districts is mainly from Bulletin 27 (Geological Series), Department of Conservation and Development:[1]

Deer Trail. This district is in the southwestern part of Stevens County, almost due west of Springdale. The iron properties in this district have been developed by means of shafts and tunnels. The principal ore mineral is magnetite, which in the lower levels of the workings is hard, compact, and stony and has associated with it more or less chalcopyrite. A chemical analysis of a single sample of the ore from this district shows it to contain about 60 per cent of metallic iron with a small amount of sulphur and phosphorous and a trace of titanium.

Clugston Creek. This district is in the northern part of Stevens County about 12 miles almost due north of Colville. The iron properties in this district were located years ago and some development done, but up to the present time they have not been shown to be of commercial importance. The ore is limonite, which, according to chemical analyses, contains about 50 to 56 per cent of metallic iron.

Deep Lake. The Deep Lake district is in the northeastern part of Stevens County, about 10 miles southeast from Northport. Two iron properties occur in this dis-

[1]Shedd, Solon, Jenkins, Olaf P., Cooper, Herschel H., Iron Ores, Fuels and Fluxes of Washington.

trict and some development work has been done on them. The principal iron mineral is brown limonite. A chemical analysis of a single sample from this district shows about 60 per cent of metallic iron and only a small amount of phosphorous and sulphur.

Myers Creek. The Myers Creek district is situated in the northeastern part of Okanogan County, about three miles northeast of Chesaw. Several properties have been located in this district and some development work has been done. The iron ore mineral in this district is magnetite with which is associated more or less pyrite and chalcopyrite. A chemical analysis of a sample of the ore from the Neutral Aztec property in this district showed it to contain 70.17 per cent of metallic iron, 0.21 per cent of sulphur, and a very small amount of phosphorous.

Some iron ore has been shipped from this district to the Northwest Magnesite Company at Chewelah to be mixed with magnesite in the production of refractory material.

Other localities. There are some other places in Washington where iron ores occur in greater or lesser amounts, and where some development work has been done. Some of these are as follows: The Blewett district in Chelan County, and Belcher district in Ferry County, and on Sumas Mountain in Whatcom County. In a number of places bodies of bog iron ore occur, but these are of little commercial value.

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MANGANESE

Manganese is an element with the properties of a metal. It has a remarkable affinity for, and in some respects a close resemblence to iron, of which it is a very frequent associate. It may be eliminated from its ores by chemical processes, the product being grayish-white in color, resembling cast-iron, but varying considerably in hardness and luster according to the nature of the methods by which it was obtained. It is very hard and brittle, has a specific gravity of about 8, and oxidizes rapidly on exposure to the air.

Ore minerals. Manganese occurs in nature in many different forms, the only ones that occur in sufficient quantities to make them important commercially are the oxides, carbonates, and silicates. Of the above, the oxides are much the most important ore of manganese.

There are many oxides of manganese, but only four or five of them are important as ores of manganese. These are psilomelane, pyrolusite, braunite, manganite, and wad.

Psilomelane is a mineral having a black or brownish-black color and a shining black streak. It occurs in globular, botryoidal, stalictitic, and massive forms exhibiting, in many instances, an obscure fibrous structure. The chemical composition of psilomelane is not definite, but Dana[1] gives (H_4MnO_5) as being a possible formula for it. A part of the manganese is often replaced by barium or potassium. The amount of the various substances occurring in psilomelane is variable, the metallic manganese being from about 45 to 60 per cent, the barite from 0 to 17 per cent, the potassa from 0 to 5 per cent, and the water from 3 to 6 per cent.

Pyrolusite is another oxide of manganese (MnO_2), containing theoretically 63.2 per cent of manganese and 36.8 per cent of oxygen. It has a metallic luster and a black or bluish-black streak. The color is iron-black, dark steel-gray, and sometimes bluish. It usually occurs associated with psilomelane.

Braunite is a heavy, black or brownish-black mineral, very hard, and occurring in both the massive and crystalline form. It has a dark brown streak and submetallic luster. It has a specific gravity of 4.8, and a hardness of 6 to 6.5. In chemical composition braunite is an anhydrous oxide containing some silica ($3Mn_2O_3 \cdot MnSiO_3$).

[1]Dana, E. S. Text-book of Mineralogy (Third Edition) (1922) p. 436.

When pure, braunite contains 69 per cent of metallic manganese but it never occurs in nature absolutely pure. In some localities, braunite is found associated with psilomelane.

Manganite ($Mn_2O_3.H_2O$) is a heavy, black mineral, softer than braunite, but harder than pyrolusite. It has a brown or black streak. Its specific gravity is 4.3 to 4.4 and its hardness is from 4 to 4.5. In chemical composition manganite is a hydrous sesquioxide of manganese containing 62.5 per cent of metallic manganese, 27.3 per cent of oxygen, and 10.2 per cent of water. Manganite is found associated with psilomelane in various places in the United States.

Wad is an impure mixture of various oxides of manganese, or with manganese carbonates and silicates as an alteration product of these. It often occurs in the oxidized portion of veins having the carbonates and silicates of manganese as gangue minerals.

Rhodochrosite ($MnCO_3$) contains 47.56 per cent metallic manganese. Its characteristic color when freshly broken is pink or light rose-red. This color, however, fades on exposure to the air and becomes white or buff, and in some cases even darker, as a result of partial oxidation of the mineral. It is easily scratched with a knife, having a hardness of from 3.5 to 4.5. Rhodochrosite has a specific gravity of 3.45 to 3.6, and is soluble in warm hydrochloric acid. Its principal occurrence is in association with ores of silver, lead, copper, and zinc.

Rhodonite ($MnSiO_3$) when pure contains 41.9 per cent metallic manganese, or 54.1 per cent of protoxide of manganese, and 45.9 per cent of silica. Its characteristic color is flesh-red or pink. Sometimes, however, when impure, it is yellow, brown, or even green. It is very often blackened on the outside by oxidation. It has a colorless streak, a vitreous luster, a specific gravity of 3.4 to 3.7, and is transparent to opaque. It has a hardness of 5.5 to 6.5. On exposure to weathering agencies, rhodonite becomes oxidized and changed to one or more of the oxides already described. In some cases this alteration has penetrated the mass down to the water level of the locality, but more often the change is more superficial and the oxidation extends down into the deposit along joint planes and cracks only.

Rhodonite is sometimes found in considerable quantities, but is not used as a source of manganese on account of the high percentage of silica contained in it. It is sometimes used, however, in the glazing of pottery, and to give a violet tint to glass.

Uses of manganese. The uses of manganese in the arts is of great antiquity, having been known as long ago at least as the time of the ancient Egyptians.[1] One of its first uses appears to have been in glass-making, the analyses of some Egyptian and Roman glasses showing two per cent and over of manganese protoxide. The principal commercial use of manganese until the latter part of the eighteenth century was to either decolorize glass, or to color glass and pottery.

Manganese is used at the present time for a great variety of purposes in the arts, but by far the largest amount of the manganese produced is used in the manufacture of the alloys of iron and manganese, known as spiegeleisen and ferromanganese, and these in turn, are used in the manufacture of steel.

The various uses to which manganese is put may be conveniently divided into three principal classes as follows: Alloys, such as spiegeleisen, ferromanganese, manganese-bronze, cupro-manganese, manganese brass, manganese amalgam, and manganese-aluminum alloys; used as an oxidizer in the manufacture of chlorine, the manufacture of bromine, as a decolorizer of glass, as a

[1]Penrose, R. A. F., Jr., Manganese, Its uses, ores, and deposits, Ann. Rept. Geol. Survey of Arkansas, for 1890, vol. 1, p. 3.

dryer in paints and varnishes, and as a disinfectant; used as a coloring material in calico-printing and dyeing, coloring glass, pottery and brick, and in paints.

In alloys. In alloys manganese is used in its metallic state, combined with other metals. Ferromanganese and spiegeleisen are alloys of manganese and iron containing some carbon and usually some silicon. Spiegeleisen includes all alloys of iron and manganese in which there is not to exceed 20 per cent of manganese, while ferromanganese contains from 20 to as much, in some cases, as 90 per cent of manganese. The carbon in high grade ferromanganese may be as much as 7 per cent.

Spiegeleisen is used in the manufacture of steel when only small amounts of manganese are required. In case larger quantities are required, ferromanganese is usually employed so as not to introduce a high percentage of carbon.

The following discussion of the physical properties of manganese steel is taken from Bulletin 427, United States Geological Survey, by Edmund D. Harder, Manganese Deposits of the United States, pp. 252-254:

"Manganese steel in its most serviceable form, contains about 13 to 14 per cent manganese. This alloy possesses a combination of hardness, tenacity and ductility which makes it valuable for many purposes. Its use, however, has been limited somewhat by its extreme hardness, on account of which it is almost impossible to work it with machine tools. The material, therefore, has to be cast in very nearly the form in which it is intended to be used.

"Manganese is not so liable to honeycomb as ordinary steel, and the addition of silicon is unnecessary. It is very fluid and can be run into thin sections, but cools more rapidly than ordinary steel and has a greater contraction. It is manufactured by any of the steel-making processes; the basis (the material before the ferromanganese is added) is preferably decarbonized iron or mild steel. The ferromanganese is added in a molten state, or very highly heated. It is important that carbon be kept as low as possible, in which it should not exceed about 1 per cent, as the product would be inferior. For this reason the ferromanganese used should contain a high percentage of manganese—that is, 80 to 84 per cent.

To obtain 14 per cent manganese steel, 14½ per cent of manganese must be added, as one-half per cent is oxidized in reducing the iron oxide.

"'Ordinary steel, whether cast or forged, may contain as much as 1¼ per cent manganese without showing any marked difference in quality, provided the carbon percentage is low. But with higher percentages there is a decrease in strength and ductility, which is accentuated to a remarkable degree between 3½ and 5 per cent.

"Cast manganese steel containing from 2½ to 6½ per cent manganese is extremely brittle and can be chipped with a small hammer and ground to a powder. When hot, however, it is extremely ductile and may be drawn down to any desired sizes. It is worthy of note that the amount of carbon in this brittle material is very small, little more than that in mild steel. The remarkable weakness of the cast product is no doubt intensified by a peculiar crystallization which resembles that of 'scalded' crucible steel. The brittleness is not so marked if the metal is poured at lower temperature, but steel with 3½ to 6½ per cent manganese in whatever shape and under whatever condition it is cast, is always deficient in strength compared with ordinary steel. With the increase of manganese beyond about 6½ per cent a remarkable change occurs, the exact point being somewhat influenced by the casting temperature and other considerations. By this change the brittleness gradually disappears and toughness and ductility return. The alloy also loses its magnetism, and at 13 per cent is practically non-magnetic. At about 14 per cent the maximum of strength is obtained; the cause of the succeeding decrease is complicated by the higher carbon content. It is possible that if the carbon content could be kept low, steel containing 25 or 30 per cent of manganese might have considerable strength."

From the above discussion, it is evident that the effect produced on steel by the addition of manganese depends largely on the percentage of manganese added and the amount of carbon present. The addition of 5 or 6 per cent of manganese to steel has the effect of making the product very hard, the cast material with this amount of manganese being so very hard that it is not possible to machine it on a practical scale. As more manganese is added the hardness decreases until it contains about 10 per cent, when the alloy has its softest condition. As the manganese increases from 10 up, the hardness increases until the steel contains 22 per cent of manganese, when another hard stage is reached. This material is not so hard, however, as that containing only 5 per cent of manganese.

Manganese steel is used for many purposes on account of its great hardness and wearing qualities. Its use for certain purposes, however, has been somewhat restricted on account of the difficulty of machining it and getting into finished shape. This property of extreme hardness has in many cases proved an economy, as articles made of manganese steel must be produced so as to avoid these expensive processes, except where grinding or special devices can be employed.

Manganese steel is used for dredger pins and bushings, bucket teeth for steam shovels, for parts of crushing and grinding machinery, such as crusher plates and shoes in mills and for crushing ores and rocks; for agricultural work manganese steel has given good results when used in plow-shares, fingers, plow-points, spades, shovels, rakes, hoes, and forks; elevator link, ore chutes, and screens; for wheels, tires, and axles on railway and street cars; for cog-wheels; and for burglar-proof safes. The above are by no means all the purposes for which manganese steel is used, but they are some of the important ones.

Manganese forms alloys with copper, tin, zinc, aluminum, lead, and other metals, the most important of these being the alloy with copper to form cupromanganese. This is used in making manganese bronze, manganese brass, and German silver. Manganese bronze varies much in appearance and properties, on account of the variation in the proportions of the various metals entering into its composition. It always contains copper and manganese and may contain aluminum, zinc, lead, and in some cases iron.

Manganese brass is an alloy of copper, manganese, and zinc, with sometimes nickel or silver. Manganese German silver is an alloy of copper, zinc, and ferromanganese with sometimes small amounts of nickel, aluminum, and silicon.

As an oxidizer. Manganese peroxide (MnO_2) is the only oxide of manganese that can be used for oxidizing purposes and the reason this can be so used is on account of the fact that one of the oxygen atoms is loosely combined and may be liberated by heat or with acids. For oxidizing purposes the manganese is of no use except as a carrier of oxygen. The fact, however, that it combines readily with a large amount of oxygen and that under certain conditions it will give up readily a part of this oxygen does make it very valuable for certain purposes.

On account of the above property, the peroxide of manganese, both the native minerals and the manufactured product, are used extensively in the manufacture of chlorine and bromine.

Manganates and permanganates are extensively used as disinfectants and oxidizers on account of the readiness with which they give up oxygen. In the manufacture of glass, peroxide of manganese is mixed with the glass during its manufacture to decolorize the glass. Peroxide of manganese is also used to a certain extent as a dryer in paints and varnishes. The oxide is immersed in the oil for a time, then removed, exposed to the air for a certain time, when it is ready to be used again. The effect is to cause the oil to dry much more quickly.

Manganese as a coloring material. In calico-printing and dyeing, compounds of manganese can be used either as coloring materials or as mordants. The color known as "manganese brown" can be obtained by the use of the chloride, sulphate, or acetate of manganese. This color is used in dyeing cotton. This color is permanent and not affected by light, soap, or dilute acids. This may be used as the color of the cloth or figures of different colors can be printed on the "manganese brown" ground, the colors being so composed as to remove the brown immediately under them, thus giving figures of any desired color on the brown background. Manganese may also be used as a mordant in "fixing" different colors.

Manganese is used in coloring glass, pottery, and bricks. A small amount of manganese free from iron will give a pink or violet color to glass, while various colors such as yellow, red, and brown, may be produced with combinations of manganese and iron.

In glazing pottery, black and various shades of brown may be produced by manganese or manganese and iron together. Black door knobs may be produced by adding an excess of manganese. Some of the low grade oxides of manganese are used for giving a chocolate color to bricks. Manganese is also used to give the spots to fancy speckled bricks, in which case the manganese in the form of grains is mixed with the clay.

Manganese is used to some extent as a paint and may give dark-chocolate to reddish-brown colors. Manganese in a manufactured form may be used for other colors, and especially green.

Manganese deposits in Washington. Manganese occurs in a number of places in Washington, but very little has been mined. When general attention was first turned toward the western sources of manganese in 1915 and 1916, some of the already known deposits of manganese in Washington were worked and some manganese produced and new deposits were located. Some of the deposits in the Olympic mountains had been developed more or less in a search for other minerals and from some of the deposits ore was shipped that carried a considerable amount of native copper.

Manganese deposits are known at the present time to occur in Grays Harbor, Jefferson, Mason, Okanogan, and Skagit Counties. The most extensive of these deposits are the ones in the Olympic Mountains in Jefferson and

Mason Counties. The manganese deposits of Washington were examined in 1917 and 1918 by J. T. Pardee and much of the data given here is from his report.[1]

Olympic Mountains. Manganiferous deposits occur in the Olympic Mountains in a belt 2 or 3 miles wide and extend from a point south of Quinault Lake to the basin of the Dungeness River, a distance of about 50 miles. Some of the earliest discovered deposits in this region are those occurring along the north and south forks of the Skykomish River and on Copper Creek, a tributary of the Dungeness River. Other deposits that are said to be very similar to those in the Olympic Mountains are said to occur on Fidalgo Island and on the mainland east of Samish Bay. These deposits are about 60 to 75 miles northeast of those in the Olympic Mountains.

The Olympic Mountains consist of a mass of very steep, narrow, serrate ridges from 3,000 to 6,000 feet in height, with some of the more prominent peaks reaching an altitude of more than 7,000 feet. The streams have cut deep, narrow, steep sided valleys along which they flow. In the manganiferous belt the local relief ranges from 2,000 to 4,000 feet. On account of the very rugged character, the thick forest growth, and the lack of roads and trails, this region has not been very thoroughly prospected.

The area is one over which there is a large amount of precipitation, much of which in the winter is in the form of snow. This accumulates in the high altitudes to such great depth that in places much of it remains throughout the summer in the form of drifts and small glaciers.

Throughout the manganiferous belt the rocks consist of greenstone, sandstone, argillite, and limestone. The greenstone forms thick beds that crop out as prominent knobs and cliffs. In some places it is massive or amyg-

[1]Pardee, J. T., Deposits of Manganese Ore in Montana, Utah, Oregon, and Washington, Bull. 725, U. S. Geol. Survey (1921), pp. 229-243.

daloidal, and is undoubtedly an altered basic intrusive igneous rock such as basalt. The sandstone shows no plainly marked bedding, but is broken by fracture or shear planes into large masses, the angular forms of which are characteristic in the outcrops. The sandstone is made up of rather sharp clastic grains of quartz, more or less decomposed grains of feldspar, and flakes of mica. The argillites are fine grained, lead gray in color, and exhibit a very distinct slaty cleavage. The limestone is a very fine-grained dense rock, having a dense deep maroon or chocolate color. It breaks with a splintery or conchoidal fracture, is traversed by irregular veins of white calcite, and the weathered surface coated with a soft brownish-red powder, composed chiefly of iron oxide with some manganese and alumina.

Manganiferous deposits. The deposits of manganese are found either in the limestones, or closely associated with them. They are tabular and lenselike bodies commonly from 5 to 20 or 30 feet in thickness and from 50 to several hundred feet in their other dimensions. In general, the ore bodies do not rise above or sink below the adjacent surface, but may be distinguished from the country rock, where not covered with vegetation, by their darker color. In most cases the ore bodies are separated from the country rock by shear or fault planes, but in some instances they grade gradually into the surrounding rock. The lodes, as a general thing, consist of two distinct parts, one of which is made up of very fine grains of quartz and hematite mixed together in varying proportions. This material is bright red in color. The other part of the lode, which in most cases is the larger part, consists of a dense, fine-grained material that is largely bementite, a silicate of manganese. In some cases the lodes carry small amounts of rhodonite, the common silicate of manganese while in some instances neotocite is found. This is another silicate of manganese closely related to bementite.

Composition. E. S. Larson, Jr., and George Steiger, of the United States Geological Survey, made a study of the physical and chemical properties of bementite. The results of this study were published in the Washington Acad. Sci. Jour., Vol. 11, pp. 25-32, 1921. The following table shows the composition of a representative sample of partly weathered bementite rock from the Black and White mine, and of the bementite and neotocite that were separated from it by heavy solutions:

ANALYSES OF BEMENTITE ROCK, BEMENTITE, AND NEOTOCITE FROM BLACK AND WHITE MINE[1]

(George Steiger, Analyst)

	Bementite Rock	Bementite	Neotocite
Silica (SiO_2)	23.68	39.92	37.15
Alumina (Al_2O_3)	3.48	1.32 }	2.58
Ferrous oxide (FeO)	....	4.15 }	
Ferric oxide (Fe_2O_3)	3.52	....	....
Manganese monoxide (MnO)	46.57	41.48	37.0
Manganese dioxide (MnO_2)	....	....	2.03
Magnesia (MgO)	1.31	4.46	2.82
Lime (CaO)	1.56	.40	2.86
Carbon dioxide (CO_2)	....	....	2.10
Water above 100° C	....	7.90 }	14.07
Water below 100° C	....	.49 }	
Loss on ignition	18.32	....	....
	98.44	100.22	100.61
Manganese (Mn)	36.08	....	....

Origin. In their present form the bementite deposits are thought to be the products of regional metamorphism. The alteration of the country rock is fairly uniform and wide spread. No intrusive rocks are exposed in the manganiferous belt, nor is there anything to suggest that the deposits are related to intrusive masses such as are generally supposed to have been the source of the metalliferous lodes in the surrounding regions.

Tripple Trip Mine. The Tripple Trip Mine is about a quarter of a mile up Boulder Creek, a tributary of the North Fork of the Skykomish River, which enters from the south about 4 miles above the upper end of Lake

[1]Larsen & Steiger, Analyses of bementite and neotocite from Black and White mine Olympic Peninsula, Washington. U. S. Geological Survey Bull. 725, p. 235.

Cushman. The ore bodies on this property have been worked by means of open cuts and two adit levels, one a few feet above the other. The richest ore in this property is a dense, hard, fine-grained black rock that is a mixture of bementite and manganese oxides. This forms a streak at least 1 foot wide in places, and more than 20 feet long.

The adit levels mentioned above have been driven to explore a body of bementite rock that ranges in width from 1 to 4 feet and has a length of at least 50 feet. At the surface the lode is exposed by an open cut from which some ore has been shipped. The bementite rock is weathered more or less, this weathered zone extending only a short distance below the surface. The analyses of six samples said to represent the lode where it is penetrated by the adits show from 6 to 25 per cent of manganese, 8 to 21 per cent of iron, 11 to 37 per cent of silica, and 4 to 36 per cent of lime.

The Apex Mine. This property is about one half mile farther up Boulder Creek from the Tripple Trip, and is about 1,500 greater altitude. The lode outcrops in the bed of Boulder Creek and rises as small cliffs on either side. The occurrence of the ore is similar to that in the Tripple Trip. The ore body in this property is made up mainly of two distinct layers, one of which is largely bementite rock, while the other is mostly red jaspery quartz. The bementite layer is at least 10 feet wide and is composed mainly of bementite containing streaks of very dense, fine-grained dark green to black oxides of manganese. The jaspery layer ranges from 10 to 20 feet in width and consists of very fine grained quartz in which are specks and flakes of specularite and bright red hematite. The ore from this property contains about 30 to 35 per cent metallic manganese, 8 to 10 per cent metallic iron, 3 to 5 per cent of lime, and about 20 per cent of silica. By carefully sorting the material from this property, an ore of better grade could undoubtedly be produced.

Black and White. The Black and White Mine is on the divide east of the North Fork of the Skykomish River and about 6 miles north of the Tripple Trip mine. Considerable development work has been done on this property and a small amount of low-grade copper ore has been shipped to the Bilrowe Alloys Co., at Tacoma. The deposit in the Black and White Mine is composed mainly of bementite rock with only a small amount of the jaspery material found in some of the other manganese properties in the Olympic Mountains. The ore from this property contains specks and flakes of native copper, which appear to have replaced the bementite. The copper in places is in sufficient quantity to form a low grade copper ore. The weathered copper-bearing rock show strongly contrasting colors of black and red, the black being due to the oxide of manganese while the red is due to the oxide of copper.

An average sample of ore from this property across 8 feet of the lode at one end of the main cut was analyzed by Benedict Salkovar in the laboratory of the United States Geological Survey with the following results: Metallic manganese 22.81 per cent, metallic iron 8.66 per cent, lime 0.706 per cent, and silica 24.35 per cent. The indications are that a large amount of low grade bementite occurs in this property.

Deposits near the Black and White. Other lodes are reported to occur on the slope east of the North Fork of the Skykomish River only a short distance from the Black and White Mine. The occurrence of the ore in all of these lodes is said to be similar to that in the Black and White Mine. Small amounts of ore have been produced from some of these properties, especially the Black Hump claim.

Steel Creek group. On the slope east of the South Fork of the Skykomish River are a number of claims that are known collectively as the Steel Creek group. These claims are about 5 miles due west from the Tripple Trip Mine. The outcrops of the ore bodies on these claims are similar to those of the bementite bodies along the North Fork of the Skykomish River. On the Bosnia claim there is an outcrop of bementite rock similar in appearance to the outcrops on the Tripple Trip and Apex properties. This ore body has a width of 8 to 10 feet, a length of at least 200 feet, and a vertical extent of 100 feet. This ore body is surrounded by red lime-stone. In some of the deposits in this district the red jaspery quartz constitutes a part of the lode. A number of outcrops of manganese are found in this district, which vary more or less in size but are usually about 10 to 15 feet wide and as much as 50 feet in length. The average of several analyses said to represent the bementite bodies from this district shows manganese 24 per cent, iron 10.5 per cent, and silica 30 per cent.

Tubal Cain. The property known as the Tubal Cain Mine is on Copper Creek, which is a tributary of the Dungeness River. This property is about 25 miles north-northeast of those on the North Fork of the Skykomish River. These deposits are best reached from the town of Quilcene. The owners of this property consider it valuable for the copper it contains, and in fact most of the work that has been done on it has been on account of the copper. This deposit is said to be similar to the bementite bodies in the Skykomish basin. The lenses of bementite occur in a red limestone and from almost a continuous lode at least 1,500 feet long. The bementite bodies have an average width of about 6 feet and where ravines cut across them, natural cross sections expose the lode to a depth of at least 500 feet and show that the ore persists to that depth, at any rate. The ore from this property is said to average about 37 per cent of manganese, 5 per cent of iron, 3.5 per cent of lime, and 35.5 per cent of silica.

Extent of deposits. From what is known of the manganese deposits in the Olympic Mountains the conclusion is justified that Washington contains quite extensive resources of manganese ore and that with a good price for manganese this State might become a producer. The location of the ores in the Olympic Mountains, however, is such that they are not easy of access. Many of the ore bodies are at high altitudes and some distance from transportation. This has been partly overcome by roads and trails and should the demand for the ore become great enough, more roads will be built. The very rugged nature of the country makes road building very expensive.

Fidalgo Island. Manganese deposits occur on Fidalgo Island a few miles south of the town of Anacortes. The occurrence of these deposits is similar to that of the deposits in the Olympic Mountains. The ore is bementite and hard black oxide which is inclosed by greenstone in which are specks of native copper. In some places the bementite rock bodies are as much as 10 feet wide.

Samish Bay. Manganese is said to occur on the mainland in the vicinity of Samish Bay. The ore is thought to be of the bementite type.

Grays Harbor. Manganese deposits are reported from a number of places in the vicinity of Grays Harbor and from some of these some ore is said to have been shipped. Little is known, however, with regard to the extent of these deposits, or the character of the ore.

Okanogan County. Manganese deposits occur in the Okanogan Valley near Omak and about two and a half miles west of the town of Nespelem. Professor O. P. Jenkins examined these deposits in 1917 and the data given here are largely from his report.[1]

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

The deposit in the Okanogan Valley is on the western side of Pogue Flat about 4 miles northwesterly from the town of Omak. The manganese mineral is of the dioxide type and contains some iron oxide. It appears to be associated with a poorly defined quartz vein in the granite. This quartz lode stands almost vertical and outcrops prominently for a distance of 100 feet or more. An analysis of the higher grade hand-picked material gave manganese 25.1 per cent, iron 4.82 per cent, silica 47.43 per cent, sulphur 0.05 per cent, and phosphorous 0.05 per cent.

The manganese found near the town of Nespelem occurs on what is known as the St. Paul claim, which is a gold and silver property. The manganese in this property is rhodochrosite, which in places has weathered to the oxides of manganese. In places the manganese dioxide is found associated with decomposed granite. Some development work has been done on this property on account of the gold and silver the ore is said to carry.

MERCURY (QUICKSILVER)

Mercury is an element having the properties of a metal but differing from most metals in that it is fluid at ordinary temperatures. It is silver-white in color, has a brilliant metallic luster, and becomes solid at about —39° C. It is a heavy metal having a specific gravity at 0° C. of 13.6.

Ores of mercury. This metal occurs as native mercury in considerable quantities at times, but by far the most important ore mineral of mercury is cinnabar. This is the sulphide of mercury (HgS) and contains, theoretically, 13.8 per cent of sulphur and 86.2 per cent of metallic mercury. Color usually cochineal-red but sometimes brownish and occasionally black. It may occur either crystalline, massive or earthy, or granular. It has a specific gravity of about 8 to 8.2.

Uses of mercury. Mercury amalgamates readily with gold and silver and some other metals and on account of this fact it is used extensively in the gold-mining industry to extract gold from its ores. This is the most important use of mercury. Mercury is also used in making thermometers, barometers, and other scientific instruments. This is also a very important use of mercury. An amalgam of tin and mercury is used for silvering mirrors. Certain salts of mercury, as calomel and corrosive sublimate are important medicinal preparations. Mercury is also used as a pigment, especially in the form of the sulphide, this constituting the essential part of the pigment vermilion. Some other mercury salts are also used in pigments of various colors.

Mercury in Washington. Mercury is reported to occur in a number of places in Washington and a small production is said to have been made in the past from some of the properties. None of the properties is producing any mercury at present, however.

Discoveries of cinnabar are reported from near the town of Orondo in Chelan County. Samples are said to show crystalline cinnabar associated with quartz. One lode is reported to be about 12 feet wide, about 1 foot of which shows liberal distribution of cinnabar and the remainder of which is low grade.[1]

Another deposit of mercury occurs in Chelan County on Squaw Mountain, 3 miles from Wenatchee, near the town of Leavenworth. But little work has been done on any of these prospects and hence nothing very definite is known in regard to them.

Prospecting and developing of mercury deposits have been carried on in Kittitas County but little if any production has resulted. Cinnabar has been reported by

[1]Mineral Resources of the United States, U. S. Geol. Survey, Part I (1911), p. 916.

Smith[1] from the head of Boulder Creek, in Kittitas County, where it occurs along a joint plane in the altered rock of the Peshastin formation. The ore is said to be very rich but to occur in such thin bands that it may have no commercial value.

The Washington Quicksilver Company was organized to develope mercury deposits near the town of Roslyn but information in regard to this property is not at hand.

Cinnabar occurs in Lewis County about two miles from Morton. Considerable work has been done prospecting and developing these deposits, a Johnson-McKay, 12 pipe, retort plant has been installed, and a small amount of metallic mercury produced.[2] The ore is low grade, the better grades averaging not more than 1.5 per cent metallic mercury.

Mercury is also reported to occur in a 6 foot ledge in the property of the Red Star Mining Company in Cowlitz County. Mercury is also said to occur in the Eclipse Lode of the Eclipse Consolidated Mining and Investment Company. This property is located in the Stilaguamish district in Snohomish County. There is, however, very little information available in regard to either of these deposits.

Deposits of mercury are reported from other parts of Washington but nothing definite is known with reference to them.

MOLYBDENUM

Molybdenum is a metal having a silver-white color, but harder than silver, and fusing only at very high temperatures. Its specific gravity is 9.01. It is closely related to chromium, tungsten, and uranium, and, like those metals, forms trioxides which are acid-forming and yield very characteristic salts. Metallic molybdenum oxidizes but

[1]Smith, George Otis, Snoqualmie Folio (No. 139) Geol. Atlas, U. S., Geol. Survey, 1906, p. 14.

[2]Mineral Resources of the U. S., U. S. Geol. Survey, Part I (1915), p. 274.

slowly at ordinary temperatures. It is remarkable for the number of oxides and corresponding chlorides which it forms. It is the least important economically of the group to which it belongs.

Ore minerals. The most important ore of molybdenum is the sulphide (MoS_2) which theoretically contains 40 per cent sulphur and 60 per cent molybdenum. Molybdenite is sometimes massive, but it usually occurs in scaly or platy forms resembling those of graphite, with which mineral it is often confused. It is a very soft mineral, having a hardness of about 1, a specific gravity of about 4.7, while graphite has a specific gravity of about 2.09 to 2.23 and a hardness of from 1 to 2. Graphite floats lightly on bromoform, while molybdenite sinks heavily in this liquid. When these two minerals occur mixed with one another, as they sometimes do, they can be separated by putting in bromoform. In color molybdenite is lead gray or bluish-black, and has a submetallic luster. It has a greasy feel and the lamina composing it are very flexible, but not elastic.

Molybdenite is found associated with various kinds of rocks and veins, but is associated most frequently with granite rocks, especially with granite pegmatites. The deposits are invariably more or less pockety.

Other minerals of lesser importance as sources of molybdenum are wulfenite ($PbMoO_4$) and molybdite ($Fe_2O_3.3MoO_3.7\frac{1}{2}\ H_2O$) which are secondary products due to alteration of molybdenite. Wulfenite contains 39.3 MnO_3 or about 26 per cent metallic molybdenum. It usually occurs as lustrous resinous yellow, orange, or red crystals in the oxidized parts of lead deposits. Molybdite or molybdenum ochre is a bright yellow powdery mineral of very little commercial value.

Uses of molybdenum. The principal use of molybdenum is in the manufacture of alloy steel, to which it gives some very desirable properties. This is especially true when it is used in connection with certain other metals as chromium, manganese, nickel, cobalt, and tungsten.

The following discussion of uses of molybdenum is largely from the report of Frederick W. Horton.[1]

It appears the early experiments with the use of molybdenum in steel were almost always unsatisfactory, and the use of the metal in steel was condemned. The results may have been due largely to the fact that impurities that were very detrimental to the steel were introduced into it along with the molybdenum. At that time, too, much less was known in regard to the effect of various treatments as regards heat and many steels that had been prepared in such a way as to be free from objectional impurities were ruined by improper heat treatment. Later experiments have shown that the addition of molybdenum to steel in certain amounts, and the steel treated in a particular way, will produce a steel with properties that make it especially well adapted for certain purposes.

Experiments have shown that with normalized steel, the addition of molybdenum increased the tensile strength with only a slight decrease in ductility. This influence was most marked in the high-carbon steels. Very high tenacity values accompanied by high ductility were shown by steels containing from 1 to 2 per cent, while those containing higher percentages when hardened and tempered, became inferior. As the amount of molybdenum increased, annealed steels diminished in strength and ductility, this being noticeable when 0.9 per cent of carbon or more was present. In a general way molybdenum acts similarly to tungsten in steel, but that it is much more active and less of it is needed to produce a certain result.

Tool and high speed steels. Molybdenum in the presence of chromium and manganese and in combination

[1]Horton, F. W., Molybdenum; Its Ores and Their Concentration, U. S. Bureau of Mines, Bull. 111, pp. 20-29, 1916.

with either of these elements and carbon produces a self-hardening steel which is said to be somewhat tougher than the corresponding tungsten steel. Molybdenum acts also in the same way as tungsten in giving to steel that property that enables the steel to retain its temper and hardness at red heat. Molybdenum high speed steels are believed by many to be superior to tungsten steels.

Some difficulties have been encountered in the use of molybdenum tool steels according to some authorities. some users say they are liable to crack in quenching, while others claim that they do not hold their cutting edge after retreatment as well as before. Service tests have in some cases shown irregular cutting speeds with molybdenum steel tools, and in some cases molybdenum steel has been found to be seamy and to contain physical defects. Many of the difficulties encountered in using molybdenum as a major constituent in tool steel have been overcome by using it in a minor capacity in conjunction with such elements as tungsten, chromium, cobalt, etc. Steels of this character are said to contain the desireable qualities of molybdenum steel.

Use of molybdenum in other alloy steels. Molybdenum steels, after being hardened, retain their magnetism longer than hardened carbon steels and on account of this fact they are used in making permanent magnets. Steel used for this purpose is similar in composition to that used for high speed tools.

Acid resisting steels may be prepared by alloying molybdenum with chromium, and sometimes tungsten is added. An alloy containing 2 to 5 per cent of molybdenum, about 10 per cent chromium, and a little or no carbon, is said to be practically acid proof.

Steels are produced from alloys of nickel, chromium, and molybdenum, in which there is used about 2 to 3 per cent of nickel, about 1 per cent of chromium, and 0.25 to 0.5 per cent of molybdenum. These steels are said to have a greater tensile strength than that possessed by chrome-nickel steel. On account of this very great tensile strength and high elastic limit, these steels are especially well suited for use in crank shafts, propeller shafts, frames and axles of automobiles, and railroad rolling stock. They are also used in making high pressure boiler plate for torpedo boats, guns of large bore, and for rifle barrels.

Uses of metallic molybdenum. Molybdenum in its metallic state has come into use for certain purposes since the discovery of certain processes by which it can be obtained in a ductile form. As wire it is used for supporting the filaments in incandescent lamps and for winding electric resistance furnaces. For this latter purpose it has proven cheaper and better than platinum.

In certain electric contact making and breaking devices metallic molybdenum has been substituted for platinum and for platinum iridium. It is also used in X-ray tubes, and in voltage rectifiers.

Uses of molybdenum in chemicals. A certain amount of molybdenum is used each year in the manufacture of various chemicals. The largest amount used in this industry is in the manufacture of ammonium molybdate $(NH_4)_2MoO_4$ and sodium molybdate (Na_2MoO_4). Ammonium molybdate is used very largely as a reagent for the determination of phosphorous in iron and steel, various ores, fertilizers, etc.

Use of molybdenum in stellite. Certain alloys of chromium and cobalt are known under the trade name of "Stellite." This was invented by Edmund Haynes and the original combination contained about 75 per cent cobalt and 25 per cent chromium. As early as 1898, Mr. Haynes produced an alloy of nickel and chromium and immediately following this he produced an alloy of cobalt and chromium. His object in this work was to produce certain metallic combinations or alloys that would resist oxidation and other harmful influences as well as possess physical properties that would make them fit for special purposes. In its original combination, it is now being manufactured into table cutlery, and seems to retain well its original luster and has a good edge.

Mr. Haynes, as early as 1907 and 1908, added to the cobalt chromium alloy molybdenum and found that it had the effect of making the alloy very hard and that it made good edged tools.

Haynes[1] makes the following statement in regard to this alloy:

"When molydenum is added to a 15 per cent cobalt-chromium alloy, the alloy rapidly hardens as the molybdenum content increases, until the content of the latter metal reaches 40 per cent, when the alloy becomes exceedingly hard and brittle. It cuts keenly and deeply into glass, and scratches quartz crystals with ease. It takes a beautiful polish, which it retains under all conditions, and on account of its extreme hardness, its surface is not easily scratched. When 25 per cent of molybdenum is added to a 15 per cent chromium alloy, a fine-grained metal results, scratches glass somewhat readily, and takes a strong keen edge. Its color and luster are magnificent, and it will doubtless find a wide application for fine hard cutlery. It cannot be forged, but casts readily, and its melting point is not abnormally high."

During 1922, as a result of the continued activities of the molybdenum interests in the United States, the use of molybdenum in steel increased rapidly. The number of large consumers of alloy steel specifying molybdenum steel has become quite large. This increase in the use of molybdenum steel has been due in part at least to its advantages in fabrication, such as ease in forging, heat-treating, and machine-ability.

Molybdenum deposits of Washington. Molybdenum is reported to occur in Chelan, Ferry, Okanogan, Pend Oreille, Skagit, Snohomish, Stevens, and Whatcom Counties. Molybdenite is found associated in most cases with granitoid rocks, and in some cases associated with the

[1]Haynes, Ellwood, Alloys of Cobalt with Chromium and Other Metals, Transactions Am. Inst. Min. Eng., Vol. 44 (1912), pp. 576-577.

copper mineral chalchopyrite. Washington has produced practically no molybdenum up to the present time, but should the demand and price increase sufficiently, it is possible that some of the deposits may become producers.

The Crown Point mine is situated at the head of Railroad Creek, Chelan County, near the summit of the Cascade Mountains, at an elevation of something more than 5,000 feet. The property is about 60 miles from the Great Northern Railway at Chelan Falls and is reached by stage from the railway to Chelan or Lakeside at the lower end of Lake Chelan, then by boat up Lake Chelan to Lucerne, and from there by wagon road and trail about 18 miles up Railroad Creek. The molybdenite bearing material at the Crown Point mine consists largely of an almost horizontal vein of white vitreous quartz, in which the molybdenite is irregularly disseminated either in minute grains or in masses as much as 4 or 5 inches in size. In many cases the molybdenite is especially well crystallized.

The quartz vein has a maximum thickness of 3 feet and pinches to 3 or 4 inches at either end of the outcrop, and also gradually diminishes in thickness as it extends back into the hill until when a distance of 75 to 100 feet is reached it practically pinches out. The quartz-vein material is very free from minerals other than molybdenite. This property is said to have produced a small amount of ore in 1901 and 1902. Some equipment, such as crushing and concentrating machinery, and compressor plant, has been installed on this property. Other deposits of molybdenite occur in the same locality, but this is the only one on which much development work has been done.

Deposits of molybdenite are reported to occur on the headwaters of Safety Harbor Creek in Chelan County. This is a small stream that empties into the north side of Lake Chelan about 25 miles above the lower end of the lake. This deposit consists of two systems of veins almost at right angles to each other. The ore consists of molybdenite and chalcopyrite in a highly altered rock, the original composition of which has not been determined definitely.

J. M. Risley, of Twisp, Washington, reports the occurrence of a molybdenite deposit on Sheep Mountain in the northern part of Okanogan County.[1] This property is about 1 mile south of Monument No. 11 of the United States and Canadian boundary line and about 20 miles from Ashnola Siding, a station in British Columbia on the branch line of the Great Northern Railway to Princeton. The deposit is claimed to consist of three, more or less, parallel veins which outcrop at practically the same altitude along the side of the mountain. The country rock is granite, the veins being well defined and from 4 to 7 feet wide. Some development work has been done on this deposit in the way of open cuts and short tunnels. Samples of ore from this deposit submitted to the United States Bureau of Mines were estimated to contain about 1 per cent molybdenite.

Andrew Starr of Tonasket owns a deposit of molybdenite ore on one of the spurs of Aeneas Mountain.[2] This is about 10 miles from Tonasket in northern Okanogan County. This deposit is said to be very large, but to be low grade, containing on an average about 1 per cent molybdenum. The mineralized zone is about 80 feet wide and has a known length of 400 feet. The molybdenite and small amount of pyrite associated with it are scattered irregularly through the mineralized zone.

Other localities in Okanogan County where molybdenum is reported to occur are on the eastern slope of the hills on the west shore of Lake Osoyoos, about 3 to 4

[1]Horton, F. W., Molybdenite, Its Ores and Their Concentration, U. S. Bureau of Mines 111 (1916), p. 84.

[2]Patty, E. N., and Glover, Sheldon, L., Mineral Resources of Washington, Wash. Geol. Survey, Bull. No. 21 (1921), p. 81.

miles north of Oroville. Molybdenite is found here associated with chalcopyrite in quartz. Molybdenite is also reported from near Conconnully and is said to occur in quartz associated with pyrrhotite.

Molybedenite is said to occur in the Sanpoil district of Ferry County in many prospects. Pardee makes the following statement in regard to molybdenite in the Sanpoil district:[1]

"Of the rare minerals molybdenite is commonly disseminated through the walls of the lodes inclosed in granite and is reported to occur in commercial quantity in the claim of E. Schminski, north of Hellgate Rapids."

On the head waters of the Skagit River, on Thunder Creek in Whatcom County, is a deposit of molybdenite which is said to be of some promise. Another deposit is reported to occur in the Castleman mine in the Mt. Baker district.

Some of the other localities in Washington in which deposits of molybdenite are known to occur are as follows: In the Monte Cristo district, Snohomish County, molybdenite occurs sparingly as fine flakes; in King County with chalcopyrite and bornite in the Miller River district; near the White River Glacier on the north side of Mount Rainier in Pierce County; in the Metaline district in Pend Oreille County; and in Stevens County east of Bossburg and in the Deer Trail district in the southwestern part of the county.

NICKEL

Nickel is an element having the properties of a metal. It is never found native in commercial quantities, but must be reduced from its ores to the metallic state. It is a lustrous, silver-white metal, with a slightly steel-gray tinge, and hard enough so that it will take a good polish.

[1]Pardee, J. T. Geology and Mineral Deposits of the Colville Indian Reservation, Washington, U. S. Geol. Survey, Bull. 677 (1918), p. 108.

Cast nickel has a specific gravity of 8.35, which may be increased to 8.6 - 8.9 by rolling or hammering.

Cast nickel is about as hard as soft steel, is very malleable and ductile, and can be rolled into very thin sheets and drawn into very fine wire. The presence of certain substances, as carbon, manganese, arsenic, or sulphur, however, tend to decrease its ductility and malleability. Nickel is magnetic at ordinary temperatures, its magnetic power being about two-thirds that of iron. It is not readily tarnished in the air at ordinary temperatures. It alloys readily with many metals and is a constituent of a large number of alloys used for special purposes.

Ore minerals. The principal ore minerals of nickel are nickeliferous pyrrhotite, garnierite, and pentlandite.

Pyrrhotite is an iron sulphide of somewhat variable composition (Fe_5S_6 to $Fe_{16}S_{17}$) and has the property of being highly magnetic. It is usually bronze-yellow in color but sometimes is much paler. It usually occurs in the massive form but is sometimes found in the form of hexagonal plates.

In many cases pyrrhotite contains nickel in the form of pentlandite ($(Fe, Ni)S$) and at the present time this is the most important source of nickel. The ore of the Sudbury, Ontario, district, which is the greatest nickel producing district in the world, is nickeliferous pyrrhotite carrying on an average a little more than 3 per cent of nickel.

Garnierite is another one of the important ores of nickel. This is a hydrated silicate of nickel and magnesium varying more or less in composition. It occurs in loosely compacted masses that range in color from a brilliant dark green to pale green.

The world's supply of nickel practically all came from New Caledonia until the discovery and development of the Sudbury deposits. At the present time, New Caledonia is second in importance in the world's production of nickel. The ore is mainly garnierite and contains, as mined, about 5.4 to 5.8 per cent nickel. The ore minerals occur as veinlets and concretionary masses in serpentine and peridotite.

Uses of nickel. The most important use of nickel is in the manufacture of the various nickel steels, some of which are chrome-nickel steel, nickel-steel, tungsten-nickel steel, and others. Nickel gives to steel greater hardness, toughness, elasticity, and tensile strength, and hence increases its value for certain purposes. It is especially suited for use in armor plate, gun shields, steel rails, marine engines, wire cables, etc.

Monel metal is an alloy of nickel, copper, and iron in about the following proportions: nickel 68 per cent, copper 30 per cent, and iron 1.5 per cent. This, on account of its wearing qualities, strength, and resistence to corrosion, is especially well suited for such things as marine pumps, mine pumps, and propeller shafts. Alloys of nickel, copper, and zinc are known as German silver and nickel silver, and are used extensively in the manufacture of tableware. German silver may be used direct for tableware and other utensils, or it may be used as a base for silver-plated ware.

The five-cent piece, or "nickel," of the United States coinage is an alloy of 25 per cent nickel and 75 per cent copper. Some other countries use nickel in their coinage and in some cases the pure metal has been used. The pure nickel coins are hard, and of good color, but the metal is not so easy to mint as the alloy of nickel and copper commonly used.

An alloy of iron and nickel containing 36 per cent of nickel, 0.5 per cent of manganese, and 0.5 per cent of carbon, is known as "invar." This has practically no expansion or contraction when subjected to varying temperatures, and on this account it is valuable for surveyors tapes, scientific instruments, pendulums, and other clockwork.

Nickel is used to a considerable extent in the manufacture of cooking utensils, and also for chemical apparatus for laboratory use. It is especially valuable for these purposes on account of the fact that it does not corrode easily. To save expense, large utensils are often made of iron and coated with nickel.

Nickel is readily deposited electrolytically on other metals and on account of this fact it is used to a considerable extent for electroplating. Electrolytically deposited nickel is hard and dull in appearance, but will take a very brilliant polish if the underlying surface is smooth. It affords a good protection to metals that are more readily affected than it is by atmospheric and other agencies.

Nickel oxide is used in the ceramic industry to produce various shades of blues and greens. The colors vary with the amount of nickel used, and the metallic oxides with which it is associated. Nickel is also used for storage batteries and as a catalyzer in the hardening of oils or fats.

Nickel deposits in Washington. Nickel deposits are reported to occur in a number of places, but none of the deposits have been developed to the point where nickel has been produced commercially. The one of these on which the most work has been done is the Congress property in the Sanpoil district.

This property is on the north side of Bridge Creek about three and a half miles above where it empties into the Sanpoil River. It was examined by Howland Bancroft[1] in 1910 and the following description is taken from his report:

[1]Bancroft, Howland; Ore Deposits of Northeastern Washington, U. S. Geol. Survey, Bull. 550 (1914), pp. 183-185.

"The deposit occupies a shear zone or fault plane in the schistose series and consists of a quartz vein from 6 to 32 feet in width, which has an average strike of N. 50° - 70° E. and a dip of 45° NW. to 90°. The strike and dip of the vein conform to the planes of schistosity of the inclosing walls. The quartz filling the vein is of a bluish-white color, is fine-grained and compact, and is cut by joints into cubical and rectangular blocks measuring from a fraction of an inch to a foot or more. The portion of the vein explored by the Congress workings is somewhat cellular, the small vugs present being filled with quartz crystals and some malachite. Talc and barite form a small part of the vein filling. Sparsely scattered through the quartz are small veinlets and aggregates of pyrite associated with some chalcopyrite. These veinlets of pyrite range from a fraction of an inch to an inch or more in width, and the quartz with scattered aggregates of pyrite may extend over a large portion of the vein. The pyrite is nickeliferous, and where oxidation has been active the sulphides have been altered and the oxidation products have been deposited as thin films along the joint planes and fractures and, in fact, along all the openings in the quartz veins. Limonite, malachite, and a carbonate of nickel are present in thin films, with the result that the whole vein is discolored, the predominant color being reddish-brown with scattered patches of light and dark green. Samples were taken by the writer to determine the approximate average tenor of parts of the vein, and the results of assays of this material should not be taken as indicative of a thorough sampling of the deposit, a matter which is quite beyond the scope of the work of the United States Geological Survey. A sample from a crosscut of the vein in the lowest or No. 1 level, 390 feet from the portal of the adit tunnel and 90 feet beyond the intersection of the adit with the vein (at this place 23 feet wide), contained 0.17 per cent of nickel and 0.013 per cent of cobalt.[1] On the No. 2 level, where the vein is cut 40 feet from the portal of the adit and then followed by a drift for 160 feet or more, a sample of 14 feet of the vein was taken along the drift. This sample contained 0.246 per cent of nickel and 0.034 per cent of cobalt. A crosscut at the end of this drift shows the vein to be approximately 32 feet wide at that place. A third sample was taken in No. 3 level in a crosscut on the vein 90 feet from the portal, where the vein is encountered. This sample extended across 20 feet of the vein from the hanging wall toward the footwall and contained 0.12 per cent of nickel and 0.016 per cent of cobalt. The silver and gold contents were determined from a composite of the three samples. The results of this assay[2] show 5.5 ounces

[1]Analyses for nickel and cobalt were made by J. G. Fairchild, of the United States Geological Survey.

[2]By Dedoux & Company, of New York.

of silver to the ton and a trace of gold. A picked specimen of sulphide ore containing chiefly pyrite was analyzed for nickel and cobalt by Mr. Fairchild and found to contain 5.71 per cent of nickel and 0.35 per cent of cobalt.

"In the oxidized ores the nickel content is low, but as the picked specimen of sulphide ore showed over 5 per cent of nickel it seems possible that this deposit might be profitably worked below water level, where oxidized material would be practically absent and where sulphides should predominate. Because of the scanty distribution of the nickel-bearing sulphide ores in the quartz vein, the ore would have to be concentrated.

"This ore deposit was probably formed by solutions accompanying the intrusion of the quartz monzonite porphyry, which caused more or less contact metamorphism in the adjacent rocks. The evidence for this conclusion lies in the presence of magnetite, epidote, and barite in the contiguous strata."

The Stepstone prospect, 12 miles north of Nespelem, was examined by J. T. Pardee[1] and is reported to contain nickel. A sample of the silicate ore found in this prospect showed 1.56 per cent of metallic nickel, while a sample of practically unoxidized ore from the dump yielded 2.65 per cent of metallic nickel.

Nickel is reported from Negro Creek, near Leavenworth, in Chelan County; on Red Butte Mountain, near Mt. Stuart, in Chelan County; at the head of the Cowlitz River in Lewis County; near Sedro Woolley in Skagit County; in the Mt. Baker district in Whatcom County; three miles south of Northport in Stevens County; and at the head of Cedar Canyon in Stevens County.

Practically no work has been done on any of these prospects and it is not possible to say anything of value with reference to them.

PLATINUM

Platinum is an element that occurs in nature alloyed with various metals as iridium, osmium, and palladium. Usually the alloy also contains some iron and copper. Its specific gravity is very high, about 21.5, being the

[1]Pardee, J. T., Geology and Mineral Deposits of the Colville Indian Reservation, Washington, U. S. Geological Survey, Bull. 677 (1918), p. 84.

highest of any known substance with one or two exceptions. Platinum is very ductile and malleable and may be easily rolled into sheets and drawn into wire. It is not oxidized in the air at any temperature and is not attacked by any of the simple acids. It is infusible in the strongest heat of the blast furnace but can be melted by means of the electric current or in the flame of the oxy-hydrogen blowpipe.

Ore minerals of platinum. The principal source of platinum is the native metal which, as stated above, is alloyed with other metals. It is found in the sands of rivers or beaches and in placer deposits in which it occurs in small grains or flakes. It is found in small amounts in many auriferous placer deposits.

Sperrylite is an arsenide of platinum ($PtAs_2$) containing 56.5 per cent of metallic platinum. It is tin white in color, has a black streak, and metallic luster. It is often found associated with pyrite, chalcopyrite, and especially nickeliferous pyrrhotite. Sperrylite is a constituent of the nickel-copper ores of Sudbury, Ontario.

Uses of platinum. The most important use of the metal platinum is in the manufacture of chemical apparatus. It is especially valuable for this purpose on account of its ability to resist heat and the fact that it is not corroded by most chemicals. It is used extensively in the form of crucibles, foil, wire, dishes, spoons, etc. It is also used by dentists, jewelers, and in the manufacture of incandescent lamps. It is also used, when alloyed with iridium, as contact points in the electrical industries. In the industries, platinum has a very important use in the manufacture of sulphuric acid. Steam and sulphur dioxide, when mixed and passed over the finely divided platinum, unite to form sulphuric acid.

Platinum in Washington. Platinum occurs in a number of places in this State and small amounts are produced almost every year as a by-product of placer gold mining. The platinum probably occurred originally very sparingly disseminated through certain basic igneous rocks and as these have been weathered it has been freed and collected along the streams with the sands and gravels. Localities are known to occur in the Cascade Mountains, where such rocks are exposed over large areas and along the streams flowing from them platinum may be expected.

A small amount of platinum has been produced from the south fork of Lewis River in Clarke County. Negro Creek, near Mt. Stuart, and Mad River in Chelan County are said to have produced some platinum. Near Anacortes in Skagit County platinum is said to occur in a massive chromite.[1] Platinum is also reported from Slate Creek, Similkamene district, Little Mt. Chopaca; and near Riverside, Okanogan County; from placer gold mining of the beach sand in Clallam County; and from black sands at Beards Hollow in Pacific County.

PYRITE

Pyrite is the disulphide of iron (FeS_2) containing 46.6 per cent metallic iron and 53.4 per cent sulphur. This is one of the most common of all minerals. It occurs under almost all conditions and in all situations. It is bright yellow in color and has a brilliant luster. It occurs in a large number of crystal forms, of which the cube is the most common.

Pyrite occurs in veins and as grains or crystals disseminated through various kinds of rocks. In veins it may occur either as structureless masses filling the entire fissure, or as crystals with other minerals. It weathers readily and forms limonite.

Uses of pyrite. Pyrite is used principally in the manufacture of sulphuric acid and as a source of sulphur. It is seldom used as an ore from which to recover iron. The

[1]Mineral Resources of the United States, U. S. Geol. Survey, 1905, p. 424.

sulphuric acid manufactured from pyrite is used in many manufacturing processes, but a considerable part of it is used in the artificial fertilizer industry.

Pyrite is also being used to a considerable extent in the paper industry in the production of sulphite paper pulp. During the early development of the sulphite pulp industry, the sulphur dioxide gas required was prepared in the easiest possible way and this was by burning raw sulphur in air. In the early development of the sulphuric acid industry sulphur was used from which to produce the sulphur dioxide gas. To the manufacturer of sulphuric acid the production of sulphur dioxide is of prime importance and he has been constantly striving to improve his process and reduce his costs. As a result of this, we find the acid manufacturer of today, except under very special circumstances, prepares his sulphur dioxide by burning pyrite in specially designed furnaces. The main reason for this is the fact that the sulphur dioxide gas can be prepared cheaper by the burning of pyrite than by burning sulphur when the relative market prices of pyrite and sulphur are what they are.

The sulphite pulp manufacturer should not fail to reduce the cost of the pulp wherever he can, and should investigate carefully the advisability of using pyrite in place of sulphur to produce the sulphur dioxide used.

Pyrite in Washington. Pyrite is a very common mineral in the various mining districts of this State. It is the most common ore mineral in Stevens County and is present in greater or lesser amounts in practically all the mines and prospects in the county. Large deposits of pyrite occur in various places in Ferry County. Among the most important of these might be mentioned the Orient district on the Kettle River in the northeastern part of the county and the Belcher district, in the north central part of the county. Pyrite occurs in many places in Okanogan County, but in most cases at any rate, not in sufficient quantity to be of commercial value.

In western Washington pyrite is a common mineral in the various mining districts, but in most cases so far as the writer is aware, the deposits are not extensive and have not been developed unless for the production of other metals such as gold or copper, which the pyrite usually contains.

To be of value commercially, a deposit of pyrite must be large enough to warrant development to a point where a regular output may be maintained. It must be favorably situated with regard to transportation, and so that it can be mined at a low cost. The ore must be practically free from gangue material and from such substances as lead, zinc, arsenic, and antimony. It should also contain a high percentage of sulphur and be of such a character that it will roast satisfactorily.

TUNGSTEN

Tungsten is an element having the properties of a metal. It is never found native, but must be reduced from its ores to the metallic condition. As thus obtained it is a gray powdery or granular mass, from which wrought or ductile tungsten can be made. In its wrought state tungsten looks very much like iron or steel, and takes a very similar polish. Tungsten does not oxidize readily, however, and is practically insoluble in the ordinary acids. The hardness of tungsten varies somewhat, but ranges from about 4.5 to 8, depending largely on the way in which it has been worked. Even with its great hardness it is very ductile and may be drawn into fine wire. It is a very heavy metal, having a specific gravity of from 19.3 to 21.4, and melting only at very high temperatures. It alloys readily with many of the common metals, such as iron, cobalt, nickel, chromium, aluminum, copper, and manganese. A considerable part of the ore used in the United States, however, is alloyed with iron and sold in that form. Tungsten is introduced into steel, either as ferrotungsten, an alloy of iron and tungsten, or as the powdered metal.

Ore minerals. The minerals of economic importance, as sources of tungsten, are wolframite, hubnerite, ferberite, and scheelite.

Wolframite is an isomorphous mixture of iron and manganese tungstates (Fe, Mn) WO_4 with 76.4 per cent tungsten oxide. One of the marked characteristics of this mineral is its high specific gravity which ranges from about 7.2 to 7.5. It has very perfect cleavage, submetallic luster, grayish or brownish-black color, and nearly black streak. Wolframite often occurs associated with tin ores and in quartz with scheelite, pyrite, galena, etc.

Hubnerite, theoretically, is a tungstate of manganese ($MnWO_4$) containing 76.6 per cent tungstic oxide and usually has some iron. This mineral closely resembles wolframite, having about the same specific gravity and hardness. It is reddish brown in color.

Ferberite is the iron tungstate ($FeWO_4$) containing 76.3 per cent of tungstic oxide. This, however, usually contains some manganese. Ferberite has a specific gravity of about 7.5, and is black with a brownish-black streak.

Scheelite is a calcium tungstate ($CaWO_4$) with 80.6 per cent tungstic oxide. It is white, yellow, brown, or greenish, with a white streak and vitreous luster. Scheelite, like the other minerals of tungsten, has a high specific gravity, 5.9 to 6.1, and may be distinguished from limestone, which it resembles, on account of this property. It is found associated with cassiterite, fluorite, molybdenite, etc.

Uses of tungsten. The greatest use of tungsten, the one which takes by far the largest part of the metal utilized, is an alloy of tool-steel, and especially those steels that are to be used in the production of "high speed" tools. By this is meant tools that are used in metal turning lathes running at high speed. Steels from which tools for this purpose are made usually contain from about 15 to 20 per cent of tungsten. This gives to the tools the property of holding their temper at high temperatures better than tools made from carbon steel. Steel containing 1 to 2 per cent is used in making saw blades.

Mr. Elwood Haynes has produced various combinations of tungsten with stellite, an alloy of cobalt and chromium, and these have been placed on the market. Some of these alloys have a greater hardness than tungsten steel and in some cases have given better results than high speed steels.

The uses of tungsten in the manufacture of incandescent lamps has become of very great importance. Tungsten filament lamps are made in great numbers at present, but on account of the very great fineness of the filament, only an extremely small part of the annual production is used for this purpose. Tungsten is very ductile and on account of this may be drawn into very fine filaments. It also melts only at high temperatures and on account of these properties, along with its behavior when an electric current is passed through it, tungsten is a very valuable material for incandescent electric lamp filaments. The gas-filled incandescent tungsten lamp consists of a metallic tungsten filament in a globe filled with nitrogen. The filling of the globe with nitrogen not only prolongs the life of the filament, but it reduces the amount of current consumed and gives a brighter and whiter light.

The following are a few of the many possible uses of tungsten:

As a substitute for platinum and platinum alloys, as contact points in spark coils, voltage regulators, resisters in electrical laboratory furnaces, and as targets in Roentgen tubes. Tungsten is also employed in coloring glass, in calibrating instruments and apparatus, such as standard weights, for electrical meters, pen points, cross bars in telescopes, and other optical instruments, and for fireproofing curtains and draperies.

Tungsten deposits of Washington. Tungsten occurs in a number of places in Washington, but the only place where tungsten has been produced so far as the writer is aware is in Stevens County, with a very small amount from Okanogan County.

The New Germania Mine is in the Deer Trail district which is in the extreme southwestern part of Stevens County. The camp of the Germania mine is about 17 miles almost west of Springdale, the nearest station on the Great Northern Railway. By wagon road from Springdale, however, the camp is about 25 miles. The ores found in the property of this company are wolframite, ferritungstite, and scheelite. Associated with these are pyrite, chalcopyrite, arsenopyrite, galenobismutite, and molybdenite.[1] The vein material is mainly massive almost pure white quartz. Along with this are small amounts of black tourmaline and green flourite.

This property was owned by German capitalists and for a number of years was worked, the ore being concentrated until the concentrates carried a high percentage of tungstic oxide, and then shipped to Germany.

In Sec. 3, T. 28 N., R. 37 E., on one of the branches of Sand Creek, in Stevens County, are properties that are said to have produced some tungsten. The country rock is principally granite in which, in places, are small veins of quartz. The quartz is milky-white and contains some pyrite and wolframite.

The Tungsten King group of claims is about 10 miles north of Deer Park and 5 or 6 miles northeast of Loon Lake. These are stations on a branch line of the Great Northern Railway from Spokane to Oroville. These deposits are on the southeast side of Big Blue Grouse Mountain at an elevation of about 3,500 feet.

The formations exposed in this locality are quartz-

[1]Bancroft, Howland; The Ore Deposits of Northeastern Washington, U. S. Geol. Survey, Bull. 550 (1914), p. 120.

mica schists, quartzite, and granite. The ore deposits occur in well-defined veins of quartz in which are crystals of the tungsten mineral hubnerite, the bismuth mineral cosalite, pyrite, and its alteration products, hematite and limonite, in the form of pseudomorphs. The veins vary in thickness from a few inches to 5 feet, are usually barren, but in places contain lenses in which the tungsten and iron minerals occur.[1]

This group of claims includes the Tungsten King, the Harrison, the Blue Grouse, and the S. L. properties. Some development work has been done on these properties and a small mill was built to treat the ore. These claims are not being worked and have not been for several years, and in fact, I have no record that they ever produced tungsten on a commercial basis.

Tungsten deposits were located in 1904 in T. 40 N., R. 22 E., near Cathedral Peak in Okanogan County. This property is reported to have produced a small amount of tungsten in 1915.

The following are some of the other localities in which tungsten is reported to occur:

Near the town of Covada in Ferry County, scheelite is said to occur. Tungsten is reported from near Kellar, Ferry County, at the head of Copper Creek. Hubnerite is reported to occur a few miles south of Tonasket near the Okanogan River. Sufficient development work has not been done here to make it possible to say anything definite with regard to this deposit. Tungsten deposits occur in Yakima County near Bumping Lake and some development work has been done on them.

Tungsten deposits are reported from a number of other places, but practically no development work has been done on them and it is not possible to say anything in regard to the character or extent of these deposits.

[1]Weaver, Charles E.; The Mineral Resources of Stevens County. Washington Geological Survey, Bull. 20 (1920), p. 220.

PART II.

Non-Metallic Minerals

NON-METALLIC MINERALS

The value of the non-metallic minerals produced in Washington is far greater than that of the metallic minerals. The most important of the non-metallics in order of value for 1922 are coal, cement, clay products, stone, and sand and gravel.

Coal. Coal mining constitutes the most important phase of the mining industry in Washington. The coal deposits occur mostly in Cowlitz, King, Kittitas, Lewis, Skagit, Thurston, and Whatcom Counties. The coal from these different localities varies more or less in appearance and composition. In the Mount Baker district of Whatcom County, some anthracite occurs while in places, in the southern counties mentioned above, lignite occurs. In King, Kittitas, and Pierce various grades of bituminous coal are mined. Some of these coals may be made into a very good grade of coke.

The largest amount of coal produced in Washington in one year prior to 1917 was in 1910. From the close of 1910 to the close of 1915 there had been such a decrease that during 1915 there was mined 1,482,899 short tons less than during 1910. Beginning with 1916, an increase in production began and continued to the close of 1918. Since then the production has fluctuated more or less but has been about 2,500,000 to 3,000,000 short tons annually.

Portland cement. The manufacture of Portland cement has become a very important industry in the State, the value of the output being second only to that of the coal output. The counties best supplied with materials from which to manufacture Portland cement are Pend Oreille, Stevens, Skagit, Whatcom, and San Juan. The growth of the cement industry has been fairly rapid in Washington, the first Portland cement having been produced in May, 1907. Now there are five good sized plants in constant operation, the output for 1922 being 1,951,414 barrels, having a value of $4,684,624. Good deposits of cement materials are available and the output may be increased at any time when the demand justifies it.

Clay industry. The value of the clay wares manufactured in Washington ranks next to that of Portland cement. The clays occurring in this State are such as may be used in the manufacture of the various grades of clay products such as paving brick, sewer pipe, terra cotta, pottery, fire brick and building brick of various kinds. The clays from which the best paving bricks are made occur in western Washington in connection with the coal measures. Fire clay is also found in these same formations. Clays from which common building brick may be made are found in almost all parts of the State. Spokane and Stevens Counties have good clays from which to manufacture architectural terra cotta and a large part of the terra cotta manufactured in Washington is made at Clayton, Stevens County.

As is natural to expect, the clay industry will be developed as near the markets as possible and as a result of this the largest clay working plants are situated near the largest cities as Seattle, Tacoma, and Spokane. In some cases, however, the best clays may be a considerable distance from a large city, as in the case of the deposits around Clayton, north of Spokane, and this may mean the shipping of the ware not only to the farthest markets but also to the nearest ones.

Stone. Washington has some very good stones for building purposes. These are mainly granite and sandstone. Granite is found on both the eastern and western side of the Cascade Mountains and quarries have been developed in various places at different times. Sandstone quarries have been operated mainly in Thurston, King, Pierce, and Whatcom Counties. The location of these quarries has been determined very largely by market and cheap transportation and there are undoubtedly many places where these sandstones have not been quarried where they would be just as good for building purposes as those that have been quarried.

The largest part of the stone quarried in this State is used for other purposes than building, the most important at present being for road construction. For this purpose basalt is extensively used.

Sand and gravel. The total value of the sand and gravel produced in Washington is quite large. These are used for various purposes such as road building, street paving, concrete foundations, sidewalks, and building construction in general. The production of sand and gravel, as reported, for 1922 was 1,802,121 tons with a value of $844,252.

Other minerals. While the above are the most important non-metallic minerals there are a number of others such as lime, magnesite, diatomaceous earth, mineral waters, and silica all of which are of some importance.

ASBESTOS

The term asbestos is now applied to any material that can be separated into flexible fibers. These minerals are all silicates which vary much in composition.

Asbestos minerals. According to the present commercial usage of the term, asbestos includes the following minerals: True asbestos—tremolite and actinolite—chrysotile, anthophyllite, and crocidolite. All of these fibrous minerals are poor conductors of heat, resist well high temperatures, and are more or less acid proof. Only two of these four minerals, true asbestos and chrysotile, are of commercial importance, and both of these consist of easily separable fibers of variable length. True asbestos usually has longer fibers than chrysotile but as a general thing they are not so strong as those of chrysotile.

Tremolite ($CaMg_3(SiO_4)_3$) and actinolite ($Ca(Mg,Fe)_3(SiO_3)_4$) are the two minerals to which the term asbestos was first applied and are the ones to which the term true asbestos is applied here. Tremolite is a calcium magnesium silicate while actinolite is a calcium, magnesium, iron silicate. These minerals vary much in color and may be white, yellowish, and greenish. The fibers from tremolite and actinolite may be long and silky but are apt not to have great strength. When these minerals are fresh and unweathered the fibers may be spun or woven into cloth.

Chrysotile, or serpentine asbestos ($H_4Mg_3Si_2O_9$), is better in quality than any of the others. The fibers are flexible and strong except when weathered. Chrysotile is a hydrated silicate of magnesia with a yellowish, greenish or brownish color. It has a specific gravity of about 2.5. This mineral is a very important source of asbestos, large deposits occurring in the Province of Quebec, Canada, and in Vermont.

Uses of Asbestos. Asbestos fiber may be spun into yarn and rope and woven into various forms. In this form it finds many uses as a fire resisting fabric. It is also used in the manufacture of paper and shingles for which a short fiber may be satisfactory. Short fiber asbestos is used as a binder in certain mineral floors. It is much used in packing steam engines, for heat insulation, cements, paints, and wall plaster. Many patented preparations composed of magnesite, plaster of Paris, wood pulp, hair, and diatomaceous earth with varying amounts of asbestos are on the market as non-conducting coverings. It has a very low electrical conductivity and on account of this fact, it is used as an insulator in electrical instruments. Its resistance to high temperatures is also in its favor as an insulating material. There is a gradually increasing demand for asbestos as new uses for it are constantly being found. Asbestos plaster as a wall covering has a number of desirable features, one of which is its property to deaden sound waves.

Asbestos in Washington. Asbestos occurs in various places in Washington but in only one or two places have the deposits produced any asbestos commercially. Near the town of Leavenworth in Chelan County is a deposit of asbestos on which some development work has been done. The Asbestomine Company has developed a deposit of asbestos in Okanogan County near Pateros. The asbestos from this deposit is used to mix with diatomaceous earth as the base of a paint which is manufactured by this company. The asbestos mineral is a short fiber amphilbole and it is ground with the diatomaceous earth. This company has factories at Wenatchee and Seattle. No production was reported by this company for 1922.

Asbestos of good quality is reported to occur near Hamilton in Skagit County. It is also reported to occur near the Skagit River in the foot hills of the Cascade Mountains in Skagit County. Another deposit is also reported from Lyman in Skagit County. Asbestos is reported to occur in Stevens County, eight miles east of Chewelah. There are probably other places in the State where asbestos occurs, but these are the principal ones from which it has been reported.

BARIUM

Barium is an element that belongs to the group of metals, the oxides of which are the alkaline earths. Barium does not occur native, but is found in nature combined with other elements. It is a yellowish-white, somewhat malleable metal with a specific gravity of about 3.6. It is fusible at high temperatures, burning readily when heated in the air.

Barium minerals. The principal source of barium is barite ($BaSO_4$), containing theoretically 65.7 per cent barium oxide. The color of the mineral varies more or less, depending on the impurities that it contains and may be white, gray, yellow, and red. It has a vitreous, almost resinous luster and is very brittle. Its specific gravity is about 4.5.

Barite is a common gangue of many ore veins, especially those of copper, lead and silver. It occurs in both igneous and sedimentary rocks, but is more common in the latter.

Uses. The metal barium is not used commercially. It combines, however, with most acids to form salts of barium, many of which are in use for various purposes.

The sulphate of barium (barites) is used extensively in paint making, where it may act simply as a filler, as a vehicle for coloring, or for putty making.

At first, barite was employed in paints purely as an adulterant on account of its weight and its cheapness as compared with white lead, with which it was mixed. Later, it was recognized that it had properties that gave to the paint certain advantages, such as longer life on account of being but little affected by weathering and chemical fumes. On account of the fine angular grains of the barite it was found to give a surface to the paint that was especially well adapted to bonding with subsequent coats.

The value of barite as a pigment is due not alone to its weight and absence of color, but to the readiness and uniformity with which it takes color-stain and makes it possible to cover a large surface with a small quantity of a decided color. This is a property not possessed to the same extent by other white substances such as gypsum and marble.

Putty may be made by simply mixing whiting and linseed oil to the consistency of thick dough; but by substituting barite for a part of the whiting, a smaller amount of oil would be necessary to produce the same bulk of putty and thus making a saving on oil.

Barite is used in the manufacture of rubber and it is claimed to be desirable up to a certain per cent on account of increasing the resiliency and durability of the product.

Barite is also used as a sizing for papers and textiles. It is also used in the preparation of certain pigments used in the printing of wall paper. For this purpose absence of color is essential and barite is finely ground and purified. Barite is also used in the tanning of leather, the dressing used in the finishing of some grades of leather containing a certain amount of barite.

Other barium compounds are used for certain purposes. The chlorate and nitrate are used for fireworks; the hydroxide, and the carbonate are used in chemistry.

Barite in Washington. The mineral barite has not been produced on a commercial scale in Washington. There are, however, places in this State where it is known to occur. Weaver[1] reports it as occurring as a vein in the calcareous argellites in the Chamokane district near the headwaters of Chamokane Creek, west of Springdale in Stevens County. But little work has been done on this deposit and the extent of it is not known.

Mr. L. K. Armstrong of Spokane has furnished me the following information in regard to some barite deposits west of Springdale:

The principal outcrops of barite in this locality are in Sec. 11, T. 30 N., R. 38 E. The dimensions of the barite deposit have not been determined, but the deposit is several feet thick and appears to parallel the strike of the formations in this locality. No analyses have been furnished me of this material hence I do not know how pure it is. Mr. Armstrong is of the opinion that it is of commercial quality. The high cost of transporation would prevent it being used commercially at the present time.

Barite is found as a gangue mineral in some of the ore deposits in the northeastern part of Washington, but these occurrences are probably of no commercial value.

[1]Weaver, C. E.; Mineral Resources of Stevens County. Washington Geological Survey, Bull. 20, p. 212, 1920.

CALCIUM

Calcium is a metal having a light yellow color and a fairly brilliant luster. It is about as hard as gold and is very ductile. It has a specific gravity of about 1.57. It oxidizes readily in moist air, and burns at a red heat forming calcium oxide or quick lime, which is one of the alkaline earths. Calcium is not found native in the metallic state but unites readily with most of the non-metallic elements in compounds which are widely distributed in nature and extensively used.

Calcium Minerals. The most important calcium minerals are calcite, dolomite, gypsum and fluorite.

Calcite is calcium carbonate ($CaCO_3$) and is the essential constituent of limestone, marble, chalk, etc. When pure it is white but may be gray, pink, red or almost any other color on account of the impurities which occur in it. It has a specific gravity of about 2.7 and a very perfect cleavage.

Dolomite is a carbonate of calcium and magnesium ($(CaMg)CO_3$) containing theoretically one molecule of calcium carbonate and one molecule of magnesium carbonate, or by weight, 54.35 per cent calcium carbonate and 45.65 per cent of magnesium carbonate. Almost all gradations are found, however, between pure calcium carbonate on one hand and pure magnesium carbonate on the other. The color of dolomite varies and may be white, gray, pink, or almost any other color, depending on the impurities in it. The luster is vitreous to pearly and at times somewhat satiny. It has a specific gravity of about 2.9 and is a little harder than calcite.

Gypsum is a hydrous sulphate of calcium ($CaSO_4.2H_2O$) and is the source of plaster of Paris of commerce. The color of gypsum may be white to gray, pink, blue, etc. It has a pearly luster, a specific gravity of about 2.3, and is a very soft mineral. It occurs in various forms known as selenite, in plates or crystals; satin spar, white and delicately fibrous gypsum; and alabaster, white compact, and very fine grained gypsum.

Fluorite is the fluoride of calcium (CaF_2) and contains 51.1 per cent calcium. It is of various colors, deep green, red, or white, with pale-green or violet-blue most common. It has a specific gravity of about 3.2. It may occur in beds but more often is found in veins and seams in gneiss, slates, sandstones, and limestones.

Uses of calcium. The metal calcium has no commercial uses but various compounds are in very general use. Calcium hydrate is manufactured in many places now and is used in mortars in place of the oxide. This saves time as it does not have to be slaked. Chloride of lime is extensively used as a bleaching agent and as a disinfectant. The bisulphite of calcium is used in the paper industry in the preparation of wood pulp and in sugar purification. Calcium nitrate is used with lime as a fertilizer. Apatite, calcium phosphate, and gypsum, hydrated calcium are also used as fertilizers. Calcium carbide is much used in the production of acetylene used for lighting purposes. Calcium fluoride is used as a flux in the manufacture of basic open hearth steel and in blast furnaces. It is also used in the manufacture of glass, enameled ware, and sanitary ware. Fluorite is also used in the manufacture of hydrofluoric acid.

Lime, calcium oxide, will be discussed under structural materials.

Calcium in Washington. Limestones are abundant in many parts of this State and as the principal constituent of limestone is calcium, it follows that calcium is also abundant. The discussion of limestones, however, will be given in another place in this report.

Dolomite. Many of the limestones which occur in the northeastern part of Washington, especially in Pend Oreille and Stevens Counties, contain more or less magnesia. In some places, these will carry practically the theoretical amount of calcium and magnesium carbonates for a true dolomite, while in other places the calcium will be high and the magnesia low, or the reverse may be true. This is due to the fact that calcium and magnesium are capable of replacing one another in practically all proportions.

The dolomite deposits of this state have been worked for dolomite in but one locality and this is about five miles east of Colville in Stevens County. In October, 1917, the Tulare Mining Company began the production of dolomite at this point. Two large rectangular kilns had been constructed, in which to calcine the dolomite, and quarries opened. The plant was operated for a number of years, but for the past two or three years it has been closed down. The dolomite after being calcined was shipped to the paper mills in Oregon where it was used in making sulphite liquor, which was to be used in the preparation of wood pulp for the manufacture of paper. The material was calcined before being shipped. It has almost the theoretical composition of dolomite. The deposits are extensive and a large tonnage is available.

Fluorite. Since the year 1916, Washington has been credited with a small annual production of fluorite. This production has been from one deposit which is near the town of Keller in southern Ferry County. This deposit is described by Pardee[1] as follows:

> "Near the northeast corner of Sec. 24, pits expose a vein of pure fluorite, 16 inches in width, that strikes N. 65° W., and stands vertically between walls of the Colville granite. Margins of the deposit show the outlines of cubical crystals, and the mass may be readily cleaved into large transparent octahedrans that show pale shades of green with zonal bands of violet."

This property is operated by Mr. C. Fogarty.

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[1]Pardee, J. T.: Geology and Mineral Deposits of the Colville Indian Reservation, Washington. U. S. Geol. Survey, Bull. 677 (1918), p. 127.

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DIATOMACEOUS EARTH

Diatomaceous earth (Infusorial Earth) is a soft whitish, grayish, or brownish, earthy material composed wholly or in large part of the siliceous shells or frustules of minute one celled plants. When pure it is white, but it usually contains more or less impurities in the form of clay, organic matter, and iron stains, and hence the variations in color. These minute plants inhabit both fresh and salt waters, and deposits of their shells are found on the bottoms of lakes and oceans. Diatomaceous earth is a very light porous earth material which resembles chalk very much in its physical appearance. When treated with dilute hydrochloric acid it does not effervesce, while chalk does. Chemically diatomaceous earth is hydrous silica.

Uses of diatomaceous earth. The pure white variety of diatomaceous earth is being used as a filtering agent in sugar refining and various chemical industries, and the demand for clean diatomaceous earth for this purpose is constantly growing. Two or three per cent of iron oxide is sufficient to impart a perceptible yellow color, and make diatomaceous earth unfit for the above purpose. Diatomaceous earth may be used as a absorbent for liquid fertilizers, and disinfectants; it may be used in the manufacture of glazes, water glass, and certain cements; it has been used extensively in the past as an absorbent for nitroglycerine in the manufacture of explosives; it has been used as a base for certain pigments; as a sizing for paper; and as a scouring powder. For this latter use it is prepared either as a dry powder to be moistened or otherwise prepared by the user; mixed with about one-third its weight in tallow or other hard grease and molded into bricks or sticks; or mixed with some cleansing liquid in the form of the well known liquid metal polishes. Diatomaceous earth is used also to some extent in the manufacture of fire-proof materials, as an insulating material for boilers, and as a sound deadener in floors and partitions.

Diatomaceous earth in Washington. Diatomaceous earth is known to occur in several places in this State and production on a commercial scale has been carried on in connection with some of the deposits. The best known of these deposits are the ones in Kittitas and Grant Counties. These deposits occur between layers of Neocene basalt and mark the sites of small lakes that existed in those localities during the time that elapsed between two basaltic overflows. In these lakes the diatoms flourished in immense quantities for a sufficient time to accumulate on the floors of these lakes a thickness of 10 to 12 feet of their microscopic skeletons.

The deposits in Kittitas County are on Squaw Creek in the southeastern part of the county. They are about 11 miles southeast of the station of Wymer on the Northern Pacific Railway, or about 18 miles from Kittitas, a town on the Chicago, Milwaukee and St. Paul Railway. The following description of these deposits is by E. N. Patty[1]:

"The best developed property is that of the Majestic Diatomaceous Earth Company, 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 tram 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

[1]Patty, E. N., and Glover, Sheldon L.; Mineral Resources of Washington, with Statistics for 1919. Bull. 21, Wash. Geol. Survey, pp. 95-96, 1921.

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 considerable extent about 12 miles south of the town of Quincy in Grant County is known to be underlaid by a deposit of diatomaceous earth. This occurs at various depths below the surface and varies more or less in thickness. This deposit has been worked at times past and diatomaceous earth produced on a commercial scale. When the deposit was being worked, the material was hauled to Quincy where it was pulverized in a small mill and then sacked and shipped.

Deposits of diatomaceous earth are known to occur in other parts of Washington, but most of them have never been worked on a commercial scale. Northwest from the town of Hatton is a deposit of this material that is very white and has the appearance of being a very high grade diatomaceous earth. This deposit was worked a good many years ago and the material marketed as a polishing powder. Diatomaceous earth is reported from near Yakima, in Yakima County. In western Washington deposits of diatomaceous earth are known to occur, but in practically all cases but little development has been done and no production on a commercial scale has been made from any of them.

In 1922 the only production reported was from the deposits in Kittitas County and this was small. The larger part of the diatomaceous earth produced in Washington goes to sugar refineries where it is used as a filtering medium.

FELDSPAR

The term feldspar includes a group of minerals, the individuals of the group differing more or less in composition but each one consisting of silicate of alumina with one or more of the alkali groups—potash, soda or lime. Orthoclase and microcline are the two feldspars of most importance commercially. These are silicates of alumina and potash ($KAlSi_3O_8$) and are identical in composition.

Uses of Feldspar. The principal use of feldspar is in the ceramic industry. It is one of the principal ingredients of the body and the glaze of porcelain. In the body of the ware it is fused during the firing process and forms a firm band between the particles of quartz and clay. When used in the glaze, it fuses and combines with the other ingredients to form an opalescent glossy covering to the ware on which it is applied. The temperature at which a feldspar will melt is an important factor in determining its suitability for certain purposes. The melting point is determined very largely by the percentage of potash in the feldspar and is lowered as the potash increases. In some cases a part of the potash is replaced by soda and then the point of fusion is still lower.

Feldspar is used in enameling brick and metal, the spar being the fluxing material that forms the porcelain-like coating of the ware. Feldspar is also used in making abrasive wheels where it acts as a bonding material. It is also used in the manufacture of opal glass.

Feldspar in Washington. A body of feldspar has been located eight miles east of Ruby in Pend O'reille

County. One of the owners of this property is Mr. H. C. Meyers of Cusick, Washington, who furnished me the information I have in regard to this property. It is located in Sec. 35, T. 35 N., R. 45 E., on what is known as North Baldy. There is said to be a very large body of this material. This feldspar is the variety known as microcline, which is a potassium aluminum silicate ($KAlSi_3O_8$). It is very light gray, almost white, in color and has very marked cleavage. The samples which I have contain small specks of iron oxide. These, however, appear to occur along the seams and cracks through the material.

Samples of this feldspar have been tested in the Department of Ceramics at the University of Washington but final conclusions, in regard to the quality of the material, have not been reached.

Feldspars are common constituents of many igneous rocks and when they decompose they form clay. Some of the very best clays found in Washington have been formed by the decomposition of granite rocks high in feldspar.

GRAPHITE

Graphite is one of the forms under which the element, carbon, occurs in nature. It has an iron-gray color and metallic luster, and occurs either as veins of crystalline graphite, lenticular masses of crystalline graphite, or as particles of graphite, either crystalline or amorphous disseminated through the country rock. It is soft and unctuous to the touch and makes a black shining streak on paper. It has a specific gravity of about 2.1. It has the same chemical composition as diamond, but differs very materially from it in its physical properties.

Graphite occurs in crystalline limestones, schists, and granites, either in the form of flaky, foliated, or granular masses and sometimes as large crystals in veins. Graphite in veins, however, in commercial quantities is of rather rare occurrence.

Uses of Graphite. Graphite is produced in several grades, each of which is adapted to special purposes. The term amorphous graphite is applied to the very fine grained non-crystalline form, while if it is produced in flakes or scales it is known as vein graphite and may be in the form of lumps, chips, or dust. Artificial graphite, which resembles the amorphous variety, is manufactured by the Acheson Graphite Co., at Niagara Falls.

One of the oldest and most important uses of graphite is as a refractory substance. Because graphite is practically pure carbon, volatilizes only at high temperatures, and is comparatively inert chemically, it is especially valuable as a material from which to manufacture crucibles to be used in the steel, brass, and bronze industries. Flake graphite is used largely for this purpose as the interlocking and overlapping of the flakes adds to the tensile strength. The most important thing in determining the value of any graphite for refractory purposes is the amount and chemical composition of the impurities in it. Graphite, similar to that used for crucibles, is used in the manufacture of such refractory products as muffles, dipping ladles, skimmers, and nozzles.

Graphite is used extensively as a lubricant. It is especially valued for this purpose on account of its softness and unctuousness. Both the crystalline and flake graphite are used for this purpose, the main requirement being that the graphite is free from gritty matter. As a lubricant, graphite is used either dry or mixed with oil or grease.

Graphite is used quite extensively in the manufacture of paints for special purposes, such as for covering structural steel work, steel stacks, and iron and steel surfaces in general that are to be exposed to the weather. Much of the graphite used for this purpose is not very pure, some of the paint pigment containing not more than 35 to 45 per cent of graphite. The remainder of the paint being, as a general thing, either siliceous, aluminous, or ferriginous material. The amorphous form of graphite is generally used in the manufacture of paint.

Another important use of graphite is in the manufacture of stove polishes. Both the amorphous and flake varieties are used for this purpose. Clay or some other material to act as a bond, is mixed with the finely ground graphite. Much graphite is used in coating molds in foundries. The object of the coating is to prevent the metal from coming into contact with the sand of the mold and at the same time give a smoother surface to the casting. Graphite has certain properties which make it especially well adapted for this purpose.

The use of graphite in the manufacture of pencils is one of the purposes to which it has been longest applied. For this purpose the better grades of amorphous graphite are largely used. The better grades of pencils are made from a blend of several kinds of graphite. In making pencils the finely ground graphite is mixed with a carefully refined clay and the wet mixture thoroughly worked until it becomes very pliable. It is then formed into shapes and baked. The hardness of the product depends upon the proportion of clay used in the mixture and the length of time and temperature of baking.

Graphite is being used for some other purposes, but the above are its principal applications as from 90 to 95 per cent of the production is taken by these industries.

Graphite in Washington. Graphite is known to occur in a number of places in this State but in most cases the deposits are practically undeveloped. Along the western foot-hills of the Cascade Mountains, deposits of schist are found in which more or less free graphite occurs.

A deposit of graphite occurs west of Mason, a station on the Great Northern Railway in Chelan County. Considerable development work has been done on this property, but on account of distance from transportation, graphite has not been produced commercially. This material is said to be very finely crystalline.

Near Samish Lake in Skagit County is a deposit of graphite from which shipments are said to have been made. Other deposits are reported from near Wilkeson on South Prairie in Pierce County and also from the Cascade Mountains in Lewis County.

Metamorphic and igneous rocks occur over large areas in Washington and graphite may occur in many places from which it has not been reported.

MAGNESIUM

Magnesium is the metallic base of the widely distributed alkaline earth, magnesia. Magnesium is a metal of a silver-white color, having a specific gravity of about 1.75. If held in the flame of a candle, it burns with a dazzling white light. Magnesium does not occur in nature as metallic magnesium but in various combinations which are widely distributed. The metal is produced, however, in certain localities on a large scale. It is formed into wire when in a semi-fluid state and then flattened into ribbon, in which form it is usually sold.

Uses of Magnesium. Magnesium has a limited use in the form of the metal but by far the larger part is used combined with some other element. In the metallic state, it is used in some chemical processes in taking photographs in places where the sunlight does not penetrate, signalling for naval and military purposes, and in pyrotechny.

The oxide of magnesium (MgO) is used as medicine; the sulphate, Epsom salt, is used in sizing fabrics, in dyeing, for tanning leather, in chemical laboratories, and for medicine; the chloride as a bleaching agent; the oxychloride in the manufacture of what is known as oxychloride or Sorrel cement; and the hydrate is used in sugar-refining.

A very important use of magnesite is as a fire retarding paint. For this purpose the finely ground caustic calcined magnesite and magnesium chloride are used. When these are dissolved in water and inflammable substances covered with them, they show a marked resistance to fire. The materials may be burned by the direct application of heat but in case of a fire the damage is more apt to be confined.

Magnesium minerals. Magnesite, the carbonate, is by far the most important compound of magnesium and is the principal source of the metal and the other compounds.

Magnesite ($MgCO_3$) contains, when pure, 47.6 per cent magnesium oxide. It often has some calcium and iron present as impurities. The color varies more or less and may be white, gray, yellowish, or pink. It has a specific gravity of about 3.1 and is a little harder than calcite. It is found associated with other magnesium minerals, such as serpentine, talc, brucite, and olivine.

Use of magnesite. In the raw state magnesite is used in the manufacture of carbon dioxide. The process consists in the decomposition of the magnesite by roasting and the recovery, purification and compression of the carbon dioxide gas. This also leaves the magnesia available for various uses.

The calcined mineral has many uses which are determined by the extent to which the calcining has been carried. In actual practice the calcining is carried out so as to produce magnesia of two quite distinct forms and with different properties.

If the magnesite is heated at a moderate temperature in the furnaces usually employed for such purposes, it is broken up into magnesia, magnesium oxide and carbon dioxide. At a medium temperature, however, this dissociation may not be complete and in actual practice the process is so conducted that from three to eight per cent of the carbon dioxide is left combined in the residue. When burned at a medium temperature, the product will recombine more readily than when burned at high temperature. The product has somewhat the same properties as caustic lime in that it is susceptible to reaction with water and with the carbon dioxide of the air. In this form it will readily combine with certain other reagents, such as magnesium chloride, and it is upon this fact that its value for certain purposes as oxychloride cement, outside stucco, etc., depends.

When magnesite is calcined at a high temperature all the moisture and carbon dioxide of the magnesite may be driven off, and if the temperature is increased above this point incipient fusion may take place. The product obtained by heating to incipent fusion is known as dead-burned magnesite and is a very different material from caustic calcined magnesite. Practically all the shrinkage due to calcining has been taken up and the resulting product is a very dense, chemically inactive, and fire-resistant substance. It will not slake in the air or on the addition of water as lime or caustic calcined magnesia do. The dead-burned magnesite is used entirely as a refractory material. The principal use is as a refractory lining for furnaces in the steel industry.

Magnesite in Washington. The magnesite deposits of Washington first came into prominence in 1916. As early as 1900 a large number of the limestone deposits in the northeastern part of Washington had been located as marble and considerable development work was being done. As a result of this activity, the State Geological Survey, which had but recently been organized, began in the summer of 1901 a study of the building stones of Washington, the writer being assigned to that work. The various limestone deposits were visited, samples collected, and chemical analyses were made of many of them. These analyses showed that some of the deposits that had been located and were being developed as marble were almost pure calcium carbonates, others were mixtures of calcium and magnesium carbonates, while still others were almost pure magnesium carbonate or magnesite.

At this time the magnesite being used in the United States was imported and was sold in the districts where it was used at a price below which it was possible to produce domestic magnesite. When the World War broke out, however, and the imports stopped, conditions changed and a domestic supply was sought. As a result of this, the Washington magnesite deposits came into prominence and are now an important factor in determining our independence with regard to this important mineral.

With the close of the war, imports of magnesite began again and it was not long until the magnesite from Austria-Hungary had largely replaced the domestic product. On account of the cheapness of this imported material, the domestic producers were not able to supply magnesite except at a loss and hence were compelled to close their plants. An effort was then made to have Congress place a duty on all imported magnesite, sufficient to enable the domestic companies to compete on a fair basis with imported magnesite. This effort was finally successful and in the tariff act of 1922 provision was made for a duty on all imported magnesite. On crude magnesite a duty of $6.25 per short ton was imposed; on magnesite brick three-fourths of one cent per pound, and ten percentum, ad valorem; caustic calcined magnesite $12.50 per short ton; and dead-burned and grain magnesite, not suitable for manufacture into oxychloride cement $11.50 per short ton.

The passage of the new tariff naturally stimulated the domestic magnesite industry considerably and during the latter part of 1922 there was considerable activity displayed and the plants in Washington were put in repair and preparations made for large scale production.

The magnesite deposits in this State are in the Huckleberry Mountains in Stevens County. The deposits are in a comparatively narrow belt, extending in a general northeast and southwest direction. They occur west of the Colville Valley and at a distance of from five to fifteen miles from the town of Chewelah and Valley on the Spokane Falls and Northern Railway, a branch of the Great Northern Railway. The magnesite is of the crystalline variety and occurs as large lenses along a comparatively narrow dolomite belt.

The most favorably situated of the magnesite deposits are what are known as the Finch, Allen, and Moss properties which are about five miles from the Great Northern Railway. The transportation problem, however, has been solved for these properties as an aerial tram has been built to connect the Finch quarries with the railroad, while a standard gauge railroad has been built from the Great Northern Railway at Valley to the Allen and Moss quarries.

The Northwest Magnesite Company has built a large calcining plant by the railroad about a mile south of Chewelah. The raw magnesite is brought by tram from the quarries to this plant where it is dead-burned for refractory purposes. A small amount of iron ore is used to mix with the magnesite and this comes either from the deposits from Valley or from iron deposits on Buckhorn Mountain about four miles east of Chesaw in Okanogan County.

The American Mineral Production Company built its plant for calcining magnesite at its quarries and transported the finished product in place of the raw. This company has put in kilns designed for the production of caustic calcined magnesite and for some time past has been producing no dead-burned magnesite.

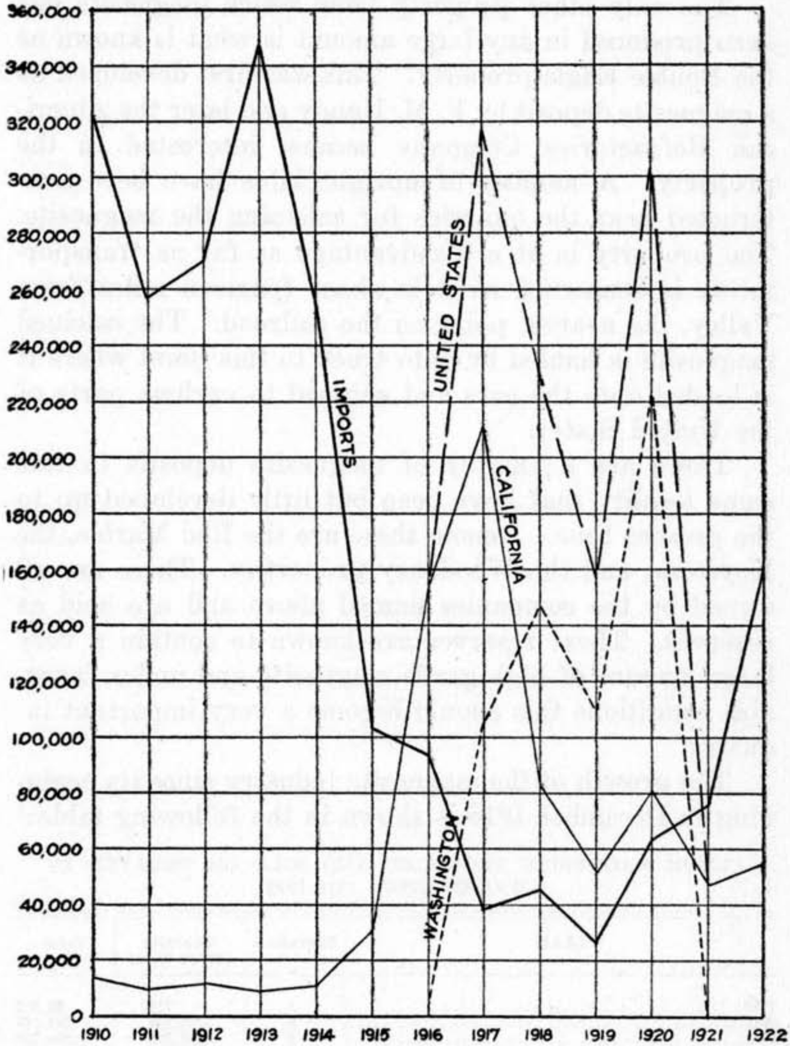

FIG. 3. Diagram showing production and imports of magnesite in the United States, 1910-1922, in short tons of crude magnesite. Statistics from U. S. Geol. Survey, Mineral Resources, and from Mineral Industry.

The only other property from which magnesite has been produced in any large amount is what is known as the Double Eagle property. This was first developed as a magnesite deposit by F. M. Handy and later the American Refractories Company became interested in the property. A number of upright kilns have been constructed near the quarries for calcining the magnesite. The property is at a disadvantage as far as transportation is concerned as it is about fourteen miles from Valley, the nearest point on the railroad. The calcined magnesite is hauled by auto truck to this point where it is loaded onto the cars and shipped to various parts of the United States.

There are a number of magnesite deposits in this same locality that have been but little developed up to the present time. Among these are the Red Marble, the Keystone, and the Woodbury properties. These are all owned by the companies named above and are held as reserves. These reserves are known to contain a very large amount of high grade magnesite and under favorable conditions this should become a very important industry.

The growth of the magnesite industry since its beginning in December 1916 is shown in the following table:[1]

CRUDE MAGNESITE PRODUCED AND SOLD OR TREATED IN WASHINGTON, 1916-1922

YEAR	Operators	Quantity (short tons)	Value
1916	1	715	$5,362
1917	3	105,175	783,188
1918	2	147,528	1,050,790
1919	3	106,206	743,442
1920	3	221,985	1,664,888
1921	....	No production	....
1922	....	No production	....
Total	....	581,609	$4,247,670

[1]U. S. Geol. Survey, Mineral Resources, 1916-1922, Part 2.

LIST OF THE COMMERCIAL MAGNESITE PROPERTIES IN WASHINGTON

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

During 1923 the magnesite industry in Washington was in a more prosperous condition than it had been in 1921 and 1922 and all three of the principal companies in this field were producing magnesite at least a part of the time.

MAGNESIUM SULPHATE (EPSOM SALTS)

Before the war began Germany supplied most of the magnesium sulphate used in this country. The German magnesium sulphate is produced as a by-product of the potash industry. With the beginning of the war, imports ceased and it was necessary for the United States to seek another source of supply. As a result of this certain deposits of natural Epsom salts which are in this State have been developed.

These deposits of Epsom salts occur in three small lakes near Oroville, two of which are in Okanogan County while the other is just across the line in British Columbia. Two of these lakes are on Krueger Mountain only a short distance apart while the third is south and west from the others. These lakes are all small, covering only a few acres but the thickness of the salt in some cases is as much as twenty-five feet.

The production of magnesium sulphate from these lakes began in April, 1916, and had been continuous with perhaps slight interruptions since. The first production was from the lake in Washington situated on Krueger Mountain and known as Spotted Lake. A plant for refining the salt was constructed on the Similkameen River a short distance north or Oroville. The crude material from this lake is conveyed to the plant either by being dissolved and pumped through pipes or hauled on trucks.

The following information was furnished me by Mr. E. Klingman, Secretary of the Epso Products Company, owner of these lakes:

In the lake known as Bitter Lake, the solid salt was in large pools and pure with the exception of some very fine mud mixed with the crude salt. Epso Lake, the deposit from which most of the salt is being obtained at present, is about ten miles south of Oroville. This deposit is said to be somewhat different from the Bitter Lake deposit. The salt occurs in one large bed and not in pools. In this case, the salt is covered with a layer of mud about 20 feet thick. The layer of salt covers about 15 acres and has a thickness of about 30 feet. The salt is very pure except in some places where it contains some very fine mud mixed with it. The salt in the Epso Lake is mined much as coal is mined and hauled to the plant and then dissolved in liquor pumped to the plant from Bitter Lake which is about three miles away. This liquor has a considerable amount of salt in it as it comes to the plant and this reduces the amount of water to be evaporated per pound of salt recovered.

The purified salt is loaded onto cars and shipped to various parts of the country where it is used for medicinal purposes, tanning leather, etc.

TALC, STEATITE, SOAPSTONE

Talc is a hydrous silicate of magnesium with a pearly luster on cleavage surfaces. It has a specific gravity of about 2.8 and is a very soft mineral. The color may be white, greenish, or greyish. Talc is found frequently as an alteration product of basic igneous rocks rich in magnesia and is therefore often found associated with chlorite-schist and serpentine. The better grades of talc occur as alteration products of tremolite associated with magnesian limestones.

Uses of talc. The particular properties of talc which make it useful in the industries are its softness, slipperiness, and resistance to the action of most chemicals. It is also quite refractory and a non-conductor of heat and electricity.

Talc is used extensively in the manufacture of paper, where it acts as a filler to produce a white opaque paper. To be used for this purpose, the talc should be practically white and free from grit. Large quantities of powdered talc are used for toilet preparations, especially talcum powder. It is also used as a filler or loader in the cheaper grades of toilet soap. For these uses it should be entirely free from grit.

Talc is also used as a filler in finishing silk goods; for filling and dressing cotton goods; as a marker under the name of French chalk; and in the preparation of cloth for window blinds.

Among the other uses may be mentioned the dressing of fine leathers and kids, as a lubricant, and as a powder for gloves and shoes. It is also used as a constituent of magnesite flooring, in foundary facings, and as a heat insulating cement.

Talc in Washington. Talc deposits are known to occur in Washington and some talc has been produced in the past. No production is recorded, however, for 1922.

The Western Talc Company has worked a deposit in Lincoln County near Reardan. The talcose material found here has been worked intermittently for the past few years and a small amount of pulverized talc has been supplied to paper plants and used as a filler in the manufacture of paper.

Talc is said to occur near Marblemount in Skagit County and also seven miles west of Anacortes in the same county.

MINERAL WATER

Mineral water, as the term is used here, includes water that is bottled and sold in its natural state, or only slightly altered from its natural state. This would include natural carbonated waters that have lost part of their carbon dioxide, natural waters that have been artificially carbonated, and waters from which iron has been removed.

The waters considered under this head may vary as far as amount and kind of mineral matter in solution, some containing large amounts, while others contain only small amounts. Some waters containing considerable amounts of dissolved mineral matter are not, however, considered here as they are not being bottled and marketed generally.

Washington has a number of localities where mineral springs and lakes occur and from a number of these the waters have been marketed in the past. The water from the different springs varies much in temperature and amount of mineral content. In some cases the water is hot, while in others it is about the temperature of ordinary spring water. The mineral content depends on the different minerals with which the water has come in contact as it percolated through the crust of the earth.

The year 1914 shows the largest production of mineral waters for this State, the value being $28,777. Since that time there has been a gradual decline in the number of producers of mineral waters, as well as in the value of the output, and since 1917 the number of producers has been so small that it has not been possible to give statistics of production without disclosing the output of individual operators.

The following are some of the localities from which production has been made in the past: Soap Lake, Grant County; Scenic Hot Springs, King County; Klickitat, Klickitat County; Collins Hot Springs and Stevenson, Skamania County; Olympia, Thurston County; Sol Duc Hot Springs, Clallam County; Yakima, Yakima County, Soda Springs and Artesian Mineral Well. Some of these are for bathing purposes only, while others are used for table and medicinal purposes. The salts from the Soap Lake waters have been marketed in package form.

PRODUCTION OF MINERAL WATERS, 1912-1917

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

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

Silica or quartz is the oxide of silicon (SiO_2) and is probably the most generally known mineral. It is very hard, is almost insoluble in ordinary acids and is but little affected by percolating water. It is colorless or white when pure, but is often colored by manganese, iron, or carbonaceous matter. Some of the varieties obtained as a result of these impurities are amethyst, rose quartz, and smoky quartz. Sand is silica and results from the weathering and breaking up of rocks. Flint is a cryptocrystalline variety of silica that is common in chalk.

Uses of silica. Silica is extensively used in the industries, the following being some of its most important uses: Finely crushed quartz is used to give body to wood fillers, to give body to certain paints, as an abrasive in certain forms as scouring soaps and polishing powders. In the smelting of some ores, quartz is used as a flux and crushed quartz is used as a lining for some metallurgical furnaces. Finely ground quartz is extensively used in the manufacture of porcelain enamel ware and enamelled bricks. Crushed quartz is used in making sand-paper, sand belts, and in sand blast apparatus. Either crushed quartz or a natural sand is used extensively in the manufacture of glass. For this purpose the quartz or sand should be very low in iron and should be free or practically so from clay, feldspar, and mica.

Silica in Washington. Deposits of almost pure quartz are known to occur in various parts of Washington some of which have been worked in a small way at various times in the past. One of the best known of these is in Spokane County about 12 miles north of Spokane. This is a very large body of almost pure silica. Some work has been done in developing this deposit and some silica shipped, most of which has been used in the manufacture of silica brick.

Other deposits of silica are reported to occur in various parts of Washington, and one east of Enumclaw in King County has been a source of supply for the Denny Renton Clay and Coal Company. The silica from this deposit has been used mainly in the manufacture of silica brick.

Large beds of quartzite are common in various parts of Washington. These vary much in purity, in some places being almost free from foreign materials and could probably be used for many of the purposes for which silica is needed. The quartzite would have to be ground, however, which would add somewhat to its cost for certain purposes.

No production of silica in Washington was reported for 1922.

SODIUM COMPOUNDS

Sodium is the metallic base of the alkali soda. It is a silver white metal with a high luster, but it oxidizes readily when exposed to the air. Heated in the air, it burns readily with a bright yellow flame very characteristic of the metal. At the ordinary temperature it has the consistency of wax and at 204° it melts and forms a liquid which resembles mercury. The most important salts of sodium from a commercial standpoint are sodium chloride or common salt, sodium carbonate or soda, and sodium sulphate, or Glauber salt.

Uses of Sodium. Metallic sodium is used in the manufacture of sodium peroxide, in the preparation of silicon and magnesium, while sodium and sodium amalgams are used as reducing agents in laboratory practice.

The various salts of sodium are used for a very large number of purposes, but the only one of these that will be discussed here will be sodium sulphate.

The sulphate of soda is used in large quantities in the manufacture of sodium carbonate. Most of this, however, is artificial sodium sulphate. It is also used in the making of glass, dyeing, and coloring.

Sodium Sulphate in Washington. Sodium sulphate deposits have been reported from a number of places in Washington but only one of these deposits has produced the salt on a commercial scale.

West of Warden, a station on the Chicago, Milwaukee and St. Paul Railway in Grant County, is a deposit of sodium sulphate from which a considerable amount of salt has been shipped at times. The deposit is said to cover a large area and to have a thickness in places of as much as ten feet.

A deposit of sodium sulphate has been reported from near Ophir in Okanogan County. It is on the east side of the Okanogan River and back about 3 miles from it. The salt is said to occur in small potholes in a lake bed. This deposit has not been worked on a commercial scale.

STRONTIUM

Strontium is a pale yellow metal with less luster than barium, malleable and fusible at red heat. It has a specific gravity of 2.54. When heated in the air, it burns with a bright flame, the oxide being formed. It does not occur native but is found in combination with other elements in the form of minerals, the two most common being strontianite and celestite.

Strontium Minerals. The only minerals containing strontium of commercial importance as raw materials in the manufacture of strontium salts are celestite and strontianite.

Strontianite is the carbonate of strontium ($SrCO_3$) with occasionally some calcium and barium. Its color varies and may be white, pale green, or yellowish. It has a vitreous or sub-vitreous luster and a specific gravity of about 2.7. It occurs as fibrous and radiating masses of fine crystals and in granular masses.

Celestite is strontium sulphate, a part of the strontium often being replaced by barium and calcium. It is colorless or white and sometimes pale blue with a vitreous to pearly luster. It has a specific gravity of about 3.95. It occurs in crystals, fibrous and radiating masses and sometimes in cleavable and granular bodies. Celestite is much more widely distributed than strontianite and is the principal source of strontium.

Uses of strontium. The metal strontium is not used commercially, but certain salts of strontium are used, the most important of these being the hydroxide, nitrate, carbonate, chloride and chlorate. Strontium hydroxide is used in some cases for refining beet sugar. The nitrate is used in fireworks when a strong crimson flame is desired. Certain organic and some inorganic salts of strontium are used in medicines.

Strontium in Washington. Strontium is known to occur in several places in this State and some strontium has been produced on a commercial scale. Near the close of 1916, a plant located in Seattle began the production of strontium from ore produced in Washington.

The following description of a deposit of strontium which occurs in Skagit County is taken from the U. S. Geol. Survey, Mineral Resources of the U. S., 1916, Part II, p. 194:

"Celestite and strontianite are found in a vien in a low serpentine hill which outcrops a mile southwest of La Conner, Skagit County. This property has been developed by the owner, Mr. D. C. Bard, 660 Stuart Building, Seattle, Wash., who has kindly furnished the Geological Survey data relative to the deposit. It is estimated that 10,000 tons of commercial strontium-bearing material are available above the water level. The celestite is well crystallized and has the typical bluish cast of the pure mineral. The strontianite, which is said to be found in greatest abundance near the outcrop, is a finely crystalline white material. Samples received by the Geological Survey were partly analyzed by A. A. Chambers, with the following results: Celestite ($SrSO_4$), 97.03 per cent; CO_2 trace: strontianite ($SrCO_3$), 75.80 per cent; SO_3, 0.75 per cent; calcium, present."

Another deposit of strontium is reported to occur in Whatcom County above the Skagit River gorge near the mouth of Ruby Creek. This deposit is said to be of good grade and quite extensive.[1]

Other deposits of strontium will probably be found in Washington, but these are the principal ones known.

STRUCTURAL AND INDUSTRIAL MATERIALS

THE CEMENT INDUSTRY

The cement industry in Washington has come to be a very important industry, the value of the output for 1922 being exceeded by only one mineral, coal. The value of the cement was $4,684,624, while that of coal was a little more than two and one-half times that amount. This is a slight increase in value over the output for 1921. The largest production so far was in 1914, when it reached 2,045,465 barrels. The average factory price per barrel

[1]U. S. Geol. Survey, Mineral Resources of the U. S., 1919, Part II, p. 98.

for that year, however, was only $1.13 as compared with $2.40 for 1922. From 1914 the amount of cement produced fluctuated slightly but was about 1,500,000 barrels until 1918 when it was only 931,489 barrels. During this time the price gradually increased so that the value of the 1918 output was almost equal to the value of that for 1914. Since 1918 the output has increased somewhat and the price per barrel has increased also, so that the value is much greater than for any previous year.

The first attempt at making cement in Washington was in 1904. In January, 1901, Mr. F. G. Jordan discovered and located a deposit of cement material near Ione on the Pend Oreille River just at the upper end of Box Canyon in Pend Oreille County. Considerable work was done in developing this property preparatory to the manufacture of natural hydraulic cement. A small plant was built and in February, 1904, the first natural hydraulic cement was manufactured in Washington. The plant was operated but a short time and cement was not produced on a commercial scale. Contests were soon started over the ownership of this property and nothing more has been done with reference to the manufacture of cement from these deposits.

The first Portland cement made in Washington was by the Washington Portland Cement Company, at Concrete on the Skagit River in Skagit County. This plant started with two small kilns but additions have been made from time to time until it had a capacity of 2,500 barrels every twenty-four hours. The materials used were clay and limestone and the dry process of manufacture employed. The clay is located about a quarter of a mile from the plant while the limestone quarries are about one mile from the plant, up the Baker River. The limestone is brought from the quarries to the plant by means of a train. Both the clay and limestone used by the company are of good quality and a good grade of cement is produced.

The next Portland cement plant to be built in Washington was the Superior, located just across the Baker River to the west of the Washington plant. The raw materials used at this plant are clay and limestone which occur only a short distance from the plant. This plant when first constructed used the dry process but has since been changed and now uses the more modern wet process. The capacity of this plant is about 2,200 barrels a day. The material used is about the same in composition as that used by the Washington Portland Cement Company.

The next cement plant built in this State was located in the northeastern corner at Metaline Falls on the Pend Oreille River in Pend Oreille County. This plant was built by the Inland Portland Cement Company and began manufacturing cement in August, 1911. Later the name of this company was changed to the Lehigh Portland Cement Company. The materials used at this plant are limestone and shale and are situated within a comparatively short distance of the plant. The dry process of manufacture is in use at this plant. The two rotary kilns have a combined capacity of 1,800 barrels every twenty-four hours.

The plant of the International Portland Cement Company is located at Irvine, Spokane County, nine miles east of Spokane. The materials used by this company are limestone and shale that are obtained from near Lake Pend Oreille, Idaho, about fifty miles from the plant. The dry process of manufacture is used at this plant and the two rotary kilns have a daily capacity of 1,600 barrels in twenty-four hours.

The Olympic Portland Cement Company, Ltd., is located at Bellingham, Whatcom County, in the northwestern part of the State. The materials used by this company are limestone and clay. The limestone is obtained from deposits situated near Kendale, about thirty-five miles northeast from Bellingham. The clay is obtained from deposits about five miles from the plant. This was the first plant in Washington to use the wet process in the manufacture of Portland cement. The capacity of this plant is 2,000 barrels every twenty-four hours.

In the fall of 1912, the building of a plant for the manufacture of Portland cement was begun at Asotin. Work was continued on the plant until it was almost completed when for some reason it was stopped and nothing has been done since. The materials to be used by this plant in the manufacture of Portland cement are up the Snake River at Lime Point about eighteen miles above Asotin. Lime and clay materials both occur at this place, the best deposits being on the Idaho side of the Snake River.

The cement industry in Washington has had a fairly rapid development since its beginning in 1907. At the present time a large part of the cement used in Washington, Oregon, Idaho, British Columbia, and Alaska is manufactured in this State. For a part of this period, conditions have been abnormal and the demand for cement has been less than usual. The years 1913 and 1914 showed a very large production, a considerable part of which was not marketed. The year 1915 saw a very great decrease in production in an effort to adjust the industry to the existing conditions. While the production was very materially decreased, it was still greater than the amount shipped so that the amount on hand at the close of 1915 was greater than it had been before.

At the beginning of the year 1916, the cement industry was already feeling the effects of a gradual revival in industry and as a result the cement mills were busy manufacturing and shipping cement. The production for this year did not equal the demand and as a result the stock on hand at the close of 1916 was much less than at the close of 1915. In 1917, the demand was especially good during the first half of the year but showed a marked falling off during the last half. The good demand during the early part of the year stimulated production to such an extent that at the close of the year the stocks on hand were considerably increased. The decline in the cement industry that began about the middle of 1917 continued through 1918 so that the output for that year was the lowest for the past seven years. Since 1918, the cement industry in Washington has been experiencing improved conditions, the production increasing and the price per barrel has been on the increase so that the value of the output is greater than ever before.

Cement materials in Washington. Materials suitable for Portland cement occur in large quantities in this state. The limestones are practically all in the northern half of the state. They occur both on the eastern and western sides of the Cascade Mountains, those on the western side as a general thing being more nearly pure calcium carbonates than those in the eastern side. A body of limestone is found in the southeastern part of this state in Asotin County and this is an exception to the general statement above. The counties in which limestone is known to occur are Asotin, Pend Oreille, Stevens, Ferry, Okanogan, Chelan, Kittitas, Whatcom, Skagit, Snohomish, King, and San Juan. Many of these deposits cover only small areas and are of little commercial importance. The deposits in eastern Washington are more extensive than those in the western part of the State.

In composition, the limestones vary a great deal. In places they carry a large amount of argillaceous material and therefore they have a high percentage of silica, alumina, and iron. In other places they are practically free from these substances and are almost pure limestone. Much of the limestone, in eastern Washington especially, contains more or less magnesia and this makes it undesirable for use in the manufacture of Portland cement. In places, however, limestone occurs from which good Portland cement can be made.

Clays and shales are quite common in various parts of Washington, the clays occurring in practically all parts of the State while the shales are more limited in distribution. In some cases these occur closely associated with the limestones while in others they may be some distance from them. Many of these clay and shale deposits are ideal materials for cement. There are a number of localities where the limestone, clay or shale occur near enough to each other to make them available for cement manufacture and in case transportation is available these deposits have a particular value.

The Northwest is developing rapidly; lumber is becoming more expensive all the time; and as a result the demand for cement as a building material is constantly increasing. The demand for cement for street paving and the hard surfacing of public highways is increasing rapidly and all of these demands should be met by local production.

Bulletin No. 4 of the Washington Geological Survey publications, entitled, "Cement Materials and Industry in the State of Washington," by Solon Shedd, gives a very complete description of the deposits of cement materials in the various parts of this State. A large number of chemical analyses are given of the limestones, clays, and shales.

PORTLAND CEMENT PRODUCED AND SHIPPED, STATE OF WASHINGTON, 1912-1922

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	1,403,191	2,367,045	1.69	1,513,792	385,707
1918	1,116,754	2,114,730	1.89	931,489	214,220
*1919	1,615,890	3,359,056	2.08	1,561,951	227,648
1920	1,806,025	4,096,227	2.27	1,798,953	189,220
1921	1,612,891	4,080,785	2.53	1,678,863	255,292
1922	1,951,414	4,684,624	2.40	1,942,781	246,660

* Includes a small production from Oregon.

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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CLAY AND CLAY PRODUCTS

Raw clay. The amount of clay produced and sold as raw clay in Washington has never been very large. In 1907, the first year for which statistics are available, the value of the raw clay sold was $4,623. The following year it had reached a value of $15,511, after which a decline took place and in 1911 the value was only $2,753. For the next five years the value fluctuated more or less but averaged about $5,000 a year. With the year 1917, an increase began and in 1919 the value of the raw clay produced was the largest for any year so far, being $21,964. A decline began in 1920 and continued through 1921, the value for that year being only $5,153. The output for 1922 showed a marked improvement over that for 1921, the value of the output for 1922 being $14,745.

The raw clay sold as such in this state at the present time is largely fire clay and consists of both the flint and the plastic fire clay. In the past some slip clay and some stoneware clay have been sold as well as very small amounts of terra cotta clay. The terra cotta clay comes largely from Stevens and Spokane Counties, the plastic fire clay mainly from Spokane and Whatcom Counties, the flint fire clay from King County, and the stoneware clay mostly from Stevens and Spokane Counties.

Washington is especially well supplied with clay suited to the manufacture of medium grade white ware, stoneware, terra cotta, pottery, and fire brick. Some of these clays are being utilized at the present time, but there is a chance for a very great development of this phase of the clay industry as time goes on. As the demand for all of the above kinds of wares increases, there will be a larger number of plants in operation and a larger number of these buying clay from people who own the clay deposits but who do not operate clay working plants. The increased demand for the higher grade clay products will thus cause an increase in the quantity of raw clay sold.

Clay products. The value of the clay products manufactured in Washington has gradually increased until at the present time the value ranges any place from $1,500,000 to about $3,000,000 a year. In 1896 the total value was given at only $161,528, but beginning with 1897 the value began to increase and continued until the close of 1909, the value for that year being $3,060,486, which is the highest value recorded for any one year. Beginning with 1910, a slight decline began and continued until the close of 1918, the value for that year being only $1,306,763. In 1919 the industry showed a slight improvement over 1918 and in 1920 the value had reached almost $3,000,000, but in 1921 it was down again to a little less than half that amount.

The following list gives the general types of these products for 1920 in order of relative values:

1. Common brick
2. Sewer pipe
3. Hollow building tile
4. Terra cotta
5. Fire brick
6. Face brick
7. Drain tile
8. Pottery
9. Miscellaneous

The price of common brick has gradually increased, with slight fluctuations, from $5.67 per thousand in 1895 to $16.30 in 1920. This increase was constant until 1902 when the price was $7.87. For the next fourteen years the price remained practically constant and was from $7.00 to $8.00 a thousand. During this time the production increased until 1909 when it was 143,198,000, which is the largest output so far. Beginning with 1911, the output began to decline and continued until the close of 1918, the output for that year being only 31,164,000. Since that time a slight increase in quantity has taken place, while the price per thousand for 1920 was $16.30, almost twice what it was in 1917.

Clays that may be used in the manufacture of common brick are widely distributed and there are but few places in Washington where common building brick may not be made from local clay. East of the Cascade Mountains the basaltic clays occur in the southern part of the state, while in the northern part clays occur that have been formed from the decomposition of igneous and metamorphic rocks. In western Washington glacial clays are common in the northern part, while in the southern part of the State clays are found that have been formed from the decomposition of igneous and sedimentary rocks.

The sewer pipe industry showed a gradual growth and marked increase in the value of the output from 1902, when it was $118,462, until 1910 when the production was valued at $817,086. Beginning with 1911, a decline set in and continued until the close of 1918, the production for that year being only $309,243. The years 1919 and 1920 showed a considerable increase in the value of the sewer pipe produced, while 1921 showed a marked decline, the value for that year being only $285,992, or $23,251 less than for 1918.

The value of the hollow building tile produced in Washington has varied more or less, but from 1910 to the year 1917 it was from $100,000 to $150,000 a year. In 1918, the value of the output rose to $183,812. The year 1919 showed a slight decline from this amount while the value for 1920 increased to $471,423, this being the largest production for any one year so far. In 1921 the value was only $139,228, which is a very marked decrease. Hollow building tile may be made from the same grade of clay as that from which common building bricks are made.

The value of the architectural terra cotta manufactured in Washington was higher in 1920 than for any other year, the amount being $461,770. Previous to this, the largest amount was $365,109 in 1912. Beginning with 1913, a decline set in and in 1918 the value of the output was only $94,361, which was the smallest amount since 1907.

Clays that may be used in the manufacture of fire brick are not very widely distributed. There are, however, a few localities where fire brick have been produced and the State is credited with a small production annually since 1895, at least. For that year the value of the output is given as $12,500, and this was slightly less in 1896. The value of the output for 1897 showed a considerable increase. For the nine years beginning with 1897 and ending with 1905, the highest value recorded for any one year, was $24,699, and the lowest was $13,932, with an average of a little more than $20,000. The maximum production was reached in 1917, but the greatest value was in 1920, when the price per thousand was $54.54. In 1921 the output decreased until it was only one-fourth what it was in 1922, and the price per thousand dropped so that the total value was only about one-fifth of that for 1920.

Front brick declined in price per thousand from 1908 when they were $28.11 to 1916 when they were only $15.93 per thousand. Beginning with 1917, an advance in price set in and continued until the close of 1920 when a maximum of $38.78 per thousand was reached. The production, however, was far below what it had been in previous years, being only 3,895,000, with a total value of $151,059 as compared with 7,802,000 in 1919 with a value of $155,600, the year of largest output and of greatest total value.

The pottery industry in Washington at one time was of considerable importance, the value of the output in 1907 being $30,695. With the close of 1907, a decline in production took place and by 1909 it had reached a point where it was not possible to give statistics without disclosing individual operations. This condition continued until 1917, when the State is credited with $966 for pottery. In 1919 the value had risen to $28,074, almost as much as in 1907, but the year 1920 was the year when the pottery manufactured in Washington had its greatest value, being $60,657.

The amount of drain tile produced in this State has never been large, but for the past three or four years it has been about $60,000. From 1908 to 1913, inclusive, the value fluctuated more or less but was around $30,000. In 1914 it reached $48,750 and then went down to $30,755 in 1917. In 1918 it increased again going to $60,132 and has remained at about that since. This state has some very good pottery clays and this phase of the clay industry should be more highly developed than it is and should be producing enough of this class of ware to at least supply the local demand.

The total value of the various clay products manufactured in Washington gradually increased from $161,528 in 1896, to $3,060,486 in 1909, this being the year of maximum production as far as value is concerned. Beginning with 1910 a decline in value set in and continued until the close of 1913, when the value was only $1,306,763. The industry was in a more prosperous condition in 1920 and the value, $2,863,030, was almost equal to that for 1896, the year of greatest value. The production for 1921 showed a considerable decrease in value over that for 1920. The number of producers and the total output has as a general thing been on the decline, but the price on the whole has been on the increase. The industry appears to be in a fairly prosperous condition.

VALUE OF CLAY PRODUCTS MANUFACTURED IN WASHINGTON, 1913-1922

PRODUCT	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
Brick—										
Common—										
Quantity	67,435,000	51,657,000	43,279,000	45,163,000	43,487,000	31,164,000	44,436,000	46,163,000	34,881,000	40,474,000
Value	$475,874	$351,565	$285,423	$309,130	$367,906	$353,857	$627,015	$752,241	$474,808	$544,748
Average price per M.	$7.06	$6.81	$6.59	$6.84	$8.46	$11.35	$14.11	$16.30	$13.61	$13.46
Vitrified—										
Quantity	42,717,000	(b)	14,861,000	20,218,000	(b)	(b)	(a)	(a)	....	....
Value	$701,550	(b)	$265,691	$322,182	(b)	(b)	(a)	(a)	(a)	(a)
Average price per M.	$16.42	$18.99	$17.88	$15.94	$20.40	$25.34	$34.23	$42.03	$53.31	....
Front—										
Quantity	6,122,000	5,319,000	4,246,000	4,425,000	3,565,000	2,476,000	3,528,000	3,895,000	3,375,000	6,795,000
Value	$128,989	$109,197	$67,740	$70,509	$60,404	$60,884	$91,947	$151,059	$113,251	$162,046
Average price per M.	$21.07	$20.53	$15.95	$15.93	$16.94	$24.59	$26.06	$38.78	$33.56	$23.85
Fancy—										
Value	....	....	....	(b)	....	....	....	....	....	(a)
Fire—										
Quantity	....	....	1,569,000	4,009,000	5,146,000	4,042,000	3,889,000	4,863,000	1,256,000	3,519,000
Value	$66,178	$29,869	$45,414	$94,992	$143,696	$151,914	$153,170	$265,206	$53,254	$113,188
Average price per M.	....	....	$28.94	$23.69	$27.92	$37.58	$39.39	$54.54	$42.40	$32.16
Drain tile—										
Value	$28,172	$48,750	$33,558	$37,138	$30,755	$60,132	$57,509	$58,585	$36,292	$27,613
Sewerpipe—										
Value	$501,102	$462,898	$318,397	$347,388	$340,621	$309,243	$430,198	$522,976	$285,992	$333,751
Arch. terra cotta—										
Value	$316,628	$220,788	$234,377	$275,693	$190,468	$94,361	$118,274	$461,770	(a)	(a)
Fireproofing and hollow bldg. tile—										
Quantity (short tons)	....	....	....	....	27,352	15,678	15,114	42,868	16,976	26,121
Value	$157,069	$127,371	$192,263	$125,083	$183,812	$112,143	$136,609	$471,423	$139,228	$232,383
Average price per ton	....	....	....	....	$6.72	$7.14	$9.04	$11.00	$8.20	....
Pottery—										
Value	(b)	(b)	(b)	(b)	$966	(b)	$28,074	$60,657	$49,006	$43,039
Miscellaneous—										
Value	$14,664	$459,053	$11,573	$5,357	$11,858	$14,465	$121,468	$179,770	$344,910	$525,991
Total value	$2,390,226	$1,809,491	$1,454,436	$1,589,574	$1,532,043	$1,306,763	$1,764,264	$2,923,687	$1,496,741	$1,982,759
Number of operators	45	51	43	40	33	32	31	34	31	28
Rank of State	15	18	21	22	26	26	26	25	26	25

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

PRODUCERS OF CLAY PRODUCTS FOR 1922

Operator	*Name of Product*	*Location of Works*
Chelan County—		
Bird & Hobson	Common Brick	Wenatchee
Wenatchee Brick & Tile Company	Common Brick	Wenatchee
Clarke County—		
Hidden Brothers	Common Brick	Vancouver
King County—		
Builders Brick Company	Common Brick, Face Brick, Sewer Pipe, Hollow Tile	Seattle
Abrahamson Brick Co	Common Brick	Seattle
Denny Renton Clay & Coal Co	Draintile and Fire Brick	Seattle
Lake Union Brick & Fireproofing Co	Common Brick, Sewer Pipe	Seattle
Puget Sound Brick & Tile	Common Brick	Seattle
Denny Renton Clay & Coal Company	Vitrified, Face, Fancy, Fire Brick and others exclusive of pottery	Renton
Denny Renton Clay & Coal Company	Tile (not drain) and others exclusive of pottery	Taylor
Kitsap County—		
Harper Clay Products Co	Common Brick, Sewer Pipe	Harper
Lewis County—		
Chehalis Brick & Tile Co	Common Brick	Chehalis
Okanogan County—		
William and Finnie Co	Common Brick	Oroville
Skagit County—		
Knapp Brick & Tile Co	Sewer Pipe, Hollow Building Tile	Tiloh Spur
Snohomish County—		
Mr. T. H. Friese	Common Brick and Hollow Building Tile	Snohomish
Everett Brick Yard	Common and Fire Brick, Hollow Building Tile	Everett
Spokane County—		
R. C. Aini	Common Brick	Spokane
Wash. Brick, Lime & Sewer Pipe Co	Sewer Pipe, Hollow Tile, Tile (not drain) and other products other than pott'y	Dishman
J. T. Davie Brick Co	Common and Vitrified Brick, Fancy or Enameled Brick	Mead
Spokane County—		
American Fire Brick Co	Face Brick, Sewer Pipe, Hollow Tile, Tile (not drain), Fire Brick, other products not including pottery	Spokane
Stevens County—		
Wash. Brick, Lime & Sewer Pipe Co	Common and Face Brick, Sewer Pipe, Fire Brick, other products exclusive of pottery	Clayton
Wash. Brick, Lime & Sewer Pipe Co	Draintile	Clayton
Walla Walla County—		
Walla Walla Construction Company	Common Brick	Walla Walla
Whitman County—		
George Herboth	Under $5,000	Uniontown
C. A. Brown & Sons	Idle 1922	Palouse
Yakima County—		
Granger Clay Products Co	Common Brick	Granger

POTTERY

Operator	*Name of Product*	*Location of Works*
King County—		
J. O. Hankins	Red earthenware (flower pots, etc.)	Seattle
Snohomish County—		
C. B. & S. D. Stoffer	Under $5,000	Meadowdale
Spokane County—		
The Pottery Company	Red earthenware (flower pots), red and brown white lined cooking ware	Spokane

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LIME

In this report the term lime has reference to limestone ($CaCO_3$) that has been calcined to lime (CaO) before being used. The figures do not include crude limestone quarried and used for building stone, road construction, smelter-flux, and a number of similar uses.

The production of lime in Washington is an industry that has been of considerable importance since early in the development of the State. In the year 1894, Washington is credited with a production of limestone valued at $59,148. Practically all the limestone produced for that year was converted into lime so that this amount represents fairly well the value of the lime. Ten years later, 1904, the total value of the lime for that year is given as $216,454 and the value per ton $5.20. The year 1906 was the banner year for quantity, the production being 59,094 tons valued at $347,924. The price increased from $5.76 a ton in 1905 to $7.53 a ton in 1910 and then declined to about $6.50, where it remained with slight fluctuations until 1918, when it went to $10.22 per ton. This high price per ton gave a total value almost equal to that for 1906, though the production was only a little more than one-third what it was for that year. In 1919, the production decreased slightly but the price per ton increased to $11.91, which made the total value slightly higher than for 1918. From 1920 to 1922, inclusive, the output has varied more or less, being 31,033 tons in 1920, which is the largest output and 17,710 in 1921, this being the smallest. The price per ton varied from $10.44 in 1920, this being the lowest, to $13.92 per ton in 1922, this being the highest. The total value of the output for 1922 was $355,412, which is maximum for any one year.

The lime produced in this state comes from San Juan, Stevens, and Whatcom Counties. The lime kilns in San Juan County are located on tidewater and have cheap water transportation to the markets on Puget Sound. The plant of the International Lime Company is located at Kendall and is the only producer of importance in Whatcom County. This company produces hydrated lime and is the only plant of the kind in the State. In Stevens County, the Idaho Lime Company operates a plant located at Evans. The Crown-Willamette Paper Company also has a plant near Colville in Stevens County.

This State has quite extensive deposits of limestone and some of these are almost pure calcium carbonate and as the demand for lime increases, this industry should develop. The larger part of the lime used in Washington goes into building operations. Small amounts, however, are used for other purposes such as a fertilizer, spraying orchards, and chemical works. The increase in price per ton of lime has been a result partly of the increased cost of fuel. The fuel used is mostly wood and the increase in cost is due largely to the higher price paid labor for cutting and the greater expense in getting it to the kilns.

The following table shows the production and value of lime from 1912 to 1922, inclusive:

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
1919	19,534	232,723	11.91	5
1920	31,033	324,042	10.44	7
1921	17,710	209,761	11.84	7
1922	25,447	355,412	13.97	6

LIME PRODUCERS NOW OR RECENTLY OPERATING

Operator	*Location*	*County*
Preston Hanley	Brewster	Okanogan
Bunker Hill Smelter	Ione	Pend o'Reille
Tacoma Lime Products & Fertilizer Company	McMillan	Pierce
Henry Cowell Lime & Cement Co.	Deer Harbor	San Juan
Henry Cowell Lime & Cement Co.	Friday Harbor	San Juan
Orcas Lime Co.	Deer Harbor	San Juan
American Smelters Securities Co.	Langdon, Orcas Island	San Juan
Tacoma & Roche Harbor Lime Co.	Roche Harbor	San Juan
Idaho Lime Co.	Evans	Stevens
Northport Smelting & Refining Company	Northport	Stevens
Crown Willamette Paper Co.	Colville	Stevens
International Lime Co.	Sumas	Whatcom

* Does not include hydrated lime.

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SAND AND GRAVEL

General occurrence. Sands and gravels are the products of weathering of various kinds of rocks and on account of this their character and distribution are determined, partly at least, by the character of the country rock. Certain parts of Washington contain rocks that have a considerable amount of quartz and when these break up sand is formed. In other parts of the State, such as the basalt area of eastern Washington and the Willapa Hills in the southwestern part of the State, the country rock has but little quartz and when it weathers but little sand is formed from it. In some cases large amounts of material are transported for long distances by glaciers and when these melt this material is deposited and distributed over the country. In the northern part of Washington sands and gravels suitable for ordinary uses occur in great abundance. These were deposited by the glaciers at the time when they melted. In many cases these sands and gravels have been transported by streams and sorted more or less before being deposited in their present positions. In the parts of the State where glacial sands and gravels do not occur, these materials are found mostly along the streams flowing across the basaltic plateau; they rise outside of the area where the rocks are such as contain more quartz and when they decompose sand is one of the products. This is carried for greater or lesser distances and then deposited so that as a result of this, even over the basaltic area of eastern Washington, sand and gravel deposits occur along the streams, at any rate.

The value of any sand or gravel deposit depends on a number of things among which are the quality of the material, and nearness to market, and ease with which the deposits may be worked. In western Washington and especially the northern part, sand and gravel deposits are of very general occurrence. These deposits are of glacial origin and consist largely of clean, fresh, unweathered material that is especially well suited for various kinds of construction work. Many of these deposits occur along the waterways of Puget Sound and may be loaded onto barges and transported cheaply. On account of the position in which many of these deposits occur, they may be cheaply worked by being washed down with water.

In the eastern part of the State and especially the southeastern part, sand and gravel deposits are not so widely distributed and have to be transported longer distances and at greater expense than west of the Cascade Mountains. In many cases, also, the quality is not so good.

Taken as a whole, Washington is fairly well supplied with sand and gravel that may be used in the various kinds of building operations. Many of the deposits are worked by the counties to furnish material for road building and the deposit to be used must be located near the line of the road to be built and when the work is completed the pit is abandoned. In other cases, the sand is used in constructing various kinds of buildings and must be of a certain grade and may be located further from the place where it is to be used. Then there are the larger companies that work some of the sand and gravel deposits on a large scale, producing a very large tonnage. Deposits to be worked in this way must be situated close to large market centers and have favorable transportation facilities.

The quantity of sand and gravel produced depends on the amount of construction work of various kinds that is being done. For the past four or five years, the number of new buildings being put up in Washington has not been very great on account of the high price of various kinds of building materials and the high price of labor. This has limited somewhat the amount of sand used for this purpose. The amount of road building, however, has been fairly large so that the total output of sand and gravel in this state has remained about the same as it had been for a number of years previous to this time. The value, however, of the sand and gravel produced has gradually increased and in 1920 reached the highest point, being for that year $1,016,926. Since then a slight decline is shown, the value for 1922 being $844,252.

The following table shows the production, value, and principal uses of sand and gravel used in Washington for a period of ten years, 1913-1922:

STATISTICS OF THE PRODUCTION OF SAND AND GRAVEL, IN SHORT TONS, 1913-1922

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	122,930	66,151	283,391	98,989	573,331	306,226	86,944	35,543	†1,231,814	536,132
1920	337,675	202,036	279,186	169,293	1,348,987	642,664	10,750	2,692	†1,976,969	1,016,926
1921	662,890	314,879	129,746	83,263	671,487	470,763	6,624	2,366	†1,481,574	881,842
1922	292,395	125,216	298,050	128,651	974,695	511,500	....	....	†1,802,121	844,252

* Concealed.

† These totals include certain amounts of sand and gravel used for other purposes.

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.

SAND AND GRAVEL PITS IN OPERATION, 1922

Operator	*Locality*	*County*
Adams County	Ritzville	Adams
Aug. Rutz	Ritzville	Adams
Triangle Construction Company	Ritzville	Adams
Fred Dole	Clarkston	Asotin
P. T. Paulsen Co., Engr	Port Angeles	Clallam
Spokane, Portland & Seattle Ry. Co		Franklin
Arthur B. Velguth	Connell	Franklin
Franklin County	various	Franklin
Chicago, Milwaukee & St. Paul R. Co		Grant
Grant County	Ephrata	Grant
Harold Blake Co	Montesano	Grays Harbor
Grays Harbor County	Montesano	Grays Harbor
Grays Harbor Construction Company	Hoquiam	Grays Harbor
Keystone Sand & Gravel Company	Coupeville	Island
Jefferson County	Port Townsend	Jefferson
Cedar River Gravel Company		King
Chicago, Milwaukee & St. Paul R. Co		King
Pembroke Investment Company		King
Pioneer Sand & Gravel Company	Seattle	King
Chicago, Milwaukee & St. Paul R. Co		Kittitas
Spokane, Portland & Seattle Ry. Co		Klickitat
Twin City Sand & Gravel Company	Centralia	Lewis
Mason County	Shelton	Mason
Chicago, Milwaukee & St. Paul R. Co		Pierce
Pioneer Sand & Gravel Company		Pierce
Steilacoom Sand & Gravel Company	Steilacoom	Pierce
Harrison Brothers Company	Tacoma	Pierce
Skagit County	Mt. Vernon	Skagit
C. L. LaPlant & Company	Sedro Woolley	Skagit
Kaiser Paving Company		Skagit
Spokane, Portland & Seattle Ry. Co		Skamania
Skamania County	Home Valley	Skamania
Snohomish County	Everett	Snohomish
Chicago, Milwaukee & St. Paul R. Co		Snohomish
Chicago, Milwaukee & St. Paul R. Co		Spokane
Hawkeye Fuel Company	Millwood	Spokane
Union Sand & Gravel Company	Spokane	Spokane
Oregon-Wash. Railroad Company	Walker Sta	Walla Walla
Ledgingham & Cooper	Acme	Whatcom
Whidby Island Sand & Gravel Co	Bellingham	Whatcom
Lind Gravel Company	Bellingham	Whatcom
Kaiser Paving Company	Custer	Whatcom
Riddle & Hawkins	Bellingham	Whatcom
Skagit Construction Company	Mt. Vernon	Whatcom
Chicago, Milwaukee & St. Paul R. Co		Whatcom
Yakima County Gravel Pit	Sunnyside	Yakima
S. A. Campbell	Sunnyside	Yakima
Yakima Paving Company	Yakima	Yakima

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Glass sand. Sand suitable for glass making may be obtained from quartz sands, sandstones, or quartzites. In the case of sand being used, it is necessary in most cases to subject it to a washing process to remove impurities, and in case of sandstone or quartzite, crushing and screening are necessary. Sand is principally silica but many sands contain small amounts of mineral grains other than quartz so that many sands when analyzed chemically may show small amounts of iron oxide, aluminum, lime, and magnesia. These substances, if present in very appreciable amounts, make the sand undesirable for glass making.

The physical condition of the sand is also considered a property of some importance. Uniformity and size of grain are important properties. The best size is from about 30 to 120 mesh. Coarser sands are harder to fuse.

Washington produces no glass sands at present but no very thorough search has been made in this state for them. Large bodies of silica and quartzite are known to occur in various places and some of these may be of such a quality that they can be used for glass making.

Foundry sands. Under this head are included those sands that are used for making the mold proper and those that are used for making the cores that occupy the hollow spaces of the cast pieces. These two differ somewhat in their properties but the main difference is that the moulding sands proper have as a general thing a fine texture and are more loamy in character.

Ries[1] gives the following as the requisite physical properties of foundry sands:

"* * * (1) sufficient cohesiveness to make the grains cohere when pressed together to form the parts of the mold, the deficiency in this respect being supplied by artificial binders; (2) sufficient refractoriness to prevent extensive fusion in the sand when exposed to the heat of the molten metal; (3) texture adapted to the grade of casting to be poured in it; (4) sufficient porosity and permeability to prevent the escape of the gases given off by the cooling metal; (5) durability, or sufficient length of life, to permit as much of the sand as possible being used over again."

No foundry sands are being produced in Washington at present.

STONE

Various kinds of stone that may be used for building purposes occur in practically all parts of Washington and the value of the stone quarried in this State in the past has been considerable. The stone industry, however, is very dependent on the general condition of the country and when a financial depression occurs, even though slight, the production of stone is apt to decrease very materially.

In a comparatively new state like Washington, people as a rule are inclined to think but little about the real permanence of buildings. Then again this State has been especially well supplied with large quantities of good timber from which excellent lumber could be produced cheaply, and the question of first cost has been the determining factor in most cases.

In the past, stone was used as a general thing for the trimmings in brick buildings but at present terra cotta is used very largely for this purpose. Stone has also been used extensively for foundations, but concrete is

[1]Ries, Henry; Economic Geology, Fourth edition, p. 335, 1916.

being used for this purpose at present, in this State at least, more than stone.

Stone is used extensively for purposes other than buildings. Some of the more important of these are road metal, curbing and flagging, paving blocks, railroad ballast, riprap, cement, and monuments. In 1922, the total value of the stone produced in Washington was $971,732. This is but little more than half the value of that produced in 1915, when a value of $1,758,817 was reported. The principal kinds of stone quarried, in their order of value for 1922, are: basalt, granite, limestone, and sandstone. From 1915 to the close of 1919 there was a very marked decline until for that year the value of the output was only $261,310. In 1920, the value increased considerably, but fell off again in 1921 and increased again in 1922 to $971,732.

RANK OF WASHINGTON FROM 1912-1922, 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	34	365,098	.44	30
1919	34	423,653	.40	21
1920	31	821,846	.60	26
1921	30	789,364	.70	28
1922	29	†887,175	.70	31

† To avoid disclosing confidential information is slightly incomplete.

PRODUCTION OF CRUSHED STONE IN WASHINGTON, 1912-1922, 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	213,069	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
1919	116,404	142,544	....	....	†	†	116,404	142,544
1920	425,730	375,508	....	....	†	†	425,730	375,508
1921	442,080	549,511	3,810	3,500	†	†	445,890	553,011
1922	391,020	464,361	*	*	†	†	391,020	464,361

* Not possible to give statistics without revealing individual operations.
†Since 1918, Crushed Rock for concrete is included with Road Metal.

Basalt. Basalt is very generally distributed throughout this State. The Columbia lava covers a large part of eastern Washington, and throughout this part of the State, the surface rock is basalt. In western Washington, basalt and related rocks occur over considerable areas either as surface flows, as sills, or as dikes cutting through other formations.

The basalt, especially in eastern Washington, varies much in texture in different places, being in some cases quite coarse, while in others it is very fine-grained and compact. In some places it is filled with cavities ranging in size from those that are not more than a sixteenth of an inch in diameter to those that are as much as a fourth of an inch in diameter, and sometimes even more. This rock, where fresh and undecomposed, is very dark, almost black in color—and changes on weathering to a more or less brownish or reddish cast on account of the iron which it contains.

This basalt has been used to a considerable extent in buildings, especially for foundations, and in some cases the entire walls of buildings have been constructed of it. It is not, however, an especially desirable building stone and will probably never be used extensively for this purpose.

At the present time, its greatest use is in road building and in concrete. On account of its wide distribution it is easily accessible in almost all localities. It may be quarried without great difficulty and is readily crushed. Much of it is very dense, tough, wears well, and makes excellent road material either for surfacing where crushed rock is used or as the coarse aggregate for concrete.

Quarries are usually opened along the line of the road, worked during the time the road is being built, and then, in many cases at least, abandoned. In some cases where there is a constant demand for this kind of material and where transportation facilities are especially good, permanent quarries are maintained that show a steady production from year to year. In some cases, quarries are owned and operated by private individuals, but in others they are owned and operated either by the State, county, or city.

VALUE OF BASALT IN WASHINGTON, 1912-1922

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
1919....	109,190	‡	142,544	....	†	....	252,435
1920....	145,671	....	375,508	....	†	....	521,179
1921....	84,936	....	549,511	3,500	†	....	637,947
1922....	136,819	....	464,361	6,750	†	....	607,930

* Value concealed so as not to disclose individual operations.

‡ Value is included in the total.

† Values for concrete are included with road metal.

BASALT QUARRIES NOW OR RECENTLY IN OPERATION

Operator	*Location*	*County*
Adams County	Ritzville	Adams
City of Ritzville	Ritzville	Adams
Thomas E. Goodenough	Hatton	Adams
‡Triangle Construction Co.		
Clarke County	Yacolt	Clarke
Columbia Contract Company	Camas	Clarke
Star Sand Co.	Kelso (Mt. Coffin)	Cowlitz
John Mohr	Waterville	Douglas
Franklin County	Mesa	Franklin
F. A. Dole		Garfield
Grant County	Ephrata	Grant
Triangle Construction Company	Almira	Kitsap
Independent Asphalt Pav. Company	Charleston	Kitsap
Simon Sinbot	Klickitat	Klickitat
John Pirie	Klickitat	Klickitat
Lewis County	Meskil, Doty, Bunker, Mayfield	Lewis
Twin City Sand & Gravel Company	Centralia	Lewis
Northern Pacific Railway Company	Enumclaw	Pierce
Seattle, Spokane & Portland Ry. Co.	Cooks	Skamania
Empire Stone Co.	Spokane	Spokane
General Construction Company	Spokane	Spokane
S. G. Kinder	Waterville	Douglas
Spokane County Quarries	Latah, Spangle, Elk, Tyler	Spokane
Sloane Construction Company	Latah, Fairfield	Spokane
Brookfield Quarry & Towage Co.	Brookfield	Wahkiakum
Walla Walla County	Dixie	Walla Walla
Triangle Construction Company	Harrington	Walla Walla
City of Palouse	Palouse	Whitman
Warren Construction Company	Colfax	Whitman
Triangle Construction Company	Garfield	Whitman
Yakima County Quarry	Yakima	Yakima
P. L. Zirkle	Yakima	Yakima
Yakima County Quarry	Union Gap	Yakima

Granite. Granite and rocks of this general character occur in many places in Washington. Quarries have been developed, however, in only a few places, the most important of these being at Index and Baring in Snohomish County, near Medical Lake, and on the Little Spokane River in Spokane County, and a little above Wawawai in Whitman County. Granite is known to occur in places in Chelan, Ferry, King, Okanogan, Pend Oreille, Skagit, Stevens and Whatcom Counties, and in all probability does occur in other parts of the State as well.

The granite quarries at Index and Baring have been operated for a long time and stone for various purposes

‡ This company constructs roads and abandons pits when job is completed.

has been produced from them. Some building stone has been produced from these quarries, but most of the stone from here has been used for other purposes such as paving blocks, and riprap. Statistics for 1922 give the value of the dressed building stone production and that used for riprap as practically the same.

Granite quarries have been operated at times in various places in Spokane County for many years and some very good building stone produced. Some of the oldest of these quarries are in the vicinity of Medical Lake. The granite that has been quarried in this locality is light gray in color and is very firm solid stone. It is composed of quartz, feldspar, and mica, and is not readily decomposed by weathering agencies. Granite from this locality has been used in a number of the State buildings as the Administration Building of the State College and the buildings for the Medical Lake Insane Asylum. Stone from here has also been used for street curbing and for gutters and in small amounts for monumental work.

Granite of good quality occurs at a number of other places in Spokane County and in a number of places at various times some of these have been quarried and the material used largely for curbing and gutters.

An outcrop of granite occurs about two miles above Wawawai on the Snake River in Whitman County. The granite at this place occurs as a ridge extending across the course of the Snake River. It was covered at one time with the basalt and has been exposed by the Snake River cutting its channel deep enough to get through the basalt at this place and into the granite. This granite is a light gray in color, works easily, and is said to take a good polish. Considerable stone has been quarried and shipped from here to different places where it has been used for building purposes, street curbing, and bridge piers.

VALUE OF GRANITE SOLD IN WASHINGTON, 1912-1922

YEAR	Sold in the Rough					Dressed for		Made Into Paving Blocks	Curbing	Flgg'ing	Crushed Stone			Other	Total
	Building	Monu-mental	Rubble	Riprap	Other	Building	Monu-mental				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	....	21,744	....	21,167	....	22,212	*	....	*	*	....	....	....	....	65,293
1919	a	13,743	a	....	a	a16,180	36,238	....	....	....	....	....	....	a	189,564
1920	a	15,911	....	a	....	....	37,953	....	....	....	....	....	....	....	85,365
1921	....	b21,364	a	a	....	a	b	....	....	....	....	....	....	....	29,551
1922	....	c	a	a	....	a	c25,007	....	....	....	....	....	....	a	184,435

* Value concealed so as not to show individual operations.
a Included in the totals.
b Dressed monumental included with undressed monumental.
c Undressed monumental included with dressed monumental.

GRANITE QUARRIES NOW OR RECENTLY OPERATED

Operator	*Location*	*County*
Baring Granite Works	Skykomish	Chelan
San Poil Granite Corporation	Keller	Ferry
Baring Granite Works	Baring	King
King County	Snoqualmie	King
Great Northern Railway Co	Index	Snohomish
Index Granite Works	Index	Snohomish
Western Granite Company	Index	Snohomish
J. W. Morris	Medical Lake	Spokane
Wash. Monumental & Cut Stone Co	Medical Lake, Silver Lake	Spokane
Empire Granite Products Co		Spokane
General Construction Co		Spokane

Limestone. The limestone deposits that are of economic importance with one exception all occur in the northern part of Washington. They occur in Pend Oreille, Stevens, Ferry, Okanogan, Chelan, Whatcom, Skagit, Snohomish, King, and San Juan Counties. In the extreme southeastern part of the State, in Asotin County, limestone occurs over a small area. The limestone deposits of Washington occur in comparatively small isolated masses that are more or less lens-shaped, that is, thick in the central part of the mass and thinning out on the edges.

The deposits have been folded, tilted and much disturbed so that stratification has been obliterated in practically all cases. This disturbance has metamorphosed the limestone so that much of it is marble. Most of the deposits, however, are so badly broken that it is not possible to quarry large sized blocks. These limestones vary much in general appearance and range in texture from those that are very fine-grained to those in which the individual crystals are large. They also vary in color from almost black to pure white with various shades of gray between.

West of the Cascade Mountains, the deposits are very high in calcium carbonate, but as a general thing they are not very extensive, while in eastern Washington they vary much in composition and range from almost pure calcium carbonates to almost pure magnesium carbonates with practically all graduations between these extremes as far as calcium and magnesium are concerned.

The limestone deposits of Stevens County, especially, have practically all at one time or another been located as marble properties, and from 1900 to 1902 considerable development work was done on some of them. As already stated, most of the deposits are so badly broken that nothing but small blocks can be quarried. Some of the very whitest, most promising deposits contain particles of iron sulphide disseminated through the marble. When this is exposed to weathering agencies, the iron changes to an oxide and is washed down over the marble and gives to it a dirty rusty color. On the whole, the outlook for the developing of these limestone deposits as marble quarries is not very promising.

The principal use of limestone in Washington is not, however, as a building stone but in the manufacture of lime and cement as a flux in the smelting of ores, in connection with agriculture and in sugar and paper manufacture. The use of limestone in the manufacture of lime and cement is not considered here, hence its most important use here considered is as a flux. The quarries producing lime for fluxing purposes are in Pend Oreille, San Juan, and Whatcom Counties.

VALUE OF LIMESTONE SOLD IN WASHINGTON, 1912-1922

Year	Roadmaking	Flux	Agriculture	Other Uses	Totals
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
1919..........	....	11,255	....	*34,732	45,957
1920..........	....	73,619	....	*45,052	118,671
1921..........	....	4,184	....	*45,357	49,541
1922..........	....	55,011	....	*41,799	94,810

* The principal uses included are for agriculture, sugar factories and paper mills.

PRODUCERS OF LIMESTONE OPERATING AT PRESENT OR RECENTLY

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

Sandstone. The sandstones of Washington are quite widely distributed, geographically, occurring in a number of the counties. The larger areas are on the western side of the Cascade Mountains, although sandstones do occur east of the Cascades, especially around Cle Elum and Roslyn, where they constitute a very considerable part of the coal formation of that district.

The principal places where sandstone has been quarried in this State are in King, Pierce, Thurston, and Whatcom Counties. In the past, large quarries have been operated at Tenino in Thurston County, Wilkeson in Pierce County, and on Chuckanut Bay near Bellingham in Whatcom County. These quarries have been operated mainly to furnish stone for building purposes. The sandstones from these different localities vary somewhat in color, texture, and hardness. In color they vary from light gray to a dark greenish, with various shades between. In texture they range from very fine to very coarse-grained. These sandstones are not so hard that they are difficult to quarry and work and yet they are hard enough so that they make a very good building stone.

The value of the sandstone produced in Washington from 1890 to 1892, inclusive, according to the U. S. Geological Survey statistics, was about $75,000 annually and was used almost entirely for building purposes. In 1898, the value had decreased until it was only $15,575. Beginning with 1899, an increase in value began and continued until 1908, when it was $464,587, the greatest value of the sandstone output of Washington for any one year previous to that time. From 1908 the value of the output has fluctuated more or less, making the maximum of $560,468 in 1913. From 1913, there was a very rapid decline, and in 1922 the total value was less than one-sixth of what it was in 1913.

The following table shows the principal uses of the sandstone quarried in Washington from 1908 to 1914. It is not possible to give statistics for later years, except 1918, when the total was $45,368, without showing individual operations. The table is interesting on account of showing how the uses have varied:

VALUE OF SANDSTONE PRODUCED IN WASHINGTON, 1908-1914

YEAR	Rough Building	Dressed Building	Paving	Rubble	Riprap	Total
1908	$1,375	$99,656	$248,973	$1,062	$113,062	a$464,587
1909	43,139	81,830	126,648	1,075	82,778	335,470
1910	46,783	145,370	79,430	9,751	11,303	b438,581
1911	154	77,472	78,706	73,968	71,543	301,843
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.
a Includes concrete $429.
b Includes under "other uses" $145,944.

SANDSTONE QUARRIES NOW OR RECENTLY OPERATED

Operator	*Location*	*County*
Walker Cut Stone Co., Inc.	Wilkeson	Pierce
Tenino Stone Co., Inc.	Tenino	Thurston
Tenino Stone & Quarry Co	Tenino	Thurston
Chuckanut Stone Co	Bellingham (Chuckanut)	Whatcom

Slate. Commercially, a slate is a rock which possesses a fairly perfect cleavage and as a result of this it is valuable for purposes for which other forms of stone are not adapted. Geologically, it is a metamorphosed clay shale. Practically all commercial slates are of sedimentary origin and have been formed from very fine-grained homogeneous clayey sediments that have been subjected to intense pressure. The colors of slates vary more or less, but the most common colors are black, gray, green, or red.

On account of their peculiar properties, slates are adapted to a variety of uses, some of the most important being for roofing, flooring, electric switchboards, blackboards, laboratory table tops, vats, tubs, and refrigerator shelves. Of the above uses, roofing is much the most important and uses the largest part of all the slate quarried.

Among the qualities to be considered as important in roofing slate are color, cleavage, strength, and ability to withstand attacks of atmospheric agencies.

The color of a roofing slate should harmonize with the surroundings in which it will be used and should be a color that will not fade or change. It should harmonize with the colors in the walls of the building on which it is to be used. The slate to have a permanent color should be composed of minerals that are stable, that is, minerals that are not readily affected by atmospheric agencies. The green slates are the ones that are most apt to change in color.

Roofing slate should be of such a nature that it will split readily into plates a fourth of an inch thick or less. The surfaces of these plates should be smooth as this will add to the appearance of the roof, and less dust will collect on the smooth surface than on the rough one. If the surface is rough, strains that may be developed would not be equally distributed and breaking is more apt to occur.

The strength of roofing slate is an important property and should be great enough so that there will not be an excessive amount of breakage in handling and shipping. They should be strong enough to withstand strains developed during usage. These are such as are produced by the workmen in laying and making repairs, impact of hailstones, objects thrown on the roof, and the expansion of such freezing water as may be able from any cause to collect in the cracks under the shingles.

Slate in Washington. Slate is known to occur in different places in this State, but so far as the writer is aware, no effort has been made to quarry it in but one locality. A number of years ago, considerable work was done toward developing a slate quarry about 10 miles west of Valley, Stevens County, in Sec. 19, T. 31 N., R. 39 E. This material varies somewhat in color, being grayish or green. The green color is probably due to the development of chlorite. This slate has the appearance of being of fairly good quality. It splits fairly easily into comparatively thin plates that have medium smooth surfaces. This material seems to be fairly strong and should stand handling and shipping without a large amount of breakage. Some cross fractures occur in this deposit but in spite of this, fairly good-sized blocks can be obtained.

The amount of slate used in this State at present is not large, but it should gradually increase. The principal roofing material used in Washington in the past has been shingles. This has been due largely to the fact that timber has been plentiful and shingles have been cheap. This condition, however, is gradually changing and a more permanent covering for buildings is being sought. Large areas in the northern part of Washington are made up largely of metamorphic rocks and it is possible that slates may occur in various places in these rocks. As the price of shingles increases, other materials will take the place of them, and slate might be one of them, if we can produce it from quarries in this State.

Marble. The term marble, in general, is used very loosely and is a commercial rather than a scientific term. By many it is made to include all limestones which are capable of being polished. Marbles are calcium carbonate with more or less impurities mixed with it. They are altered limestone in which the change that has taken place has been brought about by the action of heat and pressure. When limestone is heated to a certain temperature under ordinary atmospheric pressure, it will be changed to calcium oxide and carbon dioxide, the carbon dioxide being driven off. But if the heat be accompanied by intense pressure and the carbon dioxide gas prevented from escaping, the limestone will assume a semi-fluid condition which will allow the particles to rearrange themselves more or less and to recrystallize and a crystalline marble results. Marbles differ much in texture, color, and composition, all these differences depending on the original limestone and on the amount of metamorphism that has taken place.

Marble in Washington. The formations over large areas in the northeastern part of Washington are composed of metamorphic rocks and limestone and marble are found in places in connection with these formations. A large amount of work has been done on some of these marble deposits and some marble produced on a commercial scale. Most, if not all, of the quarries have been abandoned and no marble is being produced in Washington at present.

The marble deposits of this State have been fully discussed in a report on the Building and Ornamental Stones of Washington, published in the Annual Report, Vol. 2, 1901, Washington Geological Survey, and the reader is referred to this report for information in regard to them.

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COAL MINING IN THE STATE OF WASHINGTON DURING 1923

By Geo. Watkin Evans

INTRODUCTION

The coal areas in the State of Washington are divided geographically into two main subdivisions by the Cascade Mountains. The coal fields of eastern Washington are those located within the Roslyn, the Taneum, and Manastash fields. There are no operating mines within the Taneum or Manastash coal areas; the Roslyn field being the only commercially operated coal area in eastern Washington. On the west side of the Cascade Mountains there are several coal areas in which commercial mines exist and, arranged geographically, they are the Whatcom County, Skagit County, King County, Pierce County, Thurston County, and Lewis County coal areas. There is also some coal development in Cowlitz County.

ROSLYN COAL FIELD

The Roslyn coal field is located in Kittitas County, about eighteen miles in a direct line east of the summit of the Cascade Mountains and approximately one hundred miles southeasterly from the City of Seattle.

This coal area is of Eocene age, to which age the other coal areas of the state belong. The Roslyn bed, the most important commercial bed in this field, is being operated by the numerous coal mines of the Northwestern Improvement Company, The Roslyn Cascade Company, and the Independent Coal & Coke Company. The Roslyn Fuel Company is operating on an underlying seam which is also true of the Terrace Coal Company.

The production of each of the mines in this field for 1923 is indicated in the following table:

COAL PRODUCTION IN KITTITAS COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
Cle Elum Coal Company	Cle Elum.	1,940	2,137
Independent Coal & Coke Co.	Cle Elum.	48,767	56,516
Northwestern Improvement Co., No. 6 and 8	Roslyn...	244,860	267,740
Northwestern Improvement Co., No. 2 and 3	Jonesville.	226,355	234,337
Northwestern Improvement Co., No. 5	Roslyn...	69,560	74,524
Northwestern Improvement Co., No. 7	Cle Elum.	278,516	289,582
Roslyn Cascade Coal Co., No. 1	Roslyn...	32,521	35,080
Roslyn Cascade Coal Co., No. 2	Roslyn...	37,273	38,097
Roslyn Fuel Company	Beekman.	51,023	54,591
Terrace Coal Company	Lakedale.	935	980

The Northwestern Improvement Company, a subsidiary of the Northern Pacific Railroad, is the principal operating company within the Roslyn field. This company is not in the commercial coal business and uses the output of its mines for locomotive fuel and other uses in the Northern Pacific System.

The principal market for the product of the commercial mines of the Roslyn field is eastern Washington, but some of the coal reaches the cities of Seattle and Tacoma, as well as Portland, Oregon. The influx of cheap fuel oil into the northwest has affected the coal markets of this field, as well as other coal markets of the west.

Some prospecting was done in the Manastash coal field during 1923, but no commercial mines have been opened. This field lies to the south of the Roslyn field at a distance of from 12 to 15 miles, and occurs principally within the Manastash watershed. No work of importance was done in the Taneum field.

WHATCOM COUNTY COAL FIELD

In the Whatcom County coal areas there are two separate and distinct types of coal. Within the so-called Glacier Anthracite Coal Field on the northwest slope of Mount Baker there is an area containing a very good grade of anthracite coal. In places the coal is badly crushed, but in others it is of good quality and firm. There is a decided difference of opinion among people who are informed as to the commercial value of this field.

A considerable amount of money has been spent within this area and it is reported that large bodies of coal have been uncovered, but the writer is not in a position to verify this statement because the work has been largely done since he visited the field.

The Bellingham Coal Mine, located on the outskirts of the city limits of Bellingham, is one of the largest single producing coal mines in the state, and with normal market conditions could produce considerably more than was done during the year 1923. During the year 1923, 187,015 tons were produced from this property.

The coal is used throughout western Washington for steam and domestic purposes and some of the finer sizes are used as powdered coal in the cement plants of Skagit County.

The Bellingham Coal Mine is fortunately located close enough to tidewater so that coal can be shipped either by rail or by water. The fact that the mine is located at the outskirts of an attractive city makes it a very desirable place in which to work.

Considerable money has been spent prospecting a coal area about ten miles northeasterly from the city of Bellingham. This district is known as the Glen Echo Coal Field, but up to date very little coal has been shipped from this property. It is as yet a wagon mine.

COAL PRODUCTION IN WHATCOM COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
Bellingham Coal Company............	Bellingham...............	172,253	187,015
Glen Echo Coal Company..	Near Bellingham.........	427	427

SKAGIT COUNTY FIELD

The coal mine at Cokedale, Skagit County, did not operate during 1923; it had been closed some time previously. This mine is within a coal area in which coal of good quality exists, but there are considerable geologic disturbances within the area.

On the south side of the Skagit River, near the town of Hamilton, some prospecting was done during the past year on what appears to be a southeasterly extension of the coal beds at Cokedale. No coal was shipped from the prospect work on the south side of the river.

KING COUNTY COAL FIELD

The King County coal areas might properly be subdivided into about six different subdivisions; namely, the sub-bituminous coal areas of Newcastle, Issaquah and Grand Ridge; the Renton coal area; the Cedar Mountain coal area; the Raging River-Taylor district; and the area west of Green River, and that east of Green River.

Within the first named area only two mines operated during 1923, Newcastle and Issaquah; the Grand Ridge mine did not operate. These three mines are opened on the same series of coal beds which dip to the north and northwest at angles ranging from about 20 to 40 degrees. There are numerous coal beds within this series.

The Newcastle mine produced during the year 1923, 211,443 tons; the Issaquah mine was closed in March and had produced up to that time, 19,384 tons.

In the area lying between Newcastle and Issaquah the Harris Coal Company operated on a coal seam which belongs to the same coal series, but underlies the coal beds mined at Newcastle and Issaquah. This company produced 8,283 tons during 1923, all of which was shipped by truck, there being no railroad connections with this property.

The old May Creek Mine at Coalfield, which lies between Renton and Issaquah, a short distance off the main paved highway, was reopened during the past year, but only 306 tons of coal were produced.

COAL PRODUCTION IN THE SUB-BITUMINOUS AREA OF KING COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
Harris Coal Company	Issaquah	8,283	8,283
Lisco Coal Company	Renton Jct. (Black River)	1,434	2,013
May Creek Coal Company	Coalfield (Reopened)	306	504
Pacific Coast Coal Company	Issaquah	18,925	19,384
Pacific Coast Coal Company	Newcastle	200,622	211,443
Renton Coal Company	Renton (Sludge)	19,939	19,939
Strain Coal Company	Renton (Old mine pillars)	14,839	25,275

Within the Renton coal area, the Strain Coal Company was removing pillars from the old Renton mine, and during 1923 they produced 25,275 tons. In addition to this operation the Renton Coal Company was operating a battery of coal cleaning tables and recovering coal from an old sludge pile. This operation was discontinued in August, but up until that date they had produced 19,937 tons of coal for the year.

The Renton Coal Company also did some prospecting on a newly discovered coal seam about one mile south of the Renton Mine and drove a water level gangway about fifteen hundred feet on the coal bed; also a slope, a distance of about 550 feet across the dip of the bed. This bed underlies the No. 3 bed of the old Renton mine, and outcrops on the south side of a syncline dipping northerly.

The Lisco Coal Company has opened a small mine in the area directly west of Renton, on a coal bed which, no doubt, underlies the No. 3 bed at Renton. They produced from this mine 2,013 tons during 1923. Their operation is by slope sunk in a northerly direction towards a synclinal basin in which the coal bed occurs.

Within the old Cedar Mountain district the Pacific Coast Coal Company owns what is known as the Indian coal property, but during 1923, because of the extremely poor coal market, no work was done by this company. It is planned to develop this mine beginning the early part of the present year. There has been discovered within this area two coal beds that contain coal of very good quality.

No coal was mined during the past year within the Raging River-Taylor coal district. Two mines have been opened within this area; the Snoqualmie Mine near the town of Snoqualmie, and the Taylor Mine of the Renton Clay & Coal Company at Taylor.

There are numerous outcrops within this coal field, but more or less difficulty has been experienced in operating mines because of the faulted condition of the coal measures and the numerous intrusive rocks that occur within this district.

At Ravensdale the Dale Coal Company is opening a coal mine in the area lying between the old Ravensdale Mine of the Northwestern Improvement Company and the Black Diamond Mine of the Pacific Coast Coal Company. A rock tunnel of considerable length has been opened on this property with the view of developing the better beds within the Ravensdale coal area. Only about 72 tons of coal were extracted from the development operations on this property.

The mine of the Raven Coal Company near Ravensdale did not operate during the year. This mine had previously been opened on coal beds overlying the Ravensdale coal series.

Within the Black Diamond area no new developments have taken place during the past year, but the Pacific Coast Coal Company, operating the Black Diamond Mine, is planning on some new development within this area during the coming year.

During 1923 the Black Diamond Mine produced 229,-338 tons of coal. This mine was opened nearly thirty years ago on the well-known McKay coal seam, and it is today the deepest coal mine in the State and one of the deepest, if not the deepest, coal mine below sea level in the United States. The bottom of the main slope is approximately 1,500 feet below sea level, and about 2,100 feet under cover. Because of the excessive cover in this part of the field, some trouble has been experienced from "bumps," but the Pacific Coast Coal Company is practicing safety first with its employees and has retreated from areas in which any danger existed and in so doing has sacrificed several hundred thousand tons of coal that had already been blocked out.

East of Green River there are several mines, especially along the lines of the Chicago, Milwaukee and St. Paul, and the Northern Pacific Railroads. The Kangley Mine of the Kangley Coal Company produced 12,940 tons during 1923. This mine was opened by the Kangley Coal Company on a portion of the Kangley coal bed lying between the old Kangley Mine and the Alta Mine.

The Hiawatha Coal Mining Company, operating on a lease from the Northwestern Improvement Company, is operating the Hiawatha Mine and produced 26,120 tons during 1923. The Hiawatha Mine is located in the area between the Durham Mine and the Kangley Mine. These three mines are on the east side of the Northern Pacific Railroad in the area lying north of Green River. The Durham Mine is being operated by the Morris Coal Company, which is removing pillar and other coal from the old Durham Mine. This company produced, during 1923, 24,517 tons. The Elk Coal Company, operating a mine west of the Northern Pacific Railroad at the base of Sugar Loaf Mountain in the district lying north of Green River, produced 65,274 tons during the year 1923. A spur line from the Milwaukee Railroad was built into this property during the past year.

East and south of Green River are the Pocahontas, Occidental, Carbon, Daly, Eureka, Cannon, Hyde, Navy, Ozark, Sunset, and National Coal Mines. Of these, only the Carbon, Eureka, Navy, and Ozark Mines were producing. The Carbon Mine produced 1,316 tons up to the first of April; the Eureka Mine of the Cumberland Eureka Coal Company produced, up to the first of December, 6,028 tons; the Navy Coal Company produced 140 tons, and the Ozark Coal Company, 862 tons.

The reason this district made such a poor showing during the past year is because of the very cheap fuel oil that has been flooding the northwestern coal markets.

The Carbon Coal & Clay Company spent considerable money during the past year prospecting coal outcrops along Coal Creek, and have uncovered several seams of coal.

The Hyde Mine and the Cannon Mine, owned by the Pacific Coast Coal Company, were not operated, due largely to the very poor coal markets. The Pacific Coast Coal Company expects to mine any coal they might develop in the area lying east of Green River through their operations at the Cannon Mine when market conditions justify the reopening of that property.

COAL PRODUCTION AMONG THE BITUMINOUS MINES OF KING COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
Dale Coal Company	Ravensdale	Development work	72
Pacific Coast Coal Company	Black Diamond	225,036	229,338
Carbon Coal and Clay Company	Bayne	1,261	1,598
Cumberland-Eureka Coal Co.	Eureka	6,596	6,603
Elk Coal Company	Elkcoal	64,602	65,274
Hiawatha Coal Mining Co.	Hiawatha	26,120	26,120
Kangley Coal Company	Kangley	12,513	12,940
Morris Coal Company	Durham	24,404	24,517
Navy Coal Company	Cumberland	115	140
Ozark Coal Company	Cumberland	857	862

PIERCE COUNTY COAL FIELD

At the northern end of the Pierce County Coal Field is the Burnett Mine, operated by the Pacific Coast Coal Company. This mine, as well as the Wilkeson Mine, the Carbonado Mine, and the Fairfax Mine, all to the south of the Burnett Mine, produce coking coals. This coal area produces the only commercial coking coals now being mined in the State.

These coal beds dip at angles ranging from nearly horizontal to vertical and are handicapped by numerous faults, many of which are overthrusts and some of them over a thousand feet of displacement.

The Burnett Mine produced 157,850 tons during 1923. This mine is developed to such an extent that this tonnage could be greatly increased when the market justifies it. The Wilkeson Coal & Coke Company produced during the same period of time 52,550 tons of coal, and also 11,762 tons of coke. At the Carbonado Mine, of the Carbon Hill Coal Company, 157,859 tons of coal were produced. This coal mine, with its large reserve of coal tonnage, could be developed into a much larger producer at any time the market would justify such a development. The Fairfax Mine, of the American Smelter Company produced, during the year, 36,095 tons of coal and 21,709 tons of coke.

There is a very large total tonnage of good coking coal within the properties of the Burnett, Wilkeson, Carbonado, and Fairfax Mines. The coal from this area produces a good grade of coke and when properly cleaned there is no reason why coke suitable for any metallurgical purpose could not be produced.

No prospecting was done during the year in the southern portion of the Pierce County Field at Ashford. Coking coals occur in that part of the county, but no commercial coal mine has yet been developed.

COAL PRODUCTION IN PIERCE COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
American Smelter Company..........	Fairfax Coal..........	....	36,095
American Smelter Company..........	Fairfax Coke..........	....	21,709
Carbon Hill Coal Company..........	Carbonado	105,748	109,220
Pacific Coast Coal Company..........	Burnett	146,886	157,859
Wilkeson Coal & Coke Company......	Wilkeson Coal..........	29,083	52,550
Wilkeson Coal & Coke Company....	Wilkeson Coke..........	....	11,762

THURSTON COUNTY FIELD

The principal coal mine in Thurston County is that of the Washington Union Coal Company at Tono. This mine is owned and operated by the Washington Union Coal Company, a subsidiary of the Union Pacific System. The coal in this property is sub-bituminous and the present mine has been opened on a coal bed about sixteen feet in thickness but only about eleven feet of the coal is regularly mined; the top coal in places is somewhat boney. This mine produced during 1923, 252,032 tons of coal, a large portion of which was consumed on the locomotives of the Oregon-Washington Railway. To the northwest of Tono and on the Northern Pacific Railroad is the property of the Bucoda Coal Mining Company, which is also mining a coal bed in the sub-bituminous area. This mine produced, during the year 1923, 15,647 tons. Another small mine is operating near the line between Lewis and Thurston Counties, which is called the Centralia Coal Company. This mine produced 523 tons of coal.

COAL PRODUCTION IN THURSTON COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
Bucoda Coal Company	Bucoda	13,254	15,647
Centralia Coal Company	Centralia (new)		523
Washington Union Coal Company	Tono	242,805	252,032

LEWIS COUNTY FIELD

The coal beds in Lewis County range from sub-bituminous coals, in the western part of the county, to bituminous coals at a point farther east, and an anthracitic coal in the extreme eastern part of the county.

There are many small mines within the sub-bituminous area. The following mines were in operation within the sub-bituminous area during the past year: Chehalis Coal Company, Columbia Collieries, Fords Prairie Coal

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Company, Mendota Coal Company, Monarch Coal Company, Newaukum Coal Company, Nonpariel Coal Company, Potlatch Coal Company, Rex Coal Company, Salzer Valley Coal Company, Sunshine Coal Company, Smith Coal Company, and the Victory Coal Company.

Among the bituminous mines in the vicinity of Divide and Mineral are the Associated Coal Company, the Cambridge Coal Company, the Morton Coal Company, the Mountain Coal Company, and the Tilton River Coal Company.

No development work of any consequence was done in the anthracitic district in the extreme eastern part of the county.

Within the sub-bituminous area the production of coal ranged from 318 tons at the Nonpariel Coal Company to 36,898 tons at the Victory Coal Mining Company. This tonnage was for the year 1923.

There are at least twice as many mines in Lewis County as is necessary to supply the demand for this grade of coal. The coal from these properties is used very largely for domestic purposes at the present time and, because of the cheap fuel oil coming into the Portland and Seattle markets, there is practically no sale for the smaller sized coal produced in the sub-bituminous coal districts of Lewis County.

The coal beds within this area range from five feet to eleven feet in thickness and dip from four or five degrees to sixty degrees. Fortunately there is very little explosive gas within the district but most of the mines are slope operations which necessitate pumping water, and in some places this is an item of considerable expense.

There is a very large total tonnage of sub-bituminous coal within the Centralia-Chehalis coal district, and when better methods of burning this coal are commercialized this coal area will become a very important factor in the fuel developments of the Pacific Northwest. The coal within this district can be mined for considerably less than is true of the bituminous coals of the State of Washington; but, because of their poor storing qualities, due to high moisture content, they are not as popular with the average consumer in their present form as they will be when presented in a more attractive manner. The fact that this coal area lies midway between the two principal industrial centers of the Northwest, Portland, Oregon, and Seattle, Washington, is an important item, and the additional fact that the district surrounding these coal areas is a very attractive one in which to live is another advantage this area has over many other coal fields tributary to the Pacific Coast.

COAL PRODUCTION IN THE BITUMINOUS MINES OF LEWIS COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
Associated Coal Mining Co.	Divide (Mineral)	1,154	1,400
Cambridge Coal Company	Mineral	234	239
Morton Coal Company	Morton	187	199
Mountain Coal Company	Ladd (Mineral)	2,628	2,857
Tilton River Bit. Coal Co.	Lindberg	6,318	7,498

COAL PRODUCTION IN THE SUB-BITUMINOUS MINES OF LEWIS COUNTY FOR 1923, IN SHORT TONS

NAME OF COMPANY	Location of Mine	Coal Shipped	Total Output
Chehalis Coal Company	Chehalis	487	4,106
Columbia Collieries Co.	Galvin (Centralia)	4,414	4,447
Fords Prairie Coal Company	Fords Prairie	11,462	14,371
Mendota Coal & Coke Company	Mendota	6,757	7,359
Monarch Coal Mining Company	Kopiah	16,376	16,976
Newaukum Coal Company	Newaukum (Chehalis)	....	247
Nonpariel Coal Mining Co.	Centralia	51	318
Potlatch Coal Company	Centralia	595	595
Rex Coal Company	Centralia	1,250	1,772
Salzer Valley Coal Company	Centralia	1,655	3,066
Sunshine Coal Company	Salzer Valley	945	945
Smith Coal Company	Mendota	9,378	9,594
Victory Coal Company	Centralia	31,653	36,898

MARKETS FOR WASHINGTON COAL

In former years the steamships of the Pacific Coast, as well as all the railroads, burned coal; but since California oil production has reached such large proportions many of the steamships and several of the railroads have changed from coal to fuel oil. When the steamers were using coal a considerable tonnage of coal was shipped by water from Seattle and Tacoma to San Francisco, from which place it was distributed to the various ships entering that harbor. Also many vessels came to Seattle and Tacoma for their own coal supply.

California fuel oil production has played an exceedingly important part in the coal mining industry of the entire western slope of the United States. The production of fuel oil has increased at a greater pace than population and industries along the coast, and it is quite natural that fuel oil should encroach upon the coal market. Not only have the coal mines of the State of Washington suffered from fuel oil competition, but the coal mines of Oregon have been practically closed because of cheap fuel oil, and the coal mines of Vancouver Island have also been handicapped for the same reason.

For eight years, beginning with 1913, the oil production of the State of California ranged between six million and nine million barrels per month. For the greater part of the time the production ranged between seven million and eight and one-half million. In 1913, seventeen degree oil was sold at the wells for 35 cents per barrel, and in 1915, the price dropped to 32½ cents per barrel. During 1916, the consumption of oil was greater than the production and the price started to rise until at the end of that year it reached 73 cents per barrel, and the consumption during the following year, 1917, was greater than the production, so the price continued to rise until at the end of the year it was 98 cents per barrel at the well. During 1918 and 1919 the consumption and production about balanced each other, but the price went up to $1.23 per barrel. In 1920, the consumption was greater than the production, so the price of the oil at the well went up to $1.60 per barrel. Due to the general depression of 1921 the consumption of oil decreased materially so that there was a greater production than consumption and considerable oil was thrown on the market and the price dropped from $1.60 to $1.10 per barrel.

During the period of time covered in the foregoing statement, the production of oil had reached only about 10,500,000 barrels per month, which was the peak during the summer of 1921. During the early part of 1922, three new fields were brought in: namely, Sante Fe Springs, Huntington Beach, and Signal Hill. The production curve immediately started to climb and the consumption curve could not keep pace with it, so by the end of August, 1922, the price of oil had a further drop and reached the low figure of 60 cents a barrel at the well. By the end of 1922, production had gone up to nearly fifteen and one-half million barrels per month, but the consumption curve was following very closely the production curve, and during that month had reached a high water mark of over fourteen million barrels per month. The production of oil continued to climb during 1923 and reached the peak during August, when there was produced nearly twenty-six and one-half million barrels per month. The consumption during that month was a trifle less than twenty-two million barrels. One can imagine what would happen to the coal industry with a production of oil of over three times the average production for the ten years previously.

It has been stated by well informed oil men that the peak of production has been reached, and it is expected that the decline will be quite regular, but, perhaps, not as fast as the increased production curve was. The cheap oil produced in the three fields mentioned made it necessary for the oil companies to shut in many of their higher cost wells in the older fields. The cheap oil has disturbed the coal mining industry of the entire western part of the United States and it has also been embarrassing for many of the oil companies who could not afford to sell their product in competition with the cheaper oil. This cheap fuel oil has been a boon to many of the industries of the Pacific Coast, and many of the large consumers have changed from coal to oil. It is expected, however, that with a diminishing output, the price of oil will gradually increase and the coal mining fraternity is hopeful that it will not be very long before some of the oil users of the present day will change back to coal.

The wages of the coal miners increased from $3.95 per day for miners in 1916 to $8.25 in September of 1920. The average price of coal at the mines ranged from $2.60 per ton in 1913 to $4.23 per ton in 1922. From these figures it is very evident that the wages at the mines were increased more rapidly than the price of coal, and when the price of fuel oil dropped a dollar a barrel at the well, it meant reducing the price of steam coal about $3.00 per ton at the mine; which, of course, was impossible in view of the increased wages and the falling market. As a result it has been necessary to close several of the higher cost coal mines in the State of Washington. There has been some readjustment in the wages of the miners; the union mines are now paying $7.50 a day, or a reduction of 75 cents from that of the $8.25 rate, and the non-union companies are paying $6.00 a day as a base wage for coal miners. With the reduction in miner's wages, which, of course, is a very large item in the cost of coal mining, and when the price of fuel oil increases, which no doubt will take place during the next year or two, Washington coal can then more nearly compete with California fuel oil in the steam market, which will mean the reopening of many of the mines that are now closed.

COAL FROM VANCOUVER ISLAND AND CALIFORNIA FUEL OIL SHIPPED BY WATER TO SEATTLE DURING 1923

MONTH	Vancouver Island Coal	California Fuel Oil
January	13,824 net tons	424,010 Bbls.
February	11,836 net tons	181,335 Bbls.
March	12,481 net tons	576,314 Bbls.
April	7,150 net tons	296,866 Bbls.
May	5,570 net tons	415,014 Bbls.
June	9,759 net tons	377,518 Bbls.
July	14,169 net tons	419,644 Bbls.
August	16,893 net tons	474,330 Bbls.
September	8,812 net tons	818,568 Bbls.
October	10,427 net tons	549,498 Bbls.
November	5,204 net tons	609,606 Bbls.
	116,125 net tons	5,142,703 Bbls.

PRODUCTION OF COAL IN WASHINGTON, 1860-1923, IN SHORT TONS*

Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity
1860	5,374	1870	17,844	1880	145,015	1891	1,056,249	1902	2,690,789	1913	3,831,647
1861	6,000	1871	20,000	1881	196,000	1892	1,140,575	1903	3,290,468	1914	3,040,361
1862	7,000	1872	23,000	1882	177,340	1893	1,208,850	1904	2,998,633	1915	2,409,331
1863	8,000	1873	26,000	1883	244,990	1894	1,131,660	1905	2,846,901	1916	3,019,600
1864	10,000	1874	30,352	1884	166,936	1895	1,163,737	1906	3,290,523	1917	4,002,759
1865	12,000	1875	99,568	1885	380,250	1896	1,202,534	1907	3,722,433	1918	4,128,424
1866	13,000	1876	110,342	1886	423,525	1897	1,330,192	1908	2,977,490	1919	3,059,580
1867	14,500	1877	120,896	1887	772,601	1898	1,775,257	1909	3,590,639	1920	3,759,881
1868	15,000	1878	131,660	1888	1,215,750	1899	1,917,607	1910	3,979,569	1921	2,422,106
1869	16,200	1879	142,666	1889	1,030,578	1900	2,418,034	1911	3,548,322	1922	3,601,058
				1890	1,263,689	1901	2,466,190	1912	3,346,946	1923	2,946,007
										Total	95,157,428

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

PRODUCTION OF COAL IN WASHINGTON, 1912-1923, BY COUNTIES, IN SHORT TONS

COUNTY	1912	1913	1914	1915	1916	1917
King	1,050,953	1,359,274	1,042,607	844,956	889,275	1,314,366
Kittitas	1,235,690	1,330,596	1,237,564	879,062	1,316,993	1,741,237
Lewis	127,982	148,592	87,558	78,259	109,121	130,578
Pierce	789,320	832,272	553,841	488,693	533,162	606,049
Skagit	....	....	....	....	....	1,000
Stevens	....	....	....	....	....	....
Thurston	136,478	153,588	112,189	112,096	165,066	204,688
Whatcom	6,523	7,325	6,602	6,255	5,983	4,841
Totals	3,346,946	3,831,647	3,040,361	2,409,331	3,019,600	4,002,759
Total Value	$8,122,572	$9,965,362	$7,142,084	$5,393,524	$7,155,317	$11,356,357

COUNTY	1918	1919	1920	1921	1922	1923
King	1,331,601	952,632	983,852	340,015	717,385	663,061
Kittitas	1,739,379	1,322,534	1,837,937	1,392,813	1,053,584	1,358,359
Lewis	174,621	126,493	147,282	142,084	168,149	113,114
Pierce	600,917	397,641	413,460	102,538	303,361	555,715
Skagit	5,897	3,820	2,988	1,433	....	....
Stevens	....	844	....	....	....	....
Thurston	271,406	212,730	257,008	256,218	194,702	268,202
Whatcom	4,603	42,886	114,264	187,005	163,877	187,442
Totals	4,128,424	3,059,580	3,756,881	2,422,106	2,601,058	2,946,007
Total Value	$14,564,445	$10,997,733	$15,127,458	$10,260,805	$10,217,080	$11,405,083

PRODUCTION OF COAL BY COUNTIES, 1920

County	Tons of Coal Shipped	Sold to Local Trade	Used For Power	Charged Into Coke Ovens	Total Coal Production	Total Value	Average Value Per Ton at Mine
King	909,746	27,152	43,936	3,018	983,852	$4,500,514	$4.57
Kittitas	1,749,561	20,605	67,771	....	1,837,937	6,841,731	3.72
Lewis	126,602	13,652	7,028	....	147,282	416,755	2.83
Pierce	334,448	7,145	24,207	47,660	413,460	2,009,251	4.86
Skagit	2,472	14	....	502	2,988	16,159	6.50
Stevens	....	....	....	....	....	....	....
Thurston	249,406	2,018	5,674	....	257,008	835,666	3.25
Whatcom	101,927	8,818	3,519	....	114,264	507,380	4.44
State	3,474,162	74,404	152,135	51,180	3,756,881	$15,127,458	$4.03

PRODUCTION OF COAL BY COUNTIES, 1921

County	Tons of Coal Shipped	Sold to Local Trade	Used For Power	Charged Into Coke Ovens	Total Coal Production	Total Value	Average Value Per Ton at Mine
King	317,546	7,936	13,596	937	340,015	$1,569,403	$4.62
Kittitas	1,316,192	20,264	56,357	....	1,392,813	5,787,143	4.15
Lewis	127,291	9,167	5,626	....	142,084	446,434	3.14
Pierce	86,575	2,394	7,246	6,323	102,538	540,792	5.27
Skagit	681	....	....	752	1,433	8,328	5.81
Thurston	247,579	2,189	6,450	....	256,218	1,023,045	3.98
Whatcom	171,631	10,001	5,373	....	187,005	885,660	4.73
State	2,267,495	51,951	94,648	8,012	2,422,106	$10,260,805	$4.23

PRODUCTION OF COAL BY COUNTIES, 1922

County	Tons of Coal Shipped	Sold to Local Trade	Used For Power	Charged Into Coke Ovens	Total Coal Production	Total Value	Average Value Per Ton at Mine
King	690,761	11,681	14,943	....	717,385	$2,880,234.13	$4.17
Kittitas	991,750	....	40,021	....	1,053,584	4,260,102.02	4.04
Lewis	155,988	6,293	5,868	....	168,149	492,694.93	2.93
Pierce	245,520	2,723	13,881	41,237	303,361	1,348,701.07	4.44
Skagit	....	....	....	....	....	....	....
Thurston	185,984	4,113	4,605	....	194,702	581,900.00	2.98
Whatcom	149,087	8,929	5,861	....	163,877	653,488.79	3.99
State	2,419,090	55,552	85,179	41,237	2,601,058	$10,217,080.94	$3.92

COAL MINING STATISTICS FOR THE YEAR 1922

NAME OF COMPANY	No.	Mine	Town	Tons of Coal Shipped	Sold to Employees and Local Trade	Used for Power	Charged Into Coke Ovens	Total Coal Production	Total Coke Production
KING COUNTY—									
Carbon Coal & Clay Co.	1	Bayne		14,390	179	984		15,553	
Cumberland Eureka Coal Co.	1	Cumberland		8,905	10			8,915	
Elk Coal Mining Co.	1	Durham		49,043	122	214		49,379	
Harris Richmond Coal Co.	1	Issaquah		9,554				9,554	
Hiawatha Coal Mining Co.	1	Hiawatha		2,926				2,926	
Morris Bros. Coal Mining Co.	1	Durham		21,062	65			21,127	
Northwestern Improvement Co.	1	Hiawatha		1,301	8			1,309	
Ozark Coal Mining Co.	1	Cumberland		5,309	9			5,318	
Pacific Coast Coal Co.	1	Black Diamond		196,098	2,131	4,061		202,290	
Pacific Coast Coal Co.	1	Cannon		5,044	126	230		5,400	
Pacific Coast Coal Co.	1	Newcastle		221,005	1,796	9,454		232,255	
Pacific Coast Coal Co.	1	Issaquah		112,425	854			113,279	
Palmer Bituminous Coal Co.	1	Palmer		750	60			810	
Renton Coal Co. (Sludge)	1	Renton		28,756				28,756	
Strain Coal Co.	1	Renton		14,193	6,321			20,514	
Total for County	15			690,761	11,681	14,943		717,385	
KITTITAS COUNTY—									
Cle Elum Coal Co.	1	Cle Elum		1,940	197			2,137	
Independent Coal & Coke Co.	1	Cle Elum		48,767	2,391	5,358		56,516	
Northwestern Improvement Co.	2	Nos. 6 and 8		224,860	9,821	13,059		267,740	
Northwestern Improvement Co.	2	Nos. 2 and 3		226,355	1,294	6,688		234,337	
Northwestern Improvement Co.	1	No. 5		69,560	333	4,631		74,524	
Northwestern Improvement Co.	1	No. 7		278,516	5,329	5,737		289,582	
Roslyn Cascade Coal Co.	1	No. 1		32,521	1,937	622		35,080	
Roslyn Cascade Coal Co.	1	No. 2		37,273		824		38,097	
Roslyn Fuel Co.	1	Beekman		51,023	511	3,057		54,591	
Terrace Coal Company	1	Lakedale		935		45		980	
Total for County	12			991,750	21,813	40,021		1,053,584	

COAL MINING STATISTICS FOR THE YEAR 1922—Continued

NAME OF COMPANY	No.	Mine	Town	Tons of Coal Shipped	Sold to Employees and Local Trade	Used for Power	Charged Into Coke Ovens	Total Coal Production	Total Coke Production
LEWIS COUNTY—									
Columbia Collieries Co.	1	Centralia		9,631	24			9,655	
Ford's Prairie Coal Co.	1	Ford's Prairie		18,874	1,705	1,929		22,508	
Lincoln Hill Coal Co.	1	Lincoln		969		70		1,039	
Monarch Coal Company	1	Kopiah		22,803		530		23,333	
Nonparell Coal Co.	1	Centralia		46	95			141	
Olympia Fuel Co.	1	Packwood		11,309				12,753	
Potlatch Coal Company				800	1,444	800		800	
Roslyn Coal & Coke Co.	1	Superior		1,613	772	22		2,407	
Salzer Valley Coal Co.	1	Salzer Valley		2,837	178			3,015	
Smith Coal Company				2,605	19			2,624	
Tilton River Bituminous Coal Co.				3,350	66	344		3,760	
Victory Coal Mining Co.				81,151	3,434	1,529		86,114	
Total for County	12			155,988	6,293	5,868		168,149	
PIERCE COUNTY—									
American Smelting Sec. Co.		Coke 11790			99	1,801	16,614	18,514	11,790
Carbon Hill Coal Co.				106,951	1,014	2,210		110,175	
Pacific Coast Coal Co.	1	Burnett		126,510	1,523	9,870		137,903	
Wilkeson Coal & Coke Co.				12,059	87		24,623	36,769	14,178
Total for County				245,520	2,723	13,881	41,237	303,361	25,968
THURSTON COUNTY—									
Bucoda Coal Co.				14,881	2,418			17,299	
Washington Union Coal Co.	1	Tono		171,103	1,695	4,605		177,403	
Total for County				185,984	4,113	4,605		194,702	
WHATCOM COUNTY—									
Bellingham Coal Co.				149,087	8,929	5,861		163,877	
Total for County				149,087	8,929	5,861		163,877	
Totals for State				2,419,090	55,552	85,179	41,237	2,601,058	25,968

DIRECTORY OF COAL MINES, 1922

NAME OF COMPANY	Name of Mine	Company Postoffice Address	Mine Postoffice Address	Railroad to Mine
KING COUNTY—				
Carbon Coal & Clay Company	Bayne	Bayne, Wash.	Bayne, Wash.	N. P. and C. M. & St. P.
Cumberland Eureka Coal Co.	Cumberland	Cumberland, Wash.	Cumberland, Wash.	N. P. and C. M. & St. P.
Elk Coal Mining Company	Durham	Alaska Bldg., Seattle, Wash.	Elkol, Wash.	N. P. and C. M. & St. P.
Harris Richmond Coal Co.	Issaquah	Issaquah, Wash.	Issaquah, Wash.	N. P. and C. M. & St. P.
Hiawatha Coal Mining Co.	Hiawatha	....	Elkol, Wash.	N. P. and C. M. & St. P.
Morris Bros. Coal Mining Co.	Durham	....	Durham or Elkol, Wash.	N. P. and C. M. & St. P.
Northwestern Improvement Co.	Hiawatha	Northern Pacific Bldg., Tacoma, Wash.	Durham, Wash.	N. P.
Ozark Coal Mining Co.	Cumberland	Cumberland, Wash.	Cumberland, Wash.	N. P. and C. M. & St. P.
Pacific Coast Coal Co.	Black Diamond	L. C. Smith Building, Seattle, Wash.	Black Diamond, Wash.	Pacific Coast Railroad.
Pacific Coast Coal Co.	Cannon	L. C. Smith Building, Seattle, Wash.	Pahcosco, Wash.	Pacific Coast Railroad.
Pacific Coast Coal Co.	Newcastle	L. C. Smith Building, Seattle, Wash.	Newcastle, Wash.	Pacific Coast Railroad.
Pacific Coast Coal Co.	Issaquah	L. C. Smith Building, Seattle, Wash.	Issaquah, Wash.	N. P.
Palmer Bituminous Coal Co.	Palmer	....	Kanaskat, Wash.	N. P. and C. M. & St. P.
Renton Coal Co.	Sludge	Electric Building, Seattle, Wash.	Renton, Wash.	N. P. & P. S. E.
Strain Coal Co.	Renton	....	Renton, Wash.	N. P. & P. S. E.
KITTITAS COUNTY—				
Cle Elum Coal Company	Cle Elum	Cle Elum, Wash.	Cle Elum, Wash.	N. P.
Independent Coal & Coke Co.	Cle Elum	White Bldg., Seattle, Wash.	Cle Elum, Wash.	N. P.
Northwestern Improvement Co.	Nos. 6 and 8	Northern Pacific Bldg., Tacoma, Wash.	Roslyn, Wash.	N. P.
Northwestern Improvement Co.	Nos. 2 and 3	Northern Pacific Bldg., Tacoma, Wash.	Cle Elum, Wash.	N. P.
Northwestern Improvement Co.	No. 5	Northern Pacific Bldg., Tacoma, Wash.	Cle Elum, Wash.	N. P.
Northwestern Improvement Co.	No. 7	Northern Pacific Bldg., Tacoma, Wash.	Roslyn, Wash.	N. P.
Roslyn Cascade Coal Co.	No. 1	Roslyn, Wash.	Beekman or Roslyn, Wash.	N. P.
Roslyn Cascade Coal Co.	No. 2	Roslyn, Wash.	Beekman or Roslyn, Wash.	N. P.
Roslyn Fuel Co.	Beekman	White Bldg., Seattle, Wash.	Beekman or Roslyn, Wash.	N. P.
Terrace Coal Company	Lakedale	....	Beekman or Roslyn, Wash.	N. P.

DIRECTORY OF COAL MINES, 1922—Continued

NAME OF COMPANY	Name of Mine	Company Postoffice Address	Mine Postoffice Address	Railroad to Mine
LEWIS COUNTY—				
Columbia Collieries Co.	Centralia	Centralia, Wash.	Centralia, Wash.	O.-W. R. R. & N. and Logging Road
Ford's Prairie Coal Co.	Ford's Prairie	Centralia, Wash.	Centralia, Wasn.	C. M. & St. P.
Lincoln Hill Coal Co.	Lincoln	Centralia, Wash.	Centralia, Wash.	O.-W. R. R. & N. and Logging Road
Monarch Coal Company	Kopiah	Centralia, Wash.	Kopiah, Wash.	Eastern Railway & Lumber Co.
Nonpariel Coal Co.	Centralia		Centralia, Wash.	N. P. and O.-W. R. R. & N.
Olympia Fuel Co.	Packwood	Centralia, Wash.	Centralia, Wash.	N. P.
Potlatch Coal Company		Centralia, Wash.	Centralia, Wash.	N. P.
Roslyn Coal & Coke Co.	Superior	Chehalis, Wash.	Chehalis, Wash.	N. P.
Salzer Valley Coal Co.	Salzer Valley	Centralia, Wash.	Centralia, Wash.	No road
Smith Coal Company		Mendota or Centralia, Wash.	Mendota or Centralia, Wash.	N. P.
Tilton River Bituminous Coal Co.		Morton, Wash.	Morton, Wash.	Milwaukee
Victory Coal Mining Co.		Centralia, Wash.	Centralia, Wash.	N. P.
PIERCE COUNTY—				
American Smelting Security Co.	Fairfax	Fairfax, Wash.	Fairfax, Wash.	N. P.
Carbon Hill Coal Co.	Carbonado	Carbonado, Wash.	Carbonado, Wash.	N. P.
Pacific Coast Coal Co.	Burnett	Burnett, Wash.	Burnett, Wash.	N. P.
Wilkeson Coal & Coke Co.	Wilkeson	Wilkeson, Wash.	Wilkeson, Wash.	N. P.
THURSTON COUNTY—				
Bucoda Coal Co.	Bucoda	Bucoda, Wash.	Bucoda, Wash.	N. P.
Washington Union Coal Co.	Tono	Tono, Wash.	Tono, Wash.	O.-W. R. R. & N.
WHATCOM COUNTY—				
Bellingham Coal Company	Bellingham	Seaboard Building, Seattle, Wash.	Bellingham, Wash.	C. M. & St. P. and G. N.

THE COKE INDUSTRY IN WASHINGTON FOR 1923

During the year 1923 coke was produced in the State of Washington at Wilkeson and at Fairfax, both in Pierce County. At Wilkeson 14,041 net tons of coke were produced in 60 ovens of the 160 that the Wilkeson Coal and Coke Company owns. At Fairfax the production was 23,559 tons of coke in 50 ovens of the 60 the American Smelter and Refining Company owns.

Because of the rather poor market for copper it is not expected that the demand for coke will increase in the near future. However, the year just passed is the best one from the point of production the Wilkeson Coal and Coke Company has had since 1909.

The following table shows the production of coke in the State since 1910:

PRODUCTION OF BEE-HIVE COKE FOR THE YEARS 1910-1923

Year	NAME OF COMPANY	Mine	Town	County	Coke Production	Total Value at Ovens	Average Value at Ovens
1910	Evans Creek Coal and Coke Company	Montezuma	Fairfax	Pierce	1,656		
1910	Tacoma Smelting Company	Fairfax	Fairfax	Pierce	18,425		
1910	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	38,634		
	Total				58,715	$332,932	$5.50
1911	Tacoma Smelting Company	Fairfax	Fairfax	Pierce	14,951		
1911	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	25,350		
	Total				40,301	$233,947	$5.805
1912	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	4,680		
1912	Tacoma Smelting Company	Fairfax	Fairfax	Pierce	1,487		
1912	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	42,722		
	Total				48,889	$270,759	$5.54
1913	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	18,211		
1913	Fairfax Mine, Inc.	Fairfax	Fairfax	Pierce	20,970		
1913	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	36,551		
	Total				75,732	$425,632	$5.62
1914	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	15,172		
1914	Montezuma Coal Mining Company	Montezuma	Fairfax	Pierce	525		
1914	Fairfax Mine, Inc.	Fairfax	Fairfax	Pierce	19,201		
1914	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	43,675		
	Total				78,573	$404,126	$5.15
1915	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	19,178		
1915	Fairfax Mine, Inc.	Fairfax	Fairfax	Pierce	16,583		
1915	Washington Manganese, Coal and Copper Company	Marcy	Fairfax	Pierce	6,707		
1915	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	46,225		
	Total				88,695	$471,752	$5.32

PRODUCTION OF BEE-HIVE COKE FOR THE YEARS 1910-1923—Continued

Year	NAME OF COMPANY	Mine	Town	County	Coke Production	Total Value at Ovens	Average Value at Ovens
1916	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	27,409		
1916	Fairfax Mine, Inc	Fairfax	Fairfax	Pierce	15,151		
1916	Washington Manganese, Coal and Copper Company	Marcy	Fairfax	Pierce	2,635		
1916	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	48,527		
	Total				93,722	$487,210	$5.20
1917	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	19,611		
1917	Fairfax Mine, Inc	Fairfax	Fairfax	Pierce	21,345		
1917	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	55,471		
	Total				96,427	*$915,348	$7.46
1918	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	18,547		
1918	Fairfax Mine, Inc	Fairfax	Fairfax	Pierce	25,843		
1918	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	49,309		
	Total				93,699	*$1,295,258	$8.97
1919	Carbon Hill Coal Company	Carbonado	Carbonado	Pierce	172		
1919	Fairfax Mine, Inc	Fairfax	Fairfax	Pierce	13,565		
1919	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	22,151		
	Total				35,888	*$565,356	$8.65
1920	Western Coke and Coll. Company	Snoqualmie	Snoqualmie	King	2,174		
1920	Seattle Lighting Company		Seattle	King	23,494		
1920	Fairfax Mine, Inc	Fairfax	Fairfax	Pierce	22,732		
1920	M. S. Allison Company, Inc				7,434		
1920	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	10,368		
1920	Cokedale Coal Company	Cokedale	Cokedale	Skagit	290		
	Total				66,492	*$619,116	$9.31
1921	Western Coke and Coll. Company	Snoqualmie	Snoqualmie	King	644		
1921	Seattle Lighting Company		Seattle	King	44,012		
1921	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	3,450		
1921	Tieg-Tennant Coal Company	Cokedale	Cokedale	Skagit	401		
	Total				48,507	*$320,607	$6.59

* Includes by-product coke.

PRODUCTION OF BEE-HIVE COKE FOR THE YEARS 1910-1923—Continued

Year	NAME OF COMPANY	Mine	Town	County	Coke Production	Total Value at Ovens	Average Value at Ovens
1922	American Smelting Security Company	Fairfax	Fairfax	Pierce	11,790		
1922	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	14,178		
1922	Seattle Lighting Company		Seattle	King	6,637		
	Total				32,605	*$276,325	$8.44
1923	American Smelting Security Company	Fairfax	Fairfax	Pierce	23,559		
1923	Wilkeson Coal and Coke Company	Wilkeson	Wilkeson	Pierce	14,041		
1923	Seattle Lighting Company		Seattle	King	31,081		
	Total				68,681	*$557,598	$8.12

* Includes by-product coke.
Small amount of by-product coke produced in 1922 and 1923 by companies other than Seattle Lighting Company not included.

There are several areas in the state in which coking coal occurs, principal among them are the Burnett, Wilkeson, Carbonado, and Fairfax coal areas of Pierce County. In King County coal that will coke has been found at the Pocohontas Mine and also in the Durham-Elk area. Coke has been made from the coal mined at Snoqualmie, but not on a successful commercial scale. The coke made from Pocohontas, Elk, and Durham coals have been on an experimental scale.

At Cokedale in Skagit County, near the city of Sedro-Woolley, is an area that contains coking coal, but the operations in that district are now closed.

There is sufficient coal of good coking quality in the Pierce County area to supply a large tonnage for an indefinite period. There should be sufficient market tributary to the Puget Sound District for domestic coke, and the various by-products from a by-product coke oven, to warrant the erection of a large plant. This is one phase of the coal mining operations which the State of Washington could well afford to encourage and stimulate.

STATISTICS OF MANUFACTURE OF COKE IN WASHINGTON*
1884 TO 1922

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	
				Beehive	By-Product
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	63.4	66.9
1915	†136,552	700,832	5.13	65.4	70.0
1916	†125,872	662,987	5.27	62.1	59.5
1917	†122,758	906,318	7.38	60.1	58.5
1918	†123,788	1,196,685	9.36	60.6	74.8
1919	†62,546	531,160	8.49	65.7	60.2
1920	†59,395	627,451	10.39	69.2	58.9
1921	†27,260	194,510	7.13	55.6	54.5
1922	†30,688	285,881	9.31	63.8	59.8
Totals	1,624,229	$10,087,638			

* From Mineral Resources of the United States, U. S. Geological Survey.
† Includes by-product coke.

SUMMARY OF PRODUCTION OF COKE IN WASHINGTON FOR THE YEARS 1900-1923

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	3,040,361	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
1920	3,756,881	15,127,458	4.03	†66,492	†619,116	9.31
1921	2,422,106	10,260,805	4.24	†48,507	†320,607	6.59
1922	2,601,058	10,217,080	3.92	25,968	235,862	9.08
1923	2,964,007	11,405,083	3.87	37,600	340,031	9.04

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

† Includes by-product coke.

PRODUCTION OF BY-PRODUCT COKE IN WASHINGTON, 1914-1922*

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
1920	26,284	6,014	32,298	55.9	12.8	68.7	162,309.92	6,282.01	168,591.93
1921	23,765	6,595	30,360	49.9	15.4	65.3	164,653.80	6,594.74	171,248.54
1922	5,611	1,026	6,637	53.5	10.9	64.4	39,412.22	1,051.13	40,463.35
Totals	202,959	33,984	236,943	....	....	....	$1,372,817.51	$34,560.86	$1,407,378.37

* Figures furnished by Seattle Lighting Company.

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